Low Emissions Technologies for Fossil Fuels (LETFF) impact evaluation (phase two)

- actions arising from third Reference Group meeting

10am to 11am, Friday 31st May 2019, 8.150 Industry House

Reference Group members: s22

Observers: s22
s22

Deloitte: s22

Apologies: s22

Summary

Deloitte presented their preliminary findings for the Impact evaluation (phase two) of the LETFF programs. The findings were based on stakeholder interviews, responses to an online questionnaire, a literature scan and citation analysis conducted to date. As consultation and analysis are not yet complete, the findings may be subject to change.

Deloitte outlined their preliminary findings relating to:

- the change in knowledge, skills and capability, and industry understanding from prior to introduction of the LETFF programs to now
- the contribution of the LETFF programs to increased knowledge, skills and capability, and industry understanding
- factors that have assisted or hindered achievement of LETFF outcomes and the remaining barriers to commercial development and deployment
- stakeholder perceptions of achievements, the impact of government support, remaining research questions, and key learnings.

Members noted and generally concurred with the preliminary findings. Suggestions included:

- emphasising the finding (under *Skills and capabilities*) that Australia's research capabilities in the field are more advanced than industry capabilities
- exploring the influence of external factors, such as State government regulatory approaches
- canvassing reasons for industry under-investment in the type of research supported by LETFF.

No recommendations were included with the preliminary findings, and there was discussion about the appropriateness of lessons learned rather than recommendations given the current stage of the LETFF programs.

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Australian Government
Department of Industry, Innovation and Science

Office of the Chief Economist

Chair's briefing: Low Emissions Technologies for Fossil Fuels (LETFF)

Impact Evaluation (Phase two)

Evaluation Reference Group meeting 3

10am to 11am Friday 31st May 2019, in 8.150 Industry House

Reference group (RG): s22

Observers: s22
s22

Deloitte consultants: s22

Apologies: s22

Time	Activity	Speaker
10am	Introduction and welcome	s22

Chair's notes:

- s22
-
-
- The overall purpose of the LETFF impact evaluation is to determine the extent to which the four programs have achieved their strategic objectives:
  - Carbon Capture and Storage Flagships (CCS Flagships)
  s22
  - Low Emissions Technology Demonstration Fund (LETDF)
  s22
- The **purpose of phase two** is to evaluate the impact of the LETFF programs. As a result of the findings of phase one, phase two is focusing on the impact of the LETFF programs on increasing knowledge, skills and capability, and industry understanding about low emissions technologies.
- The **purpose of this meeting** is to consider Deloitte's preliminary findings for phase two.

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10.10am	**Presentation preliminary findings** **Chair's notes**: • s22 [redacted] will present Deloitte's preliminary findings.	Deloitte
10.30am	**Discussion of preliminary findings** **Chair's notes**: Outcome sought • Early awareness of emerging findings and any sensitivities. • Agreement on high level feedback to Deloitte.	All
10.50am	**Next steps** **Chair's notes**: • Members will have the opportunity to provide any further feedback in writing by cob Tuesday 4th June. • The Evaluation Unit will provide collated feedback to Deloitte by cob Wednesday 5th June. • Deloitte will submit their draft report on 14 June 2019.	
10.55am	**Any other updates or issues**	All
11.00am	**Meeting close**	s22

Deloitte.

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Preliminary findings

Impact Evaluation (Phase Two) of LETFF Programs – Presentation to Steering Committee

31 May 2019

Preface

The Department of Industry, Innovation and Science (the Department) is undertaking an evaluation of the Low Emissions Technologies for Fossil Fuels (LETFF) programs. The Department is undertaking the evaluation in two phase. Phase One focussed on the evaluability of the LETFF programs and was completed in March 2019.

The Department has engaged Deloitte to conduct Phase Two of the LETFF impact evaluation. The overarching purpose of Phase Two is to evaluate the impacts of the LETFF programs on increasing knowledge, skills and capability, and on improving industry understanding about low emissions technologies. The project will also seek to determine whether the Government investments made under the LETFF programs have helped move low emissions technologies closer to commercialisation, and whether the outcomes achieved are commensurate with the level of investment made by the Commonwealth Government.

This memo presents the preliminary findings of Phase 2 of the LETFF impact evaluation. These results are preliminary and may be subject to change between now and the draft report.

General use restriction

This preliminary findings memo is prepared solely for the internal use of the Department. Our preliminary findings presented in this memo are subject to change between now and the submission of Deloitte's draft report. This report is not intended to and should not be used or relied upon by anyone else and we accept no duty of care to any other person or entity. The preliminary findings report has been prepared for the purpose set out in our Proposal dated 4 March 2019 and accepted project plan dated 18 April 2019. You should not refer to or use our name or the advice for any other purpose.

Contents

Knowledge, skills and capability and industry understanding – prior to commencement of LETFF programs

Summary

- **Knowledge** of LETFF was thin, with small proportion of sector having meaningful knowledge of LETFF, supported by a small body of research with pockets of recognised world leading research expertise.
- Thin domestic **skills and capability**, with expertise limited to handful of leading organisations.
- Limited **industry understanding** of practical and technical feasibility of LETFF, predominantly limited to oil & gas sector.

Knowledge

- Not deployment-ready; significant research gaps existed.
- Australia was well-placed in terms of conceptual and theoretical understanding about LETFF.
- Limited understanding of geological storage and capabilities, and sub-surface geological conditions - Limited knowledge and understanding of Australia's geological subsurface resources for the injection and storage of CO_2:
  - location of suitable sites (both onshore and offshore)
  - potential capacity these sites
  - long-term stability of these sites and how they would react under CO_2.
- There was an underlying assumption that the geological storage 'was there'.
- Limited knowledge of capture technologies and application to existing processes - particularly in relation to coal, energy generation and industrial sectors (steel, fertilizers, manufacturing, etc.).
- Regulatory frameworks did not exist.
- Lack of research and data collection systems to structure the existing knowledge base, to direct the advance of new knowledge, and to provide a knowledge-sharing platform between government, academia and industry.

Skills and capabilities

- Technical and engineering capabilities varied by sector:
  - Oil & Gas much further developed given mature understanding of well-established sub-surface and drilling technologies.
  - Differences reflect the different technological challenges each industry faced – i.e. emissions separation/capture, transportation, and injection/storage.
- Australia had a small but highly capable CCS research community with some recognised individual world leading expertise.
- Research skills and capabilities were well developed, but restricted to small number of leading organisations:
  - CSIRO had been developing a range of technologies for some time prior
  - Academic knowledge existed at Melbourne, Monash and Newcastle universities, CSIRO and Geoscience Australia.

Industry understanding

- Limited understanding of appropriate technologies, how to apply them and under what conditions.
- Limited understanding of the practical and technical feasibility of LETFF – Oil & Gas more advanced than coal, energy generation and industrial sectors.
- Lack of detailed understanding on how to apply international technologies/practices under varying Australian conditions (with exception of Oil & Gas):
  - Storage and transport understanding further advanced due to ability to leverage Oil & Gas sector
  - Coal, energy generation and industrial sectors had yet to investigate capture technology.
- Lack of understanding of costs - no detailed cost discovery process yet undertaken across the full range of LETFF.

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Knowledge, skills and capability and industry understanding – following the commencement of LETFF programs

Summary

- **Knowledge** of LETFF is across Australia has deepened matured relative to prior to program commencement - now have multiple industry participants with knowledge of LETFF, supported by a significant body of research covering multiple technologies.
- Moderate **local domestic skills and capability**, with expertise across a moderate number of organisations on a moderate range of LETFF – but risk of losing key skills gained
- Moderate to broad **industry understanding** of technical/practical feasibility of LETFF under some processes and conditions.

Knowledge

- Australia now has a 'mature' CCS knowledge base – "the major R&D questions are largely settled" for CCS.
- Significant body of research has been delivered across the full spectrum of LETFF activities.
- Australia has an "End-to-end" understanding of CCS:
  - knowledge of Australia's geological storages and how CO2 behaves during capture, transportation and storage

s22

  - how technologies perform under different conditions and contexts (e.g. new build vs retrofit)
  - regulatory and safety implications.

➔ Consensus that technical barriers of CCS have largely been conquered.

➔ Missing piece is large-scale deployment and demonstration of CCS and LETFF in Australia under local conditions – **cost is key barrier**.

Skills and capabilities

- Australia's pool of research and technical skills and capabilities is considerably larger, more developed and vastly more experienced relative to prior to commencement of programs.
- Consensus that research capabilities are more advanced than industry capabilities – deployment of LETFF is required to further advance industry skills and capabilities.
- However, consensus that Australia has the engineering capability to deliver commercial scale LETFF – Australia's technical competence well regarded relative to U.S., Europe, China and Japan.
- Risk of losing skills and capabilities if momentum is not maintained – Australia competing in a global talent pool.

Industry understanding

- Industry has now undertaken detailed end-to-end cost discovery and engineering design process for CCS.
- Consensus that coal, energy generation and oil & gas sectors have the collective practical, financial and technical understanding of deploying CCS.

➔ Consensus is that Australia is now deployment ready in terms of its technical capability for CCS.

- However, gaps remain with respect to deploying capture technology for industrial processes (steel, fertilizer, manufacturing processes).
- s22
- Dissemination of knowledge and establishment of information sharing networks:
  - Repositories for CCS data and research knowledge have been established - e.g. s22 CO2CRC, Geoscience Australia, GCCSI
  - Extensive relationships between industry and government, both domestically and internationally now established – the value of these should not be understated.
  - But dissemination of broader learnings have not been successfully transferred to other carbon-intensive industries
  - learnings about CCS have not been clearly communicated at a general level – has not helped inform the public discourse around CCS.

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Contribution to increased knowledge, skills and capability and improved industry understanding

New research and knowledge

- Significant advancements in knowledge of Australia's geological storage resources – geological sub-surface storage mapping.
- Significant advancement knowledge of behaviour of CO_2 in the sub-surface, and how to model CO_2 plumes – directly impacts investor risk, and implications for regulatory approval.
- Trialled injection and storage of CO_2 underground – e.g. developed proof of concept that CO_2 can be safely injected, stored and monitored.
- Produced a significant body of research, data, concept designs, cost estimates, models and other project outputs – not all publically available.
- Significant technical innovations around development of subsurface modelling and data tools.
- Significant value identified by consultees in the relationships formed with foreign governments and research institutions – particularly in China
- Participation in knowledge sharing at an international level has helped Australia improve its expertise and practical understanding.
- Vast body of research developed.

Literature Scan and Citation Analysis

Programme	Publications		% scholarly articles	No. of citations	Citations per publication
	No.	%			
CCS Flagships	65	13%	2%	170	2.6
s22					
LETDF	23	5%	39%	1105	48.0
s22					

Domestic skills and capability

- **Expanded research expertise**
  - Significantly increased Australia's research capability and skills
  - Recognised world leaders in specific areas of CCS research – for example dynamic modelling of CO_2 plumes
- **Technical and operation capability**
  s22
  - Improved engineering capabilities across industries – i.e. improved the chemical engineering capabilities in coal and energy industries.
- **Improved project evaluation and management expertise**
  - Government has improved its ability to evaluate the whole of life technical and financial viability of projects, milestones, timeframes and funding requirements.

Industry understanding of practical and technical implementation of LETFF

- Greater understanding of suitability for geological resources for CCS purposes – mapping of geological storages, understanding of capping techniques etc.
- Demonstrated the operation of an injection site within regulatory bounds.
- Technical and practical feasibility of capturing, transporting and storing CO_2 has advanced, but not fully resolved.
- End-to-end understanding of engineering and cost discovery advanced significantly – however cant be completed until deployment.
- Full understanding of **site-specific conditions remains a significant hurdle** – investigation and research of site-specific issues requires commencement of local drilling and injection.
- **Significant variation across industry sectors and firms**
  - Improved understanding for those involved in LETFF programs – oil and gas, coal mining, some energy producers.
  - Very little broader dissemination of learnings to other emissions-intensive industries.

Factors and barriers affecting achievement of LETFF outcomes

Factors that have assisted

- Commencement of programs underpinned by clear policy direction and settings, significant funding allocation and support across Government:
  - provided clear signal of intent to industry, and gave industry confidence to invest
  - program design focused on addressing industry needs.
- Maintained strong technical and research capabilities to support the LETFF programs.
- A portfolio approach undertaken, with funding allocated across a suite of programs and project to maximise learnings and probability of success (viewed as barrier by some).
- Partnership approach – combining industry, research and government expertise from a range of organisations (e.g. CSIRO, GA, Universities) to support projects and research.

Factors that have hindered

- Changing and uncertain policy settings identified **as primary factor** hindering achievements and progress:
  - removal of carbon price regime and 'removal' of funding from programs
  - changing and inconsistent policy settings no longer align with policy objectives and commercial drivers
  - lack of a clear national strategy

  ➔ resulted in significant uncertainty, loss of confidence across industry and loss of momentum.
- Program design - funding agreements considered to be rigid and inflexible, funding tied to specific milestones, not reflective of large-scale industrial development projects.
- 'Removal'/clawback of program funding – many stakeholders consider that funding from unsuccessful projects should have been reallocated to remaining projects or identified 'new' projects.
- Technical complexity of LETFF not sufficiently understood prior to program. Resulted in unrealistic timeframes, program costs and expectations.
- Perception that research agenda is creating perverse outcomes – call for additional research signals to community and regulators that significant uncertainty and risk still exists.

Barriers to commercial development and deployment

- Lack of **commercial incentives and imperative** to invest in carbon abatement identified as **single largest barrier**:
  - cost of CCS is significant – high up on the emission abatement cost curve
  - significant capital costs to deploy – investment risk is heightened by current policy settings and uncertainty
  - absence of consistent national energy policy that provides industry with sufficient long-term confidence to invest
- Policy settings **do not adopt a technologically agnostic approach** to emissions abatement (e.g. CCS projects unable to apply for funding under Clean Energy Finance Corporation).
- Third party risks – key issue of who is responsible for indemnifying a storage basin in the longer term remains unaddressed.
- Insufficient government funding, and dilution of funding across too many projects.
- No nationally consistent statement on the role of CCS in assisting with emissions abatement.
- Public perception and acceptance of CCS – role of CCS in abating emissions not well understood, seen as extending life fossil fuels, renewables are more visible to the community.

Success, learnings and future program design

Perceptions on achievements relative to investment

- Consensus that government has received **very good value for money.**
- Australia now considered to have requisite scientific and engineering foundation to develop and deploy large, commercial scale CCS projects.
- Have successfully leveraged significant industry funding.

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- Australia **risks losing the significant gains** in knowledge, skills and capabilities it has established over the last 15-years if it doesn't proceed to commercialisation.

Impact of Government support

- Commonwealth Government intervention and support **considered critical to achievements** - notwithstanding Chevron–Gorgon project, which has delivered policy benefits through Government's relationship with Chevron.

Areas of research that remain unanswered

- Consensus is that focus needs to shift to implementation and deployment of technologies – specifically, funding large commercial scale deployment. However, LETFF is not currently financially feasible.
- Application of learnings to other sectors – hydrogen; enhanced oil recovery; steel, concrete and fertiliser manufacture; landfill waste and waste-water treatment; agribusiness.
- **Local and site-specific understanding** – particularly relating to the potential capacity of (onshore and offshore) storage sites. Deployment will result in new wave of site-specific research with respect to drilling, sub-surface monitoring and injection.
- Understanding how to best engage with local communities – considered critical to resetting the national conversation.

Role of Commonwealth Government in supporting LETFF

- Consensus that **there remains a critical role for Government**, but no clear consensus on what that role should be:
  - establish a **clear national energy and climate policy agenda and framework** that provides clear commercial imperative to invest
  - provision of **direct financial support** for commercial-scale deployment – but any such support would need to be economically prudent
  - support research and redevelopment of regulatory framework
  - consolidate knowledge gained to date.
- Recognition that **next critical stage is deployment** – research has gone far enough to position industry to take next step, pending financial imperative.

Key learnings for future policy and program design

- Policy settings must align to project outcomes, and future policy must consist of **'carrots'** (e.g. U.S. 45Q tax credit) and **sticks** (carbon price).
- Future programs must adjust expectations around cost and time-horizons – particularly when supporting unproven technologies for industrial/commercial scale projects.
- Improve screening and selection process to better gauge feasibility of projects at outset - but a need to be balanced with R&D nature of funding.
- Funding agreements should reflect the nature and needs of industrial development projects – stage gates should replace rigid milestone payments, funding must be flexible across years.
- Utilise independent expert panels or organisations to provide assistance when screening projects, as well as evaluating the progress of projects, and the success of projects.

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Next steps

- Finalise stakeholder interviews
- Finalise thematic analysis of interviews, online questionnaire, and literature scan.
- Development and submission of Draft Report on 14 June 2019 for Department comment and feedback
- Incorporation of feedback and submission of Final Report on 28 June 2019.

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Low Emissions Technologies for Fossil Fuels (LETFF) impact evaluation (phase two)

- actions arising from the fourth Reference Group meeting

3pm to 4pm, Tuesday 18th June 2019, 10.111 Industry House

Reference Group members: s22
s22

Observers: s22

Deloitte: s22

Apologies: s22

Summary
Deloitte presented their draft report (minus appendices C and D) for the Impact evaluation (phase two) of the LETFF programs. There were no new or significant changes to Deloitte's preliminary findings, which were presented at the previous meeting. The completion of their analysis supported and reinforced their preliminary findings.

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Australian Government
Department of Industry, Innovation and Science

Office of the Chief Economist

Chair's briefing: Low Emissions Technologies for Fossil Fuels (LETFF)

Impact Evaluation (Phase two)

Evaluation Reference Group meeting 4

3pm to 4pm Tuesday 18 June 2019, in 10.111 Industry House

Reference group (RG): s22
s22

Observers: s22

Deloitte consultants: s22

Apologies: s22

Time	Activity	Speaker
3pm	Introduction and welcome	s22

Chair's notes:

- s22
- s22
-
- Recap (if needed): The overall purpose of the LETFF impact evaluation is to determine the extent to which the four programs have achieved their strategic objectives:
  - Carbon Capture and Storage Flagships (CCS Flagships)
  s22
  - Low Emissions Technology Demonstration Fund (LETDF)
  s22
- Recap (if needed): Phase two is focusing on the impact of the LETFF programs on increasing knowledge, skills and capability, and industry understanding about low emissions technologies.
- The **purpose of this meeting** is to consider Deloitte's draft report for phase two, seek clarification if needed, and provide comments and feedback.

Australian Government
Department of Industry, Innovation and Science

Office of the Chief Economist

3.10pm	**Presentation of draft report**	Deloitte

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3.30pm	**Discussion of draft report**	All

Chair's notes:
Outcome sought

- Discussion of the draft findings, any issues and/or sensitivities.
- Agreement on high level feedback to Deloitte to inform their final report.

3.50pm	**Next steps**	

Chair's notes:

- Members will have the opportunity to provide any further feedback in writing by cob Thursday 20th June.
- The Evaluation Unit will provide collated feedback to Deloitte by cob Friday 21st June.
- Deloitte will submit their final report on 28 June 2019.

3.55pm	**Any other updates or issues**	All
4.00pm	**Meeting close**	s22

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Phase Two of the Impact Evaluation of the Low Emissions Technologies for Fossil Fuels (LETFF) programs (DRAFT)

Department of Industry, Innovation and Science

June 2019

Contents

Charts

Tables

Figures

Glossary

ACALET R&D	Australian Coal Association Low Emissions Technologies Research and Development
ANAO	Australian National Audit Office
s22	
ARENA	Australian Renewable Energy Agency
CCS	Carbon Capture and Storage
s22	
CO2CRC	Carbon Dioxide Co-operative Research Centre
CSIRO	Commonwealth Scientific and Industrial Research Organisation
GHG	Greenhouse Gases
HELE	High Efficiency Low Emissions
IDGCC	Integrated Drying Gasification Combined Cycle
IGCC	Integrated Drying Gasification Combined Cycle
KEQ	Key Evaluation Questions
LETDF	Low Emissions Technology Demonstration Fund
LETFF	Low Emissions Technologies for Fossil Fuels
s22	

Executive summary

In 2004, the Australian Government identified a need to support and promote the development and deployment of low emissions technologies to facilitate a cost-effective transition to a lower carbon economy.

The Department of Industry, Innovation and Science (the Department) has been implementing a range of policies from 2004 to support the research and development of new greenhouse gas (GHG) emissions reduction technologies under the Low Emission Technologies for Fossil Fuels (LETFF) programs.

Deloitte has been engaged by the Department to undertake Phase Two of the LETFF impact evaluation to evaluate the impacts of the LETFF programs on increasing knowledge, skills and capability, and on improving industry understanding in relation to low emissions technologies. The project also sought to answer:

- What factors have helped or hindered the achievement of the above outcomes?
- To what extent would outcomes have been achieved in the absence of the LETFF programs?
- To what extent do factors within and external to the LETFF programs remain a barrier to commercial development and deployment of LETFF?
- What (if any) unintended outcomes, positive and negative, have occurred as a result of the LETFF programs?
- What lessons can be drawn to inform future program development, including the role (if any) of the Commonwealth Government, in relation to supporting the development and implementation of LETFF technologies?

To answer these questions, the impact evaluation adopted a mixed methods approach involving semi-structured interviews with program stakeholders, an online questionnaire, and extensive scan of secondary data including citation analysis and development of case studies.

Contribution to knowledge, skills and industry understanding

The LETFF programs have significantly contributed to increasing knowledge, skills and capability, and improving industry understanding of LETFF in Australia. Overall, Australia has the research and engineering capability to develop commercial scale LETFF projects.

Overall, through the LETFF programs Australia has developed:

- a mature knowledge base with multiple industry participants with knowledge of a range of LETFF, supported by a broad body of research covering multiple technologies
- a moderate level of domestic skills and capability, with expertise across a range of organisations and LETFF
- a moderate industry understanding of the technical and practical feasibility of LETFF under a range of processes and Australian conditions.

A significant body of research has been delivered across the full spectrum of LETFF activities, and the critical research and development and technical barriers are considered to be largely settled for CCS.

Australia's pool of research and technical skills and capabilities is considerably larger, more developed and vastly more experienced relative to prior to commencement of programs. However, Australia's research capabilities are considered to be more advanced than industry capabilities, with stakeholders agreeing that deployment of LETFF is required to further advance industry skills and capabilities.

The LETFF programs have resulted in industry developing a detailed 'end-to-end' understanding of the engineering and design of LETFF, in particular CCS technologies. Furthermore, there is a consensus that the coal, energy generation, and oil and gas sectors have an understanding of the practical, technical and financial requirements necessary to deploy CCS. However, the absence of a commercial imperative to invest in emissions abatement remains the overarching barrier to LETFF deployment in Australia.

Factors contributing to the success of the LETFF programs

The commencement of LETFF programs were underpinned by clear policy direction and settings, support across Commonwealth and State Governments, and a significant funding commitment across a suite of programs and projects – factors deemed critical to the achievement of outcomes. Other contributing factors to the achievement of outcomes included:

- establishment of partnerships established between government, industry and academic stakeholders
- the direct financial involvement of the coal industry in maintaining an industry-focussed research agenda
- establishment of a portfolio of LETFF projects to maximise learnings and the probability of success.

Overall, changing, uncertain and inconsistent domestic policy settings are considered the primary factors hindering achievements and progress across the LETFF programs. Policy uncertainty has resulted in a significant loss of confidence across industry and a loss of momentum in advancing LETFF.

The unexpected complexity of LETFF, rigidity of funding agreements, regulatory uncertainty and insufficient readiness on the part of the Commonwealth and State Governments have also hindered achievements and progress across the LETFF programs.

The absence of a clear commercial imperative on the part of industry to invest in carbon abatement remains the single largest barrier to the commercial development and deployment of LETFF.

Knowledge gained throughout the LETFF programs has not been adequately disseminated to the broader public. Barriers to knowledge sharing and access to information have contributed to a 'poor' public understanding and acceptance of LETFF, and in particular CCS, and represent a barrier to the deployment of LETFF.

Success, future research and role of government

Overall, stakeholders overwhelmingly consider the LETFF programs to be successful. There was strong agreement among all stakeholders that the achievements of the LETFF programs would not have been made in the absence of Commonwealth Government support. Furthermore, stakeholders consider that the Commonwealth Government's investment in LETFF programs represents good value for money, and that achievements are commensurate with the investment.

LETFF programs have directly contributed to reducing the technical and commercial barriers to the development and deployment of commercial-scale LETFF projects. However, the achievements and knowledge gained have not been well communicated or disseminated beyond the immediate program participants, and the achievements have not be adequately communicated to the broader public.

Australia also risks losing the significant gains in knowledge, and skills and capabilities established through the LETFF programs if there is no progressing towards the commercialisation and deployment of LETFF.

The critical underlying research and technical questions to deploying large-scale LETFF (and CCS in particular) have been addressed, however some targeted research would supplement and benefit research done to date. In particular, there is need to undertake site-specific research and testing to support the eventual deployment of LETFF.

Stakeholders consider there remains a critical role for the Commonwealth Government in supporting the development and implementation of LETFF, however there is no clear consensus on the most appropriate role for Government.

Key lessons for future program design

The impact evaluation has identified the following key lessons to inform future program design and implementation:

- the need to set realistic expectations with respect to program cost and time-horizons, particularly for programs with a focus on deployment of commercial-scale projects incorporating untested technologies
- the need to set realistic expectations with respect to research and development outcomes, noting that only a proportion of projects will succeed in progressing beyond research and pre-commercial feasibility
- ensuring alignment between policy settings and program objectives, and ensuring an appropriate mechanism is in place to trigger a review of program rationale in the event of a fundamental shift in domestic and international policy settings
- enhancing the technical and financial assessment of project feasibility at program commencement, noting that this needs to be balanced with the research and development objectives and any future program
- funding and program governance arrangements should reflect the nature of program activities, in particular stage gates should replace rigid milestone reporting and payment processes for large projects to enable a more efficient provision of funding
- greater industry engagement in the design of the program, and as part of a formal risk assessment, to ensure program objectives, risks and issues are appropriately understood and reflected in the program design and implementation
- the need to embed monitoring and reporting frameworks to monitor the effects of changes to funding on the achievement of program objectives, and better enable an assessment of how remaining funds can be redistributed within the program or other programs
- the need to embed knowledge-sharing processes and systems to ensure program learnings and outcomes are appropriately captured and disseminated across relevant Commonwealth and State Government departments and agencies.

Recommendation

Should the Commonwealth Government consider any future support to further the development and implementation of LETFF, as a first step Deloitte recommends that the Commonwealth Government prioritise a detailed economic cost benefit analysis of LETFF in decarbonising the economy relative to alternative technologies. This analysis should give consideration to fossil fuel demand and the whole-of-lifecycle costs of alternative technologies.

1 Overview and purpose

1.1 Context

Australia's electricity generation and some industrial sectors (e.g. steel and concrete production) rely heavily on burning fossil fuels, such as coal, natural gas and oil, which release carbon dioxide (CO_2) and other greenhouse gases (GHG) into the atmosphere.

Low emissions technologies have the potential to reduce GHG emissions and Australia's impact on climate change. In 2004, the Australian Government identified a need to support and promote these technologies to facilitate a cost-effective transition to a lower carbon economy. The Department of Industry, Innovation and Science (the Department) has since implemented and overseen the Low Emission Technologies for Fossil Fuels (LETFF) programs. These programs fund research and development of new GHG emission reduction technologies. The LETFF programs comprise the following four programs:

- The Carbon Capture and Storage (CCS) Flagships program

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- The Low Emissions Technology Demonstration Fund (LETDF)

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These programs commenced against a backdrop of increasing and coordinated global action against climate change. However, they have experienced significant changes in funding, policy and investment conditions. In particular, the repeal of the carbon pricing mechanism has led to uncertainty regarding the future price of carbon, affecting business investment incentives.

The Department has identified the LETFF programs as a Tier One evaluation priority of high strategic importance. The Department previously accepted the recommendation of the Australian National Audit Office (ANAO) audit (2017) to evaluate the LETFF programs. The Department is conducting the evaluation of the LETFF programs in two phases, consisting of:

- Phase One - an assessment of the 'evaluability' of the four LETFF programs, previously conducted by Deloitte Access Economics. (Completed)
- Phase Two - an impact evaluation of the LETFF programs, the scope of which has been informed by the outcomes of Phase One. (Current phase)

1.2 Purpose and scope of Phase Two

The Department has engaged Deloitte to conduct Phase Two of the LETFF impact evaluation (the project). The overarching purpose of this project is to evaluate the impacts of the LETFF programs on increasing knowledge, skills and capability, and on improving industry understanding about low emissions technologies.

The project will also seek to determine whether the Government investments made under the LETFF programs have helped move low emissions technologies closer to commercialisation, and whether the outcomes achieved are commensurate with the level of investment made by the Commonwealth Government.

The findings of this project will inform future LETFF program design, including the potential role of the Commonwealth Government in supporting the further development and implementation of LETFF.

The project covers all components of the LETFF programs with the exception of the CCS Flagships Research Development and Demonstration (RD&D) fund, which is out of scope as impacts are unlikely to have been realised at the time of reporting.

1.3 The LETFF programs

The LETFF programs support low emission fossil fuel technologies by funding programs and initiatives that aim to reduce technical risks and speed up the commercialisation process. Technologies that were supported through the LETFF programs include:

- carbon capture and storage (CCS)
- high efficiency low emissions (HELE) electricity generation
- fugitive methane emission abatement technologies.

In total, although $2.8 billion was originally budgeted across all four LETFF programs, funding was substantially reduced over time and approximately $750 million has been spent to date.

A summary of the four LETFF programs, including the objectives of each program and major projects and initiatives funded under each program, is provided in Table 1.1 below. A summary of individual projects delivered under each program is presented in Appendix A.

Table 1.1: Summary of LETFF programs

LETFF Program	Description
The CCS Flagships program	Commenced in 2009 under the Federal Budget's Clean Energy Initiative with a program budget of $1.8 billion. The objective of the program was to promote the dissemination of CCS technologies through supporting a small number of demonstration projects to capture CO_2 emissions from industrial processes and safely store them underground in stable geological formations. Five flagship projects and other small-scale CCS activities have been funded over the course of the program. Two out of the five flagship projects have been deemed 'unsuccessful'. The program also includes the CCS Research, Development and Demonstration (RD&D) Fund with an objective of reducing the technical and commercial barriers to deploying large-scale CCS projects.
s22	
LETDF	Announced in June 2004 under the *Energy White Paper – Securing Australia's Energy Future*. The Fund had a $500 million budget that could be granted to projects ranging from concentrated solar to CCS technology. The aim of the program was to demonstrate the commercial potential of new technologies to contribute to long-term large-scale GHG emissions reductions. The LETDF Program funded six highly complex projects which required a high degree of due diligence. Of these six, two were transferred to other programs, three were unsuccessful and only one – the Gorgon Carbon Dioxide Injection Project, continues to operate.
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1.4 Summary of Phase One findings

Deloitte was previously engaged to assess the evaluability of the four LETFF programs under Phase One of the impact evaluation of the LETFF, to inform design and resourcing of any future impact evaluation to be undertaken in Phase Two. The evaluability assessment sought to answer three key questions:

- Was it plausible to expect an impact from the programs?
- Would an evaluation be useful, and, if so, to whom?
- Would an evaluation be feasible, based on: program evidence, data availability, baseline measures, and reporting mechanisms?

The evaluability assessment found that overall, it was reasonable and plausible to expect that the projects and activities delivered under the LETFF programs could achieve intended short-term and, to some extent, medium-term outcomes and impacts. It was not plausible to expect that the LETFF programs could reasonably have achieved the strategic longer-term objectives of demonstrating and deploying LETFF on a commercial scale, thereby reducing GHG emissions.

The evaluation assessment confirmed there was strong stakeholder support and interest for an impact evaluation. It advised that in the absence of delivery of any commercial scale projects, an impact evaluation should focus on the achievement of short and (to some extent) medium-term outcomes to guide future policy focus and direction. It also noted that any future impact evaluation of LETFF programs will require drawing on a range of qualitative evaluation methods, with a focus on stakeholder interviews and surveying, documentation review, and case studies.

The evaluability assessment recommended that the Department undertake a targeted impact evaluation of the LETFF programs that focuses on assessing the extent to which the LETFF programs have resulted in changes over the short- and medium-term against the following program outcomes:

- generation of new research, data and modelling relating to the practical and technological use and implementation of LETFF (short-term outcome)
- improved industry knowledge regarding the feasibility and safety of low emissions and abatement technologies, through collaboration and dissemination of findings from pilot and feasibility studies (short-term outcome)
- development of domestic skills and capability in low emissions and abatement technologies (medium-term outcome).

The evaluability assessment also recommended a future impact evaluation should also assess:

- whether industry knowledge and understanding of the feasibility and safe development of LETFF would have progressed in the absence of the LETFF programs
- whether changes in policy settings and other external factors have affected the ability of LETFF programs to achieve stated impacts.
- implications for future policy development and priority setting, including the role (if any) of the Commonwealth Government in supporting the further development and implementation of LETFF.

1.5 Report structure

This report presents the findings of the impact evaluation of the LETFF programs. The report is structured as follows:

- Chapter 2 outlines the approach to the impact evaluation.
- Chapter 3 presents the contributions made by the LETFF programs to knowledge, skills and industry understanding.
- Chapter 4 discusses factors contributing to the achievements of the LETFF programs.
- Chapter 5 discusses the success of the LETFF programs, including areas of future research and the role of government in supporting the development of LETFF.
- Chapter 6 presents learnings for future program design.

2 Evaluation methodology

The impact evaluation uses a mixed methods approach, including semi-structured interviews, an online questionnaire and secondary data analysis, including citation analysis, to assess the extent that the LETFF programs have contributed to increasing knowledge, skills and capability, and improving industry understanding of LETFF.

2.1 Evaluation framework

An evaluation framework has been developed to guide this evaluation. It outlines the key questions and data sources to be drawn on to address each evaluability question, and was developed in consultation with the Department. The evaluation framework has guided the key lines of enquiry and systematic organisation of analysis to ensure a consistent and robust assessment of the LETFF programs and project activities. The framework is presented in Appendix B.

2.2 Data collection and analysis

2.2.1 Semi-structured interviews

Semi-structured interviews were conducted with key LETFF program stakeholders from the Department, Commonwealth science agencies (e.g. CSIRO and Geoscience Australia), participating State Governments, industry grant recipients and representatives, academic and research grant recipients, and expert advisers. All stakeholders engaged had direct involvement in the LETTF programs. Contact details of key stakeholders were provided by the Department.

A total of 18 semi-structured interviews were conducted. An interview guide was developed based on the evaluation framework as a guide. Questions were tailored for each stakeholder depending on group and LETFF program(s) they participated in, and mapped to each evaluation question in the framework. Each interview was conducted via telephone and recorded. The interview was subsequently analysed in NVivo using coding techniques to identify common themes. A summary of stakeholders interviewed is provided in Appendix C **(to be provided in an amended Draft Report)**.

2.2.2 Online questionnaire

An online questionnaire was developed to gain further insights on stakeholders' perceptions of the impact of the LETFF programs, the factors that may have assisted or hindered the achievements, and the overall success of the LETFF programs. A total of 17 respondents completed the online questionnaire. A summary of the spread of respondents is provided in Appendix C **(to be provided in an amended Draft Report)**.

The online questionnaire was sent to the same cohort of stakeholders (via emails provided by the Department) as the semi-structured interviews, and stakeholders were then invited to forward the survey on to their peers and colleagues who had also been directly involved with the LETFF programs. As such, the online questionnaire has not enabled a true triangulation of findings relative to the interviews, however the questionnaire did provide further richness of insights with respect to the impact of the LETFF programs and supplemented the findings of the interviews.

2.2.3 Program data

The project has involved an examination of departmental documents and data and other publicly available information, to provide insights on impacts achieved by LETFF programs, including:

- final project reports
- research papers, scientific papers, technical papers produced under the LETFF programs
- project specific datasets and models
- broader literature on relevant themes.

A literature scan of research and scientific papers produced under the LETFF was undertaken due to extensive body of documentation produced. A scan of 496 publication available reports matching key search criteria was undertaken to provide sufficient insights into the impact of the

LETFF programs. This ensured an appropriate breadth and depth of documents were reviewed across the LETFF programs.

Key document sources included Department-held documentation, in addition to data, reports and documentation held by:

s22
- Global CCS Institute data and documentation
- CO2CRC
- CSIRO
- Geoscience Australia.

2.2.4 Citation analysis

The project has involved a citation analysis of 496 program publications to gauge the extent to which knowledge transfer has occurred as a result of the LETFF programs. The citation analysis has involved:

- cited reference analysis – the number of times that research publications produced by the LETFF programs have been in journal articles or scientific publications based on Google Scholar data.
- publication use – the number of times that research publications produced by the LETFF programs are accessed or requested online (where this data was available).

The results of the citation analysis were then triangulated with semi-structured interviews and results from the online questionnaire.

2.2.5 Case studies

Case studies of LETFF projects were developed from across the programs to enable the generation of findings about the program that are more generalizable. Case studies were developed from primary and secondary data sources, and illustrate the extent to which specific projects have contributed to the achievement of focus outcomes. Two case studies have been developed for each program, with the exception of the LETDF program.

Case studies are outlined in Appendix D **(to be provided in an amended Draft Report)**.

2.3 Limitations of methodology

The focus of this project is an impact evaluation of specific short and medium-term outcomes of the LETFF programs. Specifically, the intent is to assess the impact of the LETFF programs on increasing knowledge, skills and capability, and on improving industry understanding of LETFF. The project has not sought to assess the extent to which the LETFF programs have achieved any other medium or longer-term outcomes.

The qualitative data presented in this report reflect the opinions and perceptions of stakeholders engaged during the evaluation. These opinions and perceptions are presented as originally communicated. Stakeholders engaged in this evaluation have all had direct involvement in the LETFF programs. Stakeholders, by virtue of their involvement in the LETFF programs, may have had an inherent bias in their view of achievements and outcomes.

This evaluation has not engaged any stakeholders external to the LETFF programs, such as representatives of alternative technologies or programs.

The project has been limited by the significant lapse in time since the commencement of the LETFF programs and subsequent implementation. Specific issues that limited this evaluation include:

- the natural turnover of program staff; the Deloitte team was unable to engage with departmental stakeholders who had been involved in the programs since inception
- the natural turnover of participating industry and academic stakeholders; many key project proponent staff and external expert advisors have subsequently left their roles and/or organisations, meaning the Deloitte team was unable to speak to stakeholders from across all projects and activities. As such, only a sample of relevant stakeholders could be reached for the purpose of the evaluation.

3 Contribution to knowledge, skills and industry understanding

Key findings:

- The LETFF programs **have significantly contributed to increasing knowledge, skills and capability, and improving industry understanding of LETFF in Australia.** Overall, Australia has the research and engineering capability to develop commercial scale LETFF projects.
- Australia now has:
  - **a mature knowledge base** with multiple industry participants with knowledge of LETFF, supported by a broad body of research covering multiple technologies
  - **a moderate level of domestic skills and capability**, with expertise across a range of organisations and LETFF
  - **a moderate industry understanding** of the technical and practical feasibility of LETFF under a range of processes and conditions.
- A significant body of research has been delivered across the full spectrum of LETFF activities - the critical research and development and technical barriers are considered to be largely settled for CCS.
- Australia's pool of research and technical skills and capabilities is considerably larger, more developed and vastly more experienced relative to prior to commencement of programs.
- Research capabilities are more advanced than industry capabilities. Deployment of LETFF is required to further advance industry skills and capabilities.
- There is a risk of Australia losing the skills and capabilities developed if momentum is not maintained given the global demand for skills and expertise.
- The LETFF programs have resulted in industry developing a detailed 'end-to-end' understanding of the engineering and design of LETFF, in particular CCS technologies.
- There is a consensus that the coal, energy generation, and oil and gas sectors have an understanding of the practical, technical and financial requirements necessary to deploy CCS.
- However, the absence of a commercial imperative to invest in emissions abatement remains the overarching barrier to LETFF deployment in Australia.

3.1 Overall contribution of LETFF programs

Overall, there is consensus among industry, government and academic stakeholders involved in the LETFF programs that these programs have significantly contributed to increasing knowledge, skills and capability, and improving industry understanding about low emissions technologies in Australia.

There is broad stakeholder agreement that the advances in Australia's understanding of LETFF and their implementation – particularly around geological subsurface storage – would not be where it is today in the absence of the LETFF programs (discussed in greater detail in Section 5.2).

Stakeholders highlighted that the LETFF programs have involved an incremental learning process for industry, academia and government. Individual project outcomes have contributed towards a broad portfolio of achievements, rather than one single, flagship success. Even 'failures' have

provided valuable learning opportunities and insights, with most stakeholders indicating the importance of discovering what didn't work to be just as important as knowing what works.

Australia is now considered to be 'deployment ready' from a technological perspective. Australia is considered to have a mature knowledge base, supported by a well-developed body of research, with moderate skills and capability across specific LETFF (particularly CCS), and considerable industry understanding of the practical and technical feasibility of LETFF under a range of Australian conditions. There is strong agreement across all stakeholder groups that the priority for LETFF is to shift to commercial-scale deployment. Figure 3.1 illustrates the shift in the level of knowledge, understanding, and capabilities since the commencement of LETFF as perceived by key stakeholders.

Figure 3.1: Summary of the perceived shift in Australia's LETFF knowledge, understanding and capabilities since 2005

Stage	State of knowledge	Understanding of technical and practical feasibility	Local industry skills and capability
5	Deep and broad sector knowledge throughout industry, supported by extensive body of research covering full range of LETFF technologies.	Extensive industry understanding of technical/pract cal feasibility of full range of LETFF technologies under full range of processes and condit ons.	World leading industry skills and capability located w thin a wide number of industry and research organisations and across the broad spectrum of LETFF technologies.
4	Broad sector knowledge across major ty industry part cipants, supported by large body of research covering large range of technologies.	Broad industry understanding of techn cal/practical feasibility of LETFF technologies under most industrial processes and condit ons.	Broad local industry skills and capability across a large number of industry and research organisations and a across the majority of LETFF technologies.
3	Sector knowledge is moderate, w th multiple industry part cipants having knowledge of LETFF technologies, supported by a moderate body of research covering multiple technologies.	Moderate industry understanding of technical/pract cal feasibility of LETFF technologies under some processes and cond tions.	Moderate local industry skills and capability, with expertise across a moderate number of organisat ons on a moderate range of LETFF technologies.
2	Sector knowledge is thin, w th only select industry part cipants having meaningful knowledge of LETFF technologies, supported by a small body of research focussed on one or two technologies.	Lim ted industry understanding of techn cal/practical feasibility of LETFF technologies under 1 or 2 industrial processes.	Thin but growing local industry skills and capabil ty, w th expertise located across a handful of industry and research institutions.
1	Sector knowledge relating to pract cal, technolog cal and scientif c use and implementation of LETFF technologies is minimal/non-existent.	No industry understanding of techn cal/practical feasibility of LETFF technologies.	Niche local industry skills and capability, with only lim ted expertise.

High

Low

Source: Deloitte Access Economics

The LETFF programs have contributed to providing Australia with a detailed 'end-to-end' understanding of CCS, with stakeholders agreeing that the major research development questions and technological barriers largely settled and overcome. The LETFF programs have contributed to a clear understanding of the 'pathway to deployment' for LETFF and in particular CCS, including:

- the capture, transport, storage and injection technologies involved
- the costs and timeframes involved
- which technologies to deploy and under what conditions
- the locations and suitability of storage sites where technologies can be best deployed.

3.1.2 State of knowledge, capabilities, and understanding prior to commencement

Prior to the commencement of the LETFF programs, stakeholders reported Australia's knowledge and understanding of LETFF as predominantly conceptual and theoretical in nature. Understanding of how LETFF might be practically implemented was very limited, although it was noted that the oil and gas sector had a deeper understanding than other sectors, given the integral nature of drilling

in this sector. Overall, stakeholders reported that Australia, in general, had a limited knowledge and understanding of:

- the location, capacity and sub-surface condition of geological resources (both onshore and offshore)
- long-term stability of geological resources and how they would react with CO_2
- different emission capture technologies and application to Australian conditions and industrial processes
- the behaviour of CO_2 plumes under different sub-surface conditions, and how to model the behaviour of CO_2 plumes
- the behaviour of CO_2 during transportation
- the end-to-end engineering and design of capture and storage technologies
- the full life-cycle costs of designing, building and operating commercial-scale LETFF.

Additionally, there was no arrangement in place to structure the existing knowledge base, to direct the advancement of new research, or to provide a knowledge-sharing platform between government, academia and industry. Stakeholders described Australia's knowledge-base as follows:

> *"… we didn't have a good idea of where the basins were. We didn't know much about the capture technologies, we didn't know if there was Enhanced Oil Recovery potential" –* Academic/research stakeholder

> *"…there was theoretical knowledge, but less knowledge of [how] it [will] actually work in practice [There was] a gap in the knowledge in terms of the application* – Government stakeholder

> *"Go back probably 20 years, I would say that the Australian state [of knowledge] was developing. I wouldn't say it was embryonic, I'd say we were better than embryonic, but I think we were developing…. We were by no means near deployment-ready." – Academic/research stakeholder*

This is not to say that Australia did not have a meaningful understanding of LETFF relative to other developed countries – such as the European Union, the U.S., the U.K., or China. On the contrary, stakeholders interviewed reported Australia's academic and scientific research community had pockets of recognised world-leading skills and expertise. Examples identified by stakeholders include:

> *"Geoscience Australia did some very early work in geological storage… very basic basin work to get some capacity work [back] in the 90s."* – Academic/research stakeholder

> *"Geoscience Australia had been working toward CCS aspects as well and then we had CSIRO… CSIRO had been working on capture technologies at a small scale across a few sites…. There [were] capture engineers at Monash and Melbourne Universities… so that knowledge was there at a research phase."* – Academic/research stakeholder

Within industry, however, there was a lack of the technical and practical type skills necessary for deployment and implementation – such as engineering and operational type skills.

> *"… it would have been the researchers and not industry in those early days that had the expertise or understanding as well."* – Commonwealth Government stakeholder

> *"… not as much as the practical engineering because it hadn't been deployed in Australia… not enough for a full industry, which is what we very rapidly found out when the flagship projects were launched there just weren't enough people to do all the work and so what we had is the same people doing a lot of the work…"* – Research stakeholder

Across industry, there were also certain sectors that were more advanced in their understanding of and engagement with LETFF than others. Stakeholders singled out the Oil and Gas sector, in

particular, as having well-established understanding and capabilities relating to carbon capture and storage (CCS) technologies:

> *"…the Oil and Gas industry in 1999… they were fine. …injecting CO_2 and withdrawing gas from the subsurface, this is their daily bread…these guys have been doing EOR [Enhanced Oil Recovery] for 40 years. They have been injecting CO_2 for 40 years, they know how to do this."* – Academic/research stakeholder

> *"… [the Oil and Gas industries] were already way up the learning curve both in terms of capture technology and in terms of injection…"* – Industry stakeholder

In contrast, other emissions-intensive industries had yet to commence investigating the potential of LETFF in detail. In particular, the coal, energy generating, industrial (e.g. steel, concrete, and fertiliser) and agricultural sectors had yet to meaningfully investigate and engage in the development of low-emission, abatement, or monitoring technologies emission abatement and capture technologies. As some stakeholders noted of these sectors:

> *"… there wasn't necessarily much appetite to engage… there wasn't a significant driver… until I suppose the carbon taxes and things came in at that time.… as far as I understand industry weren't totally engaged."* – Commonwealth Government stakeholder

> *"…at the moment without a clear driver to do something about your CO_2, maybe there is not as much appetite to actually take up CCS, but these would be the industries that would be interested if suddenly there was a clear driver to deal with their emissions."* – Commonwealth Government stakeholder

3.1.3 State of knowledge, capabilities, and understanding today

Today, stakeholders reports that the breadth and depth of Australia's knowledge, capabilities and understanding of LETFF, in particular CCS, is significantly greater than it was prior to the commencement of the LETFF programs. Overall, stakeholders reported significant improvements in Australia's knowledge and understanding of:

- the 'end-to-end' of the implementation of low-emissions technologies, including:
  - integrating low-emissions technologies with existing production systems
  - proving low-emissions technologies under Australian conditions
  - cost discovery of implementation
  - safety and environmental implications
  - regulatory approvals process
- monitoring and measuring greenhouse gas emissions
- Australia's geological subsurface storage potential and capacity, including:
  - the importance of subsurface storage in the CCS process
  - identification of suitable subsurface storage locations, and their potential capacity
  - dynamic modelling the geological subsurface behaviour of CO_2.

The consensus among stakeholders from across industry, government, and academia is that Australia's knowledge and expertise is now well-past the conceptual and theoretical R&D phase. Australia now possesses the research and technical foundations, including an understanding of the technical challenges, costs, and risks to progress to commercial-scale deployment. Australia is considered to 'hit above its weight' with respect to LETFF on a global stage. As noted by stakeholders:

> *"… in Australia, we have a range of stakeholders that are probably world leaders in terms of understanding the whole value chain of CCS, whether it be understanding capture technologies inside the CSIRO… they are world leaders and they are winning grants from other countries at the moment. I think that monitoring and storage activities … the CO2CRC are world leading … I think we have a much better understanding of the underground storage potential in Australia, both onshore and offshore, more work to be done in that space, but when you compare 10 years ago to now… we have made great*

> *progress on the technical front of understanding CCS and I don't disagree with some people who have said we have conquered the technical barriers."* – Commonwealth Government stakeholder

> *"… we have done all the engineering to the point of construction, so from not even knowing which technology to choose, to now having chosen a technology and done all the upfront engineering, partnering with the technology providers, so that a construction decision can be made with, actually can be made today if we had the money. … That's actually been a dramatic shift"* – Industry stakeholder.

Overwhelmingly, stakeholders agreed that the progress made is almost completely attributable to the LETFF programs and the support from the Commonwealth. As one stakeholder noted:

> *"I think we would still be stuck in the theoretical research phase. I am including CSIRO in here, which are probably a little bit beyond our program funding. … So, apart from some of the work that they may have done, I think it would just still be a research activity."* – Commonwealth Government stakeholder

However, the advances in knowledge, skills and capability and understanding have been more concentrated in certain sectors than others. In particular, there was consensus among stakeholders that the advances in knowledge and capabilities in the academic and scientific research community far outweighed advances in the coal, energy generating and industrial sectors. As noted by a stakeholder:

> *"… the skills level of the academic community has indeed increased, but it's the academic skills level and not the industrial deployment skills level…"* – Industry stakeholder.

Despite the gains that have been made over the last 15 years, there are gaps that remain and new gaps that have emerged. Overall, stakeholders identified the following gaps:

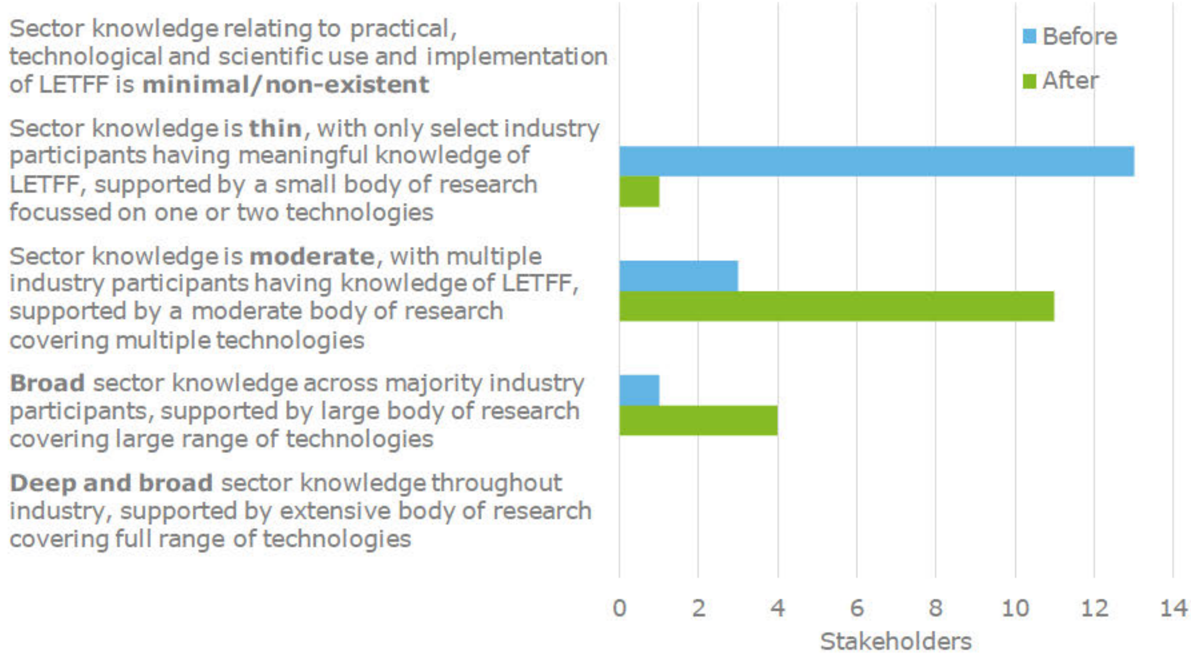
- the need to consolidate the knowledge and understanding of LETFF gained to date
- improving the accessibility, dissemination and communication about LETFF across industry sectors and the broader community
- detailed local and site-specific understanding of suitable onshore and offshore subsurface storage potential and capacity
- demonstration and deployment of LETFF on an industrial-scale, and the absence of an established CCS industry in Australia
- lack of experienced engineering skills and capabilities (mechanical, electrical etc.) for the industrial-scale deployment and operation of LETFF and CCS technologies.

3.2 Generation of new research and knowledge

There was consensus among stakeholders interviewed that Australia's overall state of knowledge progressed from being perceived as 'thin' prior to the commencement of the LETFF programs, to a mature moderate knowledge base underpinned by a well-developed body of research across multiple technologies.

This view was supported by the findings of an online questionnaire of LETFF stakeholders. Chart 3.1 illustrates the perceived change in the overall state of knowledge and understanding with respect to LETFF.

Chart 3.1: Overall state of knowledge before and after the commencement of the LETFF programs



Source: Deloitte Access Economics

In addition to the improvement and expansion of the domestic skills base, the LETFF programs are attributed with having generated a range of new and original research and technical innovations. These include outputs such as:

- **Data tools** – geological seismic data, atmospheric measurement data, and technical test data
- **Modelling tools** – geological subsurface storage mapping, models of CO_2 subsurface behaviour, energy market modelling, as well as financial models of commercialisation,
- Technological **innovations** – digital drill core technology s22
- **Methodological improvements** – improved methods for monitoring greenhouse gas emissions, technical operation methods that improve efficiency or safety, project management methods that improve the up-scaling and commercialisation of technologies
- **Formation of new relationships** – the value of the new relationships formed between industry, government, and the academic and scientific communities, as well as relationships formed between these communities in Australia with other people, communities and institutions overseas.

These provide the foundation tools and resources for industry and government to further invest in LETFF and CCS technologies with greater certainty in regard to the costs associated with deployment and ongoing operation, safety and environmental considerations, and the efficiency of production.

In addition to the above, the LETFF programs have contributed a significant body of **publications,** including academic journal articles, discussion papers, PhD dissertations, conference presentations, government policy documents, and interim and final project reports.

3.2.2 Examples of the types of innovations and knowledge generated

While a rigorous and accurate stocktake of the new research and knowledge generated is beyond the scope of this report, Table 3.1 summarises several key innovations developed across the LETFF programs identified by stakeholders.

Table 3.1: Examples of key innovations attributable to LETFF programs/projects

Title (LETFF project)	Description
s22	
Greenhous Gas Emissions Monitoring	*"… improved methodologies for measuring methane emissions from open-cut coal mines on a continuous basis … setting up monitoring stations and continuously monitoring the methane from the mines and using [ocean and atmosphere] modelling to calculate what the emission rate would be."* – Research stakeholder
s22	

As reported above, the LETFF programs have generated a significant body of research. A summary of a desktop literature scan of 496 publically available publications associated with LETFF programs and projects, as well as the results of a citation analysis, are summarised in Table 3.2 (below). Although generating published material was not an intended outcome of the LETFF programs, they provide an indication of the knowledge generated and of the understanding that has been disseminated.

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The citation analysis indicates the number of times that published materials have been cited in other domestic and international publications, providing an indication as to the extent that learnings and knowledge gained through the LETFF programs have been drawn upon and utilised in other research. Overall, the results indicate that the published material generated through the LETFF programs have been widely disseminated, and gone on to influence and inform a wider body of research and knowledge. This further supports stakeholders' observations of Australia as having world-leading research expertise and of the contribution of Australian expertise and knowledge internationally.

Table 3.2: Summary (broad) of LETFF program/project publications

LETFF program/ project	Publications No.	%	% scholarly articles	No. of citations	Citations per publication
CCS Flagships	65	13%	2%	170	2.6
s22					
LETDF	23	5%	39%	1,105	48.0
s22					

Source: Deloitte Access Economics

Notes: These estimates only include publically available publications.

Despite the plethora of publically available published materials, many materials and information remain undisclosed. There are many more publications that are held internally by government departments and scientific agencies, industry associations, or are held by 'pay walled' repositories (e.g. the CO2CRC). There is a perception among stakeholders is that this acts as a constraint on the transfer of knowledge and the wider dissemination of learnings from one project to another, and is a barrier to the commercialisation of low-emissions technologies and to the establishment of a CCS industry in Australia. s22

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Another stakeholder acknowledged that knowledge of the published information available is dependent on informal personal and community networks. That is, information sharing is about 'who you know':

> *Do we have some nice summary, not that I am aware of. … it is not on a central connected basis… The answer is an informal kind of network of people know each other, which is not ideal for information sharing."* – Commonwealth Government stakeholder

When done right, however, effective information sharing with the wider public is credited with supporting community engagement and enabling the future deployment of LETFF. As one stakeholder remarked:

> *"… the CO2CRC has done a marvellous job in addressing public concerns and public education with their Otway site. It is regarded as one of the world's best practice in that region."* – Research stakeholder

3.2.3 Summary of the intangible forms of knowledge generated

Stakeholders also identified the importance of the value of less tangible outcomes that were generated as a result of the LETFF programs.

Stakeholders widely acknowledged that the LETFF programs have encouraged collaborations between governments, industry, and the academic and scientific communities within Australia. Stakeholders from each of these communities identified the collaborative nature of the

LETFF programs as having an immense benefit for creating networks amongst groups that were unlikely to have otherwise engaged with one another.

For government, the deepening of relationships with industry and the academic and scientific research communities is credited with contributing to improved decision-making, in terms of informing the formulation of regulatory and legislative frameworks. The Gorgon Carbon Dioxide Injection project is an example of where the LETDF facilitated information sharing between the Commonwealth Government and industry partner Chevron, and generated an improved and informed policy outcome. As one industry stakeholder noted:

> *"… it was Chevron's deep understanding… of the policy and regulatory issues around [the Gorgon] project that heavily influenced the development of the [Offshore Petroleum and Greenhouse Gas Storage Act] … Chevron was heavily involved in that process where [the] lessons learnt from how the Gorgon project was going to be regulated under a project-specific legislation [were taken] and used that to help inform the Australian government in development of the greenhouse gas storage provisions they had bought on to the petroleum act. … [Chevron] used the thinking around legal and regulatory aspects around Gorgon to frame and influence how the Australian government was to regulate CCS. So, a lot of the federal generic legislation in this space comes from lessons learned from Gorgon, and that model has been picked up by a couple of other states."* – Industry stakeholder

In turn, this close relationship between Chevron and the Commonwealth Government and how it informed the development of the *Offshore Petroleum and Greenhouse Gas Storage Act 2006* is credited with helping to facilitate the establishment of the other LETFF projects, such as CarbonNet. As noted by one stakeholder:

> *"… it's quite ground-breaking… the regulatory framework that the Commonwealth has put it, because obviously that's the lever that [government] have responsibility for, so the Offshore Petroleum and Greenhouse Gas Storage Act has really I think incentivised and given industry a mechanism to at least put offshore CCS in their repertoire and that's obviously being exercised now through CarbonNet, they wouldn't have done that without that act."* – Commonwealth Government stakeholder

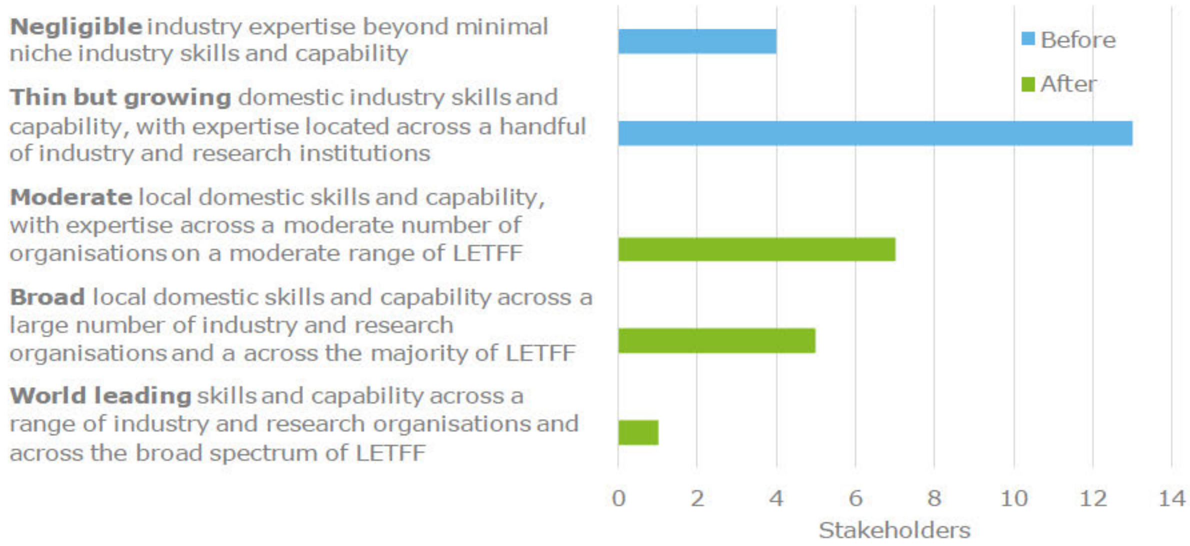
The LETFF programs are also credited with establishing valuable international collaborations between Australia and several countries developing low-emissions technologies – such as, the U.S., the U.K., the European Union, Japan, and China. In particular, stakeholders identified the value of the relationships formed through the Australia-China Joint Coordination Group funded through the CCS Flagships program. These relationships enabled Australia to access technology and expertise that would have been extremely costly to develop domestically. In return, Australia provided its expertise of regulatory frameworks, as well as project management methods (e.g. delivering projects safety, on time, and on budget). As noted by one stakeholder:

> *"the skills transfer was really quite significant, not just for the Australian government and other stakeholders in regard to accessing Chinese knowhow, and how they do it, but the Chinese certainly learned from us too … we were able to get the true and accurate set of estimates out of the Chinese stakeholders and out of the Chinese government… which speaks volumes about the quality and the importance of this project."* – Industry stakeholder

3.3 Development of greater domestic skills and capabilities

In general, stakeholders interviewed perceived that the LETFF programs had contributed to a considerable increase in skills and capabilities. Australia's overall state of skills and capabilities progressed from being perceived as **'thin but growing'** prior to the commencement of the LETFF programs, to moderate with expertise across a range of industries and research organisations. This is supported by the findings of the online questionnaire (see Chart 3.2).

Chart 3.2: Industry understanding of technical and feasibility of low-emissions technologies before and after the commencement of the LETFF programs



Source: Deloitte Access Economics

As prefaced earlier, the LETFF programs are considered to have contributed to attributed with improving and expanding the capacity capability of academic and scientific research skills at the key research institutions – such including as, CSIRO, and Geoscience Australia, Melbourne, Monash and Newcastle universities, as well as and CO2CRC and s22 Australian Petroleum CRC, ACARP and COAL21. Overall, stakeholders agreed that the skills and capabilities developed across academia were far more advanced than industry. As remarked by stakeholders:

> *"… a lot of the money has gone to the research group, so they are far more skilled than the engineering is because they have had the funding to do the research … it's going from being scientists wanting to do the research to now scientists having done the research."* – Industry stakeholder

> *"… I would say that the scientists are ahead of the engineers because the scientists have just been doing this stuff, but they can't do what engineers do and the engineers need…the time is not for R&D, the time is for doing and the scientists will then have access to real data rather than lab data."* – Industry stakeholder

However, stakeholders recognised that Australia's technical and engineering capabilities have also developed and improved through the LETFF programs, with Australia now possessing the technical and practical engineering skills necessary for deployment and implementation. There was a common view that commercial deployment is required to enable any further advancement of industry skills and capabilities. As described by one stakeholder:

> *"… we had the engineering infrastructure, but with inexperience in this technology. … at least now the engineering capability is ready to take that next step to implement, but until we have implemented, we haven't really learned all the lessons."* – Industry stakeholder.

Some stakeholders reported that through the LETFF programs Australia has developed world-leading skills and expertise, and those skills are now sought by the other countries:

> *"We actually got a group who we thought where the world's best reservoir engineers come over from University of Texas and … they felt the reservoir engineering capabilities of CO2CRC and our research members, such as CSIRO and Curtin are the best in the world"* – Academic/research stakeholder.

> *"… we basically trained up all the CCS specialists in Australia and now they have gone all around the world."* – Research stakeholder

Within industry, the LETFF programs also contributed to an 'up-skilling' and expansion in the capacity of technical and practical engineering type skills, particularly in the industry sectors that were most engaged in LETFF – that is, the coal mining, and oil and gas sectors. In addition, the LETFF programs also prompted a shift in the composition of the types of specialist skills demanded. As industry began to investigate the feasibility of integrating LETFF within existing processes, stakeholders identified increased demand for a range of engineering disciplines across the oil and gas, coal and energy generating sectors. As one stakeholder noted:

> *"We need engineering, so we need design…electrical, we need mechanical, we need ventilation specialist, we need mining specialist… risk specialists…"* – Industry stakeholder

Within the energy generating sector, there was also in an increased demand for specific engineering skills sets that were previously not associated with that industry sector, particularly chemical engineering capabilities.

> *"The big issue for them is that they went from a business of mechanical engineers, they had to go to a business of chemical engineers and that was the big problem for them."* – Research stakeholder

The composition of skills required also shifted as knowledge and understanding about the importance of geological subsurface storage became a key priority. This resulted in a shift toward and expansion of geotechnical engineering capabilities across industries.

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An exception to this is the dissemination and transfer of technical skills from the academic and scientific research communities to government. A range of stakeholders noted that the Commonwealth Government was able to readily access and draw upon specialist technical and scientific skills, particularly from CSIRO and Geoscience Australia. This supported better informed decision-making.

However, several stakeholders noted the risk of potentially losing the specialist expertise built up over time to other countries – and with it one of key Australia's competitive advantages internationally – in the absence of the eventual deployment of LETFF.

3.4 Industry understanding of low emissions technologies

In general, stakeholders perceived that there was an increase in industry understanding following the commencement of the LETFF programs. Overall, stakeholders reported that LETFF programs enhanced industry's understanding with respect to:

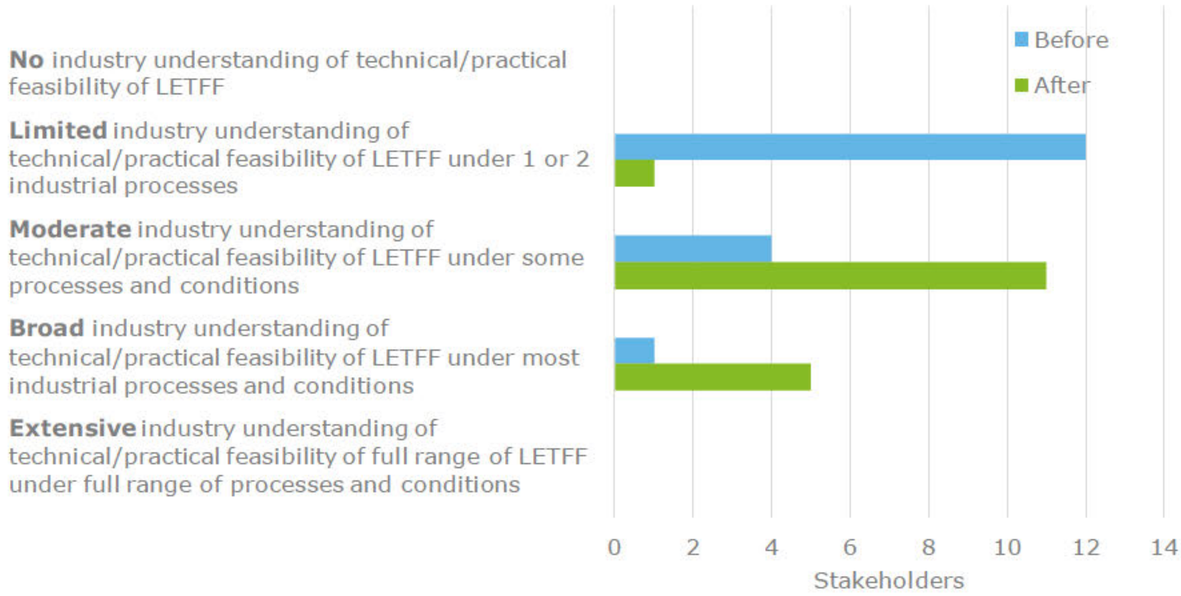
- the appropriateness and effectiveness of particular technologies at an industrial-scale
- the importance of geological subsurface and storage conditions to successful deployment
- greater certainty about the costs, timeframes, and risks involved in commercialisation.

As described by one industry stakeholder:

> *"When you look at all the work we have done to support various demonstrations… I can't help thinking that we are better placed than many of the other countries or most of the other countries when it comes to knowledge to deploy."* – Academic/research stakeholder

Using the survey responses of stakeholders, Chart 3.2 illustrates that industry understanding is perceived to have gone from being limited to now being at a moderate to broad level of understanding.

Chart 3.3: Industry understanding of technical and feasibility of low-emissions technologies before and after the commencement of the LETFF programs



Source: Deloitte Access Economics

There is a consensus among stakeholders that the LETFF programs have contributed to industry now having a detailed 'end-to-end' understanding of the engineering and design of LETFF, in particular CCS technologies. Large projects such as CarbonNet and SouthWest Hub, for example, were identified as having provided industry with valuable practical and technical insights about the pathway to large-scale commercialisation, in terms of cost-discovery and the engineering design process involved. As stakeholders noted:

> *"... projects like the CarbonNet project, like the Southwest Hub project really did allow us to get a better understanding of 'yes there is a theoretical capability to put CO_2 in these places, but here are the real commercial understandings and then capabilities that we need to improve on to do that effectively"* – Academic/research stakeholder

> *"The [projects] that have probably added most to the knowledge set are the ones where, for example, CarbonNet is really testing the whole end-to-end from the technical, regulatory through to the commercialisation."* – Commonwealth Government stakeholder

> *"CarbonNet who have tested the whole regulatory pathway more or less now or have a great understanding of it and will start drilling appraisal wells offshore within 6 to 12 months, fingers crossed. We've captured a lot of lessons."* – Commonwealth Government stakeholder

More important to industry than any single LETFF project, however, is the combined and cumulative 'end-to-end' understanding that has been gained from the portfolio of LETFF projects – 'successful' and 'unsuccessful' projects. That is, the value of the iterative nature of the journey that industry and government have been on, and the importance of the learnings from each successive step at informing the direction of the next. As two stakeholders remarked:

> *"...as a complete package of knowledge, as they have gone from step to step to step, we know what we need to do now. So, I will call that a great success ... if you are only involved at each of the little steps and that's all your involvement is, you can see each one as a failure because it didn't reach the grand scale, but in combination they have honed in on and now we know exactly what we need to do. ... We have the luxury of staying with this whole landscape for the last 12 years and taking this whole picture to learn at each of the different steps."* – Industry stakeholder

> *"… it's quite easy to look at the individual components and say we haven't actually achieved much, but for those that are able to look across the broad suite of projects and programs around capture, storage, transport, understanding where you might drill, understanding what you might retrofit, … there is a view that we have a very compelling understanding now across the implementation of CCS if you put it altogether, which we didn't have before…"* – Government stakeholder.

Even the LETFF projects widely perceived as failures (such as ZeroGen) or those perceived as being challenged and delayed (such as Gorgon), have provided industry with crucial learnings. ZeroGen, for example, despite its perceived failure, is credited with providing industry crucial learnings about the commercial viability of Integrated Gasification Combined Cycle (IGCC) technology (see Box 3.1).

ZeroGen project: a successful failure

Prior to the commencement of ZeroGen IGCC technology was considered to be the highest efficiency for low-emission coal energy generation:

> *"[IGCC Technology] was at that time seen as being the big technology, that is kind of like the biggest break, and the reasons for that was its high efficiency, it was sort of like the big bang theory. It's the highest efficiency, the biggest one, it's going to make the biggest difference at a cost. So on a CO_2 stored dollar basis, it was going to be the way to go."* – Industry stakeholder

However, following a detailed engineering feasibility study of the cost involved in establishing a new build IGCC plant at the ZeroGen site selected in Queensland, it was determined the cost of a new build under Australian conditions would be substantially greater than initially anticipated, and significantly higher than retrofitting Post-Combustion Capture technology to an existing coal fired power station.

> *"what the ZeroGen work did then which is pretty unique because it was…partly because it was a fundamentally rigorous engineering study. Because it did enough work to uncover all the hidden costs… and those costs always escalate significantly, and what we were able to do in the feasibility study of ZeroGen was figure out how those costs do escalate."* – Industry stakeholder

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While industry had a 'desktop-understanding' of Australia's geology and of the potential for subsurface storage sites, very little consideration had been given to the detailed understanding of the potential capacity and suitability of these basins or reservoirs for purposes of storing CO_2. Understanding the geological subsurface for the safe storage of CO_2 is now considered by industry as one of the key components, along with low-emission and capture technology, to the successful deployment of LETFF on a commercial scale. Geological considerations as a critical area of future research is explored further in Section 5.4.

3.5 CCS Flagships Research Development and Development (RD&D) fund

The CCS RD&D fund aims to reduce technical and commercial barriers to the deployment of large-scale carbon capture and storage projects by contributing new knowledge with respect to:

- Australia's understanding of its geological capacity to permanently store carbon dioxide
- enhanced understanding of how CO_2 plumes behave in Australian conditions
- improved knowledge of Australia's CO_2 supply chain requirements
- harnessing international knowledge and expertise and build international relationships that progress global understanding of CCS
- lowering the cost of technology adoption and deployment in Australia.

The CCS RD&D fund has yet to be completed, and is beyond the scope of this evaluation. However, a summary of the intended knowledge to be generated across the CCS RD&D fund is summarised below.

Project	**Project description**	**Intended knowledge to be generated**
Northern Australia CO_2 Store	This project builds on work carried out by Geoscience Australia's regional assessment of the CO_2 storage potential in the Petrel Sub-Basin (PSB) in NT. Project objective is to de-risk the area of interest within the PSB.	• Detailed subsurface knowledge of the PSB and local geological properties. • Understanding of the geomechanical, geochemical and geophysical properties of PSB, and behaviour of CO_2 in PSB. • Detailed assessment of equipment and facilities required to transport CO_2 from Darwin to PSB storage. • Determination of well numbers to accommodate CO_2 production.
CTSCo Integrated Surat Basin CCS project	This project delivers aspects of the CCS demonstration project that will enable a Financial Investment Decision for construction and deployment during 2018/2019, including technical, social and permitting aspects.	• Greater understanding of construction and deployment requirements of CO_2 test injection facilities. • Greater understanding of regulatory pathway for onshore storage of CO_2 in Australia. • Greater understanding of the financial viability of onshore storage of CO_2. • Greater understanding of community engagement with respect to CCS.
Australian Subsurface Carbon Sequestration Simulator	This project works towards improved understanding of how CO_2 behaves during geo-sequestration in the Australian subsurface and how this behaviour can be monitored.	• Improved simulation, forecast and monitoring of CO_2 plume behaviour. • Enhanced geophysical imaging of CO_2 plumes.

Project	Project description	Intended knowledge to be generated
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Improving safety and efficiency of CO_2 pipelines	Development of fracture and dispersion models to enhance design and reduce risk associated with CO_2 pipeline construction and development.	• Validated fracture arrest model/software and design requirements. • Validated dispersion model • Updates of Standards and Recommended Practices covering CO_2 pipelines • Development of cost benchmarks for CO_2 pipeline.
Surat Deep Aquifer Appraisal project	Assessment of real optionality for industrial scale CCS deployment linked to south-east Queensland stationary emissions generators.	• Provision of significant technical and cost information into the public (pre-competitive) domain to assist with ultimate industrial de-rising and planning. • Greater understanding of techno-economic and other deployment critical issues. • Enhanced methodologies for community engagement about energy choices (and within that how best to engage on CCS). • Discovery of the degree and criticality (costs, timing risks) to which CCS can be a real mitigation option for GHG abatement in Eastern Australia.

4 Factors contributing to achievement outcomes

Key findings:

- The commencement of LETFF programs were underpinned by clear policy direction and settings, support across Commonwealth and State Governments, and a significant funding commitment across a suite of programs and projects – factors that were critical to the achievement of outcomes.
- Other contributing factors to the achievement of outcomes included:
  - establishment of partnerships established between government, industry and academic stakeholders
  - the direct financial involvement of the coal industry in maintaining an industry-focussed research agenda
  - establishment of a portfolio of LETFF projects to maximise learnings and the probability of success.
- Changing, uncertain and inconsistent policy settings are considered the **primary factors** hindering achievements and progress across the LETFF programs. This resulted in significant **loss of confidence across industry and a loss of momentum in advancing LETFF**.
- The unexpected complexity of LETFF, rigidity of funding agreements, regulatory uncertainty and insufficient readiness on the part of the Commonwealth and State Governments have also hindered achievements and progress across the LETFF programs.
- The absence of a clear commercial imperative on the part of industry to invest in carbon abatement remains the single largest barrier to the commercial development and deployment of LETFF.
- Knowledge gained throughout the LETFF programs has not been disseminated to the broader public. Barriers to knowledge sharing and access to information have contributed to a 'poor' public understanding and acceptance of LETFF, and in particular CCS, and represent a barrier to the deployment of LETFF.

4.1 Factors that contributed to achievement of focus outcomes

There was consensus among stakeholders that the manner in which the LETFF programs were established was a major factor contributing to the achievement of focus outcomes (i.e. knowledge, skills and capability, and improved industry understanding). Specifically, stakeholders noted that the commencement of LETFF programs were underpinned by clear policy direction and settings, support across the Commonwealth Government and participating State Governments, and a significant funding commitment across a suite of programs and projects.[1] Stakeholders agreed that these factors provided a clear signal of government policy intent and focus to industry, and gave industry the confidence to participate and invest in the programs. As noted by stakeholders:

> *"The greatest assistance was right at the beginning when there was a common urgency, a common understanding that we all needed to do something. And by that, I mean the federal government, the state government, and the industry."* – Industry stakeholder.

> "[A key factor was] *the early decision to allocate funds to a suite of programs and have sort of a champion in cabinet to push these sort of issues through and make it a priority. I think it then just follows that your domestic stakeholders know that they have got backing*

[1] The original Commonwealth Government funding commitment across the four LETFF programs was approximately $2.8 billion.

> *through the government in real terms as in funding, but also from a national priority perspective"* – Commonwealth Government stakeholder.

Many stakeholders also identified the partnerships established between government, industry and academic proponents as being critical to the achievement of focus outcomes. This led to meaningful engagement between academic, technical experts, policy makers and industry proponents across the LETFF programs. In turn, these partnerships helped maintain strong technical and research capabilities to support the LETFF programs:

> *"The access that we have had to government and industry to assist with our research program has been probably the most significant factor for us." – Academic/research stakeholder.*

In particular, **the direct financial involvement of the coal industry**[2] is considered to have been critical in maintaining an industry-focussed research agenda. Stakeholders considered the industry-led research agenda to be contributing factor to the achievement of focus outcomes. As noted by a stakeholder:

> *"The manner in which the program is setup, means we have to have a combination of government and industry and researchers obviously. It allows us to not just do research for the sake of research, it allows us to understand what the industries' needs are, what the government's needs are, and do the appropriate technology development to meet those users' needs." – Academic/research stakeholder.*

> *"My job is to support demonstration, and this is very, very clear. I am greatly assisted by that because when a researcher comes to me with a good idea…I'm always able to take their idea and hold it up against this lens and say does this help deployment? If it doesn't help deployment I tell them "I'm sorry you have got a fantastic idea, but it doesn't suit my purpose." So, it's not that your idea is bad, it's just that I have a certain purpose and your idea doesn't fit here."* – Academic/research stakeholder

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4.2 Factors that hindered achievement of focus outcomes

There was consensus among stakeholders that changing, uncertain and inconsistent policy settings were the **primary factors** hindering achievements and progress across the LETFF programs. Specific examples of changing and inconsistent policy settings identified included:

- removal of the carbon price regime following the commencement of the LETFF programs
- lack of a clear national strategy and statement with respect to LETFF, and in particular CCS
- changing and inconsistent policy settings no longer aligning with program objectives
- government policy not adopting a technology 'agnostic' approach with respect to emissions abatement, with stakeholders noting that CCS projects were ineligible for funding from the Clean Energy Finance Corporation

[2] Support was focused through the former Australian Coal Association for Low Emissions Technologies Research and Development (ACALET R&D), now known as COAL21.

- loss of policy direction overtime resulting in general policy confusion among industry participants.

These issues **resulted in significant uncertainty and loss of confidence across industry, and a loss of momentum with respect to the advancement of LETFF.** As stakeholders noted:

> *"The lack of any coherent discussion at the national level on climate and energy related matters has probably hindered investors and project proponents taking risks that they would otherwise have seriously thought about."* – Commonwealth Government stakeholder.

> *"A lack of clear government policy (both state and federal) on CCS hinders progression of the demonstration projects required for future large scale CCS to be assessed and ultimately progress."* - Industry stakeholder

> *"We don't have that clear stable policy framework. We don't have that clear confidence in that framework to allow significant* [Industry] *investment."* – Academic/research stakeholder.

The changing policy settings also contributed to eroding industry engagement within the LETFF programs. Proponents no longer considered the investments to be a priority in the absence of clear policy direction. As one stakeholder noted:

> *"While the project staff were still very committed to the project, they did from time to time run into a bit of pushback from the operations staff at the mine site, because they are no longer quite as keen to have this project running at their site because there wasn't that financial impetus* [any longer]*."* – Commonwealth Government stakeholder.

There is a perception among many stakeholders that an insufficient understanding of the complexity of low emissions technologies at the commencement of the LETFF programs also hindered the achievement of focus outcomes. In particular, there is a perception that the Commonwealth Government lacked the necessary internal scientific and technical capabilities to accurately evaluate and asses the viability of projects proposed prior to the commencement of the LETFF programs. Insufficient understanding of the technical, scientific, engineering, regulatory and environmental challenges underpinning large-scale LETFF across government, industry and academia resulted in:

- unrealistic program and project timelines
- insufficient funding being committed to support development and deployment
- insufficient understanding of project financial and technical risks
- an implicit assumption relating to the commercial feasibility of geological resources.

Overall, this resulted in unrealistic program timeframes, costs and expectations. As noted by stakeholders:

> *"If you look at the CCS Flagships program, in some ways, that was too much too soon. The expectation that you were going to be commercial and up and running with in 2013* [for example] *was unrealistic."*– Industry stakeholder.

> *"The challenges with some of this have proven to be … more difficult than first thought. So, Gorgon, for example, has ended up being a much, much larger project than was originally conceived. So, the original intent* [of the LETFF programs] *got the scale completely wrong."* – Commonwealth Government stakeholder.

Stakeholders also identified regulatory uncertainty and insufficient readiness on the part of the Commonwealth and State Governments as a factor hindering the achievement of focus outcomes. Governments at both levels were ill-prepared in terms of regulation and legislation for the commercial implementation of technologies – particularly relating to the storage and monitoring of CO_2. Projects involving pilot drilling and site testing (such as CarbonNet in Victoria) required state government regulatory approval (and in the case of CarbonNet also Commonwealth Government approval due to offshore activities) before proceeding. These regulatory approval processes significantly impeded project timelines and presented considerable challenges to project proponents. As summarised by one stakeholder:

> *"It's more in the regulatory space that's been required than people realised. For example, on the CarbonNet project, there were all sorts of Victorian government approvals, but there are also Australian Government approvals because it is eventually going to be in the offshore domain… There are multiple approval processes and I think it's fair to say that's been very challenging."* – Commonwealth Government stakeholder

A range of stakeholders noted that Commonwealth Government funding agreements, where project funds are tied to specific milestone dates and activities, don't adequately reflect the nature of industrial-scale projects. The rigid nature of funding agreements were considered to impeded and slow project progress and achievement of focus outcomes.

A minority of stakeholders considered that the decision to allocate funding across a portfolio of LETFF programs and projects hindered program achievements. Rather, there was a perception that greater progress towards the development and deployment of LETFF may have achieved by focussing on a single or two LETFF projects in total. As one stakeholder noted:

> "[The Commonwealth Government] *spread the funding too thinly across several projects. There was only ever sufficient funding allocated for 1 CCS project. Running a competition* [a grant application process] *encouraging several projects to commence was ineffective and unrealistic"* – Academic/research stakeholder.

4.3 Impact of program design and implementation on achievement of focus outcomes

A majority of respondents to the online questionnaire considered that the level of funding allocated to the LETFF programs (82%) and project selection processes (59%) positively contributed to the achievement of outcomes.

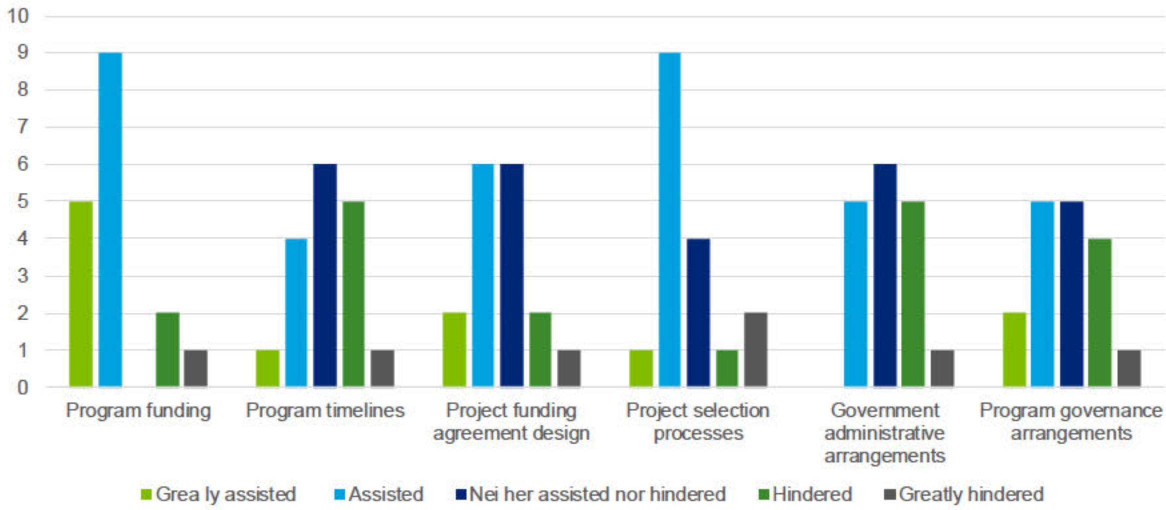
However, responses were more mixed with respect to the impact of program timelines, funding agreement design, administrative arrangements and governance arrangements on the achievement of outcomes (see Figure 4.1).

For example, while almost half (47%) of questionnaire respondents considered the design of funding agreements to have greatly assisted or assisted the achievement of focus outcomes, this view was not shared by all stakeholders. A range of stakeholders interviewed considered funding agreements to be rigid and inflexible, and a requirement to tie funding to specific milestones to be incompatible with large-scale industrial development projects. As noted by stakeholders:

> *The way all of these projects are setup, they can only take one step* [at a time]*. And therefore, the project has to wait until you have made a decision. There hasn't been that ability to take the next step after you've learnt something, change the plan a little bit, modify it to suit what you've learnt, take the next step, and having funding continue from there".* – Industry stakeholder.

> *"Here is $100 million go and do your first bit, and here is a $100 million go and do your second bit, and here is $50 million go and do your third bit. That is not the way to run a big project, you know, when BHP decides it is going to develop a mine, that is a $15 billion decision and they don't hand it out, you know, $100 million at a time. So I think the government has to think about a way on how it wants to support large-scale projects like this."* – Academic/research stakeholder.

Figure 4.1 Questionnaire respondents' perception as to what aspects of the design of the LETFF programs contributed to the achievement of focus outcomes



Source: Deloitte survey, n = 17

In addition to the above, many stakeholders noted during interviews that the 'removal' or clawback of program funding by the Department from projects deemed unfeasible/unsuccessful adversely impacted the achievement of focus outcomes. Many stakeholders considered that this funding should have been reallocated to remaining projects or new funding rounds held to identify 'new' projects, rather than have such funding returned to consolidated revenue. As noted by stakeholders:

> *"Government has taken money back of programs, which has reduced our ability to get more projects out the door or conversely has slowed existing programs down. I think it also demotivates the industry and project proponents."* – Commonwealth Government stakeholder.

> *"The CCS Flagship Demonstration Program was crippled by the withdrawal of Commonwealth funds originally allocated to it."* – Industry stakeholder

4.4 Barriers to the commercial development and deployment of LETFF

There was consensus among stakeholders interviewed that the absence of a clear commercial imperative on the part of industry to invest in carbon abatement remains the single largest barrier to the commercial development and deployment of LETFF. Key issues identified by stakeholders contributing to the absence of a commercial imperative included:

- lack of a clear, consistent national energy policy that addresses the role of LETFF and provides industry with sufficient long-term confidence to invest
- absence of Commonwealth and State Government policy instruments that directly incentivise investment in emissions abatement
- significant cost of deploying commercial scale CCS projects, noting that LETFF (and CCS in particular) has a particularly high cost relative to alternative emission abatement technologies
- investment risk is perceived to be high given current policy settings and uncertainty
- issue of third party risk remains unaddressed under current policy arrangements, specifically the issue of indemnifying storage and reservoir operators over the longer term.

As noted by stakeholders:

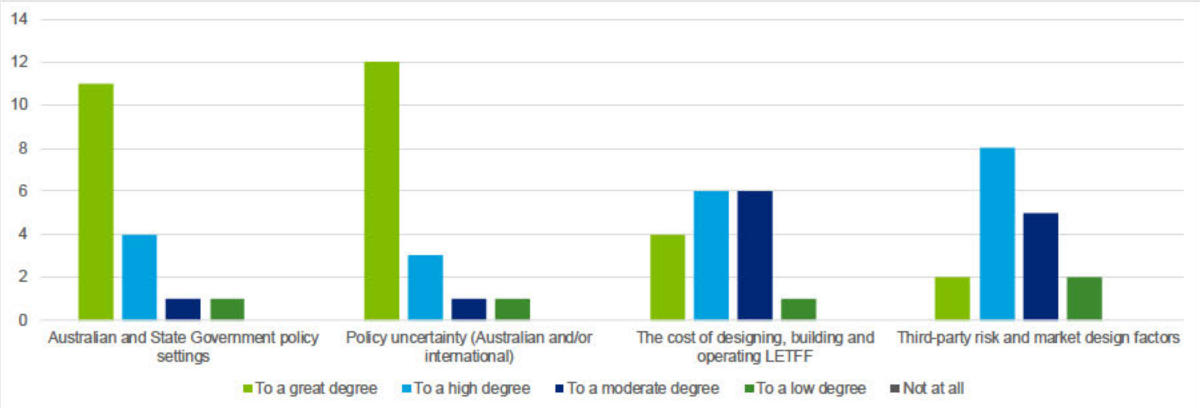
> *"The issue with all of this is cost. The investments that are required to do these things* [LETFF] *at scale invariably seem to be much larger and the costs are much larger than originally envisaged."* – Commonwealth Government Stakeholder.

> *"You cannot see* [under current arrangements] *how any of these projects are going to be funded."* – Industry stakeholder

> *"We have not had a coherent discussion at the national level on climate and energy related matters, which has probably hindered investors and project proponents taking risks that they would otherwise have seriously thought about."* – Commonwealth Government stakeholder.

Responses to the online questionnaire support the above findings. Questionnaire respondents identified existing Australian and State Government policy settings (88% of respondents consider policy setting remain a barrier to a great or high degree), domestic and international policy uncertainty (88%), cost of LETFF (59%) and third-party risk (59%) as presenting the greatest barrier to the commercial deployment of LETFF (see Figure 4.2).

Figure 4.2 Survey respondents' perception of the extent that external factors remain a barrier to the commercial deployment of LETFF



Source: Deloitte survey, n = 17

However, some stakeholders considered that some longer-term commercial drivers were already in place, and highlighted the decision by Chevron and its joint venture partners to invest in the Gorgon Carbon Dioxide Injection project. As one stakeholder noted:

> *"If you want to exploit Australia's offshore gas resources in say 25 years' time, you will have to deal with those emissions I think. I think that's going to be the world we are. So, I think that if you look at it through that lens, there is going to be a commercial driver."* – Commonwealth Government stakeholder.

Many stakeholders also identified the lack of a technologically 'agnostic' approach to emissions abatement as a barrier to the commercial deployment of LETFF. There was a perception among many stakeholders that LETFF was treated inconsistently to alternative technologies. For example, CCS projects are not eligible for funding under the Clean Energy Finance Corporation. As one stakeholder summarised:

> *"It's not about renewables versus CCS or renewables versus coal. It's about having a portfolio of solutions to reach your emissions targets." – Industry stakeholder.*

Stakeholders also identified that barriers to knowledge sharing and access to information may have adversely affected the broader public discourse and perceptions around LETTF. This has contributed to a 'poor' public understanding and acceptance of LETFF, and in particular CCS, and is considered a barrier to the deployment of LETFF by some stakeholders. All stakeholder groups recognised that the role of LETFF in abating emissions was not well understood, and that there was a broad public perception that the primary role of LETFF was to extend the 'life' of fossil fuels.

There is a perception that this has contributed to hindering the deployment and implementation of LETFF. As noted by stakeholders:

> *"… most of the knowledge is sort of really been distributed amongst people closest to these programs and various industry stakeholders, but in terms of the broader community they have been consulted where they are directly affected, but I don't think the average Australian knows where the Carbon Capture and Storage is up to in Australia."* – Commonwealth Government stakeholder.

> *"… the CCS community and industrial sectors of Australia were very good at talking to ourselves about how great CCS is and how we are going to use that as a solution. We are hopeless at talking outside that group, outside of comfort zone."* – Academic/research stakeholder.

> *"I think both government and industry have done a poor job of enunciating the benefits of CCS. I think we are probably behind the eight-ball by now."* – Industry stakeholder.

Stakeholders also recognised that falling domestic demand for fossil fuels was a potential barrier to the deployment of large scale LETFF. While a broad range of emission-intensive industrial processes (such as fertiliser production, agriculture and smelting) have potential to support demand for LETFF deployment, stakeholders agreed that the key sectors (beyond the oil and gas sector) likely to underpin the initial deployment of LETFF were the coal and energy generation sectors. As one stakeholder noted:

> *"I think anything that is going to impact on coal production levels and demand for coal is going to then impact on the operating costs and financial considerations, and so it is going to have even more of a detrimental effect of looking at the capital costs of significant abatement investments."* – Commonwealth Government stakeholder

5 Success, future research and role of government

Key findings:

- Overall, **stakeholders overwhelmingly consider the LETFF programs successful**. The LETFF programs have made significant contributions to increasing knowledge, skills and capability, and improving industry understanding of LETFF in Australia. These achievements **would not have been made in the absence of Commonwealth Government support.**
- Stakeholders consider that the Commonwealth Government's investment in LETFF programs **represents good value for money**, and **achievements are commensurate with the investment**.
- LETFF programs have directly contributed **to reducing the technical and commercial barriers** to the development and deployment of commercial-scale LETFF projects.
- However, the achievements and knowledge gained have not been well communicated or disseminated.
- Australia risks losing the significant gains in knowledge, and skills and capabilities established through the LETFF programs if Australia does not proceed to the commercialisation and deployment of LETFF.
- The critical underlying research and technical questions to deploying large-scale LETFF (and CCS in particular) have been addressed, however some targeted research would supplement and benefit research done to date.
- Stakeholders consider **there remains a critical role for Government** in supporting the development and implementation of LETFF, but there is **no clear consensus** on the most appropriate role for Government.

5.1 Success of LETFF programs

Overall, stakeholders across all groups consider that the LETFF programs have been successful, and have made a significant contribution to on increasing knowledge, skills and capability, and on improving industry understanding about low emissions technologies.

As reported above in Section 3, stakeholders consider that as a result of the LETFF programs Australia now possesses the requisite scientific and engineering knowledge, skills and industry understanding to develop and deploy large, commercial-scale LETFF programs. Through the LETFF programs, the key research and technological barriers to the deployment of LETFF have largely been overcome. Stakeholders noted:

> *"When you put all the projects on the map of Australia, show the different types of geology that we've got around Australia, and the different projects that we've* [delivered] *around Australia, the government has participated in a really good portfolio of projects"* – Industry Stakeholder

> *"Industry in Australia has gone from not having a clue of what we are doing to now being able to say where we're going to put a drill or drill a hole, where we're going to store CO_2, the technology we're going to use, and to take that next step* [of deployment]. *So, has it* [the LETFF programs] *been successful in my mind, absolutely."* – Industry stakeholder

A key element contributing to the success of the LETFF programs have been the critical learnings gained by industry and government across the suite of programs and industry. In particular, projects deemed 'unsuccessful' have provided valuable insights in progressing Australia's knowledge and understanding of LETFF. For example, the following ‘unsuccessful’ projects yielded the following learnings:

- **ZeroGen project:** was the first project which confirmed the importance of a suitable geological storage site. The Zerogen project was also the earliest LETFF project in Australia to go through a detailed feasibility engineering design and cost-discovery process, providing new insights on the costs of new integrated gasification combined cycle (IGCC) plants in Australia. As a consequence, it is now recognised that a post-combustion capture retrofit to an existing power station is a more appropriate technology fit within the Australian context for.
- **South West Hub:** resulted in significant improvements to conducting and analysing seismic survey data, monitoring and modelling CO_2 plumes, and understanding how basin configuration and structural elements affected containment capabilities of a rock formation. These areas of research were driven by the fact that the Eneaba Formation did not have the impermeable seal that other potential CO_2 storage sites had (for example sites on the east coast of Australia).

The majority of stakeholders interviewed consider that that the Commonwealth Government’s investment in LETFF programs represents good value for money, and achievements across the focus outcomes are commensurate with the investment made. In particular, stakeholders noted that the research undertaken has directly contributed to overcoming research and technological gaps and barriers with respect to LETFF. Stakeholders noted:

> *“In the research dimension…I think the returns have been immensely large. So, I think you know, yes, we’ve done a damn good job of research.” – Academic/research stakeholder*

> *“I think that there has been a pretty good return on investment for most of the projects under the LETFF. I think that there has been a couple of projects that haven’t succeeded, but that doesn’t always mean that that money hasn’t been well spent…you can learn from the failure as well.”* – Commonwealth Government stakeholder

This finding was supported by the results of the questionnaire of LETFF program participants, in which 71% of all respondents agreed or strongly agreed that the LETFF programs have achieved outcomes commensurate with the investment made. The questionnaire found that 71% also agreed or strongly agreed that the LETFF programs have directly contributed to reducing the technical and commercial barriers to deploying large-scale LETFF projects.

However, some stakeholders were more cautious when reflecting on the success of the LETFF programs, noting that Australia still lacks a pipeline of large-scale LETFF projects. As one stakeholder noted:

> *“Yeah, so it's really quite hard to answer* [the question of success] *because I think again from a technical geoscientific perspective, I think that’s clearly been a success in terms of that technical scientific knowledge. But for that [approximately $750 million] again we don’t really have a pipeline of CCS projects or kind of big things that are going to make a difference to emissions for Australia.”* – Commonwealth Government stakeholder

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Stakeholders also perceive that the knowledge and learnings gained from across the LETFF programs have not been sufficiently communicated to the general public (as reported in

Section 4.5 above, this considered a barrier to commercial deployment by some stakeholders). Overall, stakeholders noted:

- there is a lack of public understanding of the potential role of LETFF in decarbonising the economy and national energy market
- there is a 'poor' public perception of LETFF that does not match the achievements that have been made across the LETFF programs
- LETFF, and CCS in particular, are seen as technologies designed to the 'extend the life of fossil fuels'.

Lastly, stakeholders broadly agreed that Australia risks losing the significant gains in knowledge, and skills and capabilities it has established over the last 15 years through the LETFF programs if Australia does not proceed to the commercialisation and deployment of LETFF. Low emissions technologies such as CCS are increasingly being deployed in the U.S., China and Europe. If Australia does not proceed to deployment, it is likely that the specialised skills developed through the LETFF programs will be lost overseas to where LETFF is being deployed. As one stakeholder noted:

> *"… there are certainly other countries who have skilled up more effectively than Australia has in the last few years and we are at risk of being left behind to some extent. … the US has an extremely comprehensive national CCS approach, Norway, the [and] UK to some extent…. So, we are in danger of losing that capability I believe if we are not careful in what we are doing."* – Academic/research stakeholder

5.2 Would have achievements been made in the absence of government support?

Overall, there was consensus across all stakeholders interviewed that the achievements made towards increasing knowledge, skills and capability, and on improving industry understanding about low emissions technologies **would not have been made in the absence of Commonwealth Government support**. When asked what progress would have been made without support from the Commonwealth Government, stakeholders noted:

> *"Short answer is zip, nothing. I don't think we would have done much at all. Truly, I don't think we would have done much at all."* – Academic/research stakeholder

> *"It wouldn't have occurred if it wasn't for the government's investment"* – Industry stakeholder

> *"We would still be stuck in the theoretical research phase."* – Commonwealth Government stakeholder

> *"There is no likelihood that we would have achieved what we did without government involvement"* – Academic/research stakeholder

However, stakeholders did note that the Chevron-led Gorgon Carbon Dioxide Injection project would have occurred in the absence of Commonwealth Government support. Chevron Australia had publicly committed to build the injection project prior to the commencement of the LETDF and the development of the injection project was later included as a development approval condition for the LNG project.

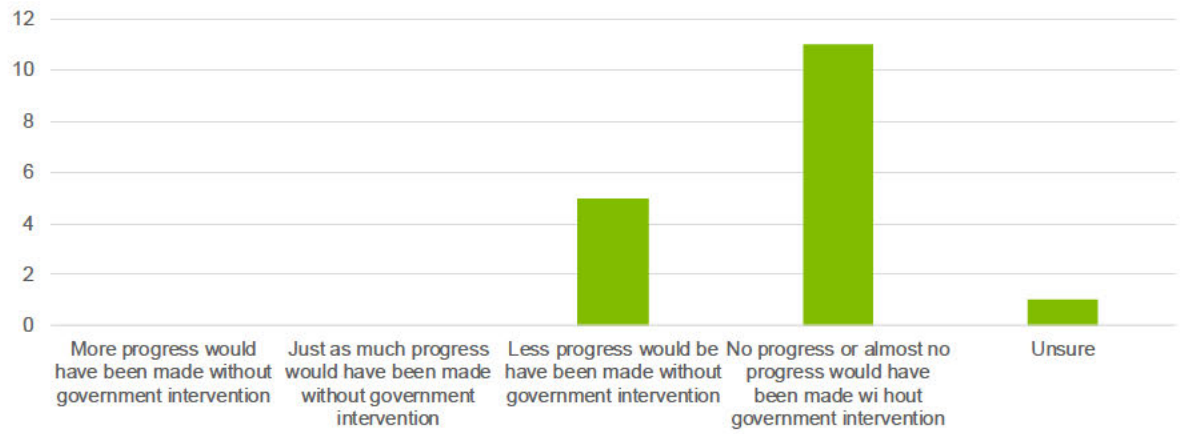
Responses to the online questionnaire supported the outcomes of the stakeholder interviews. It found that 65% of respondents consider that no progress or almost no progress would have been made towards the achievement of the focus outcomes in the absence of Commonwealth Government investment in the LETFF programs (Figure 5.1).

Stakeholders noted that in the absence of a commercial imperative to invest in LETFF (see Section 4.5), there was no incentive on the part of industry to invest in pre-commercial research and development of LETFF. A lack of commercial imperative means that there was no driver to undertake pre-commercial research into capture technologies, CO_2 transportation, storage technologies and CO_2 injection , Australia's geological resources, CO_2 subsurface behaviour, or the safety of LETFF.

By investing in LETFF, the Commonwealth Government was able to successfully leverage significant contributing funding from the coal industry and participating state governments. As one stakeholder noted:

> *"With the current absence of financial incentives for industry to pursue CCS technology, I greatly doubt the funding required to carry out the R&D completed to date would have existed. The LETFF programs provide the foundation funding (*s22
> s22 *for this research to be proposed and progress."* Academic/research stakeholder

Figure 5.1 Extent to which survey respondents consider progress would have made in the absence of the LETFF programs



Source: Deloitte survey, n = 17

5.3 Are there critical areas of research that remain unanswered

There is consensus among all stakeholder groups that the critical underlying research and technical questions to deploying large-scale LETFF (and CCS in particular) in Australia have largely been settled as a consequence of the activities delivered under the LETFF programs. Stakeholders agreed that the next critical phase to LETFF in Australia was deployment. As stakeholders noted:

> *"I think we are far, far beyond the research questions. And I think now it's about deployment, and it's about supporting deployment."* – Academic/research stakeholders

> *"The research is sufficient to take us the next step and let the engineers take the next step so that the researchers can then work on the next problems…I don't think we need more research. I think we need deployment. I don't think there's any gaping holes in research." – Industry stakeholder*

However, stakeholders did identify a range of future research that would supplement and benefit LETFF research done to date.

In particular, a range of stakeholders across all groups identified the need to undertake **site-specific research and testing to support the eventual deployment of LETFF**. While the LETFF programs have demonstrated proof of concept at the regional level, no detailed site-specific research and testing has been undertaken that would be required to support deployment of LETFF. The deployment of LETFF will require a new wave of site-specific research relating to drilling, sub-surface monitoring, seismic analysis and injection testing. Such research and analysis will be critical to project-specific planning, investment, and regulatory decisions. As stakeholders noted:

> *"There will be local specific* [research issues] *related to storage, so there will be groundwater impact concerns mostly, so that will be the Queensland story if they get any further [to deployment]… So, there will be site specific and to a large extent community specific [research requirements]."* – Academic/research stakeholder

> *"We need to do more detailed analysis on key spots. Because we've got the broader understanding of CCS in Australia, but not the actual real details [of specific sites]." –* Academic/research stakeholder

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The focus of the LETFF programs had largely been in relation to the capture, transport and storage of emissions from coal mines, liquefied natural gas (LNG) plants and stationary power stations. Some stakeholders noted, however, a need to research **the application of learnings from the LETFF programs to other emission-intensive sectors** including steel, concrete, fertiliser, and agribusiness. As one stakeholder noted:

> *"the industrial applications of CCS that we need to be putting more work into…So, it is other types of CCS technologies that we probably haven't focused on." –* Commonwealth Government stakeholder

The 'capture' process is one of the most expensive and technically complex aspects of CCS, and can typically account for approximately two-thirds of the total CCS deployment cost.[3] Recognising this, some stakeholders also noted a need to investigate CO_2 capture processes for these emission-intensive industries to assist in making CO_2 capture more commercially feasible.

As reported above, the public perception and acceptance of LETFF and CCS in particular is considered a barrier to the eventual commercial deployment of LETFF in Australia. A range of stakeholders identified the need **further research in effectively engaging with communities at the local level.** Given the nature of CCS (which involves the injection of CO_2), understanding how best to engage local communities level was seen as critical to garnering support and achieving regulatory approval, and ultimately resetting the national conversation. While some research has been undertaken on an ad-hoc individual project-level, there has been no coordinated, strategic approach across the LETFF programs. The importance of better engagement with local communities was summed by a stakeholder as thus:

> "*…the key is you don't engage them* [local communities] *about CCS, you engage them about the whole gambit of future energy choices, and within the choices and the trade-offs you then bring CCS into that equation, so that they actually see a choice. It is not just, 'Yes CCS' or 'No CCS.'"* – Academic/research stakeholder

A final area of research identified by a few stakeholders included **the nature of enhanced oil recovery** (EOR). Overall, stakeholders noted that the relative importance of EOR to supporting the commercial viability of CCS projects in Australia was not very well understood. The production of EOR requires significant quantities of CO_2, which is injected into the sub-surface as part of the EOR production process. Overseas, including the US, EOR is typically most viable where production can integrate with CCS to take advantage of a ready supply of CO_2. While the presence of EOR may not be in all locations that are deemed appropriate for CO_2, there was a view among some stakeholders that further research and investigation was required, particularly given the absence of other commercial imperatives (as reported in Section 4.5 above). As one stakeholder noted:

> *"When you look internationally a lot of the CCS projects have been underpinned by a revenue stream of oil from enhanced oil recovery… there has been this sort of view that EOR or enhanced oil recovery in Australia is not a lot, there is not many prospects. But I am not sure that that is underpinned by really good technical and exploratory work. So if*

[3] Estimate based on stakeholder interviews.

> *we are missing something it is what are the prospects for enhanced oil recovery in Australia."* – Academic/research stakeholder

5.4 Role of Commonwealth Government

There was consensus among all stakeholder interviewed that **there remains a critical role for Government** in supporting the development and implementation of LETFF following the completion of the LETFF programs. Deloitte notes that all stakeholders interviewed as part of this evaluation were directly involved in the LETFF programs, and thus there is likely to be some reported bias in stakeholders' views on the need for continued government support.

However, there was **no clear consensus** among stakeholders interviewed on the most appropriate role for the Commonwealth Government in supporting the development and implementation of LETFF.

Many stakeholders reported that the primary role of the Commonwealth Government should be in setting a clear **national energy and climate policy agenda and framework.** Such a framework would provide industry with sufficient long-term confidence to invest in large-scale LETFF projects. As noted by some stakeholders:

> *"So, absolutely there is a role for government and it links back to that national leadership. I think that we need to have strong policy settings out there that can incentivise investors coming on board for a technology which has some market values in terms of risks."* – Commonwealth Government stakeholder

> *"The government's role is to set a very clear path forward and then to work with industries and organisations that have a role to play in that path whether it be because they're impacted or because they're contributing to that path."* - Industry stakeholder

Many stakeholders, in the absence of commercial imperatives on the part of private industry to invest, saw a role for the Commonwealth Government to provide **direct financial support** for the commercial-scale deployment of LETFF. Such stakeholders considered the Commonwealth Government had a critical role in directly financially supporting the first CCS project in Australia. As one stakeholder noted:

> *"I think the investment from the government is to bring opportunities to a point where a private investor can come in and support it. That can be straight-up by supporting the first opportunities for storage and utilisation hubs in Australia." – Industry stakeholder*

Other stakeholders noted the potential role for the Commonwealth Government in **providing ongoing financial support for research and development** where there was a clear, demonstrated need and where industry was unlikely to undertake the activity without support. Specific examples included research related to broader industrial application, safety, and community acceptance. As stakeholders noted:

> *"There is a place for grants. Grants have a benefit…they give [the Commonwealth Government] what we want. So, for example, if we think industrial CCS is somewhere that needs some research and development then we could certainly put a package together. So, there is room for grants in our repertoire."* – Commonwealth Government stakeholder

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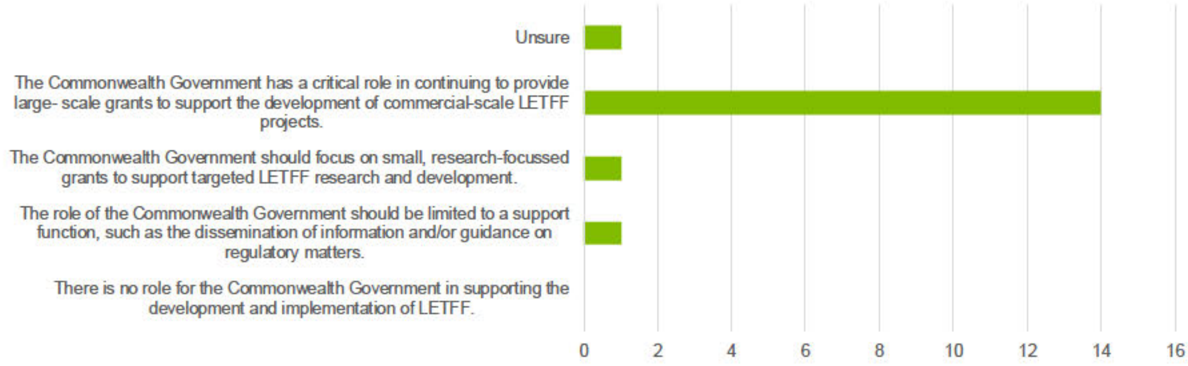
Responses to the online questionnaire were more consistent than stakeholder interviews in their views of what the primary role (if any) should be for the Commonwealth Government going forward with respect to LETFF. The questionnaire found 82% of respondents consider that Commonwealth Government has a critical role in **continuing to provide large- scale grants** to support the development of commercial-scale LETFF projects (Figure 5.2).

Figure 5.2 What primary role (if any) should the Commonwealth Government adopt in supporting the development and implementation of LETFF



Source: Deloitte survey, n = 17

Some stakeholders interviewed also identified the need for the Commonwealth Government to consolidate the research and knowledge gained to date and ensure it is disseminated to the fullest extent possible.

Despite the majority of stakeholders reporting that the primary role of the Commonwealth Government should be to provide large-scale direct financial support for the deployment of commercial scale CCS projects, **Deloitte considers it is imperative that any future support for LETFF should be informed by a rigorous economic assessment**. Such an economic assessment would specifically involve assessing the role of LETFF in decarbonising the economy and NEM relative to alternative approaches, and give consideration to fossil fuel demand and full life-cycle costs of alternative technologies.

5.5 Unintended outcomes

Many stakeholders reported a perception that the LETFF research agenda is negatively affecting the commercial deployment of LETFF, and in particular CCS. Stakeholders reported that the drive to undertake additional research has resulted in a perception among regulators, industry detractors and the general public that LETFF is not adequately understood and that significant risk remains. As one stakeholder summarised:

> *"I think research has been a drawback for CCS…the CCS researchers in their zeal to get more money for research have kept CCS in the research box.* [Researchers] *keep telling everybody, "we need to do more research, we need to do more research." So, people who are detractors of CCS say, "look it's still an experimental technology." It's not."* – Academic/research stakeholder

> *"…there is this CCS* [research] *community that is about extracting money out of government to support their pet projects without a clear line of sight to how you get this technology off the ground on a large scale."* – Industry stakeholder

Some stakeholders also reported that the lack of commercial-scale deployment has resulted in a perceived lack of progress among the general public. This, in-turn, has resulted in a perception that LETFF is in not feasible, and has potentially hindered the sector's ability to achieve a social licence to operate.

6 Learnings for future program design and recommendations

Key lessons and recommendations:

Key lessons to inform future program design and implementation include:

- setting realistic expectations with respect to program cost and time-horizons
- setting realistic expectations with respect to research and development outcomes
- ensuring alignment between policy settings and program objectives
- enhancing assessment of project feasibility at program commencement
- funding and program governance arrangements should reflect the nature of program activities
- greater industry engagement in the design of the program
- the need for ongoing monitoring of program funding
- embedding engagement processes to share knowledge gained within and across government.

It is recommended that the Commonwealth Government undertake a detailed economic cost benefit analysis of LETFF in decarbonising the economy and the national energy relative to alternative technologies.

6.1 Learning for future program design

The LETFF programs have made a significant contribution to increasing knowledge, skills and capability, and on improving industry understanding with respect to LETFF.

However, there are a range of learnings to be gained from the design and implementation of the LETFF programs to inform future program design. These are discussed in greater detail below:

- **Setting realistic expectations with respect to program cost and time-horizons:** Future programs involving the research, development and deployment of large-scale and complex technologies must set realistic expectations around program costs and time-horizons.

  Program design should not underestimate the scale of research and development required to support the development of industrial-scale projects. This has implications for the level of funding made available, the setting of timelines, and internal program governance arrangement including the establishment of internal expert panels to provide necessary technical guidance.

- **Setting realistic expectations with respect to research and development outcomes:** Future programs involving the research and development of unproven and untested technologies must set realistic expectations around outcomes realisation. It is critical that future program design explicitly recognise a realistic target in terms of research and development achievements, and that not all projects will proceed beyond the research phase.

- **Ensuring alignment between policy settings and program objectives:** Future program design must consider and reflect existing and likely future policy settings. Furthermore, there is need to ensure that underlying commercial incentives and imperatives exist to support the achievement of program objectives.

  Future programs should also include a review 'trigger' to revisit the rationale of a program if there is a fundamental shift in domestic and international policy settings that are likely to impact the achievement of program objectives.

- **Enhancing assessment of project feasibility at program commencement:** Future programs should seek to improve technical and financial screening and selection processes to better gauge the feasibility of projects at program commencement. However, this needs to be balanced with the research and development objectives and any future program.

  Future programs involving large and complex technologies should embed independent program review boards consisting of recognised domestic (and if appropriate international) experts to periodically assess project progress.

- **Funding and program governance arrangements to reflect nature of program activities:** Future programs should adopt funding agreements and decision-gates to reflect the nature and needs of industrial development projects. In particular, stage gates should replace rigid milestone reporting and payment processes. This would ensure approved project funds can be more appropriately accessed over time as the project passes through agreed stage gates.
- **Greater industry engagement in the design of the program:** Future programs should involve greater engagement with industry and academic stakeholders during program design. This would ensure program objectives, risks and issues are appropriately understood and reflected in the program design and implementation. Upfront industry stakeholder engagement should also inform an upfront formal assessment of program risks. This ensures risk mitigation strategies can be fully explored, and if possible, embedded within program design.
- **Monitoring of program funding:** Future programs should embed monitoring and reporting frameworks to monitor the effects of changes to funding on the achievement of program objectives. Such frameworks would enable an assessment of how remaining funds can be redistributed within the program (or other programs) and provide a transparent process for revisiting the project selection process to identify projects that were the next best ranked.
- **Embedding engagement within and across government:** Future programs should embed knowledge-sharing processes to ensure program learnings and outcomes are appropriately disseminated across relevant Commonwealth and State Government departments and agencies. Furthermore, program design should consider the required data and information storage and sharing systems to ensure all relevant program documentation is adequately captured and collated in a central location. This mitigates the risks of key learnings and knowledge eroding overtime, and ensures future programs can incrementally build upon the knowledge gained.

6.2 Recommendation

Should the Commonwealth Government consider any future support to further the development and implementation of LETFF, as a first step Deloitte recommends that the Commonwealth Government prioritise a detailed economic cost benefit analysis of LETFF in decarbonising the economy relative to alternative technologies. This analysis should give consideration to fossil fuel demand and the whole-of-lifecycle costs of alternative technologies.

Appendix A: Overview of projects by LETFF program

A summary of the projects delivered under the LETFF programs is presented in the following tables.

Table A.1: Summary of CCS Flagships projects

Project	Description
CarbonNet Project	The project investigates the potential for a large scale CCS network in the Gippsland region of Victoria. The network seeks to cover multiple sources of carbon dioxide captured from industrial plants or power stations.
SouthWest Hub Project	The project aims to assess the feasibility of storing industrial-generated carbon dioxide deep underground in the Lesueur Sandstone formation. The project involves collecting data and core samples through seismic surveys and stratigraphic wells.
ZeroGen Project	The project involved assessing the feasibility of a commercial-scale coal gasification power plant with integrated carbon capture and storage.
Wandoan Integrated Gasification Combined Cycle (IGCC)	A prefeasibility study which involved the following sub-projects: • Stanwell Corporation/Wandoan project which sought to develop an IGCC power station with CCS capabilities. • CTSCo Pty Ltd/Wandoan project which focused on the transportation and storage of carbon dioxide from the IGCC power station through pipelining and geo-sequestration.
Otway Geological Storage and Demonstration Project	A carbon capture and storage demonstration project that aims to address barriers to storage implementation and leverage existing and new datasets arising from the CO2CRC Otway Project to further the technology. The project also involved a monitoring program that test technologies and techniques with the aim of reducing costs.
Australia-China Joint Coordination Group on Clean Coal Technology Projects	The project aimed to build on the growing relationship between Australia and China through the Australia-China Joint Coordination Group on Clean Coal Technology (JCG).

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Table A.3 Summary of LETDF projects

Project	Description
Gorgon Carbon Dioxide Injection Project	Design, construction and operation of facilities to inject and store CO_2 into a deep reservoir unit two kilometres beneath Barrow Island. The CO_2 that is injected into the reservoir unit comes from the process of extracting gas in the Gorgon/Jansz-Io fields.
400MW Integrated Dry-gas Gasification Combined Cycle (IDGCC) Clean Coal Demonstration Project	A project that aims to increase the burning efficiency of thermal generators by drying brown coal. Reducing the moisture content of brown coal means that less energy is required to convert the coal into electricity.

Project	**Description**
Hazelwood 2030 Project	A project that aims to retrofit Low Emission Technologies at the brown coal-fired Hazelwood Power Station in the Latrobe Valley, Victoria. The process involves reducing moisture content of brown coal for an improved burning efficiency. The Hazelwood 2030 project includes CCS facilities – with demonstrated capacity to sequester carbon dioxide at a rate of 0.02mtpa.
Fairview Project	A project that aims to test the extraction of methane from coal and storing it underground

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Appendix B: Evaluation framework

The evaluation framework, including key evaluation questions and sub-questions, key data collection methods and sources guiding the impact evaluation of the LETFF programs is presented below. The evaluation framework has guided the key lines of enquiry and systematic organisation of analysis to ensure a consistent and robust assessment of the LETFF programs and project activities.

Table B.1: Evaluation framework

Domain	Key evaluation questions	Sub-questions	Data source		
			Interviews	Document review and citation analysis	Survey
Effectiveness	To what extent have the LETFF programs increased knowledge, skills and capability, and improved industry understanding in relation to low emissions technologies for fossil fuels?	To what extent have the LETFF programs generated new research, data and modelling relating to the practical and technical use and implementation of LETFF?	✓	✓	✓
		To what extent have the LETFF programs resulted in the development of greater local (Australian) skills and capabilities in LETFF?	✓	✓	✓
		To what extent have the LETFF programs improved industry understanding of the feasibility and safety of LETFF through collaboration and dissemination of new knowledge?	✓	✓	✓
		To what extent is achievement against the above outcomes commensurate with the investment made by the Commonwealth Government?	✓		✓
	To what extent would knowledge, skills and capability, and industry understanding in relation to LETFF continued to have been developed in the absence of the LETFF programs?	What was the state of knowledge, skills and capability, and industry understanding prior to the commencement of the LETFF programs?	✓	✓	✓
		What is the state of knowledge, skills and capability, and industry understanding following to the commencement of the LETFF programs?	✓	✓	✓
		To what extent has investment from the LETFF programs crowded out industry and research activity that would have occurred in the absence of the LETFF programs?	✓		✓

Domain	Key evaluation questions	Sub-questions	Data source		
			Interviews	Document review and citation analysis	Survey
		How much of the change observed in increased knowledge, skills and capability, and improved industry understanding is because of the LETFF programs?	✓		✓
Efficiency	What factors have helped or hindered the achievement of increased knowledge, skills and capability, and improved industry understanding in relation to LETFFs?	What factors have assisted the achievement of increased knowledge, skills and capability, and improved industry understanding in relation to LETFFs?	✓	✓	✓
		What factors have hindered the achievement of increased knowledge, skills and capability, and improved industry understanding in relation to LETFFs?	✓	✓	✓
		To what extent did the design and implementation of the LETFF programs assist or hinder the achievement of the increased knowledge, skills and capability, and improved industry understanding in relation to LETFFs? Did program design align with known 'best practice' examples elsewhere?	✓	✓	✓
		To what extent did the LETFF programs align with related programs or research (either government or industry)?	✓	✓	✓
		To what extent do these factors remain a barrier to the commercial development and deployment of LETFFs?	✓		✓
	How have external factors affected the ability of the LETFF programs to achieve their intended medium and long-term objectives?	How have Australian Government and international policy settings affected the achievement of medium and long-term objectives?	✓		✓
		How have the relative prices of, and demand for, renewable energy sources affected the achievement of medium and long-term objectives? How have alternative carbon abatement technologies (e.g. bio-sequestration) affected medium and long-term objectives?	✓		✓
		How has the level of demand for fossil fuel-based energy affected the achievement of medium and long-term objectives?	✓		✓
		How have general economic conditions affected the achievement of medium and long-term objectives?	✓		✓

Domain	Key evaluation questions	Sub-questions	Data source: Interviews	Data source: Document review and citation analysis	Data source: Survey
		How have issues such as third-party risk and market design factors affected the achievement of medium and long-term objectives?	✓		✓
Appropriateness	What lessons can be drawn to inform future policy and program development, including the role (if any) of the Commonwealth Government, in relation to supporting the development and implementation of LETFF technologies?	What lessons can be drawn to inform future program design and development?	✓		✓
		Did changes to the LETFF programs since inception influence the efficiency or effectiveness of the programs?	✓		✓
		Are there critical areas of research that have been missed?	✓		✓
		Was there adequate industry engagement on the role of CCS and emission abatement technologies as part of a broad mix of GHG emission mitigation measures?	✓		✓
		What is the role (if any) of the Commonwealth Government in relation to supporting LETFFs?	✓		✓
Unintended impacts	What unintended outcomes have occurred as a result of the LETFF programs?	What (if any) unintended benefits occurred as a result of the LETFF programs?	✓	✓	✓
		What were the unexpected negative impacts of the LETFF programs?	✓	✓	✓

Appendix C: Stakeholder interviews and survey responses

Draft note: to be provided in an amended Draft Report

Appendix D: Case studies

Draft note: to be provided in an amended Draft Report

Appendix E: Literature scan and citation analysis

The results of the citation analysis of publicly available reports relating to the LETFF programs is presented below.

Table E.1: Summary (detailed) of LETFF program/project publications

LETFF program/ project	Publications No.	%	% scholarly articles	No. of citations	Citations per publication
CCS Flagships	**65**	**13%**	**2%**	**170**	**2.6**
CarbonNet	20	4%	n/a	65	3.3
SouthWestHub	28	6%	4%	25	0.9
ZeroGen	2	0%	n/a	44	22.0
Wandoan	5	1%	n/a	20	4.0
CO2CRC	10	2%	n/a	16	1.6
CCSRD&D	0	0%	0%	0	0.0
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LETDF	**23**	**5%**	**39%**	**1105**	**48.0**
Gorgon	12	2%	42%	1012	84.3
IDGCC	0	0%	0%	0	0.0
Hazelwood	7	1%	57%	93	0.0
Fairview	1	0%	0%	0	0.0
Other	3	1%	0%	0	0.0
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Source: Deloitte Access Economics

Notes: These estimates only include publically available publications.

Limitation of our work

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Appendix C: Stakeholder interviews and survey responses

List of stakeholders interviewed

A list of all stakeholders interviewed as part of the evaluation assessment are outlined below. Overall, 19 stakeholders were engaged through 18 interviews as part of the evaluation.

Table A.1 List of stakeholders interviewed

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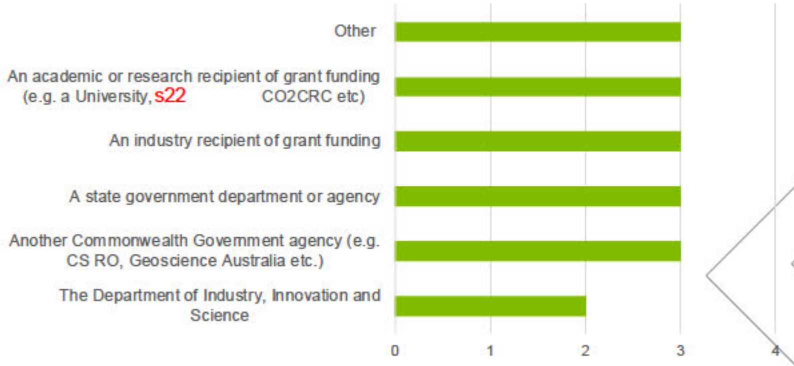
List of respondents to online questionnaire

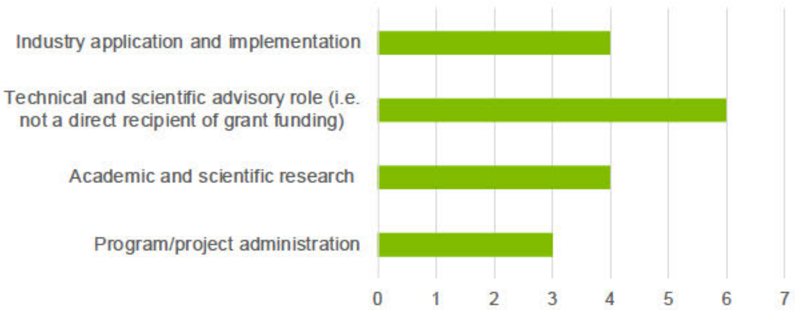
A total of 17 responses to the online questionnaire were received. A summary of the groupings of respondents is provided below.

Figure C.1 Type of organisation that respondent principally worked for during their involvement with the LETFF programs



Source: Deloitte survey, n = 17

Figure C.2 How do respondents describe their involvement with the LETFF programs?



Source: Deloitte survey, n = 17

Deloitte.

Appendix D: Case studies

This evaluation has involved the development of concise case studies highlighting the contribution to increased knowledge, domestic skills and capabilities, and improved industry understanding of LETFF made by individual projects delivered under the LETFF programs. The case studies have supported and informed the triangulation of evidence collected across the evaluation. A total of seven case studies have been developed across the LETFF programs:

- **CCS Flagships program:**
  - South West Hub Project
  - Otway Geological Storage and Demonstration project
- s22

- **LETDF:**
  - Gorgon Carbon Dioxide Injection Project
- s22

These concise case studies are presented below.

South West Hub Project

Project Summary and Objectives

The South West Hub project involved testing onshore sandstone formations as a CO_2 reservoir for nearby power plants and industrial sites in Western Australia. Its objectives were to conduct a data study and analysis of the lower Eneaba Formation to determine its suitability for injecting CO_2 underground. In its Extended Case, the facility aimed to capture, transport and store between 5-6Mt of CO_2 annually.

Contribution to Research and Knowledge

The project's unique location was chosen in part due to its proximity to CO_2 emitters, rather than any geological characteristics that make it particularly suitable for CO_2 storage. This aimed to reduce the costs of transporting CO_2 – improving the commerciality of CCS. However, the location led to challenges such as:

- determining how to keep the injected CO_2 underground, since the Eneaba Formation did not have the impermeable seal that other CO_2 storage sites have to contain the CO_2 plume
- determining how to monitor the CO_2- plume underground.

Consequently, most of the new research and knowledge gained came from addressing these challenges. Specific areas of research contributed to by the project included:

- improvements in geosequestration knowledge – including conducting and analysing seismic survey data, as well as conducting geophysical remote sensing of CO_2 sequestration
- geochemical evaluation of the well using a combination of standard and novel techniques – such as chemical tracers to determine the suitability of the area for CO_2 storage
- structural analysis of geological formations, including fault seal first-order analysis.

Stakeholders also reported that the project contributed to a greater understanding of trapping mechanisms, greater confidence in Migration Assisted Trapping (MAT) technology and a greater understanding of geological environments and depositional history at a local level.

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Stakeholders also reported that that the applied in-field research and demonstrations allowed participants to more effectively present comprehensive and compelling business cases to progress CCS technology.

Overall, this evaluation identified 28 technical reports from various public data repositories produced by the project. These reports discuss challenges and the results of geosequestration testing conducted on this project. These reports have cumulatively been cited 25 times in external reports.

Contribution to domestic skills and capabilities

The project made an important contributing to advancing domestic capabilities in the development of behavioural models of CO_2 plume movements within different rock formations. Eight of the 28 technical reports were written with the University of Western Australia or Curtin University, which focused on geophysical data analysis, stability assessments and predicting CO_2 injectivity properties.

Other technical reports also focussed on improvements in conducting and analysing seismic survey data like geochemical evaluation and residual trapping. The unique characteristics of the site meant that significant focus was placed on understanding how basin configuration and structural elements affected the containment capabilities of a rock formation.

The project also contributed to the development of domestic research skills, by enabling leading research organisations such as the University of Western Australia and Curtin University to have dedicated staff and students working on CCS research and demonstration projects.

Contribution to industry understanding of low emissions technologies

The Project's location in a low-medium permeability reservoir, without a thicker "continuous impermeable seal" that could effectively contain CO_2 plumes, added to the technical challenges of CCS. These challenges demonstrated that storage proximity to emission sources, while preferable, is neither a necessary nor a sufficient condition. However, a viable geological reservoir is certainly necessary and likely sufficient.

Stakeholders discussed how the South West Hub project was important for the industry to develop a better understanding of both the theoretical capabilities of injecting CO_2 into these types of reservoirs (i.e. with an impermeable seal) and also the commercial aspects that would need to be met before injection can be undertaken effectively.

Whilst challenging, the project was crucial for improving the industry's understanding of geological reservoirs without natural seals, particularly their potential for trapping CO_2. Modelling that was done as a result of the project indicated that geological reservoirs without traditional caps or seals can still store CO_2, potentially doubling the capacity of storage in south-west Western Australia than was previous estimated.

Technical reports and research papers discussing the processes conducted, as well as the challenges associated with geosequestration were made public – and are found on data repositories such as s22 the Global CCS Institute and WAIMPS.

Otway Geological Storage and Demonstration Project

Project Summary and Objectives

The CO_2 Co-Operative Research Centre's (CO2CRC) Otway Geological Storage and Demonstration Project (the Otway Project) aims to conduct initial site characterisation of the Otway Basin Pilot Project. The project's objective is to demonstrate the deep geological storage CO_2, and improve understanding of the potential geological storage of various sedimentary basins both onshore and offshore. The project has involved the pilot trial of CO_2 injection and storage to demonstrate proof of concept.

Contribution to Research and Knowledge

The Otway Project has involved partnerships with a range of leading universities and research organisations, including CSIRO, Geosciences Australia and Curtin University with a specific focus on sub-surface CO_2 storage, monitoring and modelling.

Research and knowledge focused on decreasing the cost of monitoring CO_2 plumes underground, as well as reducing the impact of operating on other stakeholders like land operators or the environment. The Otway Project was seen by stakeholders to be critical in demonstrating laboratory-scale technologies in the field as major prototypes. These technologies included new modelling approaches that accurately predict CO_2 plumes and experimental methods for determining tracer partition coefficients. The Otway project has directly contributed to the following areas of storage and CO_2 monitoring research:

- understanding how geological permeability may change as a function of CO_2, demonstrating a meed to monitor water and local mineralogy characteristics
- monitoring the characteristics of injected CO_2 plumes using seismic technology
- analysis and modelling of geophysical data sets (2D, 3D etc.) and downhole and temperature datasets to improve understanding of CO_2 plume behaviour and migration
- an improved understanding of the potential injectivity of reservoirs, their ability to store CO_2 and overall storage capacity
- establishing general methodologies for determining whether a CO_2 storage reservoir is leaking
- improving techniques to monitor sub-surface CO_2 plumes
- improving cost effectiveness of CO_2 monitoring.

The Otway Project has also contributed to the development of a range of new techniques. As example is working with Curtin University to develop fibre optic cable technology to receive acoustic signals. As noted by stakeholder:

> *"Previously when you do seismic monitoring you basically create an acoustic wave through the earth and receive it at a geophone – this has been the traditional way that the Oil and Gas sector has explored. What's been maturing and what Curtin has been heavily involved with is replacing geophones [with fibre optic cables]. You can now use fibre optic to receive that acoustic signal anywhere along that fibre. Now, the quality of what you receive with that fibre versus a mechanical geophone has always been a lot less, so the fibre has never been that great. But with the funding that we have received from the LETFF and combination of work with experts from Curtin and also internationally, we are now at the point where the performance of these fibres is substantially better than these geophones. Now, that all sounds very technical, but what it means is we now have the ability to not have to put major infrastructure down these wells, we can do it through very cheap wells. We can have high resolution on demand, monitoring whenever we want to give assurance of [CO_2] behaviour on the subsurface be it in CCS or be it in Oil and Gas exploration production. It's a massive improvement and a very important technology.*

This evaluation identified ten published technical reports produced through the Otway Project, which have collectively been cited in peer reviewed publications a total of 16 times.

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Contribution to domestic skills and capabilities

The Otway Project has involved collaborations with a range of international research organisations and universities – including Silixa (UK), Lawrence Berkeley National Laboratory (US), and the University of Texas (US). The research and academic institutions partnered with CO2CRC to trial new technologies on site. Through these collaborations, these organisations have assisted in developing and broadening domestic skills and capabilities. Technologies that were trialled include:

- different injection methods
- different storage and monitoring methods such as Distributed Acoustic Sensing (DAS) fibre optic cables and 4-D time-lapse surface seismic methods.

Stakeholders reported that the Otway Project directly contributed to Australia developing world-leading reservoir engineering and monitoring skills and expertise, with CSIRO and Curtin University being identified by international collaborators as world leaders.

A key aspect of the Otway Project was it being "internationalised" by CO2CRC as a preferred test site to trial a range of injection, storage and monitoring techniques for CCS. Stakeholders noted that through these trials and collaborations, Australia has developed skills in these international techniques. Australia was also able to directly develop significant skills and capabilities with respect to the application of a range of CCS technologies, including:

- site management
- managing the regulations around sites
- communications.

Contribution to industry understanding of low emissions technologies

A key aspect of the Otway Project has been its focus as a trial demonstration facility for CCS. This has enabled the project to undertake direct applied research and demonstration in the field, including extensive geoscience and engineering work, to inform future commercial scale deployment of CCS.

The Otway Project has developed a detailed understanding of the process of CO_2 injection under Australian conditions and geology, CO_2 migration and monitoring, and CO_2 stabilization. This has enabled the project to develop an end-to-end visualisation of the injection and storage of CO_2. The project has also significantly contributed to an understanding of the monitoring and modelling the behaviour of CO_2 with very advanced modelling techniques. In short, the Otway Project has made a significant contribution in providing industry, government and academia with tangible evidence that CCS works and is safe.

The Otway Project was crucial for demonstrating technologies at a prototype level – such as seismic monitoring through fibre optic rather than mechanical geophones, which are now able to perform at a much higher level.

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Gorgon Carbon Dioxide Injection Project

Project Summary and Objectives

The Gorgon Carbon Dioxide Injection Project was a commercial-scale demonstration project for capturing CO_2 emissions from the natural gas extraction process in the Gorgon field off the coast of Western Australia. The Project involved compressing, dehydrating and transporting the CO_2 by pipeline to the injection site – a saline sandstone reservoir in the Dupuy Formation. It aimed to reduce project emissions by 120Mt over its lifespan at a 3.4-4Mt annual rate, and is the first major project to significantly reduce emissions through underground injection. The Project is expected to begin CO_2 injections in 2019.

Contribution to Research and Knowledge

Research and knowledge gained from the Project may have been limited because CO_2 injections have not started and because of potential commercial-in-confidence issues. The 12 public technical reports identified as part of this evaluation covered key learnings on:

- the acquisition of quality seismic data, through petrographic, petrophysical, biostratigraphical, sedimentological and geochemical reporting – and its significance to improving the accuracy of CO_2 migration simulation models
- the impact on project execution
- well remediation programmes to ensure existing wells near the proposed injection site have been properly secured and do not pose a CO_2 containment risk
- site assessments, research and exploration work.

These technical reports have been cumulatively cited 1,012 times by external papers, demonstrating the significant contribution to enhancing knowledge of LETFF, and particularly CCS, made by the project.

Contribution to domestic skills and capabilities

The Gorgon Project involved the use of technologies, processes and equipment that have previously existed within the oil and gas sector, and as such was able to leverage the existing and significant skills base within the oil and gas sector.

However, the Gorgon Project did brought in monitoring technologies that reduced the cost of monitoring CO_2 plumes. These technologies include surveillance wells, 4D Surface Seismic testing, soil gas verification and pressure sensors on the surface.

This evaluation did not identify any technical reports that were written in partnership with universities or other research-based institutions.

Contribution to industry understanding of low emissions technologies

The Project is seen as a successful example of CCS operations on a commercial scale. While the $60 million allocated from the LETDF was not material to the Gorgon Project's success, it has enabled the development of a successful relationship that was crucial in the following ways:

- key learnings from the Gorgon Project relating to the legal and regulatory aspects influenced how the Australian Government intended to regulate CCS
- it also assisted in developing the Australian Government's Offshore Petroleum and Greenhouse Gas Storage Act.

The Project also led to technical reports associated with pumping CO_2 into reservoirs that are full of water, and its impacts on the reservoir itself. Depending on the type of report, they are either disseminated internally (where there is a commercial advantage) or published in industry journals.

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Phase Two of the Impact Evaluation of the Low Emissions Technologies for Fossil Fuels (LETFF) programs

Department of Industry, Innovation and Science

15 July 2019

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Glossary

ACALET R&D	Australian Coal Association Low Emissions Technologies Research and Development
ANAO	Australian National Audit Office
s22	
ARENA	Australian Renewable Energy Agency
CCS	Carbon Capture and Storage
s22	
CO2CRC	Carbon Dioxide Co-operative Research Centre
CSIRO	Commonwealth Scientific and Industrial Research Organisation
GCCSI	Global Carbon Capture and Storage Institute
GHG	Greenhouse Gases
HELE	High Efficiency Low Emissions
IDGCC	Integrated Drying Gasification Combined Cycle
IGCC	Integrated Drying Gasification Combined Cycle
KEQ	Key Evaluation Questions
LETDF	Low Emissions Technology Demonstration Fund
LETFF	Low Emissions Technologies for Fossil Fuels
s22	

Executive summary

In 2004, the Australian Government identified a need to support and promote the development and deployment of low emissions technologies to facilitate a cost-effective transition to a lower carbon economy.

The Department of Industry, Innovation and Science (the Department) has been implementing a range of policies from 2004 to support the research and development of new greenhouse gas (GHG) emissions reduction technologies under the Low Emission Technologies for Fossil Fuels (LETFF) programs.

Deloitte has been engaged by the Department to undertake Phase Two of the LETFF impact evaluation to evaluate the impacts of the LETFF programs on increasing knowledge, skills and capability, and on improving industry understanding in relation to low emissions technologies. The project also sought to answer:

- What factors have helped or hindered the achievement of the above outcomes?
- To what extent would outcomes have been achieved in the absence of the LETFF programs?
- To what extent do factors within and external to the LETFF programs remain a barrier to commercial development and deployment of LETFF?
- What (if any) unintended outcomes, positive and negative, have occurred as a result of the LETFF programs?
- What lessons can be drawn to inform future program development, including the role (if any) of the Commonwealth Government, in relation to supporting the development and implementation of LETFF technologies?

To answer these questions, the impact evaluation adopted a mixed methods approach involving semi-structured interviews with program stakeholders, an online questionnaire, and extensive scan of secondary data including citation analysis and development of case studies.

Contribution to knowledge, skills and industry understanding

The LETFF programs have significantly contributed to increasing knowledge, skills and capability, and improving industry understanding of LETFF in Australia. Overall, Australia has the research and engineering capability to develop commercial scale LETFF projects.

Overall, through the LETFF programs Australia has developed:

- a mature knowledge base with multiple industry participants with knowledge of a range of LETFF, supported by a broad body of research covering multiple technologies
- a moderate level of domestic skills and capability, with more advanced expertise within a number of organisations in relation to specific LETFF, most notably CCS
- a moderate industry understanding of the technical and practical feasibility of some LETFF, notably CCS, under a range of processes and Australian conditions but deployment required to further advance understanding.

A significant body of research has been delivered across the full spectrum of LETFF activities, and the critical research and development and technical barriers are considered to be largely settled for CCS.

Australia’s research skills and capabilities have been deepened with respect to specific LETFF; these skills and local experience are more developed relative to prior to commencement of programs. However, Australia’s research capabilities are considered to be more advanced than industry capabilities. Stakeholders agree that deployment of LETFF is required to further advance Australia’s industry and technical skills and capabilities.

The LETFF programs have resulted in industry developing a detailed ‘end-to-end’ understanding of the engineering and design of LETFF, in particular CCS technologies. Furthermore, there is a

consensus that the coal, energy generation, and oil and gas sectors have an understanding of the practical, technical and financial requirements necessary to deploy CCS. However, the absence of a commercial imperative to invest in emissions abatement remains the overarching barrier to LETFF deployment in Australia.

Factors contributing to the success of the LETFF programs

At commencement, the LETFF programs were underpinned by clear policy direction and settings, support across Commonwealth and State Governments, and a significant funding commitment across a suite of programs and projects – factors deemed critical to the achievement of outcomes. Other contributing factors to the achievement of outcomes included:

- establishment of partnerships between government, industry and academic stakeholders
- the direct financial involvement of the coal industry in maintaining an industry-focused research agenda
- establishment of a portfolio of LETFF projects to maximise learnings and the probability of success.

Overall, changing, uncertain and inconsistent domestic policy settings are considered the primary factors hindering achievements and progress across the LETFF programs. Policy uncertainty has resulted in a significant loss of confidence across industry and a loss of momentum in advancing LETFF.

A combination of the unexpected complexity of LETFF, inflexibility of funding agreements, and regulatory uncertainty on the part of the Commonwealth and State Governments also hindered achievements and progress across the LETFF programs.

The absence of a clear commercial imperative on the part of industry to invest in carbon abatement remains the single largest barrier to the commercial development and deployment of LETFF.

Success, future research and role of government

Overall, stakeholders overwhelmingly consider the LETFF programs to be successful. There was strong agreement among all stakeholders that the achievements of the LETFF programs would not have been made in the absence of Commonwealth Government support. Furthermore, stakeholders consider that the Commonwealth Government's investment in LETFF programs represents good value for money, and that achievements are commensurate with the investment.

LETFF programs have directly contributed to reducing the technical and commercial barriers to the development and deployment of commercial-scale LETFF projects. However, the achievements and knowledge gained could have been more effectively communicated and disseminated beyond immediate program participants, and achievements could have been more effectively communicated to the broader public. Barriers to knowledge sharing and access to information have contributed to a low level of public understanding and acceptance of LETFF, and in particular CCS, and represent one barrier to the deployment of LETFF.

Australia also risks losing the significant gains in knowledge, and skills and capabilities established through the LETFF programs if there is no progression towards the commercialisation and deployment of LETFF.

The critical underlying research and technical questions to deploying large-scale LETFF (and CCS in particular) have been addressed, however some targeted research would supplement and benefit research done to date. In particular, there is need to undertake site-specific research and testing to support the eventual deployment of LETFF.

Stakeholders consider there remains a critical role for the Commonwealth Government in supporting the development and implementation of LETFF. While there was no clear consensus on the appropriate role for the Commonwealth Government from stakeholders interviewed, a majority of respondents to the online questionnaire considered the Commonwealth Government should continue to provide large-scale grants to support LETFF research and development.

Key lessons for future program design

The impact evaluation has identified the following key lessons to inform future program design and implementation:

- the need to set realistic expectations with respect to program cost and time-horizons, particularly for programs with a focus on deployment of commercial-scale projects incorporating untested technologies
- the need to set realistic expectations with respect to research and development outcomes, noting that only a proportion of projects will succeed in progressing beyond research and pre-commercial feasibility
- ensuring alignment between policy settings and program objectives, and ensuring an appropriate mechanism is in place to trigger a review of program rationale in the event of a fundamental shift in domestic and international policy settings
- enhancing the technical and financial assessment of project feasibility at program commencement, noting that this needs to be balanced with the research and development objectives and any future program
- funding and program governance arrangements should reflect the nature of program activities, in particular stage gates should replace inflexible milestone reporting and payment processes for large projects to enable a more efficient provision of funding
- greater industry engagement in the design of the program, and as part of a formal risk assessment, to ensure program objectives, risks and issues are appropriately understood and reflected in the program design and implementation
- the need to embed monitoring and reporting frameworks to monitor the effects of changes to funding on the achievement of program objectives, and better enable an assessment of how remaining funds can be redistributed within the program or other programs
- the need to embed knowledge-sharing processes and systems to ensure program learnings and outcomes are appropriately captured and disseminated across relevant Commonwealth and State Government departments and agencies
- any consideration of future support to further the development and implementation of LETFF, as a first step, should involve a detailed economic cost benefit analysis of LETFF in decarbonising the economy relative to alternative technologies. This analysis should give consideration to fossil fuel demand and the whole-of-lifecycle costs of alternative technologies.

1 Overview and purpose

1.1 Context

Australia's electricity generation and some industrial sectors (e.g. steel and concrete production) rely heavily on burning fossil fuels, such as coal, natural gas and oil, which release carbon dioxide (CO_2) and other greenhouse gases (GHG) into the atmosphere.

Low emissions technologies have the potential to reduce GHG emissions and Australia's impact on climate change. In 2004, the Australian Government identified a need to support and promote these technologies to facilitate a cost-effective transition to a lower carbon economy. The Department of Industry, Innovation and Science (the Department)[1] has since implemented and overseen the Low Emission Technologies for Fossil Fuels (LETFF) programs. These programs fund research and development of new GHG emission reduction technologies. The LETFF programs comprise the following four programs:

- The Carbon Capture and Storage (CCS) Flagships program
- s22
- The Low Emissions Technology Demonstration Fund (LETDF)
- s22

These programs commenced against a backdrop of increasing and coordinated global action against climate change. However, they have experienced significant changes in funding, policy and investment conditions. In particular, the repeal of the carbon pricing mechanism has led to uncertainty regarding the future price of carbon, affecting business investment incentives.

The Department has identified the LETFF programs as a Tier One evaluation priority of high strategic importance. The Department previously accepted the recommendation of the Australian National Audit Office (ANAO) audit (2017) to evaluate the LETFF programs. The Department is conducting the evaluation of the LETFF programs in two phases, consisting of:

- Phase One - an assessment of the 'evaluability' of the four LETFF programs, previously conducted by Deloitte Access Economics. (Completed)
- Phase Two - an impact evaluation of the LETFF programs, the scope of which has been informed by the outcomes of Phase One. (Current phase).

1.2 Purpose and scope of Phase Two

The Department has engaged Deloitte to conduct Phase Two of the LETFF impact evaluation (the project). The overarching purpose of this project is to evaluate the impacts of the LETFF programs on increasing knowledge, skills and capability, and on improving industry understanding about low emissions technologies.

The project will also seek to determine whether the Government investments made under the LETFF programs have helped move low emissions technologies closer to commercialisation, and whether the outcomes achieved are commensurate with the level of investment made by the Commonwealth Government.

The findings of this project will inform future LETFF program design, including the potential role of the Commonwealth Government in supporting the further development and implementation of LETFF.

The project covers all components of the LETFF programs with the exception of the CCS Flagships Research Development and Demonstration (RD&D) fund, which is out of scope as impacts are unlikely to have been realised at the time of reporting.

[1] The LETFF programs were originally implemented under the former Department of Resources, Energy and Tourism.

1.3 The LETFF programs

The LETFF programs support low emission fossil fuel technologies by funding programs and initiatives that aim to reduce technical risks and speed up the commercialisation process. Technologies that were supported through the LETFF programs include:

- carbon capture and storage (CCS)
- high efficiency low emissions (HELE) electricity generation
- fugitive methane emission abatement technologies.

A total of $2.8 billion was originally budgeted across all four LETFF programs. However, funding was substantially reduced over time and approximately $750 million has been spent to date.

A summary of the four LETFF programs, including the objectives of each program, is provided in Table 1.1 below. A summary of individual projects delivered under each program is presented in Appendix A.

Table 1.1: Summary of LETFF programs

LETFF Program	Description
The CCS Flagships program	Commenced in 2009 under the Federal Budget's Clean Energy Initiative with a program budget of $1.8 billion. The objective of the program was to promote the dissemination of CCS technologies through supporting a small number of demonstration projects to capture CO_2 emissions from industrial processes and safely store them underground in stable geological formations. Five flagship projects and other small-scale CCS activities have been funded over the course of the program. Two out of the five flagship projects have been deemed 'unsuccessful'. The program also includes the CCS Research, Development and Demonstration (RD&D) Fund with an objective of reducing the technical and commercial barriers to deploying large-scale CCS projects.
s22	
LETDF	Announced in June 2004 under the *Energy White Paper – Securing Australia's Energy Future*. The Fund had a $500 million budget that could be granted to projects ranging from concentrated solar to CCS technology. The aim of the program was to demonstrate the commercial potential of new technologies to contribute to long-term large-scale GHG emissions reductions. The LETDF Program funded six highly complex projects which required a high degree of due diligence. Of these six, two were transferred to other programs, three were unsuccessful and only one – the Gorgon Carbon Dioxide Injection Project, continues to operate.
s22	

1.4 Summary of Phase One findings

Deloitte was previously engaged to assess the evaluability of the four LETFF programs under Phase One of the impact evaluation of the LETFF, to inform design and resourcing of any future impact evaluation to be undertaken in Phase Two. The evaluability assessment sought to answer three key questions:

- Was it plausible to expect an impact from the programs?
- Would an evaluation be useful, and, if so, to whom?
- Would an evaluation be feasible, based on: program evidence, data availability, baseline measures, and reporting mechanisms?

The evaluability assessment found that, overall, it was reasonable and plausible to expect that the projects and activities delivered under the LETFF programs could achieve intended short-term and, to some extent, medium-term outcomes and impacts. It was not plausible to expect that the LETFF programs could reasonably have achieved the strategic longer-term objectives of demonstrating and deploying LETFF on a commercial scale, thereby reducing GHG emissions.

The evaluation assessment confirmed there was strong stakeholder support and interest for an impact evaluation. It advised that in the absence of delivery of any commercial scale projects, an impact evaluation should focus on the achievement of short and (to some extent) medium-term outcomes to guide future policy focus and direction. It also noted that any future impact evaluation of LETFF programs will require drawing on a range of qualitative evaluation methods, with a focus on stakeholder interviews and questionnaires, documentation review, and case studies.

The evaluability assessment recommended that the Department undertake a targeted impact evaluation of the LETFF programs that focuses on assessing the extent to which the LETFF programs have resulted in changes over the short- and medium-term against the following program outcomes:

- generation of new research, data and modelling relating to the practical and technological use and implementation of LETFF (short-term outcome)
- improved industry knowledge regarding the feasibility and safety of low emissions and abatement technologies, through collaboration and dissemination of findings from pilot and feasibility studies (short-term outcome)
- development of domestic skills and capability in low emissions and abatement technologies (medium-term outcome).

The evaluability assessment recommended a future impact evaluation should also assess:

- whether industry knowledge and understanding of the feasibility and safe development of LETFF would have progressed in the absence of the LETFF programs
- whether changes in policy settings and other external factors have affected the ability of LETFF programs to achieve stated impacts
- implications for future policy development and priority setting, including the role (if any) of the Commonwealth Government in supporting the further development and implementation of LETFF.

1.5 Report structure

This report presents the findings of the impact evaluation of the LETFF programs. The report is structured as follows:

- Chapter 2 outlines the approach to the impact evaluation.
- Chapter 3 presents the contributions made by the LETFF programs to knowledge, skills and industry understanding.
- Chapter 4 discusses factors contributing to the achievements of the LETFF programs.
- Chapter 5 discusses the success of the LETFF programs, including areas of future research and the role of government in supporting the development of LETFF.
- Chapter 6 presents learnings for future program design.

2 Evaluation methodology

The impact evaluation uses a mixed methods approach to assess the extent to which the LETFF programs have contributed to increasing knowledge, skills and capability, and to improving industry understanding of LETFF. This has included semi-structured interviews, an online questionnaire and secondary data analysis, a citation analysis and development of concise case studies.

2.1 Evaluation framework

An evaluation framework has been developed to guide this evaluation. It outlines the key evaluation questions and data sources to be drawn on to address each evaluation question, and was developed in consultation with the Department. The evaluation framework has guided the key lines of enquiry and systematic organisation of analysis to ensure a consistent and robust assessment of the LETFF programs and project activities. The framework is presented in Appendix B.

2.2 Data collection and analysis

2.2.1 Semi-structured interviews

Semi-structured interviews were conducted with key LETFF program stakeholders from the Department, Commonwealth science agencies (e.g. CSIRO and Geoscience Australia), participating State Governments, industry grant recipients and representatives, academic and research grant recipients, and expert advisers. All stakeholders engaged had direct involvement in the LETTF programs. Contact details of key stakeholders were provided by the Department.

A total of 18 semi-structured interviews were conducted. An interview guide was developed based on the evaluation framework. Questions were tailored for each stakeholder depending on group and LETFF program(s) they participated in, and mapped to each evaluation question in the framework. Each interview was conducted via telephone and recorded. The interview was subsequently analysed in NVivo, using coding techniques to identify common themes. A summary of stakeholders interviewed is provided in Appendix C.

2.2.2 Online questionnaire

An online questionnaire was developed to gain further insights into stakeholders' perceptions of the impact of the LETFF programs, the factors that may have assisted or hindered the achievements, and the overall success of the LETFF programs. A total of 17 respondents completed the online questionnaire. A summary of the spread of respondents is provided in Appendix C.

The online questionnaire was sent to the same cohort of stakeholders as the semi-structured interviews (via emails provided by the Department). Stakeholders were invited to forward the questionnaire on to their peers and colleagues who had also been directly involved with the LETFF programs. As such, the online questionnaire has not enabled a true triangulation of findings relative to the interviews. However, the questionnaire did provide further richness of insights with respect to the impact of the LETFF programs and supplemented the findings of the interviews.

2.2.3 Program data

The project has involved an examination of departmental documents and data and other publicly available information, to provide insights on impacts achieved by LETFF programs, including:

- final project reports
- research papers, scientific papers, technical papers produced under the LETFF programs
- project specific datasets and models
- broader literature on relevant themes.

A literature scan of research and scientific papers produced under the LETFF was undertaken due to the extensive body of documentation produced. A scan of 496 publically available reports matching key search criteria was undertaken to provide insights into the impact of the LETFF

programs. This ensured an appropriate breadth and depth of documents were reviewed across the LETFF programs.

Key document sources included Department-held documentation, in addition to data, reports and documentation held by:

- s22
- Global CCS Institute (GCCSI) data and documentation
- CO2CRC
- CSIRO
- Geoscience Australia.

2.2.4 Citation analysis

The project has involved a citation analysis of the 496 program publications identified in a literature scan up to 29 May 2019 to gauge the extent to which knowledge transfer has occurred as a result of the LETFF programs. The citation analysis involved:

- cited reference analysis – the number of times that research publications produced by the LETFF programs have been cited in journal articles or scientific publications based on Google Scholar data.
- publication use – the number of times that research publications produced by the LETFF programs have been accessed or requested online (where this data was available).

The results of the citation analysis were then triangulated with semi-structured interviews and results from the online questionnaire.

2.2.5 Case studies

Case studies of individual LETFF projects were developed from across the LETFF programs. This enabled the identification of general findings about the LETFF program. Case studies were developed from primary and secondary data sources, and illustrate the extent to which specific projects have contributed to the achievement of focus outcomes. Two case studies were developed for each program, with the exception of the LETDF program.

Case studies are outlined in Appendix D.

2.3 Limitations of methodology

The focus of this project is an impact evaluation of specific short and medium-term outcomes of the LETFF programs. Specifically, the intent is to assess the impact of the LETFF programs on increasing knowledge, skills and capability, and on improving industry understanding of LETFF. The project has not sought to assess the extent to which the LETFF programs have achieved any other medium or longer-term outcomes.

The qualitative data presented in this report reflect the opinions and perceptions of stakeholders engaged during the evaluation. These opinions and perceptions are presented as originally communicated. Stakeholders engaged in this evaluation have all had direct involvement in the LETFF programs. Stakeholders, by virtue of their involvement in the LETFF programs, may have had an inherent bias in their view of achievements and outcomes.

This evaluation has not engaged any stakeholders external to the LETFF programs, such as representatives of alternative technologies or programs.

The project has been limited by the significant lapse in time since the commencement of the LETFF programs and subsequent implementation. Specific issues that limited this evaluation include:

- the natural turnover of program staff; the Deloitte team was unable to engage with departmental stakeholders who had been involved in the programs at inception
- the natural turnover of participating industry and academic stakeholders; many key project proponent staff and external expert advisors have subsequently left their roles and/or organisations, meaning the Deloitte team was unable to speak to stakeholders from across all projects and activities. As such, only a sample of relevant stakeholders could be reached for the purpose of the evaluation.

3 Contribution to knowledge, skills and industry understanding

Key findings:

- The LETFF programs **have significantly contributed to increasing knowledge, skills and capability, and improving industry understanding of LETFF in Australia.** Overall, Australia has the research and engineering capability to develop commercial scale LETFF projects.
- Australia now has:
  - **a mature knowledge base** with multiple industry participants with knowledge of LETFF, supported by a broad body of research covering multiple technologies
  - **a moderate level of domestic skills and capability**, with more advanced expertise within a number of organisations in relation to specific LETFF, most notably CCS
  - **a moderate industry understanding** of the technical and practical feasibility of specific LETFF under a range of processes and conditions, but further advances in understanding will require deployment.
- A significant body of research has been delivered across the full spectrum of LETFF activities - the critical research and development and technical barriers are considered to be largely settled for CCS.
- Australia's pool of research and technical skills and capabilities is considerably larger, more developed and vastly more experienced relative to prior to commencement of programs.
- Research capabilities are more advanced than industry capabilities. Deployment of LETFF is required to further advance industry skills and capabilities.
- There is a risk of Australia losing the skills and capabilities developed if momentum is not maintained given the global demand for skills and expertise.
- The LETFF programs have resulted in industry developing a detailed 'end-to-end' understanding of the engineering and design of LETFF, in particular CCS technologies.
- There is a consensus that the coal, energy generation, and oil and gas sectors have an understanding of the practical, technical and financial requirements necessary to deploy CCS.
- However, the absence of a commercial imperative to invest in emissions abatement remains the overarching barrier to LETFF deployment in Australia.

3.1 Overall contribution of LETFF programs

Overall, there is consensus among industry, government and academic stakeholders involved in the LETFF programs that these programs have significantly contributed to increasing knowledge, skills and capability, and improving industry understanding about low emissions technologies in Australia.

There is broad stakeholder agreement that the advances in Australia's understanding of LETFF and their implementation – particularly around geological subsurface storage – would not be where it is today in the absence of the LETFF programs (discussed in greater detail in Section 5.2).

Stakeholders highlighted that the LETFF programs have involved an incremental learning process for industry, academia and government. Individual project outcomes have contributed towards a broad portfolio of achievements, rather than one single, flagship success. Even 'failures' have

provided valuable learning opportunities and insights, with most stakeholders indicating the importance of discovering what didn't work to be just as important as knowing what works.

Australia is now considered to be 'deployment ready' from a technological perspective. Australia is considered to have a mature knowledge base, supported by a well-developed body of research, with moderate skills and capability across specific LETFF (particularly CCS), and considerable industry understanding of the practical and technical feasibility of LETFF under a range of Australian conditions. There is strong agreement across all stakeholder groups that the priority for LETFF is to shift to commercial-scale deployment. Figure 3.1 illustrates the shift in the level of knowledge, understanding, and capabilities since the commencement of LETFF as perceived by key stakeholders and reflected in available evidence.

Figure 3.1: Summary of evidence of perceived shift in Australia's LETFF knowledge, understanding and capabilities since 2005

High

Stage	State of knowledge	Understanding of technical and practical feasibility	Local industry skills and capability
5	Deep and broad sector knowledge throughout industry, supported by extensive body of research covering full range of LETFF technologies.	Extensive industry understanding of technical/pract cal feasibility of full range of LETFF technologies under full range of processes and conditions.	World leading industry skills and capabil ty located within a wide number of industry and research organisat ons and across the broad spectrum of LETFF technologies.
4	Broad sector knowledge across major ty industry part cipants, supported by large body of research covering large range of technologies.	Broad industry understanding of techn cal/practical feasibil ty of LETFF technologies under most industrial processes and conditions.	Broad local industry skills and capabil ty across a large number of industry and research organisat ons and a across the major ty of LETFF technologies.
3	Sector knowledge is moderate, w th multiple industry part cipants having knowledge of LETFF technologies, supported by a moderate body of research covering multiple technologies.	Moderate industry understanding of technical/pract cal feasibility of LETFF technologies under some processes and cond t ons.	Moderate local industry skills and capabil ty, with expertise across a moderate number of organisations on a moderate range of LETFF technologies.
2	Sector knowledge is thin, w th only select industry part cipants having meaningful knowledge of LETFF technologies, supported by a small body of research focussed on one or two technologies.	Lim ted industry understanding of techn cal/practical feasibil ty of LETFF technologies under 1 or 2 industrial processes.	Thin but growing local industry skills and capabil ty, with expertise located across a handful of industry and research institut ons.
1	Sector knowledge relating to pract cal, technolog cal and scientif c use and implementation of LETFF technologies is minimal/non-existent.	No industry understanding of techn cal/practical feasibil ty of LETFF technologies.	N che local industry skills and capabil ty, with only lim ted expertise.

Low

Source: Deloitte Access Economics

The LETFF programs have contributed to providing Australia with a detailed 'end-to-end' understanding of CCS, with stakeholders agreeing that the major research development questions and technological barriers have been largely settled and overcome. The LETFF programs have contributed to a clear understanding of the 'pathway to deployment' for LETFF and in particular CCS, including:

- the capture, transport, storage and injection technologies involved
- the costs and timeframes involved
- which technologies to deploy and under what conditions
- the locations and suitability of storage sites where technologies can be best deployed.

3.1.2 State of knowledge, capabilities, and understanding prior to commencement

Prior to the commencement of the LETFF programs, stakeholders reported Australia's knowledge and understanding of LETFF as predominantly conceptual and theoretical in nature. Understanding of how LETFF might be practically implemented was very limited, although it was noted that the oil and gas sector had a deeper understanding than other sectors, given the integral nature of drilling

in this sector. Overall, stakeholders reported that Australia, in general, had limited knowledge and understanding of:

- the location, capacity and sub-surface condition of geological resources (both onshore and offshore)
- long-term stability of geological resources and how they would react with CO_2
- different emission capture technologies and application to Australian conditions and industrial processes
- the behaviour of CO_2 plumes under different sub-surface conditions, and how to model the behaviour of CO_2 plumes
- the behaviour of CO_2 during transportation
- the end-to-end engineering and design of capture and storage technologies
- the full life-cycle costs of designing, building and operating commercial-scale LETFF.

Additionally, there was no arrangement in place to structure the existing knowledge base, to direct the advancement of new research, or to provide a knowledge-sharing platform between government, academia and industry. Stakeholders described Australia's knowledge-base as follows:

> *"… we didn't have a good idea of where the basins were. We didn't know much about the capture technologies, we didn't know if there was Enhanced Oil Recovery potential"* – Academic/research stakeholder

> *"…there was theoretical knowledge, but less knowledge of [how] it [will] actually work in practice. [There was] a gap in the knowledge in terms of the application* – Government stakeholder

> *"Go back probably 20 years, I would say that the Australian state [of knowledge] was developing. I wouldn't say it was embryonic, I'd say we were better than embryonic, but I think we were developing…. We were by no means near deployment-ready." – Academic/research stakeholder*

This is not to say that Australia did not have a meaningful understanding of LETFF relative to other developed countries – such as the European Union, the U.S., the U.K., or China. On the contrary, stakeholders interviewed reported Australia's academic and scientific research community had pockets of recognised world-leading skills and expertise. Examples identified by stakeholders include:

> *"Geoscience Australia did some very early work in geological storage… very basic basin work to get some capacity work [back] in the 90s."* – Academic/research stakeholder

> *"Geoscience Australia had been working toward CCS aspects as well and then we had CSIRO… CSIRO had been working on capture technologies at a small scale across a few sites…. There [were] capture engineers at Monash and Melbourne Universities… so that knowledge was there at a research phase."* – Academic/research stakeholder

Within industry, however, there was a lack of the technical and practical type skills necessary for deployment and implementation – such as engineering and operational type skills. As noted by some stakeholders:

> *"… it would have been the researchers and not industry in those early days that had the expertise or understanding as well."* – Commonwealth Government stakeholder

> *"… not as much as the practical engineering because it hadn't been deployed in Australia… not enough for a full industry, which is what we very rapidly found out when the flagship projects were launched there just weren't enough people to do all the work and so what we had is the same people doing a lot of the work…"* – Research stakeholder

Across industry, there were also certain sectors that were more advanced in their understanding of and engagement with LETFF than others. Stakeholders singled out the Oil and Gas sector, in

particular, as having well-established understanding and capabilities relating to carbon capture and storage (CCS) technologies:

> *"…the Oil and Gas industry in 1999… they were fine. …injecting CO_2 and withdrawing gas from the subsurface, this is their daily bread…these guys have been doing EOR [Enhanced Oil Recovery] for 40 years. They have been injecting CO_2 for 40 years, they know how to do this."* – Academic/research stakeholder

> *"… [the Oil and Gas industries] were already way up the learning curve both in terms of capture technology and in terms of injection…"* – Industry stakeholder

In contrast, other emissions-intensive industries had yet to commence investigating the potential of LETFF in detail. In particular, the coal, energy generating, industrial (e.g. steel, concrete, and fertiliser) and agricultural sectors had yet to meaningfully investigate and engage in the development of low-emission, abatement, or monitoring technologies emission abatement and capture technologies. As some stakeholders noted of these sectors:

> *"… there wasn't necessarily much appetite to engage… there wasn't a significant driver… until I suppose the carbon taxes and things came in at that time.… as far as I understand industry weren't totally engaged."* – Commonwealth Government stakeholder

> *"…the electricity sector has traditionally been happy to produce electricity and run their coal-fired power stations…the big issue for them is that they went from a business of mechanical engineers to a business of chemical engineers [to understand LETFF] and that was a big problem for them. They are low-risk engineers and they had to move into a high risk [investment]."* – Industry stakeholder

3.1.3 State of knowledge, capabilities, and understanding today

Today, stakeholders report that the breadth and depth of Australia's knowledge, capabilities and understanding of LETFF, in particular CCS, is significantly greater than it was prior to the commencement of the LETFF programs. Overall, stakeholders reported significant improvements in Australia's knowledge and understanding of:

- the 'end-to-end' of the implementation of low-emissions technologies, including:
  - integrating low-emissions technologies with existing production systems
  - proving low-emissions technologies under Australian conditions
  - cost discovery of implementation
  - safety and environmental implications
  - regulatory approvals process
- monitoring and measuring greenhouse gas emissions
- Australia's geological subsurface storage potential and capacity, including:
  - the importance of subsurface storage in the CCS process
  - identification of suitable subsurface storage locations, and their potential capacity
  - dynamic modelling the geological subsurface behaviour of CO_2.

The consensus among stakeholders from across industry, government, and academia is that Australia's knowledge and expertise is now well-past the conceptual and theoretical R&D phase. Australia now possesses the research and technical foundations, including an understanding of the technical challenges, costs, and risks to progress to commercial-scale deployment. Australia is considered to 'hit above its weight' with respect to LETFF on a global stage. As noted by stakeholders:

> *"… in Australia, we have a range of stakeholders that are probably world leaders in terms of understanding the whole value chain of CCS, whether it be understanding capture technologies inside the CSIRO… they are world leaders and they are winning grants from other countries at the moment. I think that monitoring and storage activities … the CO2CRC are world leading … I think we have a much better understanding of the underground storage potential in Australia, both onshore and offshore, more work to be done in that space, but when you compare 10 years ago to now… we have made great progress on the technical front of understanding CCS and I don't disagree with some people who have said we have conquered the technical barriers."* – Commonwealth Government stakeholder

> *"… we have done all the engineering to the point of construction, so from not even knowing which technology to choose, to now having chosen a technology and done all the upfront engineering, partnering with the technology providers, so that a construction decision can be made with, actually can be made today if we had the money. … That's actually been a dramatic shift"* – Industry stakeholder.

However, the advances in knowledge, skills and capability and understanding have been more concentrated in certain sectors than others. In particular, there was consensus among stakeholders that the advances in knowledge and capabilities in the academic and scientific research community far outweighed advances in the coal, energy generating and industrial sectors. As noted by a stakeholder:

> *"… the skills level of the academic community has indeed increased, but it's the academic skills level and not the industrial deployment skills level…"* – Industry stakeholder.

Despite the gains that have been made over the last 15 years, there are gaps that remain and new gaps have emerged. Overall, stakeholders identified the following gaps:

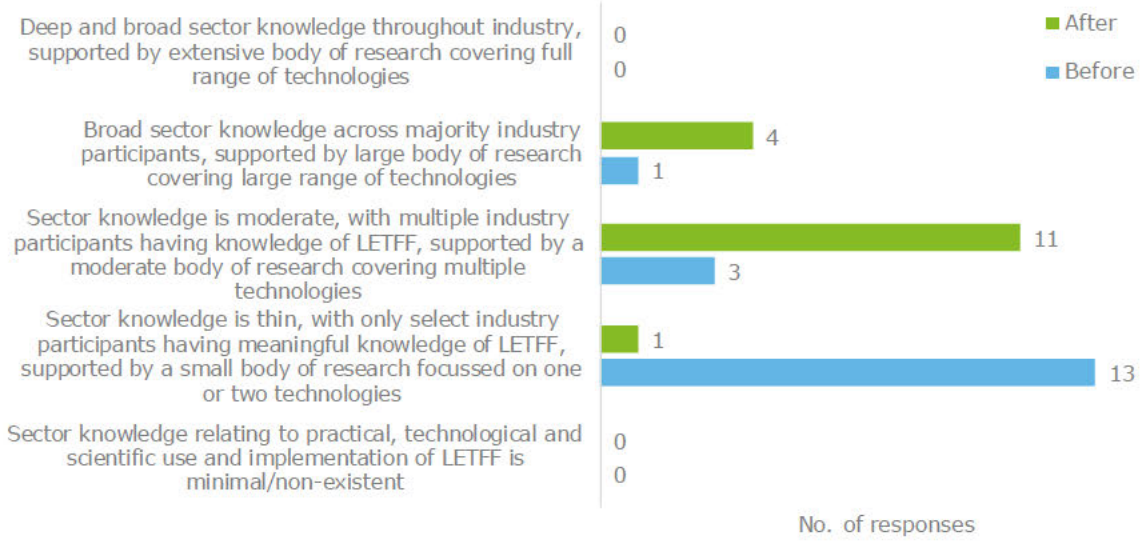
- the need to consolidate the knowledge and understanding of LETFF gained to date
- improving the accessibility, dissemination and communication about LETFF across industry sectors and the broader community
- detailed local and site-specific understanding of suitable onshore and offshore subsurface storage potential and capacity
- demonstration and deployment of LETFF on an industrial-scale, and the absence of an established CCS industry in Australia
- lack of experienced engineering skills and capabilities (mechanical, electrical etc.) for the industrial-scale deployment and operation of LETFF and CCS technologies.

3.2 Generation of new research and knowledge

There was consensus among stakeholders interviewed that Australia's overall state of knowledge progressed from being perceived as 'thin' prior to the commencement of the LETFF programs, to a mature moderate knowledge base underpinned by a well-developed body of research across multiple technologies.

This view was supported by the findings of an online questionnaire of LETFF stakeholders. Chart 3.1 illustrates the perceived change in the overall state of knowledge and understanding with respect to LETFF.

Chart 3.1: Questionnaire responses on overall state of knowledge before and after the commencement of the LETFF programs



Source: Deloitte questionnaire, n = 17

In addition to the improvement and expansion of the domestic skills base, the LETFF programs are attributed with having generated a range of new and original research and technical innovations. These include outputs such as:

- **Data tools** – geological seismic data, atmospheric measurement data, and technical test data
- **Modelling tools** – geological subsurface storage mapping, models of CO_2 subsurface behaviour, energy market modelling, as well as financial models of commercialisation
- Technological **innovations** – digital drill core technology s22
- **Methodological improvements** – improved methods for monitoring greenhouse gas emissions, technical operation methods that improve efficiency or safety, project management methods that improve the up-scaling and commercialisation of technologies
- **Formation of new relationships** – the value of the new relationships formed between industry, government, and the academic and scientific communities, as well as relationships formed between these communities in Australia with other people, communities and institutions overseas.

These provide the foundation tools and resources for industry and government to further invest in LETFF and CCS technologies with greater certainty in regard to the costs associated with deployment and ongoing operation, safety and environmental considerations, and the efficiency of production.

In addition to the above, the LETFF programs have contributed a significant body of **publications,** including academic journal articles, discussion papers, PhD dissertations, conference presentations, government policy documents, and interim and final project reports.

The GCCSI also contributed to the knowledge, skills and industry understanding achieved through the LETFF programs. The GCCSI is an important contributor to research and has an extensive repository of program reports and datasets. It is noted that the Commonwealth Government was instrumental in establishing the GCCSI.

3.2.2 Examples of the types of innovations and knowledge generated

While a rigorous and accurate stocktake of the new research and knowledge generated is beyond the scope of this report, Table 3.1 lists several key innovations developed across the LETFF programs identified by stakeholders.

Table 3.1: Examples of key innovations attributable to LETFF programs/projects

Title (LETFF project)	Description
s22	
Seismic monitoring fibre optic cable technology (CCS Flagships program – Otway Geological Storage and Demonstration Project)	The project involved the development of seismic monitoring fibre optic technology to enhance the performance of seismic monitoring of drills. The technology has effectively replaced traditional geophone technology and significantly reduced the cost of undertaking seismic analysis. *"…with the funding that we have received from the LETFF and a combination of work with experts from Curtin* [University] *and also internationally, we are now at the point where the performance of these fibres is substantially better than these geophones. Now, that all sounds very technical, but what it means is we now have the ability to not have to put major infrastructure down these wells, we can do it through very cheap wells."* – Research stakeholder
s22	

As reported above, the LETFF programs have generated a significant body of research. An analysis of 496 publically available publications associated with LETFF programs and projects, as well as the results of a citation analysis, are provided in Table 3.2 (below). Although generating published material was not an intended outcome of the LETFF programs, they provide an indication of the knowledge generated and of the understanding that has been disseminated.

s22

The citation analysis indicates the number of times that published materials have been cited in other domestic and international publications, providing an indication as to the extent that learnings and knowledge gained through the LETFF programs have been drawn upon and utilised in other research. Overall, the results indicate that the published material generated through the LETFF programs have been widely disseminated, and gone on to influence and inform a wider body of research and knowledge. This further supports stakeholders' observations of Australia as having world-leading research expertise and of the contribution of Australian expertise and knowledge internationally.

Table 3.2: Summary (broad) of LETFF program and project publications

LETFF program/ project	Publications		Scholarly articles (as a share of publications)	No. of citations	Citations per publication
	No.	%	%		
CCS Flagships	65	13%	2%	170	2.6
s22					
LETDF	23	5%	39%	1,105	48.0
s22					

Source: Deloitte Access Economics

Notes: These estimates only include publically available publications; Scholarly articles are considered to be publications that appear in peer-reviewed academic or scientific journals.

Despite the plethora of publically available published materials, many materials and information remain undisclosed. There are many more publications that are held internally by government departments and scientific agencies, industry associations, or are held by 'pay walled' repositories (e.g. the CO2CRC). There is a perception among stakeholders that this acts as a constraint on the transfer of knowledge and the wider dissemination of learnings from one project to another, and is a barrier to the commercialisation of low-emissions technologies and to the establishment of a CCS industry in Australia. s22

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Another stakeholder acknowledged that knowledge of the published information available is dependent on informal personal and community networks. That is, information sharing is about 'who you know':

> *Do we have some nice summary, not that I am aware of … it is not on a central connected basis… The answer is an informal kind of network of people know each other, which is not ideal for information sharing."* – Commonwealth Government stakeholder

When done right, however, effective information sharing with the wider public is credited with supporting community engagement and enabling the future deployment of LETFF. As one stakeholder remarked:

> *"… the CO2CRC has done a marvellous job in addressing public concerns and public education with their Otway site. It is regarded as one of the world's best practice in that region."* – Research stakeholder

3.2.3 Summary of the intangible forms of knowledge generated

Stakeholders also identified the importance of the value of less tangible outcomes that were generated as a result of the LETFF programs.

Stakeholders widely acknowledged that the LETFF programs have encouraged collaborations between governments, industry, and the academic and scientific communities within Australia. Stakeholders from each of these communities identified the collaborative nature of the LETFF programs as having an immense benefit for creating networks amongst groups that were unlikely to have otherwise engaged with one another.

For government, the deepening of relationships with industry and the academic and scientific research communities is credited with contributing to improved decision-making, in terms of informing the formulation of regulatory and legislative frameworks. The Gorgon Carbon Dioxide Injection project is an example of where the LETDF facilitated information sharing between the Commonwealth Government and industry partner Chevron, and generated an improved and informed policy outcome. One industry stakeholder noted the role of Chevron in advising and informing the development of the Offshore Petroleum and Greenhouse Gas Storage Act 2006 and the broader regulation of CCS:

> *"a lot of the federal generic legislation in this space comes from lessons learned from Gorgon, and that model has been picked up by a couple of other states."* – Industry stakeholder

In turn, development of the *Offshore Petroleum and Greenhouse Gas Storage Act 2006* is credited with enabling industry to consider offshore CCS opportunities and promote the role of other LETFF projects, such as CarbonNet. As noted by one stakeholder:

> *"… it's quite ground-breaking… the regulatory framework that the Commonwealth has put in, because obviously that's the lever that* [government] *have responsibility for, so the Offshore Petroleum and Greenhouse Gas Storage Act has really I think incentivised and given industry a mechanism to at least put offshore CCS in their repertoire and that's obviously being exercised now through CarbonNet, they wouldn't have done that without that act."* – Commonwealth Government stakeholder

The LETFF programs are also credited with establishing valuable international collaborations between Australia and several countries developing low-emissions technologies – such as, the U.S., the U.K., the European Union, Japan, and China. In particular, stakeholders identified the value of the relationships formed through the Australia-China Joint Coordination Group funded through the CCS Flagships program. These relationships enabled Australia to access technology and expertise that would have been extremely costly to develop domestically. In return, Australia provided its expertise of regulatory frameworks, as well as project management methods (e.g. delivering projects safety, on time, and on budget).

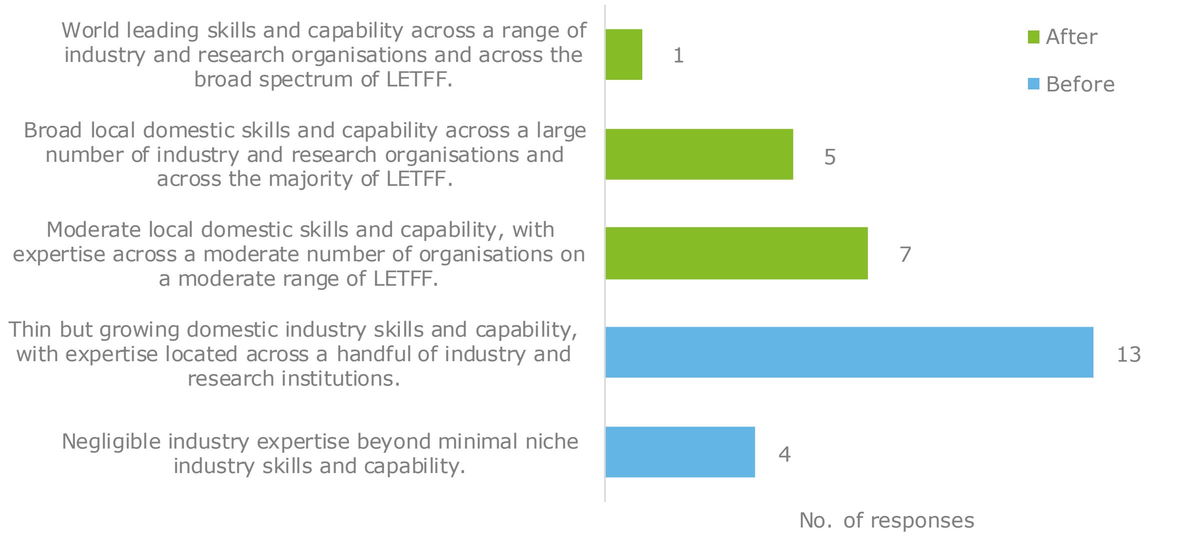
As noted by one stakeholder:

> *"the skills transfer was really quite significant, not just for the Australian government and other stakeholders in regard to accessing Chinese know-how, and how they do it, but the Chinese certainly learned from us too."* – Industry stakeholder

3.3 Development of greater domestic skills and capabilities

In general, stakeholders interviewed perceived that the LETFF programs had contributed to a considerable increase in skills and capabilities. Australia's overall state of skills and capabilities progressed from being perceived as **'thin but growing'** prior to the commencement of the LETFF programs, to moderate with expertise across a range of industries and research organisations. This is supported by the findings of the online questionnaire (see Chart 3.2).

Chart 3.2: Questionnaire responses on the level of domestic skills and capabilities with respect to low-emissions technologies before and after the commencement of the LETFF programs



Source: Deloitte questionnaire, n = 17

As prefaced earlier, the LETFF programs are considered to have contributed to improving and expanding the capacity of academic and scientific research skills at the key research institutions – such including as, CSIRO, and Geoscience Australia, Melbourne, Monash and Newcastle universities, as well as and CO2CRC, the Global CCS Institute s22 Australian Petroleum CRC, ACARP and COAL21. Overall, stakeholders agreed that the skills and capabilities developed across academia were far more advanced than industry. As remarked by stakeholders:

> *"… a lot of the money has gone to the research group, so they are far more skilled than the engineering is because they have had the funding to do the research … it's going from being scientists wanting to do the research to now scientists having done the research."* – Industry stakeholder

> *"… I would say that the scientists are ahead of the engineers because the scientists have just been doing this stuff, but they can't do what engineers do and the engineers need…the time is not for R&D, the time is for doing and the scientists will then have access to real data rather than lab data."* – Industry stakeholder

However, stakeholders recognised that Australia's technical and engineering capabilities have also developed and improved through the LETFF programs, with Australia now possessing the technical and practical engineering skills necessary for deployment and implementation. There was a common view that commercial deployment is required to enable any further advancement of industry skills and capabilities. As described by one stakeholder:

> *"… we had the engineering infrastructure, but with inexperience in this technology. … at least now the engineering capability is ready to take that next step to implement, but until we have implemented, we haven't really learned all the lessons."* – Industry stakeholder

Some stakeholders reported that Australia has developed world-leading skills and expertise through the LETFF programs, and those skills are now sought by the other countries:

> *"We actually got a group who we thought were the world's best reservoir engineers come over from University of Texas and … they felt the reservoir engineering capabilities of CO2CRC and our research members, such as CSIRO and Curtin* [University] *are the best in the world"* – Academic/research stakeholder

> *"… we basically trained up all the CCS specialists in Australia and now they have gone all around the world."* – Research stakeholder

Within industry, the LETFF programs also contributed to an 'up-skilling' and expansion in the capacity of technical and practical engineering type skills, particularly in the industry sectors that were most engaged in LETFF – that is, the coal mining, and oil and gas sectors. In addition, the LETFF programs prompted a shift in the composition of the types of specialist skills demanded. As industry began to investigate the feasibility of integrating LETFF within existing processes, stakeholders identified increased demand for a range of engineering disciplines across the oil and gas, coal and energy generating sectors. As one stakeholder noted:

> *"We need engineering, so we need design…electrical, we need mechanical, we need ventilation specialists, we need mining specialists… risk specialists…"* – Industry stakeholder

Within the energy generating sector, there was also an increased demand for specific engineering skill sets that were previously not associated with that industry sector, particularly chemical engineering capabilities.

The composition of skills required also shifted as knowledge and understanding about the importance of geological subsurface storage became a key priority. This resulted in a shift toward and expansion of geotechnical engineering capabilities across industries.

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An exception to this is the dissemination and transfer of technical skills from the academic and scientific research communities to government. A range of stakeholders noted that the Commonwealth Government was able to readily access and draw upon specialist technical and scientific skills, particularly from CSIRO and Geoscience Australia. This supported better informed decision-making.

However, several stakeholders noted the risk of potentially losing the specialist expertise built up over time to other countries – and with it one of key Australia's competitive advantages internationally – in the absence of the eventual deployment of LETFF.

3.4 Industry understanding of low emissions technologies

In general, stakeholders perceived that there was an increase in industry understanding following the commencement of the LETFF programs, albeit from a low base. Overall, stakeholders reported that LETFF programs enhanced industry's understanding with respect to:

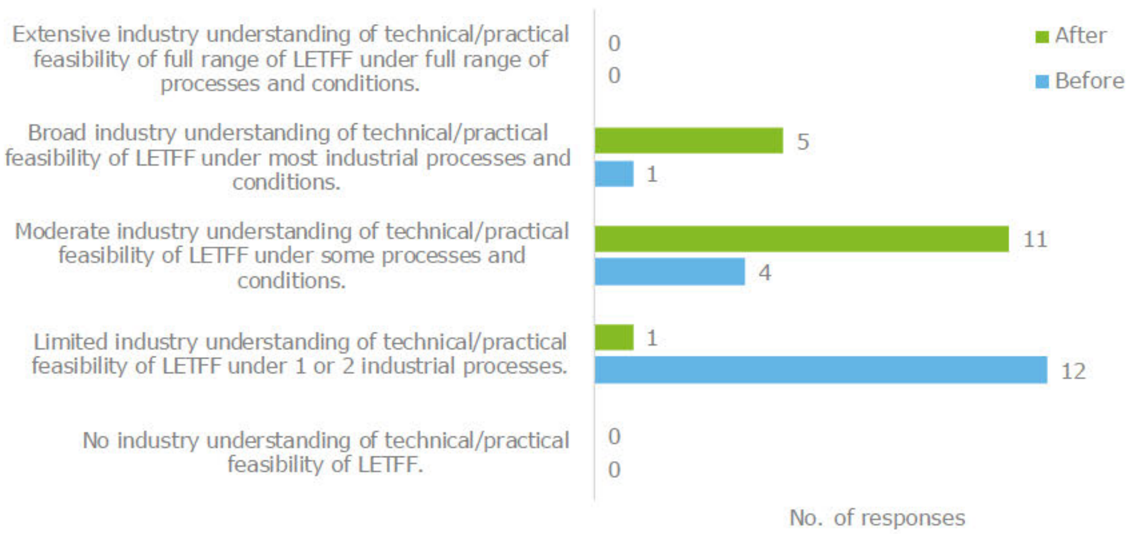
- the appropriateness and effectiveness of particular technologies at an industrial-scale
- the importance of geological subsurface and storage conditions to successful deployment
- greater certainty about the costs, timeframes, and risks involved in commercialisation.

As described by one industry stakeholder:

> *"When you look at all the work we have done to support various demonstrations... I can't help thinking that we are better placed than many of the other countries or most of the other countries when it comes to knowledge to deploy."* – Academic/research stakeholder

Using the questionnaire responses of stakeholders, Chart 3.3 illustrates that industry understanding is perceived to have gone from being limited to now being at a moderate to broad level of understanding.

Chart 3.3: Questionnaire responses on industry understanding of technical and feasibility of low-emissions technologies before and after the commencement of the LETFF programs



Source: Deloitte questionnaire, n = 17

There is a consensus among stakeholders that the LETFF programs have contributed to industry now having a detailed 'end-to-end' understanding of the engineering and design of LETFF, in particular CCS technologies. Large projects such as CarbonNet and SouthWest Hub, for example, were identified as having provided industry with valuable practical and technical insights about the pathway to large-scale commercialisation, in terms of cost-discovery and the engineering design process involved. As stakeholders noted:

> *"... projects like the CarbonNet project, like the Southwest Hub project really did allow us to get a better understanding of 'yes there is a theoretical capability to put CO_2 in these places, but here are the real commercial understandings and then capabilities that we need to improve on to do that effectively"* – Academic/research stakeholder

> *"The [projects] that have probably added most to the knowledge set are the ones where, for example, CarbonNet is really testing the whole end-to-end from the technical, regulatory through to the commercialisation."* – Commonwealth Government stakeholder

More important to industry than any single LETFF project, however, is the combined and cumulative 'end-to-end' understanding that has been gained from the portfolio of LETFF projects –

'successful' and 'unsuccessful' projects. That is, the value of the iterative nature of the journey that industry and government have been on, and the importance of the learnings from each successive step at informing the direction of the next. As two stakeholders remarked:

> *"...as a complete package of knowledge, as they have gone from step to step to step, we know what we need to do now. So, I will call that a great success ... if you are only involved at each of the little steps and that's all your involvement is, you can see each one as a failure because it didn't reach the grand scale, but in combination they have honed in on and now we know exactly what we need to do. ... We have the luxury of staying with this whole landscape for the last 12 years and taking this whole picture to learn at each of the different steps."* – Industry stakeholder

> *"... it's quite easy to look at the individual components and say we haven't actually achieved much, but for those that are able to look across the broad suite of projects and programs around capture, storage, transport, understanding where you might drill, understanding what you might retrofit, ... there is a view that we have a very compelling understanding now across the implementation of CCS if you put it altogether, which we didn't have before..."* – Government stakeholder

Even those LETFF projects widely perceived as failures (such as ZeroGen) or those perceived as being challenged and delayed (such as Gorgon), have provided industry with crucial learnings. ZeroGen, for example, despite its perceived failure, is credited with providing industry crucial learnings about the commercial viability of Integrated Gasification Combined Cycle (IGCC) technology (see Box 3.1).

Box 3.1: Learnings from ZeroGen

ZeroGen project: a successful failure

Prior to the commencement of ZeroGen IGCC technology was considered to be the highest efficiency for low-emission coal energy generation:

> *"[IGCC Technology] was at that time seen as being the big technology, that is kind of like the biggest break, and the reasons for that was its high efficiency, it was sort of like the big bang theory. It's the highest efficiency, the biggest one, it's going to make the biggest difference at a cost. So on a CO_2 stored dollar basis, it was going to be the way to go."* – Industry stakeholder

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While industry had a 'desktop-understanding' of Australia's geology and of the potential for subsurface storage sites, very little consideration had been given to the detailed understanding of the potential capacity and suitability of these basins or reservoirs for the purpose of storing CO_2. Understanding the geological subsurface for the safe storage of CO_2 is now considered by industry as one of the key components, along with low-emission and capture technology, to the successful deployment of LETFF on a commercial scale. However, significant gaps in industry understanding of site specific geological conditions and requirements exist. Geological considerations as a critical area of future research is explored further in Section 5.3.

Industry understanding with respect to methane abatement technologies within coal mine sites has not progressed as significantly as that of CCS. Overall, significantly more work is required across the research, design, technical testing and demonstration of methane abatement technology to allow for the technology to progress.

3.5 CCS Flagships Research Development and Development (RD&D) fund

The CCS RD&D fund aims to reduce technical and commercial barriers to the deployment of large-scale carbon capture and storage projects by contributing new knowledge with respect to:

- Australia's understanding of its geological capacity to permanently store carbon dioxide
- enhanced understanding of how CO_2 plumes behave in Australian conditions
- improved knowledge of Australia's CO_2 supply chain requirements
- harnessing international knowledge and expertise and building international relationships that progress global understanding of CCS
- lowering the cost of technology adoption and deployment in Australia.

The CCS RD&D fund has yet to be completed, and is beyond the scope of this evaluation. However, a summary of the intended knowledge to be generated across the CCS RD&D fund is summarised below.

Table 3.3: Summary of intended knowledge to be generated from CCS RD&D fund

Project	Project description	Intended knowledge to be generated
Northern Australia CO_2 Store	This project builds on work carried out by Geoscience Australia's regional assessment of the CO_2 storage potential in the Petrel Sub-Basin (PSB) in NT. The project objective is to de-risk the area of interest within the PSB.	• Detailed subsurface knowledge of the PSB and local geological properties. • Understanding of the geomechanical, geochemical and geophysical properties of the PSB, and behaviour of CO_2 in the PSB. • Detailed assessment of equipment and facilities required to transport CO_2 from Darwin to the PSB storage. • Determination of well numbers to accommodate CO_2 production.

Project	Project description	Intended knowledge to be generated
CTSCo Integrated Surat Basin CCS project	This project delivers aspects of the CCS demonstration project that will enable a Financial Investment Decision for construction and deployment during 2018/2019, including technical, social and permitting aspects.	• Greater understanding of construction and deployment requirements of CO_2 test injection facilities. • Greater understanding of the regulatory pathway for onshore storage of CO_2 in Australia. • Greater understanding of the financial viability of onshore storage of CO_2. • Greater understanding of community engagement with respect to CCS.
Australian Subsurface Carbon Sequestration Simulator	This project works towards improved understanding of how CO_2 behaves during geo-sequestration in the Australian subsurface and how this behaviour can be monitored.	• Improved simulation, forecast and monitoring of CO_2 plume behaviour. • Enhanced geophysical imaging of CO_2 plumes.
s22		
Improving safety and efficiency of CO_2 pipelines	Development of fracture and dispersion models to enhance design and reduce risk associated with CO_2 pipeline construction and development.	• Validated fracture arrest model/software and design requirements. • Validated dispersion model • Updates of Standards and Recommended Practices covering CO_2 pipelines • Development of cost benchmarks for CO_2 pipeline.
Surat Deep Aquifer Appraisal project	Assessment of real optionality for industrial scale CCS deployment linked to south-east Queensland stationary emissions generators.	• Provision of significant technical and cost information into the public (pre-competitive) domain to assist with ultimate de-risking and planning of projects. • Greater understanding of techno-economic and other deployment critical issues. • Enhanced methodologies for community engagement about energy choices (and within that how best to engage on CCS). • Discovery of the degree and criticality (costs, timing risks) to which CCS can be a real mitigation option for GHG abatement in Eastern Australia.

4 Factors contributing to achievement outcomes

Key findings:

- At commencement, the LETFF programs were underpinned by clear policy direction and settings, support across Commonwealth and State Governments, and a significant funding commitment across a suite of programs and projects – factors that were critical to the achievement of outcomes.
- Other contributing factors to the achievement of outcomes included:
  - establishment of partnerships between government, industry and academic stakeholders
  - the direct financial involvement of the coal industry in maintaining an industry-focused research agenda
  - establishment of a portfolio of LETFF projects to maximise learnings and the probability of success.
- Changing, uncertain and inconsistent policy settings are considered the **primary factors** hindering achievements and progress across the LETFF programs. This resulted in significant **loss of confidence across industry and a loss of momentum in advancing LETFF**.

  The unexpected complexity of LETFF, inflexibility of funding agreements, regulatory uncertainty and insufficient readiness on the part of the Commonwealth and State Governments have also hindered achievements and progress across the LETFF programs.

  The absence of a clear commercial imperative on the part of industry to invest in carbon abatement remains the single largest barrier to the commercial development and deployment of LETFF.
- Knowledge gained throughout the LETFF programs could have been more effectively disseminated to the broader public. Barriers to knowledge sharing and access to information have contributed to a low level of public understanding and acceptance of LETFF, and in particular CCS, and represent a barrier to the deployment of LETFF.

4.1 Factors that contributed to achievement of focus outcomes

There was consensus among stakeholders that the manner in which the LETFF programs were established was a major factor contributing to the achievement of focus outcomes (i.e. knowledge, skills and capability, and improved industry understanding). Specifically, stakeholders noted that, at commencement, the LETFF programs were underpinned by clear policy direction and settings, support across the Commonwealth Government and participating State Governments, and a significant funding commitment across a suite of programs and projects.[2] Stakeholders agreed that these factors provided a clear signal of government policy intent and focus to industry, and gave industry the confidence to participate and invest in the programs. As noted by stakeholders:

> *"The greatest assistance was right at the beginning when there was a common urgency, a common understanding that we all needed to do something. And by that, I mean the federal government, the state government, and the industry."* – Industry stakeholder.
>
> "[A key factor was] *the early decision to allocate funds to a suite of programs and have sort of a champion in cabinet to push these sort of issues through and make it a priority. I think it then just follows that your domestic stakeholders know that they have got backing*

[2] The original Commonwealth Government funding commitment across the four LETFF programs was approximately $2.8 billion.

> *through the government in real terms as in funding, but also from a national priority perspective"* – Commonwealth Government stakeholder.

Many stakeholders also identified the partnerships established between government, industry and academic proponents as being critical to the achievement of focus outcomes. This led to meaningful engagement between academic, technical experts, policy makers and industry proponents across the LETFF programs. In turn, these partnerships helped maintain strong technical and research capabilities to support the LETFF programs:

> *"The access that we have had to government and industry to assist with our research program has been probably the most significant factor for us." – Academic/research stakeholder.*

In particular, **the direct financial involvement of the coal industry**[3] is considered to have been critical in maintaining an industry-focused research agenda. Stakeholders considered the industry-led research agenda to be contributing factor to the achievement of focus outcomes. As noted by two stakeholders:

> *"The manner in which the program is set up, means we have to have a combination of government and industry and researchers obviously. It allows us to not just do research for the sake of research, it allows us to understand what the industries' needs are, what the government's needs are, and do the appropriate technology development to meet those users' needs." – Academic/research stakeholder*

> *"My job is to support demonstration, and this is very, very clear. I am greatly assisted by that because when a researcher comes to me with a good idea…I'm always able to take their idea and hold it up against this lens and say does this help deployment? If it doesn't help deployment I tell them "I'm sorry you have got a fantastic idea, but it doesn't suit my purpose." So, it's not that your idea is bad, it's just that I have a certain purpose and your idea doesn't fit here."* – Academic/research stakeholder

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4.2 Factors that hindered achievement of focus outcomes

There was consensus among stakeholders that changing, uncertain and inconsistent policy settings were the **primary factors** hindering achievements and progress across the LETFF programs. Specific examples of changing and inconsistent policy settings identified included:

- removal of the carbon price regime following the commencement of the LETFF programs
- lack of a clear national strategy and statement with respect to LETFF, and in particular CCS
- changing and inconsistent policy settings no longer aligning with program objectives
- government policy not adopting a technology 'agnostic' approach with respect to emissions abatement, with stakeholders noting that CCS projects were ineligible for funding from the Clean Energy Finance Corporation

[3] Support was focused through the former Australian Coal Association for Low Emissions Technologies Research and Development (ACALET R&D), now known as COAL21.

- loss of policy direction over time resulting in general policy confusion among industry participants.

These issues **resulted in significant uncertainty and loss of confidence across industry, and a loss of momentum with respect to the advancement of LETFF.** As stakeholders noted:

> *"A lack of clear government policy (both state and federal) on CCS hinders progression of the demonstration projects required for future large scale CCS to be assessed and ultimately progress."* - Industry stakeholder

> *"We don't have that clear stable policy framework. We don't have that clear confidence in that framework to allow significant* [Industry] *investment."* – Academic/research stakeholder.

The changing policy settings also contributed to eroding industry engagement within the LETFF programs. Proponents no longer considered the investments to be a priority in the absence of clear policy direction. As one stakeholder noted:

> *"While the project staff were still very committed to the project, they did from time to time run into a bit of pushback from the operations staff at the mine site, because they are no longer quite as keen to have this project running at their site because there wasn't that financial impetus* [any longer]*."* – Commonwealth Government stakeholder.

There is a perception among many stakeholders that an insufficient understanding of the complexity of low emissions technologies at the commencement of the LETFF programs also hindered the achievement of focus outcomes. In particular, there is a perception that the Commonwealth Government lacked the necessary internal scientific and technical capabilities to accurately evaluate and assess the viability of projects proposed prior to the commencement of the LETFF programs. Insufficient understanding of the technical, scientific, engineering, regulatory and environmental challenges underpinning large-scale LETFF across government, industry and academia resulted in:

- unrealistic program and project timelines
- insufficient funding being committed to support development and deployment
- insufficient understanding of project financial and technical risks
- an implicit assumption relating to the commercial feasibility of geological resources.

Overall, this resulted in unrealistic program timeframes, costs and expectations. As noted by stakeholders:

> *"If you look at the CCS Flagships program, in some ways, that was too much too soon. The expectation that you were going to be commercial and up and running in 2013* [for example] *was unrealistic."*– Industry stakeholder.

> *"The challenges with some of this have proven to be … more difficult than first thought. So, Gorgon, for example, has ended up being a much, much larger project than was originally conceived. So, the original intent* [of the LETFF programs] *got the scale completely wrong."* – Commonwealth Government stakeholder.

Stakeholders also identified regulatory uncertainty and insufficient readiness on the part of the Commonwealth and State Governments as a factor hindering the achievement of focus outcomes. Governments at both levels were ill-prepared in terms of regulation and legislation for the commercial implementation of technologies – particularly relating to the storage and monitoring of CO_2. Projects involving pilot drilling and site testing (such as CarbonNet in Victoria) required state government regulatory approval (and in the case of CarbonNet also Commonwealth Government approval due to offshore activities) before proceeding. These regulatory approval processes significantly impeded project timelines and presented considerable challenges to project proponents. As summarised by one stakeholder:

> *"It's more in the regulatory space that's been required than people realised. For example, on the CarbonNet project, there were all sorts of Victorian government approvals, but*

> *there are also Australian Government approvals because it is eventually going to be in the offshore domain… There are multiple approval processes and I think it's fair to say that's been very challenging."* – Commonwealth Government stakeholder

A range of stakeholders noted that Commonwealth Government funding agreements, where project funds are tied to specific milestone dates and activities, don't adequately reflect the nature of industrial-scale projects. The inflexible nature of funding agreements were considered to have impeded and slowed project progress and achievement of focus outcomes.

A minority of stakeholders considered that the decision to allocate funding across a portfolio of LETFF programs and projects hindered program achievements. They perceived that greater progress towards the development and deployment of LETFF may have been achieved by focussing on a single or two LETFF projects in total. As one of these stakeholders noted:

> "[The Commonwealth Government] *spread the funding too thinly across several projects. There was only ever sufficient funding allocated for one CCS project. Running a competition* [a grant application process] *encouraging several projects to commence was ineffective and unrealistic"* – Academic/research stakeholder.

4.3 Impact of program design and implementation on achievement of focus outcomes

A majority of respondents to the online questionnaire considered that the level of funding allocated to the LETFF programs (82%) and project selection processes (59%) positively contributed to the achievement of outcomes.

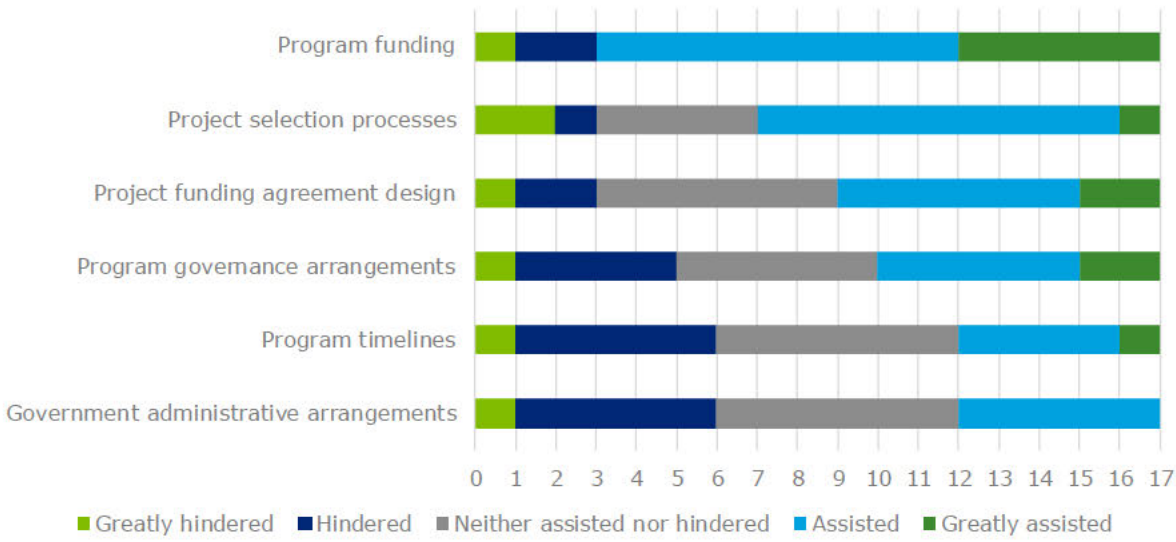
However, responses were more mixed with respect to the impact of program timelines, funding agreement design, administrative arrangements and governance arrangements on the achievement of outcomes (see Chart 4.1).

For example, while almost half (47%) of questionnaire respondents considered the design of funding agreements to have greatly assisted or assisted the achievement of focus outcomes, this view was not shared by all stakeholders. A range of stakeholders interviewed considered funding agreements to be inflexible, and a requirement to tie funding to specific milestones to be incompatible with large-scale industrial development projects. As noted by stakeholders:

> *The way all of these projects are setup, they can only take one step* [at a time]*. And therefore, the project has to wait until you have made a decision. There hasn't been that ability to take the next step after you've learnt something, change the plan a little bit, modify it to suit what you've learnt, take the next step, and having funding continue from there".* – Industry stakeholder.

> *"Here is $100 million go and do your first bit, and here is a $100 million go and do your second bit, and here is $50 million go and do your third bit. That is not the way to run a big project, you know, when BHP decides it is going to develop a mine, that is a $15 billion decision and they don't hand it out, you know, $100 million at a time. So I think the government has to think about a way on how it wants to support large-scale projects like this."* – Academic/research stakeholder.

Chart 4.1: Questionnaire respondents' perception on which aspects of the design of the LETFF programs contributed to the achievement of focus outcomes



Source: Deloitte questionnaire, n = 17

In addition to the above, many stakeholders noted during interviews that the 'removal' or clawback of program funding by the Department from projects deemed infeasible/unsuccessful adversely impacted the achievement of focus outcomes. Many stakeholders considered that this funding should have been reallocated to remaining projects or new funding rounds held to identify 'new' projects, rather than have such funding returned to consolidated revenue. As noted by stakeholders:

> *"The CCS Flagship Demonstration Program was crippled by the withdrawal of Commonwealth funds originally allocated to it."* – Industry stakeholder

4.4 Barriers to the commercial development and deployment of LETFF

There was consensus among stakeholders interviewed that the absence of a clear commercial imperative on the part of industry to invest in carbon abatement remains the single largest barrier to the commercial development and deployment of LETFF. Key issues identified by stakeholders contributing to the absence of a commercial imperative included:

- lack of a clear, consistent national energy policy that addresses the role of LETFF and provides industry with sufficient long-term confidence to invest
- absence of Commonwealth and State Government policy instruments that directly incentivise investment in emissions abatement
- significant cost of deploying commercial-scale CCS projects, noting that LETFF (and CCS in particular) has a particularly high cost relative to alternative emission abatement technologies
- investment risk is perceived to be high given current policy settings and uncertainty
- issue of third party risk remains unaddressed under current policy arrangements, specifically the issue of indemnifying storage and reservoir operators over the longer term.

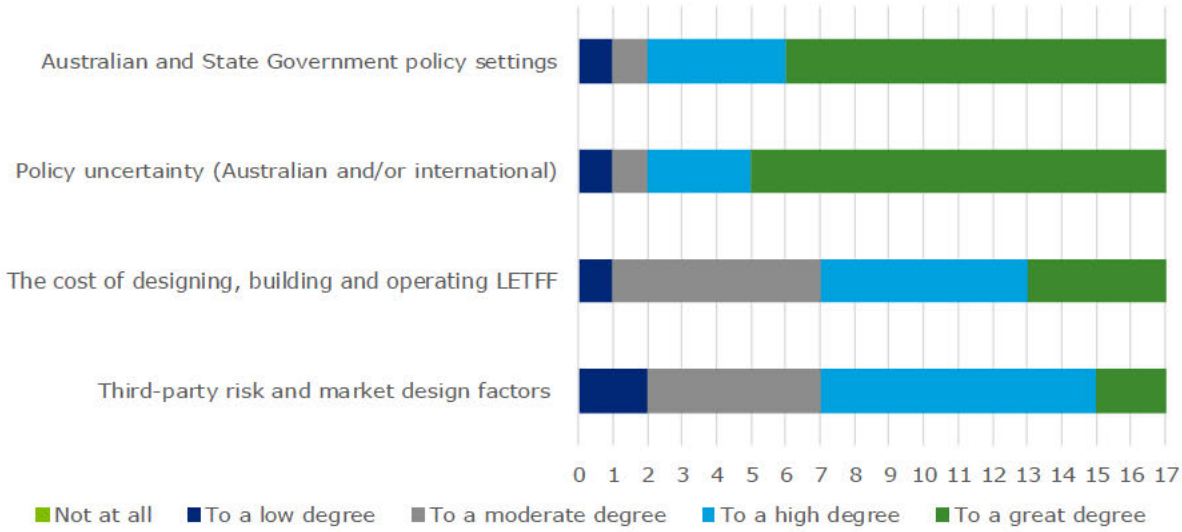
As noted by stakeholders:

> *"The issue with all of this is cost. The investments that are required to do these things* [LETFF] *at scale invariably seem to be much larger and the costs are much larger than originally envisaged."* – Commonwealth Government Stakeholder.

> *"You cannot see* [under current arrangements] *how any of these projects are going to be funded."* – Industry stakeholder

Responses to the online questionnaire support the above findings. Questionnaire respondents identified existing Australian and State Government policy settings (88% of respondents consider policy setting remain a barrier to a high or great degree), domestic and international policy uncertainty (88%), cost of LETFF (59%) and third-party risk (59%) as presenting the greatest barrier to the commercial deployment of LETFF (see Chart 4.2).

Chart 4.2: Questionnaire respondents' perception of the extent to which external factors remain a barrier to the commercial deployment of LETFF



Source: Deloitte questionnaire, n = 17

However, some stakeholders considered that some longer-term commercial drivers were already in place, and highlighted the decision by Chevron and its joint venture partners to invest in the Gorgon Carbon Dioxide Injection project. As one stakeholder noted:

> *"If you want to exploit Australia's offshore gas resources in say 25 years' time, you will have to deal with those emissions I think. I think that's going to be the world we are. So, I think that if you look at it through that lens, there is going to be a commercial driver."* – Commonwealth Government stakeholder.

Many stakeholders also identified the lack of a technologically 'agnostic' approach to emissions abatement as a barrier to the commercial deployment of LETFF. There was a perception among many stakeholders that LETFF was treated inconsistently to alternative technologies. For example, CCS projects are not eligible for funding under the Clean Energy Finance Corporation. As one stakeholder summarised:

> *"It's not about renewables versus CCS or renewables versus coal. It's about having a portfolio of solutions to reach your emissions targets." – Industry stakeholder.*

Stakeholders also identified that barriers to knowledge sharing and access to information may have adversely affected the broader public discourse and perceptions around LETTF. This has contributed to a low level of public understanding and acceptance of LETFF, and in particular CCS, and is considered a barrier to the deployment of LETFF by some stakeholders. All stakeholder groups recognised that the role of LETFF in abating emissions was not well understood by the general public, and that there was a broad public perception that the primary role of LETFF was to extend the 'life' of fossil fuels. There is a perception that this has contributed to hindering the deployment and implementation of LETFF. As noted by stakeholders:

> *"... most of the knowledge is sort of really been distributed amongst people closest to these programs and various industry stakeholders, but in terms of the broader community they have been consulted where they are directly affected, but I don't think the average*

> *Australian knows where the Carbon Capture and Storage is up to in Australia."* – Commonwealth Government stakeholder.

> *"… the CCS community and industrial sectors of Australia, we are very good at talking to ourselves about how great CCS is and how we are going to use that as a solution. We are hopeless at talking outside that group, outside of* [our] *comfort zone."* – Academic/research stakeholder

> *"I think both government and industry have done a poor job of enunciating the benefits of CCS. I think we are probably behind the eight-ball by now."* – Industry stakeholder

Stakeholders also recognised that falling domestic demand for fossil fuels was a potential barrier to the deployment of large scale LETFF. While a broad range of emission-intensive industrial processes (such as fertiliser production, agriculture and smelting) have potential to support demand for LETFF deployment, stakeholders agreed that the key sectors (beyond the oil and gas sector) likely to underpin the initial deployment of LETFF were the coal and energy generation sectors. As one stakeholder noted:

> *"I think anything that is going to impact on coal production levels and demand for coal is going to then impact on the operating costs and financial considerations, and so it is going to have even more of a detrimental effect of looking at the capital costs of significant abatement investments."* – Commonwealth Government stakeholder

5 Success, future research and role of government

Key findings:

- Overall, **stakeholders overwhelmingly consider the LETFF programs to be successful**. The LETFF programs have made significant contributions to increasing knowledge, skills and capability, and improving industry understanding of LETFF in Australia. These achievements **would not have been made in the absence of Commonwealth Government support.**
- Stakeholders consider that the Commonwealth Government's investment in LETFF programs **represents good value for money**, and **achievements are commensurate with the investment.**
- LETFF programs have directly contributed **to reducing the technical and commercial barriers** to the development and deployment of commercial-scale LETFF projects.
- However, the achievements and knowledge gained could have been more effectively communicated or disseminated among industry and the general public.
- Australia risks losing the significant gains in knowledge, and skills and capabilities established through the LETFF programs if Australia does not proceed to the commercialisation and deployment of LETFF.
- The critical underlying research and technical questions to deploying large-scale LETFF (and CCS in particular) have been addressed, however some targeted research would supplement and benefit research done to date.
- Stakeholders consider **there remains a critical role for Government** in supporting the development and implementation of LETFF. While there was no clear consensus from stakeholders interviewed, a majority of respondents to the online questionnaire considered the Commonwealth Government should continue to provide large-scale grants to support LETFF research and development.

5.1 Success of LETFF programs

Overall, stakeholders across all groups consider that the LETFF programs have been successful, and have made a significant contribution to increasing knowledge, skills and capability, and to improving industry understanding about low emissions technologies.

As reported above in Section 3, stakeholders consider that as a result of the LETFF programs Australia now possesses the requisite scientific and engineering knowledge, skills and industry understanding to develop and deploy large, commercial-scale LETFF projects. Through the LETFF programs, the key research and technological barriers to the deployment of LETFF have largely been overcome. Stakeholders noted:

> *"When you put all the projects on the map of Australia, show the different types of geology that we've got around Australia, and the different projects that we've* [delivered] *around Australia, the government has participated in a really good portfolio of projects"* – Industry Stakeholder

> *"Industry in Australia has gone from not having a clue of what we are doing to now being able to say where we're going to put a drill or drill a hole, where we're going to store* CO_2*, the technology we're going to use, and to take that next step* [of deployment]*. So, has it* [the LETFF programs] *been successful? In my mind, absolutely."* – Industry stakeholder

A key element contributing to the success of the LETFF programs has been the critical learnings gained by industry and government across the suite of programs and industry. In particular,

projects deemed 'unsuccessful' have provided valuable insights in progressing Australia's knowledge and understanding of LETFF. For example, the 'unsuccessful' **South West Hub** project yielded the following learnings:

- significant improvements to conducting and analysing seismic data, monitoring and modelling CO_2 plumes
- understanding how basin configuration and structural elements affected containment capabilities of a rock formation.

These areas of research were driven by the fact that the Eneaba Formation did not have the impermeable seal that other potential CO_2 storage sites had (for example sites on the east coast of Australia).

The majority of stakeholders interviewed consider that the Commonwealth Government's investment in LETFF programs represents good value for money, and achievements across the focus outcomes are commensurate with the investment made. In particular, stakeholders noted that the research undertaken has directly contributed to overcoming research and technological gaps and barriers with respect to LETFF. Stakeholders noted:

> *"In the research dimension…I think the returns have been immensely large. So, I think you know, yes, we've done a damn good job of research." – Academic/research stakeholder*

> *"I think that there has been a pretty good return on investment for most of the projects under the LETFF. I think that there has been a couple of projects that haven't succeeded, but that doesn't always mean that that money hasn't been well spent…you can learn from the failure as well."* – Commonwealth Government stakeholder

This finding was supported by the results of the questionnaire of LETFF program stakeholders, in which 71% of all respondents agreed or strongly agreed that the LETFF programs have achieved outcomes commensurate with the investment made. The questionnaire found that 71% also agreed or strongly agreed that the LETFF programs have directly contributed to reducing the technical and commercial barriers to deploying large-scale LETFF projects.

However, some stakeholders were more cautious when reflecting on the success of the LETFF programs, noting that Australia still lacks a pipeline of large-scale LETFF projects. As one stakeholder noted:

> *"Yeah, so it's really quite hard to answer* [the question of success] *because I think again from a technical geoscientific perspective, I think that's clearly been a success in terms of that technical scientific knowledge. But for that [approximately $750 million] again we don't really have a pipeline of CCS projects or kind of big things that are going to make a difference to emissions for Australia."* – Commonwealth Government stakeholder

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Stakeholders also perceive that the knowledge and learnings gained from across the LETFF programs have not been sufficiently communicated to the general public (as reported in Section 4.5 above, this was considered a barrier to commercial deployment by some stakeholders). Overall, stakeholders noted:

- there is a lack of public understanding of the potential role of LETFF in decarbonising the economy and national energy market

- there is a 'poor' public perception of LETFF that does not match the achievements that have been made across the LETFF programs
- LETFF, and CCS in particular, are seen as technologies designed to 'extend the life of fossil fuels'.

Lastly, stakeholders broadly agreed that Australia risks losing the significant gains in knowledge, and skills and capabilities it has established over the last 15 years through the LETFF programs if it does not proceed to the commercialisation and deployment of LETFF. Low emissions technologies such as CCS are increasingly being deployed in the U.S., China and Europe. If Australia does not proceed to deployment, it is likely that the specialised skills developed through the LETFF programs will be lost overseas to where LETFF is being deployed. As one stakeholder noted:

> *"… there are certainly other countries who have skilled up more effectively than Australia has in the last few years and we are at risk of being left behind to some extent. … the US has an extremely comprehensive national CCS approach, Norway, the [and] UK to some extent…. So, we are in danger of losing that capability I believe if we are not careful in what we are doing."* – Academic/research stakeholder

5.2 Would have achievements been made in the absence of government support?

Overall, there was consensus across all stakeholders interviewed that the achievements made towards increasing knowledge, skills and capability, and on improving industry understanding about low emissions technologies **would not have been made in the absence of Commonwealth Government support**. When asked what progress would have been made without support from the Commonwealth Government, stakeholders noted:

> *"Short answer is zip, nothing. I don't think we would have done much at all. Truly, I don't think we would have done much at all."* – Academic/research stakeholder

> *"It wouldn't have occurred if it wasn't for the government's investment"* – Industry stakeholder

> *"We would still be stuck in the theoretical research phase."* – Commonwealth Government stakeholder

> *"There is no likelihood that we would have achieved what we did without government involvement"* – Academic/research stakeholder

However, stakeholders did note that the Chevron-led Gorgon Carbon Dioxide Injection project would have occurred in the absence of Commonwealth Government support. Chevron Australia had publicly committed to build the injection project prior to the commencement of the LETDF and the development of the injection project was later included as a development approval condition for the LNG project.

Responses to the online questionnaire supported the outcomes of the stakeholder interviews. The questionnaire showed that 65% of respondents consider that no progress or almost no progress would have been made towards the achievement of the focus outcomes in the absence of Commonwealth Government investment in the LETFF programs (Chart 5.1).

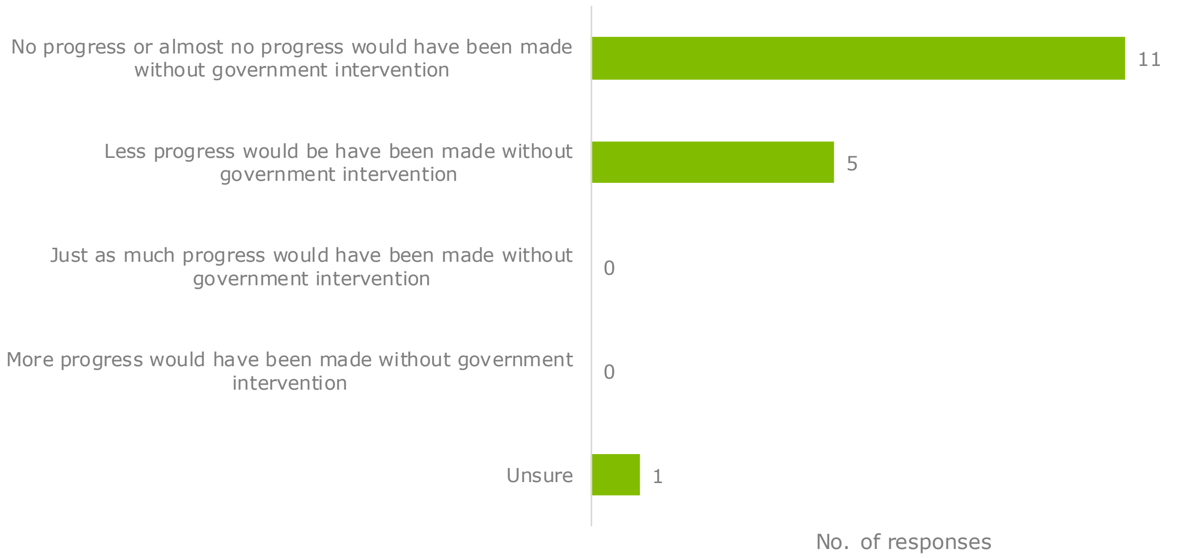
Stakeholders noted that in the absence of a commercial imperative to invest in LETFF (see Section 4.4), there was no incentive on the part of industry to invest in pre-commercial research and development of LETFF. A lack of commercial imperative means that there was no driver to undertake pre-commercial research into capture technologies, CO_2 transportation, storage technologies and CO_2 injection, Australia's geological resources, CO_2 subsurface behaviour, or the safety of LETFF.

By investing in LETFF, the Commonwealth Government was able to successfully leverage significant contributing funding from the coal industry and participating state governments. As one stakeholder noted:

> *"With the current absence of financial incentives for industry to pursue CCS technology, I greatly doubt the funding required to carry out the R&D completed to date would have*

> *existed. The LETFF programs provide the foundation funding (*s22 s22 *for this research to be proposed and progress."* Academic/research stakeholder

Chart 5.1: Extent to which questionnaire respondents consider progress would have made in the absence of the LETFF programs



Source: Deloitte questionnaire, n = 17

5.3 Are there critical areas of research that remain unanswered

There is consensus among all stakeholder groups that the critical underlying research and technical questions to deploying large-scale LETFF (and CCS in particular) in Australia have largely been settled as a consequence of the activities delivered under the LETFF programs. Stakeholders agreed that the next critical phase to LETFF in Australia was deployment. As stakeholders noted:

> *"I think we are far, far beyond the research questions. And I think now it's about deployment, and it's about supporting deployment."* – Academic/research stakeholders

> *"The research is sufficient to take us the next step and let the engineers take the next step so that the researchers can then work on the next problems…I don't think we need more research. I think we need deployment. I don't think there's any gaping holes in research." – Industry stakeholder*

However, stakeholders did identify a range of future research that would supplement and benefit LETFF research done to date.

In particular, a range of stakeholders across all groups identified the need to undertake **site-specific research and testing to support the eventual deployment of LETFF**. While the LETFF programs have demonstrated proof of concept at the regional level, none of the detailed site-specific research and testing has been undertaken that would be required to support deployment of LETFF. The deployment of LETFF will require a new wave of site-specific research relating to drilling, sub-surface monitoring, seismic analysis and injection testing. Such research and analysis will be critical to project-specific planning, investment, and regulatory decisions. As stakeholders noted:

> *"There will be local specific* [research issues] *related to storage, so there will be groundwater impact concerns mostly, so that will be the Queensland story if they get any further [to deployment]… So, there will be site specific and to a large extent community specific [research requirements]."* – Academic/research stakeholder

> *"We need to do more detailed analysis on key spots. Because we've got the broader understanding of CCS in Australia, but not the actual real details [of specific sites]." –* Academic/research stakeholder

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The focus of the LETFF programs had largely been in relation to the capture, transport and storage of emissions from coal mines, liquefied natural gas (LNG) plants and stationary power stations. Some stakeholders noted, however, a need to research **the application of learnings from the LETFF programs to other emission-intensive sectors** including steel, concrete, fertiliser, and agribusiness. As one stakeholder noted:

> *"the industrial applications of CCS that we need to be putting more work into…So, it is other types of CCS technologies that we probably haven't focused on."* – Commonwealth Government stakeholder

The 'capture' process is one of the most expensive and technically complex aspects of CCS, and can typically account for approximately two-thirds of the total CCS deployment cost.[4] Recognising this, some stakeholders also noted a need to investigate CO_2 capture processes for these emission-intensive industries to assist in making CO_2 capture more commercially feasible.

As reported above, public perception and acceptance of LETFF and CCS in particular is considered a barrier to the eventual commercial deployment of LETFF in Australia. A range of stakeholders identified the need for **further research in effectively engaging with communities at the local level.** Given the nature of CCS (which involves the injection of CO_2), understanding how best to engage local communities level was seen as critical to garnering support and achieving regulatory approval, and ultimately resetting the national conversation. While some research has been undertaken on an ad-hoc, individual project-level, there has been no coordinated, strategic approach across the LETFF programs. The importance of better engagement with local communities was summed up by a stakeholder thus:

> "…*the key is you don't engage them* [local communities] *about CCS, you engage them about the whole gambit of future energy choices, and within the choices and the trade-offs you then bring CCS into that equation, so that they actually see a choice. It is not just, 'Yes CCS' or 'No CCS.'"* – Academic/research stakeholder

A final area of research identified by a few stakeholders included **the nature of enhanced oil recovery** (EOR). Overall, stakeholders noted that the relative importance of EOR to supporting the commercial viability of CCS projects in Australia was not very well understood. The production of EOR requires significant quantities of CO_2, which is injected into the sub-surface as part of the EOR production process. Overseas, including in the US, EOR is typically most viable where production can integrate with CCS to take advantage of a ready supply of CO_2. While the presence of EOR may not be in all locations that are deemed appropriate for CO_2, there was a view among some stakeholders that further research and investigation was required, particularly given the absence of other commercial imperatives (as reported in Section 4.4 above). As one stakeholder noted:

> *"When you look internationally a lot of the CCS projects have been underpinned by a revenue stream of oil from enhanced oil recovery… there has been this sort of view that EOR or enhanced oil recovery in Australia is not a lot, there is not many prospects. But I am not sure that that is underpinned by really good technical and exploratory work. So if*

[4] Estimate based on stakeholder interviews.

> *we are missing something it is: 'What are the prospects for enhanced oil recovery in Australia?'"* – Academic/research stakeholder

5.4 Role of Commonwealth Government

There was consensus among all stakeholder interviewed that **there remains a critical role for Government** in supporting the development and implementation of LETFF following the completion of the LETFF programs. Deloitte notes that all stakeholders interviewed as part of this evaluation were directly involved in the LETFF programs, and thus there is likely to be some reported bias in stakeholders' views on the need for continued government support.

However, there was **no clear consensus** among stakeholders interviewed on the most appropriate role for the Commonwealth Government in supporting the development and implementation of LETFF.

Many stakeholders reported that the primary role of the Commonwealth Government should be in setting a clear **national energy and climate policy agenda and framework.** Such a framework would provide industry with sufficient long-term confidence to invest in large-scale LETFF projects. As noted by some stakeholders:

> *"So, absolutely there is a role for government and it links back to that national leadership. I think that we need to have strong policy settings out there that can incentivise investors coming on board for a technology which has some market values in terms of risks." –* Commonwealth Government stakeholder

> *"The government's role is to set a very clear path forward and then to work with industries and organisations that have a role to play in that path whether it be because they're impacted or because they're contributing to that path."* - Industry stakeholder

Many stakeholders, in the absence of commercial imperatives on the part of private industry to invest, saw a role for the Commonwealth Government to provide **direct financial support** for the commercial-scale deployment of LETFF. Such stakeholders considered the Commonwealth Government had a critical role in directly financially supporting the first CCS project in Australia. As one stakeholder noted:

> *"I think the investment from the government is to bring opportunities to a point where a private investor can come in and support it. That can be straight-up by supporting the first opportunities for storage and utilisation hubs in Australia." – Industry stakeholder*

Other stakeholders noted the potential role for the Commonwealth Government in **providing ongoing financial support for research and development** where there was a clear, demonstrated need and where industry was unlikely to undertake the activity without support. Specific examples included research related to broader industrial application, safety, and community acceptance. As stakeholders noted:

> *"There is a place for grants. Grants have a benefit…they give [the Commonwealth Government] what we want. So, for example, if we think industrial CCS is somewhere that needs some research and development then we could certainly put a package together. So, there is room for grants in our repertoire."* – Commonwealth Government stakeholder

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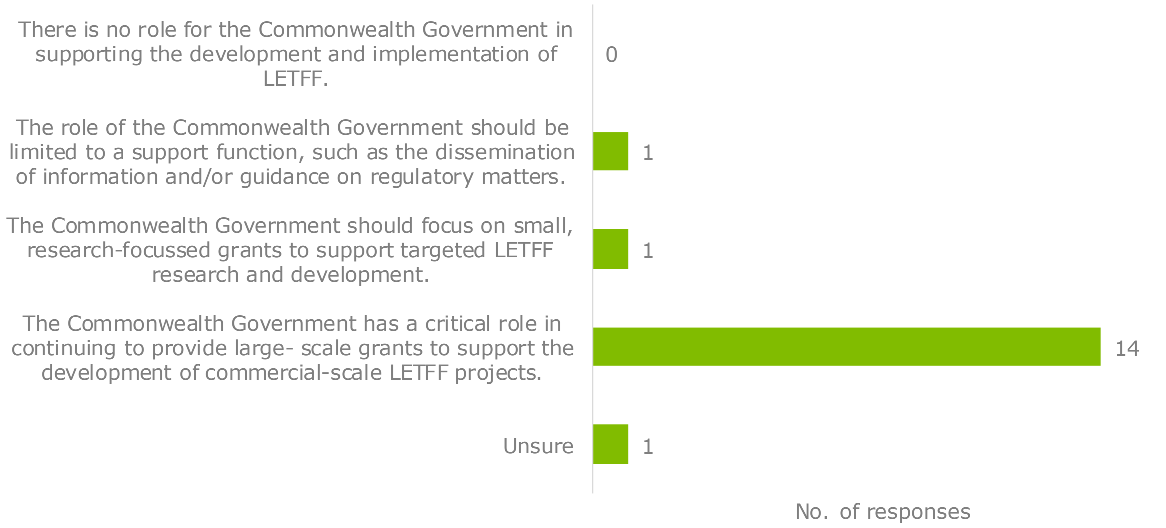
Responses to the online questionnaire were more consistent than stakeholder interviews in their views of what the primary role (if any) should be for the Commonwealth Government going forward with respect to LETFF. The questionnaire found 82% of respondents consider that the Commonwealth Government has a critical role in **continuing to provide large- scale grants** to support the development of commercial-scale LETFF projects (Chart 5.2).

Chart 5.2: Questionnaire responses re what primary role (if any) should the Commonwealth Government adopt in supporting the development and implementation of LETFF



Source: Deloitte questionnaire, n = 17

Some stakeholders interviewed also identified the need for the Commonwealth Government to consolidate the research and knowledge gained to date and ensure it is disseminated to the fullest extent possible.

Despite the majority of stakeholders reporting that the primary role of the Commonwealth Government should be to provide large-scale direct financial support for the deployment of commercial scale CCS projects, **Deloitte considers it is imperative that any future support for LETFF should be informed by a rigorous economic assessment**. Such an economic assessment would specifically involve assessing the role of LETFF in decarbonising the economy and NEM relative to alternative approaches, and give consideration to fossil fuel demand and full life-cycle costs of alternative technologies.

5.5 Unintended outcomes

Many stakeholders reported a perception that the LETFF research agenda is negatively affecting the commercial deployment of LETFF, and in particular CCS. Stakeholders reported that the drive to undertake additional research has resulted in a perception among regulators, industry detractors and the general public that LETFF is not adequately understood and that significant risk remains. As noted by a stakeholder:

> *"I think research has been a drawback for CCS*. [Researchers] *keep telling everybody, "we need to do more research" So, people who are detractors of CCS say, "look it's still an experimental technology." It's not."* – Academic/research stakeholder

Some stakeholders also reported that the lack of commercial-scale deployment has resulted in a perceived lack of progress among the general public. This, in turn, has resulted in a perception that LETFF is not feasible, and has potentially hindered the sector's ability to achieve a social licence to operate.

6 Learnings for future program design

Key lessons to inform future program design and implementation include:

- setting realistic expectations with respect to program cost and time-horizons
- setting realistic expectations with respect to research and development outcomes
- ensuring alignment between policy settings and program objectives
- enhancing assessment of project feasibility at program commencement
- funding and program governance arrangements should reflect the nature of program activities
- greater industry engagement in the design of the program
- the need for ongoing monitoring of program funding
- embedding engagement processes to share knowledge gained within and across government
- improved understanding of the costs and benefits of LETFF in decarbonising the economy relative to alternative technologies, through a detailed Cost Benefit Analysis, as a first step in any future consideration of LETFF.

6.1 Learning for future program design

The LETFF programs have made a significant contribution to increasing knowledge, skills and capability, and on improving industry understanding with respect to LETFF.

However, there are a range of learnings to be gained from the design and implementation of the LETFF programs to inform future program design. These are discussed in greater detail below:

- **Setting realistic expectations with respect to program cost and time-horizons:** Future programs involving the research, development and deployment of large-scale and complex technologies must set realistic expectations around program costs and time-horizons.

  Program design should not underestimate the scale of research and development required to support the development of industrial-scale projects. This has implications for the level of funding made available, the setting of timelines, and internal program governance arrangement, including the establishment of internal expert panels to provide necessary technical guidance.

- **Setting realistic expectations with respect to research and development outcomes:** Future programs involving the research and development of unproven and untested technologies must set realistic expectations around outcomes realisation. It is critical that future program design explicitly recognise a realistic target in terms of research and development achievements, and that not all projects will proceed beyond the research phase.

- **Ensuring alignment between policy settings and program objectives:** Future program design must consider and reflect existing and likely future policy settings. Furthermore, there is a need to ensure that underlying commercial incentives and imperatives exist to support the achievement of program objectives.

  Future programs should also include a review 'trigger' to revisit the rationale of a program if there is a fundamental shift in domestic and international policy settings that are likely to impact the achievement of program objectives.

- **Enhancing assessment of project feasibility at program commencement:** Future programs should seek to improve technical and financial screening and selection processes to better gauge the feasibility of projects at program commencement. However, this needs to be balanced with the research and development objectives of any future program.

Future programs involving large and complex technologies should embed independent program review boards consisting of recognised domestic (and if appropriate international) experts to periodically assess project progress.

- **Funding and program governance arrangements to reflect the nature of program activities:** Future programs should adopt funding agreements and decision-gates to reflect the nature and needs of industrial development projects. In particular, stage gates should replace inflexible milestone reporting and payment processes. This would ensure approved project funds can be more appropriately accessed over time as the project passes through agreed stage gates.
- **Greater industry engagement in the design of the program:** Future programs should involve greater engagement with industry and academic stakeholders during program design. This would ensure program objectives, risks and issues are appropriately understood and reflected in the program design and implementation. Upfront industry stakeholder engagement should also inform an upfront formal assessment of program risks. This ensures risk mitigation strategies can be fully explored, and if possible, embedded within program design.
- **Monitoring of program funding:** Future programs should embed monitoring and reporting frameworks to monitor the effects of changes to funding on the achievement of program objectives. Such frameworks would enable an assessment of how remaining funds can be redistributed within the program (or other programs) and provide a transparent process for revisiting the project selection process to identify projects that were the next best ranked.
- **Embedding engagement within and across government:** Future programs should embed knowledge-sharing processes to ensure program learnings and outcomes are appropriately disseminated across relevant Commonwealth and State Government departments and agencies. Furthermore, program design should consider the required data and information storage and sharing systems to ensure all relevant program documentation is adequately captured and collated in a central location. This mitigates the risks of key learnings and knowledge eroding overtime, and ensures future programs can incrementally build upon the knowledge gained.
- **Undertaking a detailed economic costs benefit analysis:** Any consideration of future support to further the development and implementation of LETFF should, as a first step, involve a detailed cost benefit analysis of LETFF in decarbonising the economy relative to alternative technologies. This analysis should give consideration to fossil fuel demand and the whole-of-lifecycle costs of alternative technologies.

Appendix A: Overview of projects by LETFF program

A summary of the projects delivered under the LETFF programs is presented in the following tables.

Table A.1: Summary of CCS Flagships projects

Project	Description
CarbonNet Project	The project investigates the potential for a large scale CCS network in the Gippsland region of Victoria. The network seeks to cover multiple sources of carbon dioxide captured from industrial plants or power stations.
SouthWest Hub Project	The project aimed to assess the feasibility of storing industrial-generated carbon dioxide deep underground in the Lesueur Sandstone formation. The project involved collecting data and core samples through seismic questionnaires and stratigraphic wells.
ZeroGen Project	The project involved assessing the feasibility of a commercial-scale coal gasification power plant with integrated carbon capture and storage.
Wandoan Integrated Gasification Combined Cycle (IGCC)	A prefeasibility study which involved the following sub-projects: • Stanwell Corporation/Wandoan project which sought to develop an IGCC power station with CCS capabilities. • CTSCo Pty Ltd/Wandoan project which focused on the transportation and storage of carbon dioxide from the IGCC power station through pipelining and geo-sequestration.
Otway Geological Storage and Demonstration Project	A carbon capture and storage demonstration project that aims to address barriers to storage implementation and leverage existing and new datasets arising from the CO2CRC Otway Project to further the technology. The project also involved a monitoring program that test technologies and techniques with the aim of reducing costs.
Australia-China Joint Coordination Group on Clean Coal Technology Projects	The project aimed to build on the growing relationship between Australia and China through the Australia-China Joint Coordination Group on Clean Coal Technology (JCG).

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Table A.3: Summary of LETDF projects

Project	Description
Gorgon Carbon Dioxide Injection Project	Design, construction and operation of facilities to inject and store CO_2 into a deep reservoir unit two kilometres beneath Barrow Island. The CO_2 that is injected into the reservoir unit comes from the process of extracting gas in the Gorgon/Jansz-Io fields.
400MW Integrated Dry-gas Gasification Combined Cycle (IDGCC) Clean Coal Demonstration Project	A project that aimed to increase the burning efficiency of thermal generators by drying brown coal. Reducing the moisture content of brown coal means that less energy is required to convert the coal into electricity.

Project	Description
Hazelwood 2030 Project	A project that aimed to retrofit Low Emission Technologies at the brown coal-fired Hazelwood Power Station in the Latrobe Valley, Victoria. The process involves reducing moisture content of brown coal for an improved burning efficiency. The Hazelwood 2030 project includes CCS facilities – with demonstrated capacity to sequester carbon dioxide at a rate of 0.02mtpa.
Fairview Project	A project that aimed to test the extraction of methane from coal and storing it underground

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Appendix B: Evaluation framework

The evaluation framework, including key evaluation questions and sub-questions, key data collection methods and sources guiding the impact evaluation of the LETFF programs is presented below. The evaluation framework has guided the key lines of enquiry and systematic organisation of analysis to ensure a consistent and robust assessment of the LETFF programs and project activities.

Table B.1: Evaluation framework

Domain	Key evaluation questions	Sub-questions	Data source		
			Interviews	Document review and citation analysis	Questionnaire
Effectiveness	To what extent have the LETFF programs increased knowledge, skills and capability, and improved industry understanding in relation to low emissions technologies for fossil fuels?	To what extent have the LETFF programs generated new research, data and modelling relating to the practical and technical use and implementation of LETFF?	✓	✓	✓
		To what extent have the LETFF programs resulted in the development of greater local (Australian) skills and capabilities in LETFF?	✓	✓	✓
		To what extent have the LETFF programs improved industry understanding of the feasibility and safety of LETFF through collaboration and dissemination of new knowledge?	✓	✓	✓
		To what extent is achievement against the above outcomes commensurate with the investment made by the Commonwealth Government?	✓		✓
	To what extent would knowledge, skills and capability, and industry understanding in relation to LETFF continued to have been developed in the absence of the LETFF programs?	What was the state of knowledge, skills and capability, and industry understanding prior to the commencement of the LETFF programs?	✓	✓	✓
		What is the state of knowledge, skills and capability, and industry understanding following to the commencement of the LETFF programs?	✓	✓	✓
		To what extent has investment from the LETFF programs crowded out industry and research activity that would have occurred in the absence of the LETFF programs?	✓		✓

Domain	Key evaluation questions	Sub-questions	Data source		
			Interviews	Document review and citation analysis	Questionnaire
		How much of the change observed in increased knowledge, skills and capability, and improved industry understanding is because of the LETFF programs?	✓		✓
Efficiency	What factors have helped or hindered the achievement of increased knowledge, skills and capability, and improved industry understanding in relation to LETFFs?	What factors have assisted the achievement of increased knowledge, skills and capability, and improved industry understanding in relation to LETFFs?	✓	✓	✓
		What factors have hindered the achievement of increased knowledge, skills and capability, and improved industry understanding in relation to LETFFs?	✓	✓	✓
		To what extent did the design and implementation of the LETFF programs assist or hinder the achievement of the increased knowledge, skills and capability, and improved industry understanding in relation to LETFFs? Did program design align with known 'best practice' examples elsewhere?	✓	✓	✓
		To what extent did the LETFF programs align with related programs or research (either government or industry)?	✓	✓	✓
		To what extent do these factors remain a barrier to the commercial development and deployment of LETFFs?	✓		✓
	How have external factors affected the ability of the LETFF programs to achieve their intended medium and long-term objectives?	How have Australian Government and international policy settings affected the achievement of medium and long-term objectives?	✓		✓
		How have the relative prices of, and demand for, renewable energy sources affected the achievement of medium and long-term objectives? How have alternative carbon abatement technologies (e.g. bio-sequestration) affected medium and long-term objectives?	✓		✓
		How has the level of demand for fossil fuel-based energy affected the achievement of medium and long-term objectives?	✓		✓
		How have general economic conditions affected the achievement of medium and long-term objectives?	✓		✓
		How have issues such as third-party risk and market design factors affected the achievement of medium and long-term objectives?	✓		✓

Domain	Key evaluation questions	Sub-questions	Data source: Interviews	Data source: Document review and citation analysis	Data source: Questionnaire
Appropriateness	What lessons can be drawn to inform future policy and program development, including the role (if any) of the Commonwealth Government, in relation to supporting the development and implementation of LETFF technologies?	What lessons can be drawn to inform future program design and development?	✓		✓
		Did changes to the LETFF programs since inception influence the efficiency or effectiveness of the programs?	✓		✓
		Are there critical areas of research that have been missed?	✓		✓
		Was there adequate industry engagement on the role of CCS and emission abatement technologies as part of a broad mix of GHG emission mitigation measures?	✓		✓
		What is the role (if any) of the Commonwealth Government in relation to supporting LETFFs?	✓		✓
Unintended impacts	What unintended outcomes have occurred as a result of the LETFF programs?	What (if any) unintended benefits occurred as a result of the LETFF programs?	✓	✓	✓
		What were the unexpected negative impacts of the LETFF programs?	✓	✓	✓

Appendix C: Stakeholder interviews and questionnaire responses

List of stakeholders interviewed

A list of all stakeholders interviewed as part of the evaluation assessment are outlined below. Overall, 19 stakeholders were engaged through 18 interviews as part of the evaluation.

Table C.1: List of stakeholders interviewed

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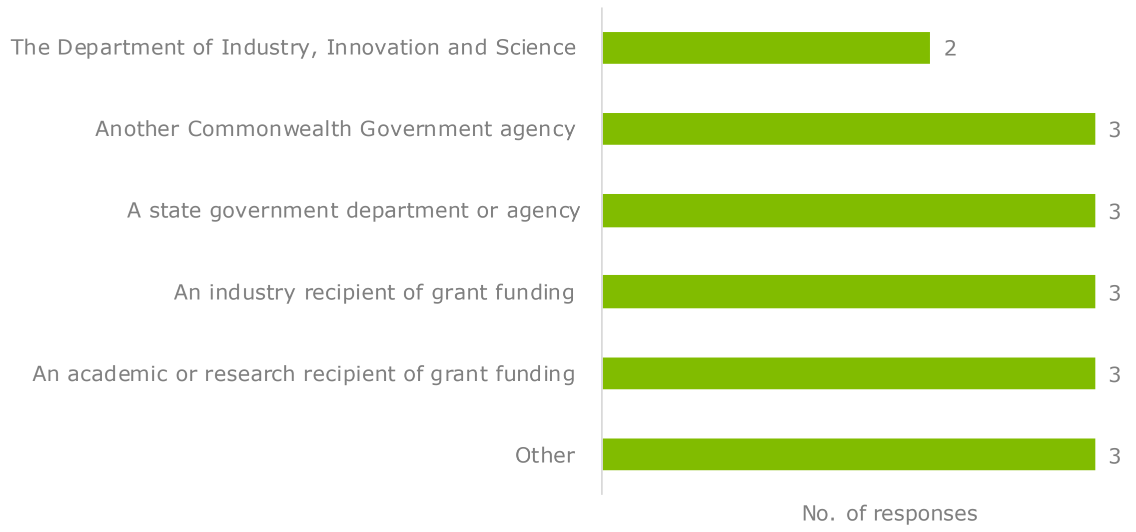
List of respondents to online questionnaire

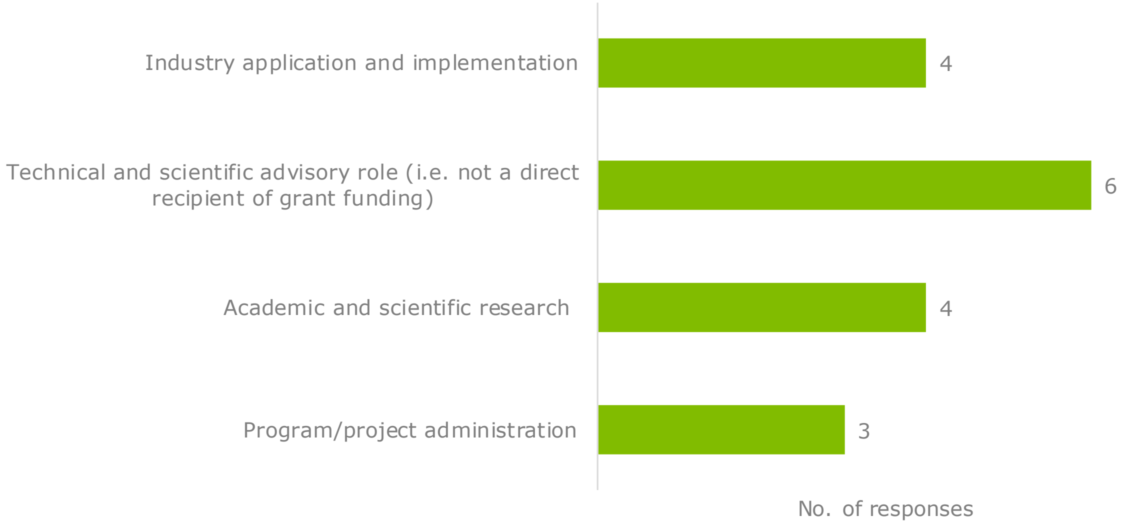
A total of 17 responses to the online questionnaire were received. A summary of the groupings of respondents is provided below.

Chart C.1: Type of organisations that respondent principally worked for during their involvement with the LETFF programs



Source: Deloitte survey, n = 17

Chart C.2: How do respondents describe their involvement with the LETFF programs?



Source: Deloitte survey, n = 17

Appendix D: Case studies

This evaluation has involved the development of concise case studies highlighting the contribution to increased knowledge, domestic skills and capabilities, and improved industry understanding of LETFF made by individual projects delivered under the LETFF programs. The case studies have supported and informed the triangulation of evidence collected across the evaluation. A total of seven case studies have been developed across the LETFF programs:

- **CCS Flagships program:**
  - South West Hub Project
  - Otway Geological Storage and Demonstration project
- s22
- **LETDF:**
  - Gorgon Carbon Dioxide Injection Project
- s22

These concise case studies are presented below.

South West Hub Project

Project Summary and Objectives

The South West Hub project involved testing onshore sandstone formations as a CO_2 reservoir for nearby power plants and industrial sites in Western Australia. Its objectives were to conduct a data study and analysis of the lower Eneaba Formation to determine its suitability for injecting CO_2 underground. In its Extended Case, the facility aimed to capture, transport and store between 5-6Mt of CO_2 annually.

Contribution to Research and Knowledge

The project's unique location was chosen in part due to its proximity to CO_2 emitters, rather than any geological characteristics that make it particularly suitable for CO_2 storage. This aimed to reduce the costs of transporting CO_2 – improving the commerciality of CCS. However, the location led to challenges such as:

- determining how to keep the injected CO_2 underground, since the Eneaba Formation did not have the impermeable seal that other CO_2 storage sites have to contain the CO_2 plume
- determining how to monitor the CO_2 plume underground.

Consequently, most of the new research and knowledge gained came from addressing these challenges. Specific areas of research contributed to by the project included:

- improvements in geosequestration knowledge – including conducting and analysing seismic survey data, as well as conducting geophysical remote sensing of CO_2 sequestration
- geochemical evaluation of the well using a combination of standard and novel techniques – such as chemical tracers to determine the suitability of the area for CO_2 storage
- structural analysis of geological formations, including fault seal first-order analysis.

Stakeholders also reported that the project contributed to a greater understanding of trapping mechanisms, greater confidence in Migration Assisted Trapping (MAT) technology and a greater understanding of geological environments and depositional history at a local level.

Stakeholders also reported that by applying research in the field and conducting demonstrations, they were able to more effectively present comprehensive and compelling business cases to progress CCS technology.

Overall, this evaluation identified 28 technical reports from various public data repositories produced by the project. These reports discuss challenges and the results of geosequestration testing conducted during this project. These reports have cumulatively been cited 25 times in external reports.

Contribution to domestic skills and capabilities

The project made an important contribution to advancing domestic capabilities in the development of behavioural models of CO_2 plume movements within different rock formations. Of the 28 technical reports, eight were written by the University of Western Australia or Curtin University. These reports focused on geophysical data analysis, stability assessments and predicting CO_2 injectivity properties.

Other technical reports also focused on improvements in conducting and analysing seismic survey data like geochemical evaluation and residual trapping. The unique characteristics of the site meant that significant focus was placed on understanding how basin configuration and structural elements affected the containment capabilities of a rock formation.

The project also contributed to the development of domestic research skills, by enabling leading research organisations such as the University of Western Australia and Curtin University to have dedicated staff and students working on CCS research and demonstration projects.

Contribution to industry understanding of low emissions technologies

The Project's location in a low-medium permeability reservoir, without a thicker "continuous impermeable seal" that could effectively contain CO_2 plumes, added to the technical challenges of CCS. These challenges demonstrated that storage proximity to emission sources, while preferable, is neither a necessary nor a sufficient condition. However, a viable geological reservoir is certainly necessary and likely sufficient.

Stakeholders discussed how the South West Hub project was important for the industry to develop a better understanding of both the theoretical capabilities of injecting CO_2 into these types of reservoirs (i.e. without an impermeable seal) and also the commercial aspects that would need to be met before injection can be undertaken effectively.

Whilst challenging, the project was crucial for improving the industry's understanding of geological reservoirs without natural seals, particularly their potential for trapping CO_2. Modelling that was done as a result of the project indicated that geological reservoirs without traditional caps or seals can still store CO_2, potentially doubling the previously estimated storage capacity in south-west Western.

Technical reports and research papers discussing the processes conducted, as well as the challenges associated with geosequestration, were made public – and are found on data repositories such as s22 the Global CCS Institute and WAIMPS.

Otway Geological Storage and Demonstration Project

Project Summary and Objectives

The CO_2 Co-Operative Research Centre's (CO2CRC) Otway Geological Storage and Demonstration Project (the Otway Project) aims to conduct initial site characterisation of the Otway Basin Pilot Project. The project's objective is to demonstrate the deep geological storage of CO_2, and improve understanding of the potential geological storage of various sedimentary basins both onshore and offshore. The project has involved the pilot trial of CO_2 injection and storage to demonstrate proof of concept.

Contribution to Research and Knowledge

The Otway Project has involved partnerships with a range of leading universities and research organisations, including CSIRO, Geosciences Australia and Curtin University, with a specific focus on sub-surface CO_2 storage, monitoring and modelling.

Research and knowledge focused on decreasing the cost of monitoring CO_2 plumes underground, as well as reducing the impact of operating on other stakeholders like land operators or the environment. The Otway Project was seen by stakeholders as critical in demonstrating laboratory-scale technologies in the field as major prototypes. These technologies included new modelling approaches that accurately predict CO_2 plumes and experimental methods for determining tracer partition coefficients. The Otway Project has directly contributed to the following areas of storage and CO_2 monitoring research:

- understanding how geological permeability may change as a function of CO_2, demonstrating a need to monitor water and local mineralogy characteristics
- monitoring the characteristics of injected CO_2 plumes using seismic technology
- analysis and modelling of geophysical data sets (2D, 3D etc.) and downhole pressure and temperature datasets to improve understanding of CO_2 plume behaviour and migration
- an improved understanding of the potential injectivity of reservoirs, their ability to store CO_2 and overall storage capacity
- establishing general methodologies for determining whether a CO_2 storage reservoir is leaking
- improving techniques to monitor sub-surface CO_2 plumes
- improving cost effectiveness of CO_2 monitoring.

The Otway Project has also contributed to the development of a range of new techniques. An example is working with Curtin University to develop fibre optic cable technology to receive acoustic signals. As noted by stakeholder:

> *"Previously when you do seismic monitoring you basically create an acoustic wave through the earth and receive it at a geophone – this has been the traditional way that the Oil and Gas sector has explored. What's been maturing and what Curtin has been heavily involved with is replacing geophones [with fibre optic cables]. You can now use fibre optic to receive that acoustic signal anywhere along that fibre. Now, the quality of what you receive with that fibre versus a mechanical geophone has always been a lot less, so the fibre has never been that great. But with the funding that we have received from the LETFF and combination of work with experts from Curtin and also internationally, we are now at the point where the performance of these fibres is substantially better than these geophones. Now, that all sounds very technical, but what it means is we now have the ability to not have to put major infrastructure down these wells, we can do it through very cheap wells. We can have high resolution on demand, monitoring whenever we want to give assurance of [CO_2] behaviour on the subsurface be it in CCS or be it in Oil and Gas exploration production. It's a massive improvement and a very important technology*.

This evaluation identified ten published technical reports produced through the Otway Project, which have collectively been cited in peer reviewed publications a total of 16 times.

Contribution to domestic skills and capabilities

The Otway Project has involved collaborations with a range of international research organisations and universities – including Silixa (UK), Lawrence Berkeley National Laboratory (US), and the University of Texas. The research and academic institutions partnered with CO2CRC to trial new technologies on site. Through these collaborations, these organisations have assisted in developing and broadening domestic skills and capabilities. Technologies that were trialled include:

- different injection methods
- different storage and monitoring methods such as Distributed Acoustic Sensing (DAS) fibre optic cables and 4-D time-lapse surface seismic methods.

Stakeholders reported that the Otway Project directly contributed to Australia developing world-leading reservoir engineering and monitoring skills and expertise, with CSIRO and Curtin University being identified by international collaborators as world leaders.

A key aspect of the Otway Project was it being "internationalised" by CO2CRC as a preferred test site to trial a range of injection, storage and monitoring techniques for CCS. Stakeholders noted that through these trials and collaborations, Australia has developed skills in these international techniques. Australia was also able to directly develop significant skills and capabilities with respect to the application of a range of CCS technologies, including:

- site management
- managing the regulations around sites
- communications.

Contribution to industry understanding of low emissions technologies

A key aspect of the Otway Project has been its focus as a trial demonstration facility for CCS. This has enabled the project to undertake direct applied research and demonstration in the field, including extensive geoscience and engineering work, to inform future commercial scale deployment of CCS.

The Otway Project has developed a detailed understanding of the process of CO_2 injection under Australian conditions and geology, CO_2 migration and monitoring, and CO_2 stabilization. This has enabled the project to develop an end-to-end visualisation of the injection and storage of CO_2. The project has also significantly contributed to an understanding of monitoring and modelling the behaviour of CO_2 with very advanced modelling techniques. In short, the Otway Project has made a significant contribution in providing industry, government and academia with tangible evidence that CCS works and is safe.

The Otway Project was crucial for demonstrating technologies at a prototype level – such as seismic monitoring through fibre optic rather than mechanical geophones, which are now able to perform at a much higher level.

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Gorgon Carbon Dioxide Injection Project

Project Summary and Objectives

The Gorgon Carbon Dioxide Injection Project was a commercial-scale demonstration project for capturing CO_2 emissions from the natural gas extraction process in the Gorgon field off the coast of Western Australia. The Project involved compressing, dehydrating and transporting the CO_2 by pipeline to the injection site – a saline sandstone reservoir in the Dupuy Formation. It aimed to reduce project emissions by 120Mt over its lifespan at a 3.4-4Mt annual rate, and is the first major project to significantly reduce emissions through underground injection. The Project is expected to begin CO_2 injections in 2019.

Contribution to Research and Knowledge

Research and knowledge gained from the Project may have been limited because CO_2 injections have not started and because of potential commercial-in-confidence issues. The 12 public technical reports identified as part of this evaluation covered key learnings on:

- the acquisition of quality seismic data, through petrographic, petrophysical, biostratigraphical, sedimentological and geochemical reporting – and its significance to improving the accuracy of CO_2 migration simulation models
- the impact on project execution
- well remediation programmes to ensure existing wells near the proposed injection site have been properly secured and do not pose a CO_2 containment risk
- site assessments, research and exploration work.

These technical reports have been cumulatively cited 1,012 times by external papers, demonstrating the significant contribution to enhancing knowledge of LETFF, and particularly CCS, made by the project.

Contribution to domestic skills and capabilities

The Gorgon Project involved the use of technologies, processes and equipment that have previously existed within the oil and gas sector, and as such was able to leverage the existing and significant skills base within the oil and gas sector.

However, the Gorgon Project did bring in monitoring technologies that reduced the cost of monitoring CO_2 plumes. These technologies include surveillance wells, 4D Surface Seismic testing, soil gas verification and pressure sensors on the surface.

This evaluation did not identify any technical reports that were written in partnership with universities or other research-based institutions.

Contribution to industry understanding of low emissions technologies

The Project is seen as a successful example of CCS operations on a commercial scale. While the $60 million allocated from the LETDF was not material to the Gorgon Project’s success, it has enabled the development of a successful relationship that was crucial in the following ways:

- key learnings from the Gorgon Project relating to the legal and regulatory aspects influenced how the Australian Government intended to regulate CCS
- it also assisted in developing the Australian Government’s Offshore Petroleum and Greenhouse Gas Storage Act.

The Project also led to technical reports associated with pumping CO_2 into reservoirs that are full of water, and its impacts on the reservoir itself. Depending on the type of report, they are either disseminated internally (where there is a commercial advantage) or published in industry journals.

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Appendix E: Literature scan and citation analysis

The results of the citation analysis of publicly available reports relating to the LETFF programs is presented below. This citation analysis covers publications available up until 28 May 2019.

Table E.1: Detailed Analysis of LETFF program/project publications

LETFF program/ project	Publications No.	Publications %	Scholarly articles (as a share of publications) %	No. of citations	Citations per publication
CCS Flagships	**65**	**13%**	**2%**	**170**	**2.6**
CarbonNet	20	4%	n/a	65	3.3
SouthWestHub	28	6%	4%	25	0.9
ZeroGen	2	0%	n/a	44	22.0
Wandoan	5	1%	n/a	20	4.0
CO2CRC	10	2%	n/a	16	1.6
CCSRD&D	0	0%	0%	0	0.0
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LETDF	**23**	**5%**	**39%**	**1105**	**48.0**
Gorgon	12	2%	42%	1012	84.3
IDGCC	0	0%	0%	0	0.0
Hazelwood	7	1%	57%	93	0.0
Fairview	1	0%	0%	0	0.0
Other	3	1%	0%	0	0.0
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Source: Deloitte

Notes: The above analayis only includes publically available publications.

Scholarly articles are considered to be publications that appear in peer-reviewed academic or scientific journals.

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Phase Two of the Impact Evaluation of the Low Emissions Technologies for Fossil Fuels (LETFF) programs

Department of Industry, Innovation and Science

8 August 2019

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Glossary

ACALET R&D	Australian Coal Association Low Emissions Technologies Research and Development
ANAO	Australian National Audit Office
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ARENA	Australian Renewable Energy Agency
CCS	Carbon Capture and Storage
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CO2CRC	Carbon Dioxide Co-operative Research Centre
CSIRO	Commonwealth Scientific and Industrial Research Organisation
GCCSI	Global Carbon Capture and Storage Institute
GHG	Greenhouse Gases
HELE	High Efficiency Low Emissions
IDGCC	Integrated Drying Gasification Combined Cycle
IGCC	Integrated Drying Gasification Combined Cycle
KEQ	Key Evaluation Questions
LETDF	Low Emissions Technology Demonstration Fund
LETFF	Low Emissions Technologies for Fossil Fuels
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Executive summary

In 2004, the Australian Government identified a need to support and promote the development and deployment of low emissions technologies to facilitate a cost-effective transition to a lower carbon economy.

The Department of Industry, Innovation and Science (the Department) has been implementing a range of policies from 2004 to support the research and development of new greenhouse gas (GHG) emissions reduction technologies under the Low Emission Technologies for Fossil Fuels (LETFF) programs.

Deloitte has been engaged by the Department to undertake Phase Two of the LETFF impact evaluation to evaluate the impacts of the LETFF programs on increasing knowledge, skills and capability, and on improving industry understanding in relation to low emissions technologies. The project also sought to answer:

- What factors have helped or hindered the achievement of the above outcomes?
- To what extent would outcomes have been achieved in the absence of the LETFF programs?
- To what extent do factors within and external to the LETFF programs remain a barrier to commercial development and deployment of LETFF?
- What (if any) unintended outcomes, positive and negative, have occurred as a result of the LETFF programs?
- What lessons can be drawn to inform future program development, including the role (if any) of the Commonwealth Government, in relation to supporting the development and implementation of LETFF technologies?

To answer these questions, the impact evaluation adopted a mixed methods approach involving semi-structured interviews with program stakeholders, an online questionnaire, and extensive scan of secondary data including citation analysis and development of case studies.

Contribution to knowledge, skills and industry understanding

The LETFF programs have significantly contributed to increasing knowledge, skills and capability, and improving industry understanding of LETFF in Australia. Overall, Australia has the research and engineering capability to develop commercial scale LETFF projects.

Overall, through the LETFF programs Australia has developed:

- a mature knowledge base with multiple industry participants with knowledge of a range of LETFF, supported by a broad body of research covering multiple technologies
- a moderate level of domestic skills and capability, with more advanced expertise within a number of organisations in relation to specific LETFF, most notably CCS
- a moderate industry understanding of the technical and practical feasibility of some LETFF, notably CCS, under a range of processes and Australian conditions but deployment required to further advance understanding.

A significant body of research has been delivered across the full spectrum of LETFF activities, and the critical research and development and technical barriers are considered to be largely settled for CCS.

Australia's research skills and capabilities have been deepened with respect to specific LETFF; these skills and local experience are more developed relative to prior to commencement of programs. However, Australia's research capabilities are considered to be more advanced than industry capabilities. Stakeholders agree that deployment of LETFF is required to further advance Australia's industry and technical skills and capabilities.

The LETFF programs have resulted in industry developing a detailed 'end-to-end' understanding of the engineering and design of LETFF, in particular CCS technologies. Furthermore, there is a

consensus that the coal, energy generation, and oil and gas sectors have an understanding of the practical, technical and financial requirements necessary to deploy CCS. However, the absence of a commercial imperative to invest in emissions abatement remains the overarching barrier to LETFF deployment in Australia.

Factors contributing to the success of the LETFF programs

At commencement, the LETFF programs were underpinned by clear policy direction and settings, support across Commonwealth and State governments, and a significant funding commitment across a suite of programs and projects – factors deemed critical to the achievement of outcomes. Other contributing factors to the achievement of outcomes included:

- establishment of partnerships between government, industry and academic stakeholders
- the direct financial involvement of the coal industry in maintaining an industry-focused research agenda
- establishment of a portfolio of LETFF projects to maximise learnings and the probability of success.

Overall, changing, uncertain and inconsistent domestic policy settings are considered the primary factors hindering achievements and progress across the LETFF programs. Policy uncertainty has resulted in a significant loss of confidence across industry and a loss of momentum in advancing LETFF.

A combination of the unexpected complexity of LETFF, inflexibility of funding agreements, and regulatory uncertainty on the part of the Commonwealth and State governments also hindered achievements and progress across the LETFF programs.

The absence of a clear commercial imperative on the part of industry to invest in carbon abatement remains the single largest barrier to the commercial development and deployment of LETFF.

Success, future research and role of government

Overall, stakeholders overwhelmingly consider the LETFF programs to be successful. There was strong agreement among all stakeholders that the achievements of the LETFF programs would not have been made in the absence of Commonwealth Government support. Furthermore, stakeholders consider that the Commonwealth Government's investment in LETFF programs represents good value for money, and that achievements are commensurate with the investment.

LETFF programs have directly contributed to reducing the technical and commercial barriers to the development and deployment of commercial-scale LETFF projects. However, the achievements and knowledge gained could have been more effectively communicated and disseminated beyond immediate program participants, and achievements could have been more effectively communicated to the broader public. Barriers to knowledge sharing and access to information have contributed to a low level of public understanding and acceptance of LETFF, and in particular CCS, and represent one barrier to the deployment of LETFF.

Australia also risks losing the significant gains in knowledge, and skills and capabilities established through the LETFF programs if there is no progression towards the commercialisation and deployment of LETFF.

The critical underlying research and technical questions to deploying large-scale LETFF (and CCS in particular) have been addressed, however some targeted research would supplement and benefit research done to date. In particular, there is need to undertake site-specific research and testing to support the eventual deployment of LETFF.

Stakeholders consider there remains a critical role for the Commonwealth Government in supporting the development and implementation of LETFF. While there was no clear consensus on the appropriate role for the Commonwealth Government from stakeholders interviewed, a majority of respondents to the online questionnaire considered the Commonwealth Government should continue to provide large-scale grants to support LETFF research and development.

Key lessons for future program design

The impact evaluation has identified the following key lessons to inform future program design and implementation:

- the need to set realistic expectations with respect to program cost and time-horizons, particularly for programs with a focus on deployment of commercial-scale projects incorporating untested technologies
- the need to set realistic expectations with respect to research and development outcomes, noting that only a proportion of projects will succeed in progressing beyond research and pre-commercial feasibility
- ensuring alignment between policy settings and program objectives, and ensuring an appropriate mechanism is in place to trigger a review of program rationale in the event of a fundamental shift in domestic and international policy settings
- enhancing the technical and financial assessment of project feasibility at program commencement, noting that this needs to be balanced with the research and development objectives and any future program
- funding and program governance arrangements should reflect the nature of program activities, in particular stage gates should replace inflexible milestone reporting and payment processes for large projects to enable a more efficient provision of funding
- greater industry engagement in the design of the program, and as part of a formal risk assessment, to ensure program objectives, risks and issues are appropriately understood and reflected in the program design and implementation
- the need to embed monitoring and reporting frameworks to monitor the effects of changes to funding on the achievement of program objectives, and better enable an assessment of how remaining funds can be redistributed within the program or other programs
- the need to embed knowledge-sharing processes and systems to ensure program learnings and outcomes are appropriately captured and disseminated across relevant Commonwealth and State government departments and agencies
- any consideration of future support to further the development and implementation of LETFF, as a first step, should involve a detailed economic cost benefit analysis of LETFF in decarbonising the economy relative to alternative technologies. This analysis should give consideration to fossil fuel demand and the whole-of-lifecycle costs of alternative technologies.

Management response

The Onshore Minerals and Energy Resources Branch endorses the findings of the Impact Evaluation of the Low Emissions Technologies for Fossil Fuel (LETFF) programs. In particular, the Branch notes the evaluation's findings that the LETFF programs have helped to develop a mature knowledge base supported by a broad body of research; a moderate level of skills and expertise; and a moderate industry understanding of the technical and practical feasibility of some LETFF, notably carbon capture and storage (CCS).

The Branch is pleased with the evaluation's finding that stakeholders overwhelmingly consider the LETFF programs to be successful, and the factors identified as being critical to that success (including the establishment of partnerships between government, industry and researchers; the direct financial investment of industry stakeholders; and the establishment of a portfolio of projects to maximise the probability of success); while noting the present risk of losing momentum and knowledge without further progress towards the deployment of LETFF.

The evaluation provides useful insights into the programs' successes, as well as the factors that have hindered achievements across the programs; and stakeholders' views on the need for future government support. These insights, as well as lessons for future program design, will be useful inputs for the design and management of any future programs of a similar scale, duration and complexity.

1 Overview and purpose

1.1 Context

Australia's electricity generation and some industrial sectors (e.g. steel and concrete production) rely heavily on burning fossil fuels, such as coal, natural gas and oil, which release carbon dioxide (CO_2) and other greenhouse gases (GHG) into the atmosphere.

Low emissions technologies have the potential to reduce GHG emissions and Australia's impact on climate change. In 2004, the Australian Government identified a need to support and promote these technologies to facilitate a cost-effective transition to a lower carbon economy. The Department of Industry, Innovation and Science (the Department)[1] has since implemented and overseen the Low Emission Technologies for Fossil Fuels (LETFF) programs. These programs fund research and development of new GHG emission reduction technologies. The LETFF programs comprise the following four programs:

- The Carbon Capture and Storage (CCS) Flagships program
- s22
- The Low Emissions Technology Demonstration Fund (LETDF)
- s22

These programs commenced against a backdrop of increasing and coordinated global action against climate change. However, they have experienced significant changes in funding, policy and investment conditions. In particular, the repeal of the carbon pricing mechanism has led to uncertainty regarding the future price of carbon, affecting business investment incentives.

The Department has identified the LETFF programs as a Tier One evaluation priority of high strategic importance. The Department previously accepted the recommendation of the Australian National Audit Office (ANAO) audit (2017) to evaluate the LETFF programs. The Department is conducting the evaluation of the LETFF programs in two phases, consisting of:

- Phase One - an assessment of the 'evaluability' of the four LETFF programs, previously conducted by Deloitte Access Economics. (Completed)
- Phase Two - an impact evaluation of the LETFF programs, the scope of which has been informed by the outcomes of Phase One. (Current phase).

1.2 Purpose and scope of Phase Two

The Department has engaged Deloitte to conduct Phase Two of the LETFF impact evaluation (the project). The overarching purpose of this project is to evaluate the impacts of the LETFF programs on increasing knowledge, skills and capability, and on improving industry understanding about low emissions technologies.

The project will also seek to determine whether the Government investments made under the LETFF programs have helped move low emissions technologies closer to commercialisation, and whether the outcomes achieved are commensurate with the level of investment made by the Commonwealth Government.

The findings of this project will inform future LETFF program design, including the potential role of the Commonwealth Government in supporting the further development and implementation of LETFF.

The project covers all components of the LETFF programs with the exception of the CCS Flagships Research Development and Demonstration (RD&D) fund, which is out of scope as impacts are unlikely to have been realised at the time of reporting.

[1] The LETFF programs were originally implemented under the former Department of Resources, Energy and Tourism.

1.3 The LETFF programs

The LETFF programs support low emission fossil fuel technologies by funding programs and initiatives that aim to reduce technical risks and speed up the commercialisation process. Technologies that were supported through the LETFF programs include:

- carbon capture and storage (CCS)
- high efficiency low emissions (HELE) electricity generation
- fugitive methane emission abatement technologies.

A total of $2.8 billion was originally budgeted across all four LETFF programs. However, funding was substantially reduced over time and approximately $750 million has been spent to date.

A summary of the four LETFF programs, including the objectives of each program, is provided in Table 1.1 below. A summary of individual projects delivered under each program is presented in Appendix A.

Table 1.1: Summary of LETFF programs

LETFF Program	Description
The CCS Flagships program	Commenced in 2009 under the Federal Budget's Clean Energy Initiative with a program budget of $1.8 billion. The objective of the program was to promote the dissemination of CCS technologies through supporting a small number of demonstration projects to capture CO_2 emissions from industrial processes and safely store them underground in stable geological formations. Five flagship projects and other small-scale CCS activities have been funded over the course of the program. Two out of the five flagship projects have been deemed 'unsuccessful'. The program also includes the CCS Research, Development and Demonstration (RD&D) Fund with an objective of reducing the technical and commercial barriers to deploying large-scale CCS projects.
s22	
LETDF	Announced in June 2004 under the *Energy White Paper – Securing Australia's Energy Future*. The Fund had a $500 million budget that could be granted to projects ranging from concentrated solar to CCS technology. The aim of the program was to demonstrate the commercial potential of new technologies to contribute to long-term large-scale GHG emissions reductions. The LETDF Program funded six highly complex projects which required a high degree of due diligence. Of these six, two were transferred to other programs, three were unsuccessful and only one – the Gorgon Carbon Dioxide Injection Project, continues to operate.
s22	

1.4 Summary of Phase One findings

Deloitte was previously engaged to assess the evaluability of the four LETFF programs under Phase One of the impact evaluation of the LETFF, to inform design and resourcing of any future impact evaluation to be undertaken in Phase Two. The evaluability assessment sought to answer three key questions:

- Was it plausible to expect an impact from the programs?
- Would an evaluation be useful, and, if so, to whom?
- Would an evaluation be feasible, based on: program evidence, data availability, baseline measures, and reporting mechanisms?

The evaluability assessment found that, overall, it was reasonable and plausible to expect that the projects and activities delivered under the LETFF programs could achieve intended short-term and, to some extent, medium-term outcomes and impacts. It was not plausible to expect that the LETFF programs could reasonably have achieved the strategic longer-term objectives of demonstrating and deploying LETFF on a commercial scale, thereby reducing GHG emissions.

The evaluation assessment confirmed there was strong stakeholder support and interest for an impact evaluation. It advised that in the absence of delivery of any commercial scale projects, an impact evaluation should focus on the achievement of short and (to some extent) medium-term outcomes to guide future policy focus and direction. It also noted that any future impact evaluation of LETFF programs will require drawing on a range of qualitative evaluation methods, with a focus on stakeholder interviews and questionnaires, documentation review, and case studies.

The evaluability assessment recommended that the Department undertake a targeted impact evaluation of the LETFF programs that focuses on assessing the extent to which the LETFF programs have resulted in changes over the short- and medium-term against the following program outcomes:

- generation of new research, data and modelling relating to the practical and technological use and implementation of LETFF (short-term outcome)
- improved industry knowledge regarding the feasibility and safety of low emissions and abatement technologies, through collaboration and dissemination of findings from pilot and feasibility studies (short-term outcome)
- development of domestic skills and capability in low emissions and abatement technologies (medium-term outcome).

The evaluability assessment recommended a future impact evaluation should also assess:

- whether industry knowledge and understanding of the feasibility and safe development of LETFF would have progressed in the absence of the LETFF programs
- whether changes in policy settings and other external factors have affected the ability of LETFF programs to achieve stated impacts
- implications for future policy development and priority setting, including the role (if any) of the Commonwealth Government in supporting the further development and implementation of LETFF.

1.5 Report structure

This report presents the findings of the impact evaluation of the LETFF programs. The report is structured as follows:

- Chapter 2 outlines the approach to the impact evaluation.
- Chapter 3 presents the contributions made by the LETFF programs to knowledge, skills and industry understanding.
- Chapter 4 discusses factors contributing to the achievements of the LETFF programs.
- Chapter 5 discusses the success of the LETFF programs, including areas of future research and the role of government in supporting the development of LETFF.
- Chapter 6 presents learnings for future program design.

2 Evaluation methodology

The impact evaluation uses a mixed methods approach to assess the extent to which the LETFF programs have contributed to increasing knowledge, skills and capability, and to improving industry understanding of LETFF. This has included semi-structured interviews, an online questionnaire and secondary data analysis, a citation analysis and development of concise case studies.

2.1 Evaluation framework

An evaluation framework has been developed to guide this evaluation. It outlines the key evaluation questions and data sources to be drawn on to address each evaluation question, and was developed in consultation with the Department. The evaluation framework has guided the key lines of enquiry and systematic organisation of analysis to ensure a consistent and robust assessment of the LETFF programs and project activities. The framework is presented in Appendix B.

2.2 Data collection and analysis

2.2.1 Semi-structured interviews

Semi-structured interviews were conducted with key LETFF program stakeholders from the Department, Commonwealth science agencies (e.g. CSIRO and Geoscience Australia), participating State governments, industry grant recipients and representatives, academic and research grant recipients, and expert advisers. All stakeholders engaged had direct involvement in the LETTF programs. Contact details of key stakeholders were provided by the Department.

A total of 18 semi-structured interviews were conducted. An interview guide was developed based on the evaluation framework. Questions were tailored for each stakeholder depending on group and LETFF program(s) they participated in, and mapped to each evaluation question in the framework. Each interview was conducted via telephone and recorded. The interview was subsequently analysed in NVivo, using coding techniques to identify common themes. A summary of stakeholders interviewed is provided in Appendix C.

2.2.2 Online questionnaire

An online questionnaire was developed to gain further insights into stakeholders' perceptions of the impact of the LETFF programs, the factors that may have assisted or hindered the achievements, and the overall success of the LETFF programs. A total of 17 respondents completed the online questionnaire. A summary of the spread of respondents is provided in Appendix C.

The online questionnaire was sent to the same cohort of stakeholders as the semi-structured interviews (via emails provided by the Department). Stakeholders were invited to forward the questionnaire on to their peers and colleagues who had also been directly involved with the LETFF programs. As such, the online questionnaire has not enabled a true triangulation of findings relative to the interviews. However, the questionnaire did provide further richness of insights with respect to the impact of the LETFF programs and supplemented the findings of the interviews.

2.2.3 Program data

The project has involved an examination of departmental documents and data and other publicly available information, to provide insights on impacts achieved by LETFF programs, including:

- final project reports
- research papers, scientific papers, technical papers produced under the LETFF programs
- project specific datasets and models
- broader literature on relevant themes.

A literature scan of research and scientific papers produced under the LETFF was undertaken due to the extensive body of documentation produced. A scan of 496 publically available reports matching key search criteria was undertaken to provide insights into the impact of the LETFF

programs. This ensured an appropriate breadth and depth of documents were reviewed across the LETFF programs.

Key document sources included Department-held documentation, in addition to data, reports and documentation held by:

- s22
- Global CCS Institute (GCCSI) data and documentation
- CO2CRC
- CSIRO
- Geoscience Australia.

2.2.4 Citation analysis

The project has involved a citation analysis of the 496 program publications identified in a literature scan up to 29 May 2019 to gauge the extent to which knowledge transfer has occurred as a result of the LETFF programs. The citation analysis involved:

- cited reference analysis – the number of times that research publications produced by the LETFF programs have been cited in journal articles or scientific publications based on Google Scholar data.
- publication use – the number of times that research publications produced by the LETFF programs have been accessed or requested online (where this data was available).

The results of the citation analysis were then triangulated with semi-structured interviews and results from the online questionnaire.

2.2.5 Case studies

Case studies of individual LETFF projects were developed from across the LETFF programs. This enabled the identification of general findings about the LETFF program. Case studies were developed from primary and secondary data sources, and illustrate the extent to which specific projects have contributed to the achievement of focus outcomes. Two case studies were developed for each program, with the exception of the LETDF program.

Case studies are outlined in Appendix D.

2.3 Limitations of methodology

The focus of this project is an impact evaluation of specific short and medium-term outcomes of the LETFF programs. Specifically, the intent is to assess the impact of the LETFF programs on increasing knowledge, skills and capability, and on improving industry understanding of LETFF. The project has not sought to assess the extent to which the LETFF programs have achieved any other medium or longer-term outcomes.

The qualitative data presented in this report reflect the opinions and perceptions of stakeholders engaged during the evaluation. These opinions and perceptions are presented as originally communicated. Stakeholders engaged in this evaluation have all had direct involvement in the LETFF programs. Stakeholders, by virtue of their involvement in the LETFF programs, may have had an inherent bias in their view of achievements and outcomes.

This evaluation has not engaged any stakeholders external to the LETFF programs, such as representatives of alternative technologies or programs.

The project has been limited by the significant lapse in time since the commencement of the LETFF programs and subsequent implementation. Specific issues that limited this evaluation include:

- the natural turnover of program staff; the Deloitte team was unable to engage with departmental stakeholders who had been involved in the programs at inception
- the natural turnover of participating industry and academic stakeholders; many key project proponent staff and external expert advisors have subsequently left their roles and/or organisations, meaning the Deloitte team was unable to speak to stakeholders from across all projects and activities. As such, only a sample of relevant stakeholders could be reached for the purpose of the evaluation.

3 Contribution to knowledge, skills and industry understanding

Key findings:

- The LETFF programs **have significantly contributed to increasing knowledge, skills and capability, and improving industry understanding of LETFF in Australia.** Overall, Australia has the research and engineering capability to develop commercial scale LETFF projects.
- Australia now has:
  - **a mature knowledge base** with multiple industry participants with knowledge of LETFF, supported by a broad body of research covering multiple technologies
  - **a moderate level of domestic skills and capability**, with more advanced expertise within a number of organisations in relation to specific LETFF, most notably CCS
  - **a moderate industry understanding** of the technical and practical feasibility of specific LETFF under a range of processes and conditions, but further advances in understanding will require deployment.
- A significant body of research has been delivered across the full spectrum of LETFF activities - the critical research and development and technical barriers are considered to be largely settled for CCS.
- Australia's pool of research and technical skills and capabilities is considerably larger, more developed and vastly more experienced relative to prior to commencement of programs.
- Research capabilities are more advanced than industry capabilities. Deployment of LETFF is required to further advance industry skills and capabilities.
- There is a risk of Australia losing the skills and capabilities developed if momentum is not maintained given the global demand for skills and expertise.
- The LETFF programs have resulted in industry developing a detailed 'end-to-end' understanding of the engineering and design of LETFF, in particular CCS technologies.
- There is a consensus that the coal, energy generation, and oil and gas sectors have an understanding of the practical, technical and financial requirements necessary to deploy CCS.
- However, the absence of a commercial imperative to invest in emissions abatement remains the overarching barrier to LETFF deployment in Australia.

3.1 Overall contribution of LETFF programs

Overall, there is consensus among industry, government and academic stakeholders involved in the LETFF programs that these programs have significantly contributed to increasing knowledge, skills and capability, and improving industry understanding about low emissions technologies in Australia.

There is broad stakeholder agreement that the advances in Australia's understanding of LETFF and their implementation – particularly around geological subsurface storage – would not be where it is today in the absence of the LETFF programs (discussed in greater detail in Section 5.2).

Stakeholders highlighted that the LETFF programs have involved an incremental learning process for industry, academia and government. Individual project outcomes have contributed towards a broad portfolio of achievements, rather than one single, flagship success. Even 'failures' have

provided valuable learning opportunities and insights, with most stakeholders indicating the importance of discovering what didn't work to be just as important as knowing what works.

Australia is now considered to be 'deployment ready' from a technological perspective. Australia is considered to have a mature knowledge base, supported by a well-developed body of research, with moderate skills and capability across specific LETFF (particularly CCS), and considerable industry understanding of the practical and technical feasibility of LETFF under a range of Australian conditions. There is strong agreement across all stakeholder groups that the priority for LETFF is to shift to commercial-scale deployment. Figure 3.1 illustrates the shift in the level of knowledge, understanding, and capabilities since the commencement of LETFF as perceived by key stakeholders and reflected in available evidence.

Figure 3.1: Summary of evidence of perceived shift in Australia's LETFF knowledge, understanding and capabilities since 2005

High

Stage	State of knowledge	Understanding of technical and practical feasibility	Local industry skills and capability
5	Deep and broad sector knowledge throughout industry, supported by extensive body of research covering full range of LETFF technologies.	Extensive industry understanding of technical/pract cal feasibility of full range of LETFF technologies under full range of processes and condit ons.	World leading industry skills and capability located w thin a wide number of industry and research organisations and across the broad spectrum of LETFF technologies.
4	Broad sector knowledge across major ty industry part cipants, supported by large body of research covering large range of technologies.	Broad industry understanding of techn cal/practical feasibility of LETFF technologies under most industrial processes and condit ons.	Broad local industry skills and capability across a large number of industry and research organisations and a across the majority of LETFF technologies.
3	Sector knowledge is moderate, w th multiple industry part cipants having knowledge of LETFF technologies, supported by a moderate body of research covering multiple technologies.	Moderate industry understanding of technical/pract cal feasibility of LETFF technologies under some processes and cond tions.	Moderate local industry skills and capability, with expertise across a moderate number of organisat ons on a moderate range of LETFF technologies.
2	Sector knowledge is thin, w th only select industry part cipants having meaningful knowledge of LETFF technologies, supported by a small body of research focussed on one or two technologies.	Lim ted industry understanding of techn cal/practical feasibility of LETFF technologies under 1 or 2 industrial processes.	Thin but growing local industry skills and capabil ty, w th expertise located across a handful of industry and research institutions.
1	Sector knowledge relating to pract cal, technolog cal and scientif c use and implementation of LETFF technologies is minimal/non-existent.	No industry understanding of techn cal/practical feasibility of LETFF technologies.	Niche local industry skills and capability, with only lim ted expertise.

Low

Source: Deloitte Access Economics

The LETFF programs have contributed to providing Australia with a detailed 'end-to-end' understanding of CCS, with stakeholders agreeing that the major research development questions and technological barriers have been largely settled and overcome. The LETFF programs have contributed to a clear understanding of the 'pathway to deployment' for LETFF and in particular CCS, including:

- the capture, transport, storage and injection technologies involved
- the costs and timeframes involved
- which technologies to deploy and under what conditions
- the locations and suitability of storage sites where technologies can be best deployed.

3.1.2 State of knowledge, capabilities, and understanding prior to commencement

Prior to the commencement of the LETFF programs, stakeholders reported Australia's knowledge and understanding of LETFF as predominantly conceptual and theoretical in nature. Understanding of how LETFF might be practically implemented was very limited, although it was noted that the oil and gas sector had a deeper understanding than other sectors, given the integral nature of drilling

in this sector. Overall, stakeholders reported that Australia, in general, had limited knowledge and understanding of:

- the location, capacity and sub-surface condition of geological resources (both onshore and offshore)
- long-term stability of geological resources and how they would react with CO_2
- different emission capture technologies and application to Australian conditions and industrial processes
- the behaviour of CO_2 plumes under different sub-surface conditions, and how to model the behaviour of CO_2 plumes
- the behaviour of CO_2 during transportation
- the end-to-end engineering and design of capture and storage technologies
- the full life-cycle costs of designing, building and operating commercial-scale LETFF.

Additionally, there was no arrangement in place to structure the existing knowledge base, to direct the advancement of new research, or to provide a knowledge-sharing platform between government, academia and industry. Stakeholders described Australia's knowledge-base as follows:

> *"... we didn't have a good idea of where the basins were. We didn't know much about the capture technologies, we didn't know if there was Enhanced Oil Recovery potential"* – Academic/research stakeholder.

> *"...there was theoretical knowledge, but less knowledge of [how] it [will] actually work in practice. [There was] a gap in the knowledge in terms of the application* – Government stakeholder.

> *"Go back probably 20 years, I would say that the Australian state [of knowledge] was developing. I wouldn't say it was embryonic, I'd say we were better than embryonic, but I think we were developing.... We were by no means near deployment-ready." – Academic/research stakeholder.*

This is not to say that Australia did not have a meaningful understanding of LETFF relative to other developed countries – such as the European Union, the U.S., the U.K., or China. On the contrary, stakeholders interviewed reported Australia's academic and scientific research community had pockets of recognised world-leading skills and expertise. Examples identified by stakeholders include:

> *"Geoscience Australia did some very early work in geological storage... very basic basin work to get some capacity work [back] in the 90s."* – Academic/research stakeholder.

> *"Geoscience Australia had been working toward CCS aspects as well and then we had CSIRO... CSIRO had been working on capture technologies at a small scale across a few sites.... There [were] capture engineers at Monash and Melbourne Universities... so that knowledge was there at a research phase."* – Academic/research stakeholder.

Within industry, however, there was a lack of the technical and practical type skills necessary for deployment and implementation – such as engineering and operational type skills. As noted by some stakeholders:

> *"... it would have been the researchers and not industry in those early days that had the expertise or understanding as well."* – Commonwealth Government stakeholder.

> *"... not as much as the practical engineering because it hadn't been deployed in Australia... not enough for a full industry, which is what we very rapidly found out when the flagship projects were launched there just weren't enough people to do all the work and so what we had is the same people doing a lot of the work..."* – Research stakeholder.

Across industry, there were also certain sectors that were more advanced in their understanding of and engagement with LETFF than others. Stakeholders singled out the Oil and Gas sector, in

particular, as having well-established understanding and capabilities relating to carbon capture and storage (CCS) technologies:

> *"...the Oil and Gas industry in 1999... they were fine. ...injecting CO_2 and withdrawing gas from the subsurface, this is their daily bread...these guys have been doing EOR [Enhanced Oil Recovery] for 40 years. They have been injecting CO_2 for 40 years, they know how to do this."* – Academic/research stakeholder.

> *"... [the Oil and Gas industries] were already way up the learning curve both in terms of capture technology and in terms of injection..."* – Industry stakeholder.

In contrast, other emissions-intensive industries had yet to commence investigating the potential of LETFF in detail. In particular, the coal, energy generating, industrial (e.g. steel, concrete, and fertiliser) and agricultural sectors had yet to meaningfully investigate and engage in the development of low-emission, abatement, or monitoring technologies emission abatement and capture technologies. As some stakeholders noted of these sectors:

> *"... there wasn't necessarily much appetite to engage... there wasn't a significant driver... until I suppose the carbon taxes and things came in at that time.... as far as I understand industry weren't totally engaged."* – Commonwealth Government stakeholder.

> *"...the electricity sector has traditionally been happy to produce electricity and run their coal-fired power stations...the big issue for them is that they went from a business of mechanical engineers to a business of chemical engineers [to understand LETFF] and that was a big problem for them. They are low-risk engineers and they had to move into a high risk [investment]."* – Industry stakeholder.

3.1.3 State of knowledge, capabilities, and understanding today

Today, stakeholders report that the breadth and depth of Australia's knowledge, capabilities and understanding of LETFF, in particular CCS, is significantly greater than it was prior to the commencement of the LETFF programs. Overall, stakeholders reported significant improvements in Australia's knowledge and understanding of:

- the 'end-to-end' of the implementation of low-emissions technologies, including:
  - integrating low-emissions technologies with existing production systems
  - proving low-emissions technologies under Australian conditions
  - cost discovery of implementation
  - safety and environmental implications
  - regulatory approvals process
- monitoring and measuring greenhouse gas emissions
- Australia's geological subsurface storage potential and capacity, including:
  - the importance of subsurface storage in the CCS process
  - identification of suitable subsurface storage locations, and their potential capacity
  - dynamic modelling the geological subsurface behaviour of CO_2.

The consensus among stakeholders from across industry, government, and academia is that Australia's knowledge and expertise is now well-past the conceptual and theoretical R&D phase. Australia now possesses the research and technical foundations, including an understanding of the technical challenges, costs, and risks to progress to commercial-scale deployment. Australia is considered to 'hit above its weight' with respect to LETFF on a global stage. As noted by stakeholders:

> "… in Australia, we have a range of stakeholders that are probably world leaders in terms of understanding the whole value chain of CCS, whether it be understanding capture technologies inside the CSIRO… they are world leaders and they are winning grants from other countries at the moment. I think that monitoring and storage activities … the CO2CRC are world leading … I think we have a much better understanding of the underground storage potential in Australia, both onshore and offshore, more work to be done in that space, but when you compare 10 years ago to now… we have made great progress on the technical front of understanding CCS and I don't disagree with some people who have said we have conquered the technical barriers."* – Commonwealth Government stakeholder.

> *"… we have done all the engineering to the point of construction, so from not even knowing which technology to choose, to now having chosen a technology and done all the upfront engineering, partnering with the technology providers, so that a construction decision can be made with, actually can be made today if we had the money. … That's actually been a dramatic shift"* – Industry stakeholder.

However, the advances in knowledge, skills and capability and understanding have been more concentrated in certain sectors than others. In particular, there was consensus among stakeholders that the advances in knowledge and capabilities in the academic and scientific research community far outweighed advances in the coal, energy generating and industrial sectors. As noted by a stakeholder:

> *"… the skills level of the academic community has indeed increased, but it's the academic skills level and not the industrial deployment skills level…"* – Industry stakeholder.

Despite the gains that have been made over the last 15 years, there are gaps that remain and new gaps have emerged. Overall, stakeholders identified the following gaps:

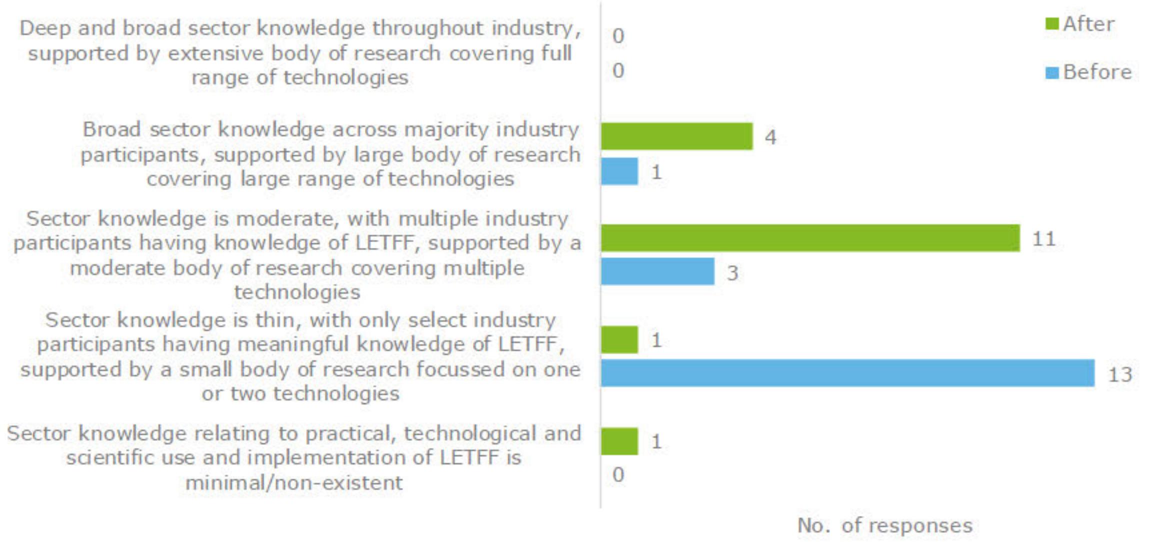
- the need to consolidate the knowledge and understanding of LETFF gained to date
- improving the accessibility, dissemination and communication about LETFF across industry sectors and the broader community
- detailed local and site-specific understanding of suitable onshore and offshore subsurface storage potential and capacity
- demonstration and deployment of LETFF on an industrial-scale, and the absence of an established CCS industry in Australia
- lack of experienced engineering skills and capabilities (mechanical, electrical etc.) for the industrial-scale deployment and operation of LETFF and CCS technologies.

3.2 Generation of new research and knowledge

There was consensus among stakeholders interviewed that Australia's overall state of knowledge progressed from being perceived as 'thin' prior to the commencement of the LETFF programs, to a mature moderate knowledge base underpinned by a well-developed body of research across multiple technologies.

This view was supported by the findings of an online questionnaire of LETFF stakeholders. Chart 3.1 illustrates the perceived change in the overall state of knowledge and understanding with respect to LETFF.

Chart 3.1: Questionnaire responses on overall state of knowledge before and after the commencement of the LETFF programs



Source: Deloitte questionnaire, n = 17

In addition to the improvement and expansion of the domestic skills base, the LETFF programs are attributed with having generated a range of new and original research and technical innovations. These include outputs such as:

- **Data tools** – geological seismic data, atmospheric measurement data, and technical test data
- **Modelling tools** – geological subsurface storage mapping, models of CO_2 subsurface behaviour, energy market modelling, as well as financial models of commercialisation
- Technological **innovations** – digital drill core technology s22
- **Methodological improvements** – improved methods for monitoring greenhouse gas emissions, technical operation methods that improve efficiency or safety, project management methods that improve the up-scaling and commercialisation of technologies
- **Formation of new relationships** – the value of the new relationships formed between industry, government, and the academic and scientific communities, as well as relationships formed between these communities in Australia with other people, communities and institutions overseas.

These provide the foundation tools and resources for industry and government to further invest in LETFF and CCS technologies with greater certainty in regard to the costs associated with deployment and ongoing operation, safety and environmental considerations, and the efficiency of production.

In addition to the above, the LETFF programs have contributed a significant body of **publications,** including academic journal articles, discussion papers, PhD dissertations, conference presentations, government policy documents, and interim and final project reports.

The GCCSI also contributed to the knowledge, skills and industry understanding achieved through the LETFF programs. The GCCSI is an important contributor to research and has an extensive repository of program reports and datasets. It is noted that the Commonwealth Government was instrumental in establishing the GCCSI.

3.2.2 Examples of the types of innovations and knowledge generated

While a rigorous and accurate stocktake of the new research and knowledge generated is beyond the scope of this report, Table 3.1 lists several key innovations developed across the LETFF programs identified by stakeholders.

Table 3.1: Examples of key innovations attributable to LETFF programs/projects

Title (LETFF project)	Description
s22	
Seismic monitoring fibre optic cable technology (CCS Flagships program – Otway Geological Storage and Demonstration Project)	The project involved the development of seismic monitoring fibre optic technology to enhance the performance of seismic monitoring of drills. The technology has effectively replaced traditional geophone technology and significantly reduced the cost of undertaking seismic analysis. *"…with the funding that we have received from the LETFF and a combination of work with experts from Curtin* [University] *and also internationally, we are now at the point where the performance of these fibres is substantially better than these geophones. Now, that all sounds very technical, but what it means is we now have the ability to not have to put major infrastructure down these wells, we can do it through very cheap wells."* – Research stakeholder.
s22	

As reported above, the LETFF programs have generated a significant body of research. An analysis of 496 publically available publications associated with LETFF programs and projects, as well as the results of a citation analysis, are provided in Table 3.2 (below). Although generating published material was not an intended outcome of the LETFF programs, they provide an indication of the knowledge generated and of the understanding that has been disseminated.

s22

The citation analysis indicates the number of times that published materials have been cited in other domestic and international publications, providing an indication as to the extent that learnings and knowledge gained through the LETFF programs have been drawn upon and utilised in other research. Overall, the results indicate that the published material generated through the LETFF programs have been widely disseminated, and gone on to influence and inform a wider body of research and knowledge. This further supports stakeholders' observations of Australia as having world-leading research expertise and of the contribution of Australian expertise and knowledge internationally.

Table 3.2: Summary (broad) of LETFF program and project publications

LETFF program/ project	Publications No.	Publications %	Scholarly articles (as a share of publications) %	No. of citations	Ave. citations per publication
CCS Flagships	65	13%	2%	170	2.6
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LETDF	23	5%	39%	1,105	48.0
s22					

Source: Deloitte Access Economics

Notes: These estimates only include publically available publications; Scholarly articles are considered to be publications that appear in peer-reviewed academic or scientific journals.

Despite the plethora of publically available published materials, many materials and information remain undisclosed. There are many more publications that are held internally by government departments and scientific agencies, industry associations, or are held by 'pay walled' repositories (e.g. the CO2CRC). There is a perception among stakeholders that this acts as a constraint on the transfer of knowledge and the wider dissemination of learnings from one project to another, and is a barrier to the commercialisation of low-emissions technologies and to the establishment of a CCS industry in Australia. s22

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Another stakeholder acknowledged that knowledge of the published information available is dependent on informal personal and community networks. That is, information sharing is about 'who you know':

> *Do we have some nice summary, not that I am aware of … it is not on a central connected basis… The answer is an informal kind of network of people know each other, which is not ideal for information sharing."* – Commonwealth Government stakeholder.

When done right, however, effective information sharing with the wider public is credited with supporting community engagement and enabling the future deployment of LETFF. As one stakeholder remarked:

> *"… the CO2CRC has done a marvellous job in addressing public concerns and public education with their Otway site. It is regarded as one of the world's best practice in that region."* – Research stakeholder.

3.2.3 Summary of the intangible forms of knowledge generated

Stakeholders also identified the importance of the value of less tangible outcomes that were generated as a result of the LETFF programs.

Stakeholders widely acknowledged that the LETFF programs have encouraged collaborations between governments, industry, and the academic and scientific communities within Australia. Stakeholders from each of these communities identified the collaborative nature of the LETFF programs as having an immense benefit for creating networks amongst groups that were unlikely to have otherwise engaged with one another.

For government, the deepening of relationships with industry and the academic and scientific research communities is credited with contributing to improved decision-making, in terms of informing the formulation of regulatory and legislative frameworks. The Gorgon Carbon Dioxide Injection project is an example of where the LETDF facilitated information sharing between the Commonwealth Government and industry partner Chevron, and generated an improved and informed policy outcome. One industry stakeholder noted the role of Chevron in advising and informing the development of the Offshore Petroleum and Greenhouse Gas Storage Act 2006 and the broader regulation of CCS:

> *"a lot of the federal generic legislation in this space comes from lessons learned from Gorgon, and that model has been picked up by a couple of other States."* – Industry stakeholder.

In turn, development of the *Offshore Petroleum and Greenhouse Gas Storage Act 2006* is credited with enabling industry to consider offshore CCS opportunities and promote the role of other LETFF projects, such as CarbonNet. As noted by one stakeholder:

> *"… it's quite ground-breaking… the regulatory framework that the Commonwealth has put in, because obviously that's the lever that* [government] *have responsibility for, so the Offshore Petroleum and Greenhouse Gas Storage Act has really I think incentivised and given industry a mechanism to at least put offshore CCS in their repertoire and that's obviously being exercised now through CarbonNet, they wouldn't have done that without that act."* – Commonwealth Government stakeholder.

The LETFF programs are also credited with establishing valuable international collaborations between Australia and several countries developing low-emissions technologies – such as, the U.S., the U.K., the European Union, Japan, and China. In particular, stakeholders identified the value of the relationships formed through the Australia-China Joint Coordination Group funded through the CCS Flagships program. These relationships enabled Australia to access technology and expertise that would have been extremely costly to develop domestically. In return, Australia provided its expertise of regulatory frameworks, as well as project management methods (e.g. delivering projects safety, on time, and on budget).

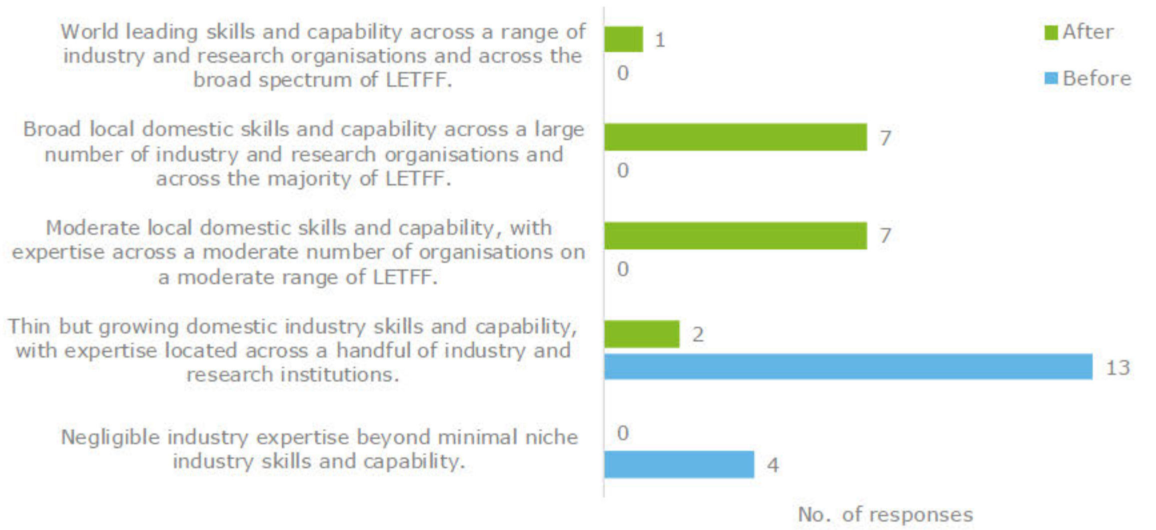
As noted by one stakeholder:

> *"the skills transfer was really quite significant, not just for the Australian government and other stakeholders in regard to accessing Chinese know-how, and how they do it, but the Chinese certainly learned from us too."* – Industry stakeholder.

3.3 Development of greater domestic skills and capabilities

In general, stakeholders interviewed perceived that the LETFF programs had contributed to a considerable increase in skills and capabilities. Australia's overall state of skills and capabilities progressed from being perceived as **'thin but growing'** prior to the commencement of the LETFF programs, to moderate with expertise across a range of industries and research organisations. This is supported by the findings of the online questionnaire (see Chart 3.2).

Chart 3.2: Questionnaire responses on the level of domestic skills and capabilities with respect to low-emissions technologies before and after the commencement of the LETFF programs



Source: Deloitte questionnaire, n = 17

As prefaced earlier, the LETFF programs are considered to have contributed to improving and expanding the capacity of academic and scientific research skills at the key research institutions – such including as, CSIRO, and Geoscience Australia, Melbourne, Monash and Newcastle universities, as well as and CO2CRC, the Global CCS Institute, s22 Australian Petroleum CRC, ACARP and COAL21. Overall, stakeholders agreed that the skills and capabilities developed across academia were far more advanced than industry. As remarked by stakeholders:

> *"… a lot of the money has gone to the research group, so they are far more skilled than the engineering is because they have had the funding to do the research … it's going from being scientists wanting to do the research to now scientists having done the research."* – Industry stakeholder.

> *"… I would say that the scientists are ahead of the engineers because the scientists have just been doing this stuff, but they can't do what engineers do and the engineers need…the time is not for R&D, the time is for doing and the scientists will then have access to real data rather than lab data."* – Industry stakeholder.

However, stakeholders recognised that Australia's technical and engineering capabilities have also developed and improved through the LETFF programs, with Australia now possessing the technical and practical engineering skills necessary for deployment and implementation. There was a common view that commercial deployment is required to enable any further advancement of industry skills and capabilities. As described by one stakeholder:

"*… we had the engineering infrastructure, but with inexperience in this technology. … at least now the engineering capability is ready to take that next step to implement, but until we have implemented, we haven't really learned all the lessons.*" – Industry stakeholder.

Some stakeholders reported that Australia has developed world-leading skills and expertise through the LETFF programs, and those skills are now sought by the other countries:

"*We actually got a group who we thought were the world's best reservoir engineers come over from University of Texas and … they felt the reservoir engineering capabilities of CO2CRC and our research members, such as CSIRO and Curtin* [University] *are the best in the world*" – Academic/research stakeholder.

"*… we basically trained up all the CCS specialists in Australia and now they have gone all around the world.*" – Research stakeholder.

Within industry, the LETFF programs also contributed to an 'up-skilling' and expansion in the capacity of technical and practical engineering type skills, particularly in the industry sectors that were most engaged in LETFF – that is, the coal mining, and oil and gas sectors. In addition, the LETFF programs prompted a shift in the composition of the types of specialist skills demanded. As industry began to investigate the feasibility of integrating LETFF within existing processes, stakeholders identified increased demand for a range of engineering disciplines across the oil and gas, coal and energy generating sectors. As one stakeholder noted:

"*We need engineering, so we need design…electrical, we need mechanical, we need ventilation specialists, we need mining specialists… risk specialists…*" – Industry stakeholder.

Within the energy generating sector, there was also an increased demand for specific engineering skill sets that were previously not associated with that industry sector, particularly chemical engineering capabilities.

The composition of skills required also shifted as knowledge and understanding about the importance of geological subsurface storage became a key priority. This resulted in a shift toward and expansion of geotechnical engineering capabilities across industries.

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An exception to this is the dissemination and transfer of technical skills from the academic and scientific research communities to government. A range of stakeholders noted that the Commonwealth Government was able to readily access and draw upon specialist technical and scientific skills, particularly from CSIRO and Geoscience Australia. This supported better informed decision-making.

However, several stakeholders noted the risk of potentially losing the specialist expertise built up over time to other countries – and with it one of key Australia's competitive advantages internationally – in the absence of the eventual deployment of LETFF.

3.4 Industry understanding of low emissions technologies

In general, stakeholders perceived that there was an increase in industry understanding following the commencement of the LETFF programs, albeit from a low base. Overall, stakeholders reported that LETFF programs enhanced industry's understanding with respect to:

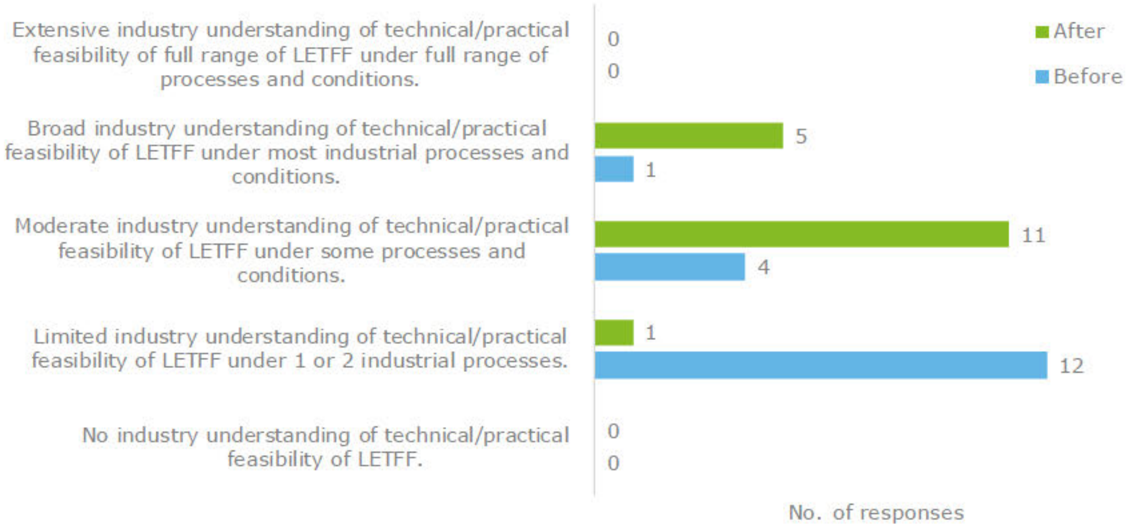
- the appropriateness and effectiveness of particular technologies at an industrial-scale
- the importance of geological subsurface and storage conditions to successful deployment
- greater certainty about the costs, timeframes, and risks involved in commercialisation.

As described by one industry stakeholder:

> *"When you look at all the work we have done to support various demonstrations... I can't help thinking that we are better placed than many of the other countries or most of the other countries when it comes to knowledge to deploy."* – Academic/research stakeholder.

Using the questionnaire responses of stakeholders, Chart 3.3 illustrates that industry understanding is perceived to have gone from being limited to now being at a moderate to broad level of understanding.

Chart 3.3: Questionnaire responses on industry understanding of technical and feasibility of low-emissions technologies before and after the commencement of the LETFF programs



Source: Deloitte questionnaire, n = 17

There is a consensus among stakeholders that the LETFF programs have contributed to industry now having a detailed 'end-to-end' understanding of the engineering and design of LETFF, in particular CCS technologies. Large projects such as CarbonNet and SouthWest Hub, for example, were identified as having provided industry with valuable practical and technical insights about the pathway to large-scale commercialisation, in terms of cost-discovery and the engineering design process involved. As stakeholders noted:

> *"... projects like the CarbonNet project, like the Southwest Hub project really did allow us to get a better understanding of 'yes there is a theoretical capability to put CO_2 in these places, but here are the real commercial understandings and then capabilities that we need to improve on to do that effectively"* – Academic/research stakeholder.

> *"The [projects] that have probably added most to the knowledge set are the ones where, for example, CarbonNet is really testing the whole end-to-end from the technical, regulatory through to the commercialisation."* – Commonwealth Government stakeholder.

More important to industry than any single LETFF project, however, is the combined and cumulative 'end-to-end' understanding that has been gained from the portfolio of LETFF projects –

'successful' and 'unsuccessful' projects. That is, the value of the iterative nature of the journey that industry and government have been on, and the importance of the learnings from each successive step at informing the direction of the next. As two stakeholders remarked:

> *"...as a complete package of knowledge, as they have gone from step to step to step, we know what we need to do now. So, I will call that a great success ... if you are only involved at each of the little steps and that's all your involvement is, you can see each one as a failure because it didn't reach the grand scale, but in combination they have honed in on and now we know exactly what we need to do. ... We have the luxury of staying with this whole landscape for the last 12 years and taking this whole picture to learn at each of the different steps."* – Industry stakeholder.

> *"... it's quite easy to look at the individual components and say we haven't actually achieved much, but for those that are able to look across the broad suite of projects and programs around capture, storage, transport, understanding where you might drill, understanding what you might retrofit, ... there is a view that we have a very compelling understanding now across the implementation of CCS if you put it altogether, which we didn't have before..."* – Government stakeholder.

Even those LETFF projects widely perceived as failures (such as ZeroGen) or those perceived as being challenged and delayed (such as Gorgon), have provided industry with crucial learnings. ZeroGen, for example, despite its perceived failure, is credited with providing industry crucial learnings about the commercial viability of Integrated Gasification Combined Cycle (IGCC) technology (see Box 3.1).

Box 3.1: Learnings from ZeroGen

ZeroGen project: a successful failure
Prior to the commencement of ZeroGen IGCC technology was considered to be the highest efficiency for low-emission coal energy generation:

> *"[IGCC Technology] was at that time seen as being the big technology, that is kind of like the biggest break, and the reasons for that was its high efficiency, it was sort of like the big bang theory. It's the highest efficiency, the biggest one, it's going to make the biggest difference at a cost. So on a CO_2 stored dollar basis, it was going to be the way to go."* – Industry stakeholder

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While industry had a 'desktop-understanding' of Australia's geology and of the potential for subsurface storage sites, very little consideration had been given to the detailed understanding of the potential capacity and suitability of these basins or reservoirs for the purpose of storing CO_2. Understanding the geological subsurface for the safe storage of CO_2 is now considered by industry as one of the key components, along with low-emission and capture technology, to the successful deployment of LETFF on a commercial scale. However, significant gaps in industry understanding of site specific geological conditions and requirements exist. Geological considerations as a critical area of future research is explored further in Section 5.3.

Industry understanding with respect to methane abatement technologies within coal mine sites has not progressed as significantly as that of CCS. Overall, significantly more work is required across the research, design, technical testing and demonstration of methane abatement technology to allow for the technology to progress.

3.5 CCS Flagships Research Development and Development (RD&D) fund

The CCS RD&D fund aims to reduce technical and commercial barriers to the deployment of large-scale carbon capture and storage projects by contributing new knowledge with respect to:

- Australia's understanding of its geological capacity to permanently store carbon dioxide
- enhanced understanding of how CO_2 plumes behave in Australian conditions
- improved knowledge of Australia's CO_2 supply chain requirements
- harnessing international knowledge and expertise and building international relationships that progress global understanding of CCS
- lowering the cost of technology adoption and deployment in Australia.

The CCS RD&D fund has yet to be completed, and is beyond the scope of this evaluation. However, a summary of the intended knowledge to be generated across the CCS RD&D fund is summarised below.

Table 3.3: Summary of intended knowledge to be generated from CCS RD&D fund

Project	Project description	Intended knowledge to be generated
Northern Australia CO_2 Store	This project builds on work carried out by Geoscience Australia's regional assessment of the CO_2 storage potential in the Petrel Sub-Basin (PSB) in NT. The project objective is to de-risk the area of interest within the PSB.	• Detailed subsurface knowledge of the PSB and local geological properties. • Understanding of the geomechanical, geochemical and geophysical properties of the PSB, and behaviour of CO_2 in the PSB. • Detailed assessment of equipment and facilities required to transport CO_2 from Darwin to the PSB storage. • Determination of well numbers to accommodate CO_2 production.

Project	Project description	Intended knowledge to be generated
CTSCo Integrated Surat Basin CCS project	This project delivers aspects of the CCS demonstration project that will enable a Financial Investment Decision for construction and deployment during 2018/2019, including technical, social and permitting aspects.	• Greater understanding of construction and deployment requirements of CO_2 test injection facilities. • Greater understanding of the regulatory pathway for onshore storage of CO_2 in Australia. • Greater understanding of the financial viability of onshore storage of CO_2. • Greater understanding of community engagement with respect to CCS.
Australian Subsurface Carbon Sequestration Simulator	This project works towards improved understanding of how CO_2 behaves during geo-sequestration in the Australian subsurface and how this behaviour can be monitored.	• Improved simulation, forecast and monitoring of CO_2 plume behaviour. • Enhanced geophysical imaging of CO_2 plumes.
s22		
Improving safety and efficiency of CO_2 pipelines	Development of fracture and dispersion models to enhance design and reduce risk associated with CO_2 pipeline construction and development.	• Validated fracture arrest model/software and design requirements. • Validated dispersion model • Updates of Standards and Recommended Practices covering CO_2 pipelines • Development of cost benchmarks for CO_2 pipeline.
Surat Deep Aquifer Appraisal project	Assessment of real optionality for industrial scale CCS deployment linked to south-east Queensland stationary emissions generators.	• Provision of significant technical and cost information into the public (pre-competitive) domain to assist with ultimate de-risking and planning of projects. • Greater understanding of techno-economic and other deployment critical issues. • Enhanced methodologies for community engagement about energy choices (and within that how best to engage on CCS). • Discovery of the degree and criticality (costs, timing risks) to which CCS can be a real mitigation option for GHG abatement in Eastern Australia.

4 Factors contributing to achievement outcomes

Key findings:

- At commencement, the LETFF programs were underpinned by clear policy direction and settings, support across Commonwealth and State governments, and a significant funding commitment across a suite of programs and projects – factors that were critical to the achievement of outcomes.
- Other contributing factors to the achievement of outcomes included:
  - establishment of partnerships between government, industry and academic stakeholders
  - the direct financial involvement of the coal industry in maintaining an industry-focused research agenda
  - establishment of a portfolio of LETFF projects to maximise learnings and the probability of success.
- Changing, uncertain and inconsistent policy settings are considered the **primary factors** hindering achievements and progress across the LETFF programs. This resulted in significant **loss of confidence across industry and a loss of momentum in advancing LETFF**.

  The unexpected complexity of LETFF, inflexibility of funding agreements, regulatory uncertainty and insufficient readiness on the part of the Commonwealth and State governments have also hindered achievements and progress across the LETFF programs.

  The absence of a clear commercial imperative on the part of industry to invest in carbon abatement remains the single largest barrier to the commercial development and deployment of LETFF.
- Knowledge gained throughout the LETFF programs could have been more effectively disseminated to the broader public. Barriers to knowledge sharing and access to information have contributed to a low level of public understanding and acceptance of LETFF, and in particular CCS, and represent a barrier to the deployment of LETFF.

4.1 Factors that contributed to achievement of focus outcomes

There was consensus among stakeholders that the manner in which the LETFF programs were established was a major factor contributing to the achievement of focus outcomes (i.e. knowledge, skills and capability, and improved industry understanding). Specifically, stakeholders noted that, at commencement, the LETFF programs were underpinned by clear policy direction and settings, support across the Commonwealth Government and participating State governments, and a significant funding commitment across a suite of programs and projects.[2] Stakeholders agreed that these factors provided a clear signal of government policy intent and focus to industry, and gave industry the confidence to participate and invest in the programs. As noted by stakeholders:

> *"The greatest assistance was right at the beginning when there was a common urgency, a common understanding that we all needed to do something. And by that, I mean the Federal Government, the State Government, and the industry."* – Industry stakeholder.

> "[A key factor was] *the early decision to allocate funds to a suite of programs and have sort of a champion in cabinet to push these sort of issues through and make it a priority. I think it then just follows that your domestic stakeholders know that they have got backing*

[2] The original Commonwealth Government funding commitment across the four LETFF programs was approximately $2.8 billion.

through the government in real terms as in funding, but also from a national priority perspective" – Commonwealth Government stakeholder.

Many stakeholders also identified the partnerships established between government, industry and academic proponents as being critical to the achievement of focus outcomes. This led to meaningful engagement between academic, technical experts, policy makers and industry proponents across the LETFF programs. In turn, these partnerships helped maintain strong technical and research capabilities to support the LETFF programs:

"The access that we have had to government and industry to assist with our research program has been probably the most significant factor for us." – Academic/research stakeholder.

In particular, **the direct financial involvement of the coal industry**[3] is considered to have been critical in maintaining an industry-focused research agenda. Stakeholders considered the industry-led research agenda to be contributing factor to the achievement of focus outcomes. As noted by two stakeholders:

"The manner in which the program is set up, means we have to have a combination of government and industry and researchers obviously. It allows us to not just do research for the sake of research, it allows us to understand what the industries' needs are, what the government's needs are, and do the appropriate technology development to meet those users' needs." – Academic/research stakeholder.

"My job is to support demonstration, and this is very, very clear. I am greatly assisted by that because when a researcher comes to me with a good idea…I'm always able to take their idea and hold it up against this lens and say does this help deployment? If it doesn't help deployment I tell them "I'm sorry you have got a fantastic idea, but it doesn't suit my purpose." So, it's not that your idea is bad, it's just that I have a certain purpose and your idea doesn't fit here." – Academic/research stakeholder.

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4.2 Factors that hindered achievement of focus outcomes

There was consensus among stakeholders that changing, uncertain and inconsistent policy settings were the **primary factors** hindering achievements and progress across the LETFF programs. Specific examples of changing and inconsistent policy settings identified included:

- removal of the carbon price regime following the commencement of the LETFF programs
- lack of a clear national strategy and statement with respect to LETFF, and in particular CCS
- changing and inconsistent policy settings no longer aligning with program objectives
- government policy not adopting a technology 'agnostic' approach with respect to emissions abatement, with stakeholders noting that CCS projects were ineligible for funding from the Clean Energy Finance Corporation

[3] Support was focused through the former Australian Coal Association for Low Emissions Technologies Research and Development (ACALET R&D), now known as COAL21.

- loss of policy direction over time resulting in general policy confusion among industry participants.

These issues **resulted in significant uncertainty and loss of confidence across industry, and a loss of momentum with respect to the advancement of LETFF.** As stakeholders noted:

> *"A lack of clear government policy (both State and Federal) on CCS hinders progression of the demonstration projects required for future large scale CCS to be assessed and ultimately progress."* - Industry stakeholder.

> *"We don't have that clear stable policy framework. We don't have that clear confidence in that framework to allow significant* [Industry] *investment."* – Academic/research stakeholder.

The changing policy settings also contributed to eroding industry engagement within the LETFF programs. Proponents no longer considered the investments to be a priority in the absence of clear policy direction. As one stakeholder noted:

> *"While the project staff were still very committed to the project, they did from time to time run into a bit of pushback from the operations staff at the mine site, because they are no longer quite as keen to have this project running at their site because there wasn't that financial impetus* [any longer]*."* – Commonwealth Government stakeholder.

There is a perception among many stakeholders that an insufficient understanding of the complexity of low emissions technologies at the commencement of the LETFF programs also hindered the achievement of focus outcomes. In particular, there is a perception that the Commonwealth Government lacked the necessary internal scientific and technical capabilities to accurately evaluate and assess the viability of projects proposed prior to the commencement of the LETFF programs. Insufficient understanding of the technical, scientific, engineering, regulatory and environmental challenges underpinning large-scale LETFF across government, industry and academia resulted in:

- unrealistic program and project timelines
- insufficient funding being committed to support development and deployment
- insufficient understanding of project financial and technical risks
- an implicit assumption relating to the commercial feasibility of geological resources.

Overall, this resulted in unrealistic program timeframes, costs and expectations. As noted by stakeholders:

> *"If you look at the CCS Flagships program, in some ways, that was too much too soon. The expectation that you were going to be commercial and up and running in 2013* [for example] *was unrealistic."*– Industry stakeholder.

> *"The challenges with some of this have proven to be … more difficult than first thought. So, Gorgon, for example, has ended up being a much, much larger project than was originally conceived. So, the original intent* [of the LETFF programs] *got the scale completely wrong."* – Commonwealth Government stakeholder.

Stakeholders also identified regulatory uncertainty and insufficient readiness on the part of the Commonwealth and State governments as a factor hindering the achievement of focus outcomes. Governments at both levels were ill-prepared in terms of regulation and legislation for the commercial implementation of technologies – particularly relating to the storage and monitoring of CO_2. Projects involving pilot drilling and site testing (such as CarbonNet in Victoria) required State government regulatory approval (and in the case of CarbonNet also Commonwealth Government approval due to offshore activities) before proceeding. These regulatory approval processes significantly impeded project timelines and presented considerable challenges to project proponents. As summarised by one stakeholder:

> *"It's more in the regulatory space that's been required than people realised. For example, on the CarbonNet project, there were all sorts of Victorian government approvals, but*

> *there are also Australian Government approvals because it is eventually going to be in the offshore domain… There are multiple approval processes and I think it's fair to say that's been very challenging."* – Commonwealth Government stakeholder.

A range of stakeholders noted that Commonwealth Government funding agreements, where project funds are tied to specific milestone dates and activities, don't adequately reflect the nature of industrial-scale projects. The inflexible nature of funding agreements were considered to have impeded and slowed project progress and achievement of focus outcomes.

A minority of stakeholders considered that the decision to allocate funding across a portfolio of LETFF programs and projects hindered program achievements. They perceived that greater progress towards the development and deployment of LETFF may have been achieved by focussing on a single or two LETFF projects in total. As one of these stakeholders noted:

> "[The Commonwealth Government] *spread the funding too thinly across several projects. There was only ever sufficient funding allocated for one CCS project. Running a competition* [a grant application process] *encouraging several projects to commence was ineffective and unrealistic"* – Academic/research stakeholder.

4.3 Impact of program design and implementation on achievement of focus outcomes

A majority of respondents to the online questionnaire considered that the level of funding allocated to the LETFF programs (82%) and project selection processes (59%) positively contributed to the achievement of outcomes.

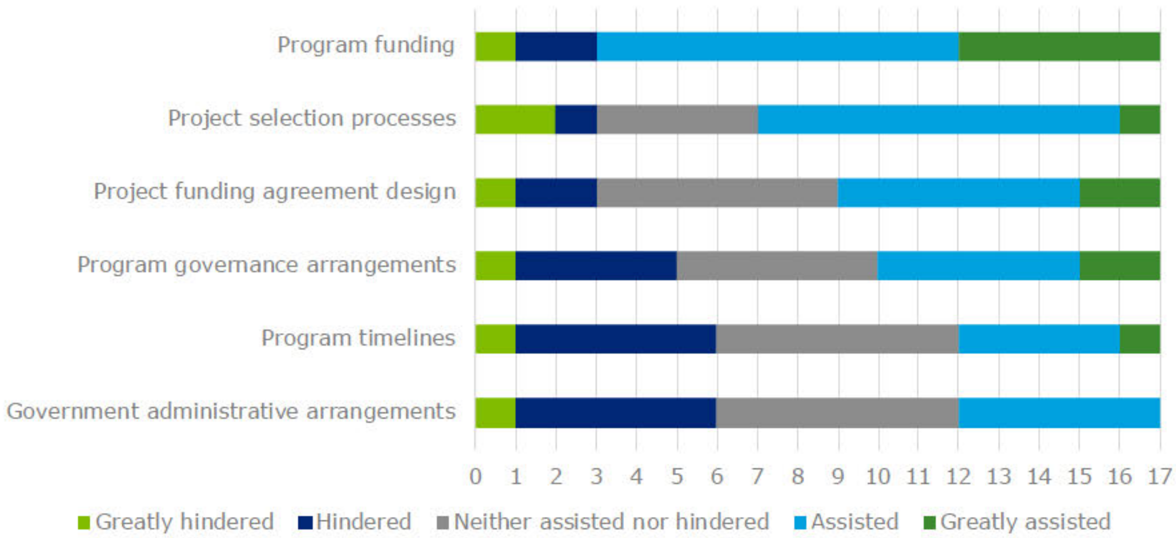
However, responses were more mixed with respect to the impact of program timelines, funding agreement design, administrative arrangements and governance arrangements on the achievement of outcomes (see Chart 4.1).

For example, while almost half (47%) of questionnaire respondents considered the design of funding agreements to have greatly assisted or assisted the achievement of focus outcomes, this view was not shared by all stakeholders. A range of stakeholders interviewed considered funding agreements to be inflexible, and a requirement to tie funding to specific milestones to be incompatible with large-scale industrial development projects. As noted by stakeholders:

> *The way all of these projects are setup, they can only take one step* [at a time]. *And therefore, the project has to wait until you have made a decision. There hasn't been that ability to take the next step after you've learnt something, change the plan a little bit, modify it to suit what you've learnt, take the next step, and having funding continue from there".* – Industry stakeholder.

> *"Here is $100 million go and do your first bit, and here is a $100 million go and do your second bit, and here is $50 million go and do your third bit. That is not the way to run a big project, you know, when BHP decides it is going to develop a mine, that is a $15 billion decision and they don't hand it out, you know, $100 million at a time. So I think the government has to think about a way on how it wants to support large-scale projects like this."* – Academic/research stakeholder.

Chart 4.1: Questionnaire respondents' perception on which aspects of the design of the LETFF programs contributed to the achievement of focus outcomes



Source: Deloitte questionnaire, n = 17

In addition to the above, many stakeholders noted during interviews that the 'removal' or clawback of program funding by the Department from projects deemed infeasible/unsuccessful adversely impacted the achievement of focus outcomes. Many stakeholders considered that this funding should have been reallocated to remaining projects or new funding rounds held to identify 'new' projects, rather than have such funding returned to consolidated revenue. As noted by stakeholders:

> *"The CCS Flagship Demonstration Program was crippled by the withdrawal of Commonwealth funds originally allocated to it."* – Industry stakeholder.

4.4 Barriers to the commercial development and deployment of LETFF

There was consensus among stakeholders interviewed that the absence of a clear commercial imperative on the part of industry to invest in carbon abatement remains the single largest barrier to the commercial development and deployment of LETFF. Key issues identified by stakeholders contributing to the absence of a commercial imperative included:

- lack of a clear, consistent national energy policy that addresses the role of LETFF and provides industry with sufficient long-term confidence to invest
- absence of Commonwealth and State government policy instruments that directly incentivise investment in emissions abatement
- significant cost of deploying commercial-scale CCS projects, noting that LETFF (and CCS in particular) has a particularly high cost relative to alternative emission abatement technologies
- investment risk is perceived to be high given current policy settings and uncertainty
- issue of third party risk remains unaddressed under current policy arrangements, specifically the issue of indemnifying storage and reservoir operators over the longer term.

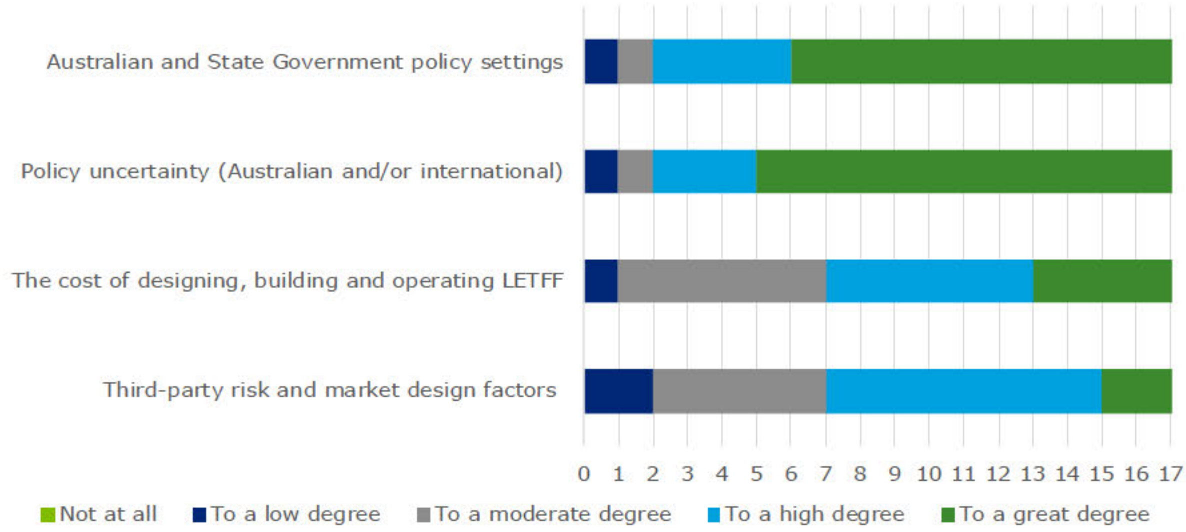
As noted by stakeholders:

> *"The issue with all of this is cost. The investments that are required to do these things* [LETFF] *at scale invariably seem to be much larger and the costs are much larger than originally envisaged."* – Commonwealth Government Stakeholder.

> *"You cannot see* [under current arrangements] *how any of these projects are going to be funded."* – Industry stakeholder.

Responses to the online questionnaire support the above findings. Questionnaire respondents identified existing Australian and State government policy settings (88% of respondents consider policy setting remain a barrier to a high or great degree), domestic and international policy uncertainty (88%), cost of LETFF (59%) and third-party risk (59%) as presenting the greatest barrier to the commercial deployment of LETFF (see Chart 4.2).

Chart 4.2: Questionnaire respondents' perception of the extent to which external factors remain a barrier to the commercial deployment of LETFF



Source: Deloitte questionnaire, n = 17

However, some stakeholders considered that some longer-term commercial drivers were already in place, and highlighted the decision by Chevron and its joint venture partners to invest in the Gorgon Carbon Dioxide Injection project. As one stakeholder noted:

> *"If you want to exploit Australia's offshore gas resources in say 25 years' time, you will have to deal with those emissions I think. I think that's going to be the world we are. So, I think that if you look at it through that lens, there is going to be a commercial driver."* – Commonwealth Government stakeholder.

Many stakeholders also identified the lack of a technologically 'agnostic' approach to emissions abatement as a barrier to the commercial deployment of LETFF. There was a perception among many stakeholders that LETFF was treated inconsistently to alternative technologies. For example, CCS projects are not eligible for funding under the Clean Energy Finance Corporation. As one stakeholder summarised:

> *"It's not about renewables versus CCS or renewables versus coal. It's about having a portfolio of solutions to reach your emissions targets." – Industry stakeholder.*

Stakeholders also identified that barriers to knowledge sharing and access to information may have adversely affected the broader public discourse and perceptions around LETTF. This has contributed to a low level of public understanding and acceptance of LETFF, and in particular CCS, and is considered a barrier to the deployment of LETFF by some stakeholders. All stakeholder groups recognised that the role of LETFF in abating emissions was not well understood by the general public, and that there was a broad public perception that the primary role of LETFF was to extend the 'life' of fossil fuels. There is a perception that this has contributed to hindering the deployment and implementation of LETFF. As noted by stakeholders:

> *"... most of the knowledge is sort of really been distributed amongst people closest to these programs and various industry stakeholders, but in terms of the broader community they have been consulted where they are directly affected, but I don't think the average*

> *Australian knows where the Carbon Capture and Storage is up to in Australia."* – Commonwealth Government stakeholder.

> *"… the CCS community and industrial sectors of Australia, we are very good at talking to ourselves about how great CCS is and how we are going to use that as a solution. We are hopeless at talking outside that group, outside of* [our] *comfort zone."* – Academic/research stakeholder

> *"I think both government and industry have done a poor job of enunciating the benefits of CCS. I think we are probably behind the eight-ball by now."* – Industry stakeholder.

Stakeholders also recognised that falling domestic demand for fossil fuels was a potential barrier to the deployment of large scale LETFF. While a broad range of emission-intensive industrial processes (such as fertiliser production, agriculture and smelting) have potential to support demand for LETFF deployment, stakeholders agreed that the key sectors (beyond the oil and gas sector) likely to underpin the initial deployment of LETFF were the coal and energy generation sectors. As one stakeholder noted:

> *"I think anything that is going to impact on coal production levels and demand for coal is going to then impact on the operating costs and financial considerations, and so it is going to have even more of a detrimental effect of looking at the capital costs of significant abatement investments."* – Commonwealth Government stakeholder.

5 Success, future research and role of government

Key findings:

- Overall, **stakeholders overwhelmingly consider the LETFF programs to be successful.** The LETFF programs have made significant contributions to increasing knowledge, skills and capability, and improving industry understanding of LETFF in Australia. These achievements **would not have been made in the absence of Commonwealth Government support.**
- Stakeholders consider that the Commonwealth Government's investment in LETFF programs **represents good value for money**, and **achievements are commensurate with the investment.**
- LETFF programs have directly contributed **to reducing the technical and commercial barriers** to the development and deployment of commercial-scale LETFF projects.
- However, the achievements and knowledge gained could have been more effectively communicated or disseminated among industry and the general public.
- Australia risks losing the significant gains in knowledge, and skills and capabilities established through the LETFF programs if Australia does not proceed to the commercialisation and deployment of LETFF.
- The critical underlying research and technical questions to deploying large-scale LETFF (and CCS in particular) have been addressed, however some targeted research would supplement and benefit research done to date.
- Stakeholders consider **there remains a critical role for Government** in supporting the development and implementation of LETFF. While there was no clear consensus from stakeholders interviewed, a majority of respondents to the online questionnaire considered the Commonwealth Government should continue to provide large-scale grants to support LETFF research and development.

5.1 Success of LETFF programs

Overall, stakeholders across all groups consider that the LETFF programs have been successful, and have made a significant contribution to increasing knowledge, skills and capability, and to improving industry understanding about low emissions technologies.

As reported above in Section 3, stakeholders consider that as a result of the LETFF programs Australia now possesses the requisite scientific and engineering knowledge, skills and industry understanding to develop and deploy large, commercial-scale LETFF projects. Through the LETFF programs, the key research and technological barriers to the deployment of LETFF have largely been overcome. Stakeholders noted:

> *"When you put all the projects on the map of Australia, show the different types of geology that we've got around Australia, and the different projects that we've* [delivered] *around Australia, the government has participated in a really good portfolio of projects"* – Industry Stakeholder.

> *"Industry in Australia has gone from not having a clue of what we are doing to now being able to say where we're going to put a drill or drill a hole, where we're going to store CO_2, the technology we're going to use, and to take that next step* [of deployment]*. So, has it* [the LETFF programs] *been successful? In my mind, absolutely."* – Industry stakeholder.

A key element contributing to the success of the LETFF programs has been the critical learnings gained by industry and government across the suite of programs and industry. In particular,

projects deemed 'unsuccessful' have provided valuable insights in progressing Australia's knowledge and understanding of LETFF. For example, the 'unsuccessful' **South West Hub** project yielded the following learnings:

- significant improvements to conducting and analysing seismic data, monitoring and modelling CO_2 plumes
- understanding how basin configuration and structural elements affected containment capabilities of a rock formation.

These areas of research were driven by the fact that the Eneaba Formation did not have the impermeable seal that other potential CO_2 storage sites had (for example sites on the east coast of Australia).

The majority of stakeholders interviewed consider that the Commonwealth Government's investment in LETFF programs represents good value for money, and achievements across the focus outcomes are commensurate with the investment made. In particular, stakeholders noted that the research undertaken has directly contributed to overcoming research and technological gaps and barriers with respect to LETFF. Stakeholders noted:

> *"In the research dimension…I think the returns have been immensely large. So, I think you know, yes, we've done a damn good job of research." – Academic/research stakeholder.*

> *"I think that there has been a pretty good return on investment for most of the projects under the LETFF. I think that there has been a couple of projects that haven't succeeded, but that doesn't always mean that that money hasn't been well spent…you can learn from the failure as well."* – Commonwealth Government stakeholder.

This finding was supported by the results of the questionnaire of LETFF program stakeholders, in which 71% of all respondents agreed or strongly agreed that the LETFF programs have achieved outcomes commensurate with the investment made. The questionnaire found that 71% also agreed or strongly agreed that the LETFF programs have directly contributed to reducing the technical and commercial barriers to deploying large-scale LETFF projects.

However, some stakeholders were more cautious when reflecting on the success of the LETFF programs, noting that Australia still lacks a pipeline of large-scale LETFF projects. As one stakeholder noted:

> *"Yeah, so it's really quite hard to answer* [the question of success] *because I think again from a technical geoscientific perspective, I think that's clearly been a success in terms of that technical scientific knowledge. But for that [approximately $750 million] again we don't really have a pipeline of CCS projects or kind of big things that are going to make a difference to emissions for Australia."* – Commonwealth Government stakeholder.

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Stakeholders also perceive that the knowledge and learnings gained from across the LETFF programs have not been sufficiently communicated to the general public (as reported in Section 4.5 above, this was considered a barrier to commercial deployment by some stakeholders). Overall, stakeholders noted:

- there is a lack of public understanding of the potential role of LETFF in decarbonising the economy and national energy market

- there is a 'poor' public perception of LETFF that does not match the achievements that have been made across the LETFF programs
- LETFF, and CCS in particular, are seen as technologies designed to 'extend the life of fossil fuels'.

Lastly, stakeholders broadly agreed that Australia risks losing the significant gains in knowledge, and skills and capabilities it has established over the last 15 years through the LETFF programs if it does not proceed to the commercialisation and deployment of LETFF. Low emissions technologies such as CCS are increasingly being deployed in the U.S., China and Europe. If Australia does not proceed to deployment, it is likely that the specialised skills developed through the LETFF programs will be lost overseas to where LETFF is being deployed. As one stakeholder noted:

> *"… there are certainly other countries who have skilled up more effectively than Australia has in the last few years and we are at risk of being left behind to some extent. … the US has an extremely comprehensive national CCS approach, Norway, the [and] UK to some extent…. So, we are in danger of losing that capability I believe if we are not careful in what we are doing."* – Academic/research stakeholder.

5.2 Would have achievements been made in the absence of government support?

Overall, there was consensus across all stakeholders interviewed that the achievements made towards increasing knowledge, skills and capability, and on improving industry understanding about low emissions technologies **would not have been made in the absence of Commonwealth Government support**. When asked what progress would have been made without support from the Commonwealth Government, stakeholders noted:

> *"Short answer is zip, nothing. I don't think we would have done much at all. Truly, I don't think we would have done much at all."* – Academic/research stakeholder.

> *"It wouldn't have occurred if it wasn't for the government's investment"* – Industry stakeholder.

> *"We would still be stuck in the theoretical research phase."* – Commonwealth Government stakeholder.

> *"There is no likelihood that we would have achieved what we did without government involvement"* – Academic/research stakeholder.

However, stakeholders did note that the Chevron-led Gorgon Carbon Dioxide Injection project would have occurred in the absence of Commonwealth Government support. Chevron Australia had publicly committed to build the injection project prior to the commencement of the LETDF and the development of the injection project was later included as a development approval condition for the LNG project.

Responses to the online questionnaire supported the outcomes of the stakeholder interviews. The questionnaire showed that 65% of respondents consider that no progress or almost no progress would have been made towards the achievement of the focus outcomes in the absence of Commonwealth Government investment in the LETFF programs (Chart 5.1).

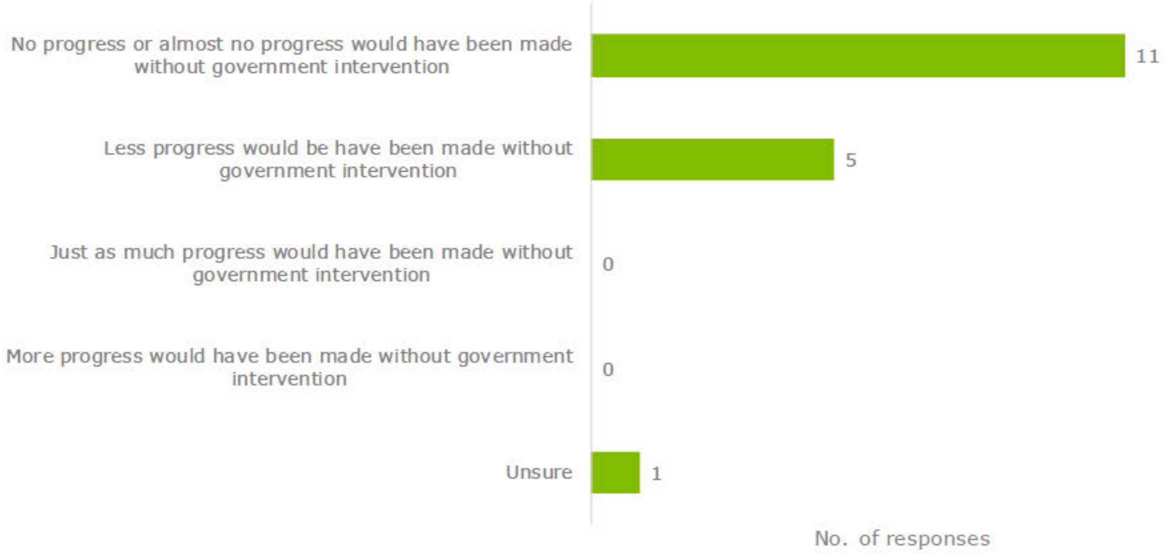
Stakeholders noted that in the absence of a commercial imperative to invest in LETFF (see Section 4.4), there was no incentive on the part of industry to invest in pre-commercial research and development of LETFF. A lack of commercial imperative means that there was no driver to undertake pre-commercial research into capture technologies, CO_2 transportation, storage technologies and CO_2 injection, Australia's geological resources, CO_2 subsurface behaviour, or the safety of LETFF.

By investing in LETFF, the Commonwealth Government was able to successfully leverage significant contributing funding from the coal industry and participating State governments. As one stakeholder noted:

> *"With the current absence of financial incentives for industry to pursue CCS technology, I greatly doubt the funding required to carry out the R&D completed to date would have*

existed. The LETFF programs provide the foundation funding (s22
s22 *) for this research to be proposed and progress."* Academic/research stakeholder.

Chart 5.1: Extent to which questionnaire respondents consider progress would have made in the absence of the LETFF programs



Source: Deloitte questionnaire, n = 17

5.3 Are there critical areas of research that remain unanswered

There is consensus among all stakeholder groups that the critical underlying research and technical questions to deploying large-scale LETFF (and CCS in particular) in Australia have largely been settled as a consequence of the activities delivered under the LETFF programs. Stakeholders agreed that the next critical phase to LETFF in Australia was deployment. As stakeholders noted:

> *"I think we are far, far beyond the research questions. And I think now it's about deployment, and it's about supporting deployment."* – Academic/research stakeholders.

> *"The research is sufficient to take us the next step and let the engineers take the next step so that the researchers can then work on the next problems...I don't think we need more research. I think we need deployment. I don't think there's any gaping holes in research." – Industry stakeholder.*

However, stakeholders did identify a range of future research that would supplement and benefit LETFF research done to date.

In particular, a range of stakeholders across all groups identified the need to undertake **site-specific research and testing to support the eventual deployment of LETFF**. While the LETFF programs have demonstrated proof of concept at the regional level, none of the detailed site-specific research and testing has been undertaken that would be required to support deployment of LETFF. The deployment of LETFF will require a new wave of site-specific research relating to drilling, sub-surface monitoring, seismic analysis and injection testing. Such research and analysis will be critical to project-specific planning, investment, and regulatory decisions. As stakeholders noted:

> *"There will be local specific* [research issues] *related to storage, so there will be groundwater impact concerns mostly, so that will be the Queensland story if they get any further [to deployment]... So, there will be site specific and to a large extent community specific [research requirements]."* – Academic/research stakeholder.

"We need to do more detailed analysis on key spots. Because we've got the broader understanding of CCS in Australia, but not the actual real details [of specific sites]." – Academic/research stakeholder.

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The focus of the LETFF programs had largely been in relation to the capture, transport and storage of emissions from coal mines, liquefied natural gas (LNG) plants and stationary power stations. Some stakeholders noted, however, a need to research **the application of learnings from the LETFF programs to other emission-intensive sectors** including steel, concrete, fertiliser, and agribusiness. As one stakeholder noted:

"the industrial applications of CCS that we need to be putting more work into…So, it is other types of CCS technologies that we probably haven't focused on." – Commonwealth Government stakeholder.

The 'capture' process is one of the most expensive and technically complex aspects of CCS, and can typically account for approximately two-thirds of the total CCS deployment cost.[4] Recognising this, some stakeholders also noted a need to investigate CO_2 capture processes for these emission-intensive industries to assist in making CO_2 capture more commercially feasible.

As reported above, public perception and acceptance of LETFF and CCS in particular is considered a barrier to the eventual commercial deployment of LETFF in Australia. A range of stakeholders identified the need for **further research in effectively engaging with communities at the local level.** Given the nature of CCS (which involves the injection of CO_2), understanding how best to engage local communities level was seen as critical to garnering support and achieving regulatory approval, and ultimately resetting the national conversation. While some research has been undertaken on an ad-hoc, individual project-level, there has been no coordinated, strategic approach across the LETFF programs. The importance of better engagement with local communities was summed up by a stakeholder thus:

"…the key is you don't engage them [local communities] *about CCS, you engage them about the whole gambit of future energy choices, and within the choices and the trade-offs you then bring CCS into that equation, so that they actually see a choice. It is not just, 'Yes CCS' or 'No CCS.'"* – Academic/research stakeholder.

A final area of research identified by a few stakeholders included **the nature of enhanced oil recovery** (EOR). Overall, stakeholders noted that the relative importance of EOR to supporting the commercial viability of CCS projects in Australia was not very well understood. The production of EOR requires significant quantities of CO_2, which is injected into the sub-surface as part of the EOR production process. Overseas, including in the US, EOR is typically most viable where production can integrate with CCS to take advantage of a ready supply of CO_2. While the presence of EOR may not be in all locations that are deemed appropriate for CO_2, there was a view among some stakeholders that further research and investigation was required, particularly given the absence of other commercial imperatives (as reported in Section 4.4 above). As one stakeholder noted:

"When you look internationally a lot of the CCS projects have been underpinned by a revenue stream of oil from enhanced oil recovery… there has been this sort of view that EOR or enhanced oil recovery in Australia is not a lot, there is not many prospects. But I am not sure that that is underpinned by really good technical and exploratory work. So if

[4] Estimate based on stakeholder interviews.

we are missing something it is: 'What are the prospects for enhanced oil recovery in Australia?'" – Academic/research stakeholder.

5.4 Role of Commonwealth Government

There was consensus among all stakeholder interviewed that **there remains a critical role for Government** in supporting the development and implementation of LETFF following the completion of the LETFF programs. Deloitte notes that all stakeholders interviewed as part of this evaluation were directly involved in the LETFF programs, and thus there is likely to be some reported bias in stakeholders' views on the need for continued government support.

However, there was **no clear consensus** among stakeholders interviewed on the most appropriate role for the Commonwealth Government in supporting the development and implementation of LETFF.

Many stakeholders reported that the primary role of the Commonwealth Government should be in setting a clear **national energy and climate policy agenda and framework.** Such a framework would provide industry with sufficient long-term confidence to invest in large-scale LETFF projects. As noted by some stakeholders:

> *"So, absolutely there is a role for government and it links back to that national leadership. I think that we need to have strong policy settings out there that can incentivise investors coming on board for a technology which has some market values in terms of risks."* – Commonwealth Government stakeholder.

> *"The government's role is to set a very clear path forward and then to work with industries and organisations that have a role to play in that path whether it be because they're impacted or because they're contributing to that path."* - Industry stakeholder.

Many stakeholders, in the absence of commercial imperatives on the part of private industry to invest, saw a role for the Commonwealth Government to provide **direct financial support** for the commercial-scale deployment of LETFF. Such stakeholders considered the Commonwealth Government had a critical role in directly financially supporting the first CCS project in Australia. As one stakeholder noted:

> *"I think the investment from the government is to bring opportunities to a point where a private investor can come in and support it. That can be straight-up by supporting the first opportunities for storage and utilisation hubs in Australia." – Industry stakeholder*

Other stakeholders noted the potential role for the Commonwealth Government in **providing ongoing financial support for research and development** where there was a clear, demonstrated need and where industry was unlikely to undertake the activity without support. Specific examples included research related to broader industrial application, safety, and community acceptance. As stakeholders noted:

> *"There is a place for grants. Grants have a benefit…they give [the Commonwealth Government] what we want. So, for example, if we think industrial CCS is somewhere that needs some research and development then we could certainly put a package together. So, there is room for grants in our repertoire."* – Commonwealth Government stakeholder.

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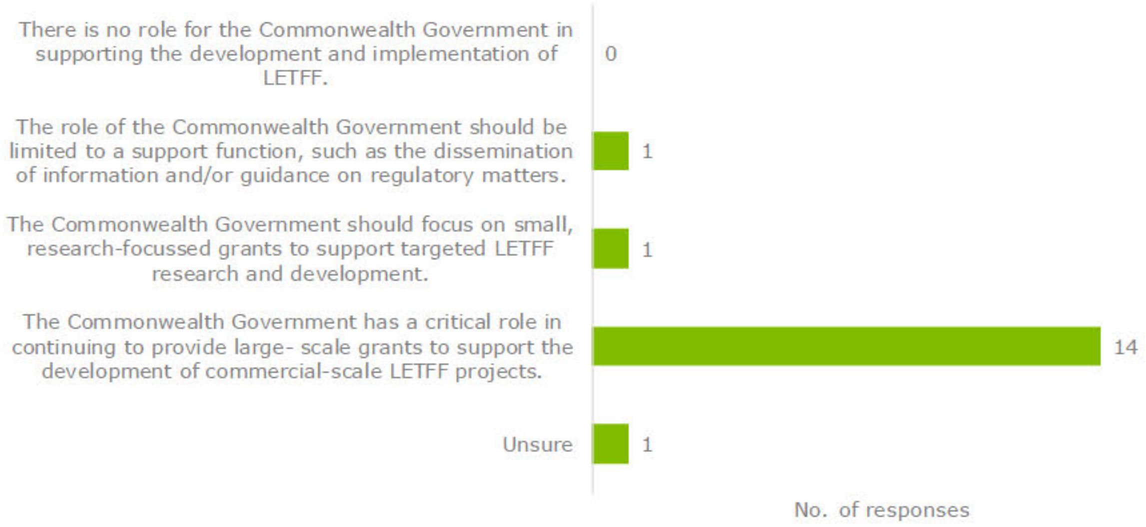
Responses to the online questionnaire were more consistent than stakeholder interviews in their views of what the primary role (if any) should be for the Commonwealth Government going forward with respect to LETFF. The questionnaire found 82% of respondents consider that the Commonwealth Government has a critical role in **continuing to provide large- scale grants** to support the development of commercial-scale LETFF projects (Chart 5.2).

Chart 5.2: Questionnaire responses re what primary role (if any) should the Commonwealth Government adopt in supporting the development and implementation of LETFF



Source: Deloitte questionnaire, n = 17

Some stakeholders interviewed also identified the need for the Commonwealth Government to consolidate the research and knowledge gained to date and ensure it is disseminated to the fullest extent possible.

Despite the majority of stakeholders reporting that the primary role of the Commonwealth Government should be to provide large-scale direct financial support for the deployment of commercial scale CCS projects, **Deloitte considers it is imperative that any future support for LETFF should be informed by a rigorous economic assessment**. Such an economic assessment would specifically involve assessing the role of LETFF in decarbonising the economy and NEM relative to alternative approaches, and give consideration to fossil fuel demand and full life-cycle costs of alternative technologies.

5.5 Unintended outcomes

Many stakeholders reported a perception that the LETFF research agenda is negatively affecting the commercial deployment of LETFF, and in particular CCS. Stakeholders reported that the drive to undertake additional research has resulted in a perception among regulators, industry detractors and the general public that LETFF is not adequately understood and that significant risk remains. As noted by a stakeholder:

> *"I think research has been a drawback for CCS.* [Researchers] *keep telling everybody, "we need to do more research" So, people who are detractors of CCS say, "look it's still an experimental technology." It's not."* – Academic/research stakeholder.

Some stakeholders also reported that the lack of commercial-scale deployment has resulted in a perceived lack of progress among the general public. This, in turn, has resulted in a perception that LETFF is not feasible, and has potentially hindered the sector's ability to achieve a social licence to operate.

6 Learnings for future program design

Key lessons to inform future program design and implementation include:

- setting realistic expectations with respect to program cost and time-horizons
- setting realistic expectations with respect to research and development outcomes
- ensuring alignment between policy settings and program objectives
- enhancing assessment of project feasibility at program commencement
- funding and program governance arrangements should reflect the nature of program activities
- greater industry engagement in the design of the program
- the need for ongoing monitoring of program funding
- embedding engagement processes to share knowledge gained within and across government
- improved understanding of the costs and benefits of LETFF in decarbonising the economy relative to alternative technologies, through a detailed Cost Benefit Analysis, as a first step in any future consideration of LETFF.

6.1 Learning for future program design

The LETFF programs have made a significant contribution to increasing knowledge, skills and capability, and on improving industry understanding with respect to LETFF.

However, there are a range of learnings to be gained from the design and implementation of the LETFF programs to inform future program design. These are discussed in greater detail below:

- **Setting realistic expectations with respect to program cost and time-horizons:** Future programs involving the research, development and deployment of large-scale and complex technologies must set realistic expectations around program costs and time-horizons.

  Program design should not underestimate the scale of research and development required to support the development of industrial-scale projects. This has implications for the level of funding made available, the setting of timelines, and internal program governance arrangement, including the establishment of internal expert panels to provide necessary technical guidance.

- **Setting realistic expectations with respect to research and development outcomes:** Future programs involving the research and development of unproven and untested technologies must set realistic expectations around outcomes realisation. It is critical that future program design explicitly recognise a realistic target in terms of research and development achievements, and that not all projects will proceed beyond the research phase.

- **Ensuring alignment between policy settings and program objectives:** Future program design must consider and reflect existing and likely future policy settings. Furthermore, there is a need to ensure that underlying commercial incentives and imperatives exist to support the achievement of program objectives.

  Future programs should also include a review 'trigger' to revisit the rationale of a program if there is a fundamental shift in domestic and international policy settings that are likely to impact the achievement of program objectives.

- **Enhancing assessment of project feasibility at program commencement:** Future programs should seek to improve technical and financial screening and selection processes to better gauge the feasibility of projects at program commencement. However, this needs to be balanced with the research and development objectives of any future program.

Future programs involving large and complex technologies should embed independent program review boards consisting of recognised domestic (and if appropriate international) experts to periodically assess project progress.

- **Funding and program governance arrangements to reflect the nature of program activities:** Future programs should adopt funding agreements and decision-gates to reflect the nature and needs of industrial development projects. In particular, stage gates should replace inflexible milestone reporting and payment processes. This would ensure approved project funds can be more appropriately accessed over time as the project passes through agreed stage gates.
- **Greater industry engagement in the design of the program:** Future programs should involve greater engagement with industry and academic stakeholders during program design. This would ensure program objectives, risks and issues are appropriately understood and reflected in the program design and implementation. Upfront industry stakeholder engagement should also inform an upfront formal assessment of program risks. This ensures risk mitigation strategies can be fully explored, and if possible, embedded within program design.
- **Monitoring of program funding:** Future programs should embed monitoring and reporting frameworks to monitor the effects of changes to funding on the achievement of program objectives. Such frameworks would enable an assessment of how remaining funds can be redistributed within the program (or other programs) and provide a transparent process for revisiting the project selection process to identify projects that were the next best ranked.
- **Embedding engagement within and across government:** Future programs should embed knowledge-sharing processes to ensure program learnings and outcomes are appropriately disseminated across relevant Commonwealth and State government departments and agencies. Furthermore, program design should consider the required data and information storage and sharing systems to ensure all relevant program documentation is adequately captured and collated in a central location. This mitigates the risks of key learnings and knowledge eroding overtime, and ensures future programs can incrementally build upon the knowledge gained.
- **Undertaking a detailed economic costs benefit analysis:** Any consideration of future support to further the development and implementation of LETFF should, as a first step, involve a detailed cost benefit analysis of LETFF in decarbonising the economy relative to alternative technologies. This analysis should give consideration to fossil fuel demand and the whole-of-lifecycle costs of alternative technologies.

Appendix A: Overview of projects by LETFF program

A summary of the projects delivered under the LETFF programs is presented in the following tables.

Table A.1: Summary of CCS Flagships projects

Project	Description
CarbonNet Project	The project investigates the potential for a large scale CCS network in the Gippsland region of Victoria. The network seeks to cover multiple sources of carbon dioxide captured from industrial plants or power stations.
SouthWest Hub Project	The project aimed to assess the feasibility of storing industrial-generated carbon dioxide deep underground in the Lesueur Sandstone formation. The project involved collecting data and core samples through seismic questionnaires and stratigraphic wells.
ZeroGen Project	The project involved assessing the feasibility of a commercial-scale coal gasification power plant with integrated carbon capture and storage.
Wandoan Integrated Gasification Combined Cycle (IGCC)	A prefeasibility study which involved the following sub-projects: • Stanwell Corporation/Wandoan project which sought to develop an IGCC power station with CCS capabilities. • CTSCo Pty Ltd/Wandoan project which focused on the transportation and storage of carbon dioxide from the IGCC power station through pipelining and geo-sequestration.
Otway Geological Storage and Demonstration Project	A carbon capture and storage demonstration project that aims to address barriers to storage implementation and leverage existing and new datasets arising from the CO2CRC Otway Project to further the technology. The project also involved a monitoring program that test technologies and techniques with the aim of reducing costs.
Australia-China Joint Coordination Group on Clean Coal Technology Projects	The project aimed to build on the growing relationship between Australia and China through the Australia-China Joint Coordination Group on Clean Coal Technology (JCG).

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Table A.3: Summary of LETDF projects

Project	Description
Gorgon Carbon Dioxide Injection Project	Design, construction and operation of facilities to inject and store CO_2 into a deep reservoir unit two kilometres beneath Barrow Island. The CO_2 that is injected into the reservoir unit comes from the process of extracting gas in the Gorgon/Jansz-Io fields.
400MW Integrated Dry-gas Gasification Combined Cycle (IDGCC) Clean Coal Demonstration Project	A project that aimed to increase the burning efficiency of thermal generators by drying brown coal. Reducing the moisture content of brown coal means that less energy is required to convert the coal into electricity.

Project	Description
Hazelwood 2030 Project	A project that aimed to retrofit Low Emission Technologies at the brown coal-fired Hazelwood Power Station in the Latrobe Valley, Victoria. The process involves reducing moisture content of brown coal for an improved burning efficiency. The Hazelwood 2030 project includes CCS facilities – with demonstrated capacity to sequester carbon dioxide at a rate of 0.02mtpa.
Fairview Project	A project that aimed to test the extraction of methane from coal and storing it underground

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Appendix B: Evaluation framework

The evaluation framework, including key evaluation questions and sub-questions, key data collection methods and sources guiding the impact evaluation of the LETFF programs is presented below. The evaluation framework has guided the key lines of enquiry and systematic organisation of analysis to ensure a consistent and robust assessment of the LETFF programs and project activities.

Table B.1: Evaluation framework

Domain	Key evaluation questions	Sub-questions	Data source		
			Interviews	Document review and citation analysis	Questionnaire
Effectiveness	To what extent have the LETFF programs increased knowledge, skills and capability, and improved industry understanding in relation to low emissions technologies for fossil fuels?	To what extent have the LETFF programs generated new research, data and modelling relating to the practical and technical use and implementation of LETFF?	✓	✓	✓
		To what extent have the LETFF programs resulted in the development of greater local (Australian) skills and capabilities in LETFF?	✓	✓	✓
		To what extent have the LETFF programs improved industry understanding of the feasibility and safety of LETFF through collaboration and dissemination of new knowledge?	✓	✓	✓
		To what extent is achievement against the above outcomes commensurate with the investment made by the Commonwealth Government?	✓		✓
	To what extent would knowledge, skills and capability, and industry understanding in relation to LETFF continued to have been developed in the absence of the LETFF programs?	What was the state of knowledge, skills and capability, and industry understanding prior to the commencement of the LETFF programs?	✓	✓	✓
		What is the state of knowledge, skills and capability, and industry understanding following to the commencement of the LETFF programs?	✓	✓	✓
		To what extent has investment from the LETFF programs crowded out industry and research activity that would have occurred in the absence of the LETFF programs?	✓		✓

Domain	Key evaluation questions	Sub-questions	Data source		
			Interviews	Document review and citation analysis	Questionnaire
		How much of the change observed in increased knowledge, skills and capability, and improved industry understanding is because of the LETFF programs?	✓		✓
Efficiency	What factors have helped or hindered the achievement of increased knowledge, skills and capability, and improved industry understanding in relation to LETFFs?	What factors have assisted the achievement of increased knowledge, skills and capability, and improved industry understanding in relation to LETFFs?	✓	✓	✓
		What factors have hindered the achievement of increased knowledge, skills and capability, and improved industry understanding in relation to LETFFs?	✓	✓	✓
		To what extent did the design and implementation of the LETFF programs assist or hinder the achievement of the increased knowledge, skills and capability, and improved industry understanding in relation to LETFFs? Did program design align with known 'best practice' examples elsewhere?	✓	✓	✓
		To what extent did the LETFF programs align with related programs or research (either government or industry)?	✓	✓	✓
		To what extent do these factors remain a barrier to the commercial development and deployment of LETFFs?	✓		✓
	How have external factors affected the ability of the LETFF programs to achieve their intended medium and long-term objectives?	How have Australian Government and international policy settings affected the achievement of medium and long-term objectives?	✓		✓
		How have the relative prices of, and demand for, renewable energy sources affected the achievement of medium and long-term objectives? How have alternative carbon abatement technologies (e.g. bio-sequestration) affected medium and long-term objectives?	✓		✓
		How has the level of demand for fossil fuel-based energy affected the achievement of medium and long-term objectives?	✓		✓
		How have general economic conditions affected the achievement of medium and long-term objectives?	✓		✓
		How have issues such as third-party risk and market design factors affected the achievement of medium and long-term objectives?	✓		✓

Domain	Key evaluation questions	Sub-questions	Data source		
			Interviews	Document review and citation analysis	Questionnaire
Appropriateness	What lessons can be drawn to inform future policy and program development, including the role (if any) of the Commonwealth Government, in relation to supporting the development and implementation of LETFF technologies?	What lessons can be drawn to inform future program design and development?	✓		✓
		Did changes to the LETFF programs since inception influence the efficiency or effectiveness of the programs?	✓		✓
		Are there critical areas of research that have been missed?	✓		✓
		Was there adequate industry engagement on the role of CCS and emission abatement technologies as part of a broad mix of GHG emission mitigation measures?	✓		✓
		What is the role (if any) of the Commonwealth Government in relation to supporting LETFFs?	✓		✓
Unintended impacts	What unintended outcomes have occurred as a result of the LETFF programs?	What (if any) unintended benefits occurred as a result of the LETFF programs?	✓	✓	✓
		What were the unexpected negative impacts of the LETFF programs?	✓	✓	✓

Appendix C: Stakeholder interviews and questionnaire responses

List of stakeholders interviewed

A list of all stakeholders interviewed as part of the evaluation assessment are outlined below. Overall, 19 stakeholders were engaged through 18 interviews as part of the evaluation.

Table C.1: List of stakeholders interviewed

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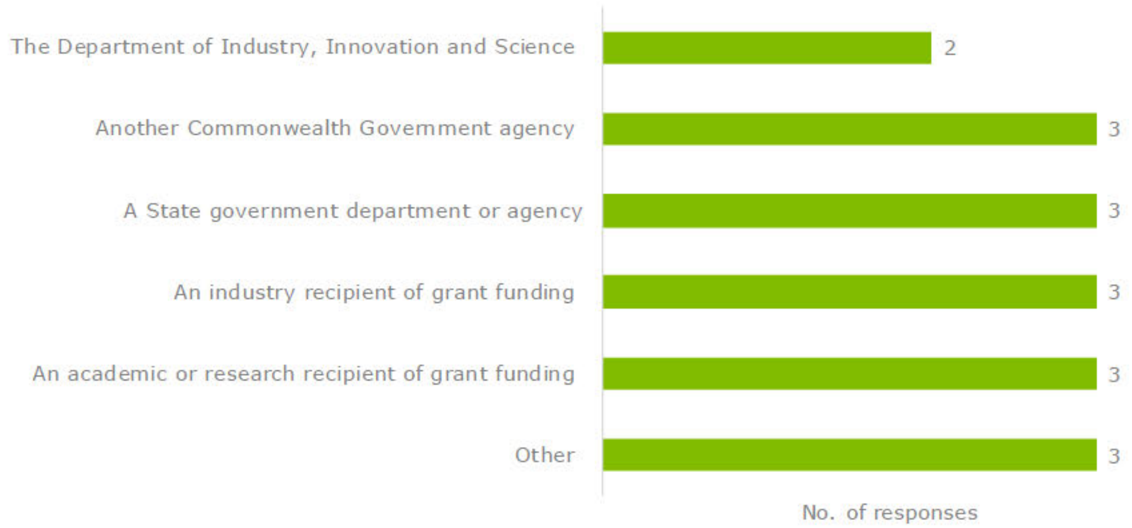
List of respondents to online questionnaire

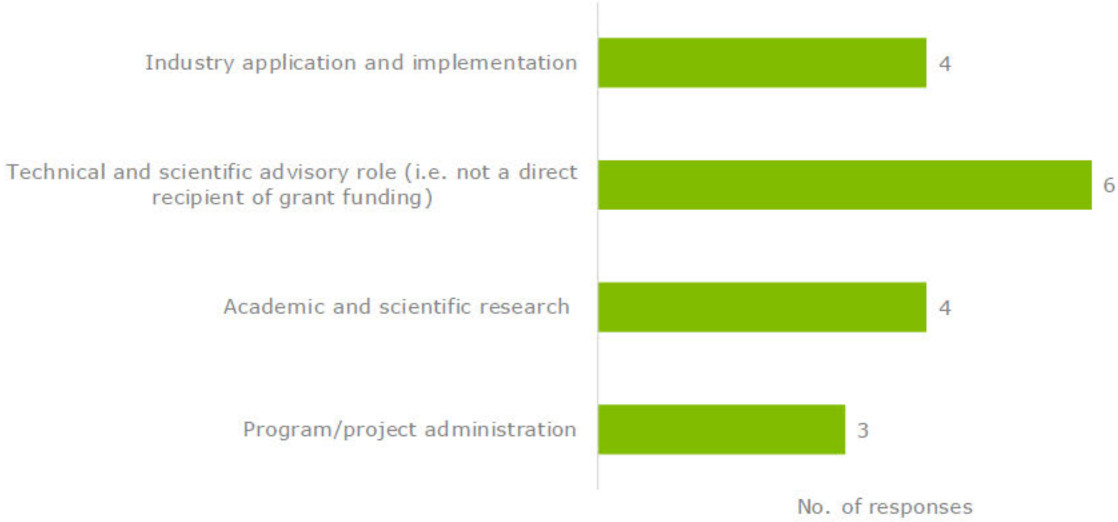
A total of 17 responses to the online questionnaire were received. A summary of the groupings of respondents is provided below.

Chart C.1: Type of organisations that respondent principally worked for during their involvement with the LETFF programs



Source: Deloitte survey, n = 17

Chart C.2: How do respondents describe their involvement with the LETFF programs?



Source: Deloitte survey, n = 17

Appendix D: Case studies

This evaluation has involved the development of concise case studies highlighting the contribution to increased knowledge, domestic skills and capabilities, and improved industry understanding of LETFF made by individual projects delivered under the LETFF programs. The case studies have supported and informed the triangulation of evidence collected across the evaluation. A total of seven case studies have been developed across the LETFF programs:

- **CCS Flagships program:**
  - South West Hub Project
  - Otway Geological Storage and Demonstration project
- s22

- **LETDF:**
  - Gorgon Carbon Dioxide Injection Project
- s22

These concise case studies are presented below.

South West Hub Project

Project Summary and Objectives

The South West Hub project involved testing onshore sandstone formations as a CO_2 reservoir for nearby power plants and industrial sites in Western Australia. Its objectives were to conduct a data study and analysis of the lower Eneaba Formation to determine its suitability for injecting CO_2 underground. In its Extended Case, the facility aimed to capture, transport and store between 5-6Mt of CO_2 annually.

Contribution to Research and Knowledge

The project's unique location was chosen in part due to its proximity to CO_2 emitters, rather than any geological characteristics that make it particularly suitable for CO_2 storage. This aimed to reduce the costs of transporting CO_2 – improving the commerciality of CCS. However, the location led to challenges such as:

- determining how to keep the injected CO_2 underground, since the Eneaba Formation did not have the impermeable seal that other CO_2 storage sites have to contain the CO_2 plume
- determining how to monitor the CO_2 plume underground.

Consequently, most of the new research and knowledge gained came from addressing these challenges. Specific areas of research contributed to by the project included:

- improvements in geosequestration knowledge – including conducting and analysing seismic survey data, as well as conducting geophysical remote sensing of CO_2 sequestration
- geochemical evaluation of the well using a combination of standard and novel techniques – such as chemical tracers to determine the suitability of the area for CO_2 storage
- structural analysis of geological formations, including fault seal first-order analysis.

Stakeholders also reported that the project contributed to a greater understanding of trapping mechanisms, greater confidence in Migration Assisted Trapping (MAT) technology and a greater understanding of geological environments and depositional history at a local level.

Stakeholders also reported that by applying research in the field and conducting demonstrations, they were able to more effectively present comprehensive and compelling business cases to progress CCS technology.

Overall, this evaluation identified 28 technical reports from various public data repositories produced by the project. These reports discuss challenges and the results of geosequestration testing conducted during this project. These reports have cumulatively been cited 25 times in external reports.

Contribution to domestic skills and capabilities

The project made an important contribution to advancing domestic capabilities in the development of behavioural models of CO_2 plume movements within different rock formations. Of the 28 technical reports, eight were written by the University of Western Australia or Curtin University. These reports focused on geophysical data analysis, stability assessments and predicting CO_2 injectivity properties.

Other technical reports also focused on improvements in conducting and analysing seismic survey data like geochemical evaluation and residual trapping. The unique characteristics of the site meant that significant focus was placed on understanding how basin configuration and structural elements affected the containment capabilities of a rock formation.

The project also contributed to the development of domestic research skills, by enabling leading research organisations such as the University of Western Australia and Curtin University to have dedicated staff and students working on CCS research and demonstration projects.

Contribution to industry understanding of low emissions technologies

The Project's location in a low-medium permeability reservoir, without a thicker "continuous impermeable seal" that could effectively contain CO_2 plumes, added to the technical challenges of CCS. These challenges demonstrated that storage proximity to emission sources, while preferable, is neither a necessary nor a sufficient condition. However, a viable geological reservoir is certainly necessary and likely sufficient.

Stakeholders discussed how the South West Hub project was important for the industry to develop a better understanding of both the theoretical capabilities of injecting CO_2 into these types of reservoirs (i.e. without an impermeable seal) and also the commercial aspects that would need to be met before injection can be undertaken effectively.

Whilst challenging, the project was crucial for improving the industry's understanding of geological reservoirs without natural seals, particularly their potential for trapping CO_2. Modelling that was done as a result of the project indicated that geological reservoirs without traditional caps or seals can still store CO_2, potentially doubling the previously estimated storage capacity in south-west Western.

Technical reports and research papers discussing the processes conducted, as well as the challenges associated with geosequestration, were made public – and are found on data repositories such as s22 the Global CCS Institute and WAIMPS.

Otway Geological Storage and Demonstration Project

Project Summary and Objectives

The CO_2 Co-Operative Research Centre's (CO2CRC) Otway Geological Storage and Demonstration Project (the Otway Project) aims to conduct initial site characterisation of the Otway Basin Pilot Project. The project's objective is to demonstrate the deep geological storage of CO_2, and improve understanding of the potential geological storage of various sedimentary basins both onshore and offshore. The project has involved the pilot trial of CO_2 injection and storage to demonstrate proof of concept.

Contribution to Research and Knowledge

The Otway Project has involved partnerships with a range of leading universities and research organisations, including CSIRO, Geosciences Australia and Curtin University, with a specific focus on sub-surface CO_2 storage, monitoring and modelling.

Research and knowledge focused on decreasing the cost of monitoring CO_2 plumes underground, as well as reducing the impact of operating on other stakeholders like land operators or the environment. The Otway Project was seen by stakeholders as critical in demonstrating laboratory-scale technologies in the field as major prototypes. These technologies included new modelling approaches that accurately predict CO_2 plumes and experimental methods for determining tracer partition coefficients. The Otway Project has directly contributed to the following areas of storage and CO_2 monitoring research:

- understanding how geological permeability may change as a function of CO_2, demonstrating a need to monitor water and local mineralogy characteristics
- monitoring the characteristics of injected CO_2 plumes using seismic technology
- analysis and modelling of geophysical data sets (2D, 3D etc.) and downhole pressure and temperature datasets to improve understanding of CO_2 plume behaviour and migration
- an improved understanding of the potential injectivity of reservoirs, their ability to store CO_2 and overall storage capacity
- establishing general methodologies for determining whether a CO_2 storage reservoir is leaking
- improving techniques to monitor sub-surface CO_2 plumes
- improving cost effectiveness of CO_2 monitoring.

The Otway Project has also contributed to the development of a range of new techniques. An example is working with Curtin University to develop fibre optic cable technology to receive acoustic signals. As noted by stakeholder:

> *"Previously when you do seismic monitoring you basically create an acoustic wave through the earth and receive it at a geophone – this has been the traditional way that the Oil and Gas sector has explored. What's been maturing and what Curtin has been heavily involved with is replacing geophones [with fibre optic cables]. You can now use fibre optic to receive that acoustic signal anywhere along that fibre. Now, the quality of what you receive with that fibre versus a mechanical geophone has always been a lot less, so the fibre has never been that great. But with the funding that we have received from the LETFF and combination of work with experts from Curtin and also internationally, we are now at the point where the performance of these fibres is substantially better than these geophones. Now, that all sounds very technical, but what it means is we now have the ability to not have to put major infrastructure down these wells, we can do it through very cheap wells. We can have high resolution on demand, monitoring whenever we want to give assurance of [CO_2] behaviour on the subsurface be it in CCS or be it in Oil and Gas exploration production. It's a massive improvement and a very important technology.*

This evaluation identified ten published technical reports produced through the Otway Project, which have collectively been cited in peer reviewed publications a total of 16 times.

Contribution to domestic skills and capabilities

The Otway Project has involved collaborations with a range of international research organisations and universities – including Silixa (UK), Lawrence Berkeley National Laboratory (US), and the University of Texas. The research and academic institutions partnered with CO2CRC to trial new technologies on site. Through these collaborations, these organisations have assisted in developing and broadening domestic skills and capabilities. Technologies that were trialled include:

- different injection methods
- different storage and monitoring methods such as Distributed Acoustic Sensing (DAS) fibre optic cables and 4-D time-lapse surface seismic methods.

Stakeholders reported that the Otway Project directly contributed to Australia developing world-leading reservoir engineering and monitoring skills and expertise, with CSIRO and Curtin University being identified by international collaborators as world leaders.

A key aspect of the Otway Project was it being "internationalised" by CO2CRC as a preferred test site to trial a range of injection, storage and monitoring techniques for CCS. Stakeholders noted that through these trials and collaborations, Australia has developed skills in these international techniques. Australia was also able to directly develop significant skills and capabilities with respect to the application of a range of CCS technologies, including:

- site management
- managing the regulations around sites
- communications.

Contribution to industry understanding of low emissions technologies

A key aspect of the Otway Project has been its focus as a trial demonstration facility for CCS. This has enabled the project to undertake direct applied research and demonstration in the field, including extensive geoscience and engineering work, to inform future commercial scale deployment of CCS.

The Otway Project has developed a detailed understanding of the process of CO_2 injection under Australian conditions and geology, CO_2 migration and monitoring, and CO_2 stabilization. This has enabled the project to develop an end-to-end visualisation of the injection and storage of CO_2. The project has also significantly contributed to an understanding of monitoring and modelling the behaviour of CO_2 with very advanced modelling techniques. In short, the Otway Project has made a significant contribution in providing industry, government and academia with tangible evidence that CCS works and is safe.

The Otway Project was crucial for demonstrating technologies at a prototype level – such as seismic monitoring through fibre optic rather than mechanical geophones, which are now able to perform at a much higher level.

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Gorgon Carbon Dioxide Injection Project

Project Summary and Objectives

The Gorgon Carbon Dioxide Injection Project was a commercial-scale demonstration project for capturing CO_2 emissions from the natural gas extraction process in the Gorgon field off the coast of Western Australia. The Project involved compressing, dehydrating and transporting the CO_2 by pipeline to the injection site – a saline sandstone reservoir in the Dupuy Formation. It aimed to reduce project emissions by 120Mt over its lifespan at a 3.4-4Mt annual rate, and is the first major project to significantly reduce emissions through underground injection. The Project is expected to begin CO_2 injections in 2019.

Contribution to Research and Knowledge

Research and knowledge gained from the Project may have been limited because CO_2 injections have not started and because of potential commercial-in-confidence issues. The 12 public technical reports identified as part of this evaluation covered key learnings on:

- the acquisition of quality seismic data, through petrographic, petrophysical, biostratigraphical, sedimentological and geochemical reporting – and its significance to improving the accuracy of CO_2 migration simulation models
- the impact on project execution
- well remediation programmes to ensure existing wells near the proposed injection site have been properly secured and do not pose a CO_2 containment risk
- site assessments, research and exploration work.

These technical reports have been cumulatively cited 1,012 times by external papers, demonstrating the significant contribution to enhancing knowledge of LETFF, and particularly CCS, made by the project.

Contribution to domestic skills and capabilities

The Gorgon Project involved the use of technologies, processes and equipment that have previously existed within the oil and gas sector, and as such was able to leverage the existing and significant skills base within the oil and gas sector.

However, the Gorgon Project did bring in monitoring technologies that reduced the cost of monitoring CO_2 plumes. These technologies include surveillance wells, 4D Surface Seismic testing, soil gas verification and pressure sensors on the surface.

This evaluation did not identify any technical reports that were written in partnership with universities or other research-based institutions.

Contribution to industry understanding of low emissions technologies

The Project is seen as a successful example of CCS operations on a commercial scale. While the $60 million allocated from the LETDF was not material to the Gorgon Project's success, it has enabled the development of a successful relationship that was crucial in the following ways:

- key learnings from the Gorgon Project relating to the legal and regulatory aspects influenced how the Australian Government intended to regulate CCS
- it also assisted in developing the Australian Government's Offshore Petroleum and Greenhouse Gas Storage Act.

The Project also led to technical reports associated with pumping CO_2 into reservoirs that are full of water, and its impacts on the reservoir itself. Depending on the type of report, they are either disseminated internally (where there is a commercial advantage) or published in industry journals.

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Appendix E: Literature scan and citation analysis

The results of the citation analysis of publicly available reports relating to the LETFF programs is presented below. This citation analysis covers publications available up until 28 May 2019.

Table E.1: Detailed Analysis of LETFF program/project publications

LETFF program/ project	Publications No.	Publications %	Scholarly articles (as a share of publications) %	No. of citations	Average citations per publication
CCS Flagships	**65**	**13%**	**2%**	**170**	**2.6**
CarbonNet	20	4%	n/a	65	3.3
SouthWestHub	28	6%	4%	25	0.9
ZeroGen	2	0%	n/a	44	22.0
Wandoan	5	1%	n/a	20	4.0
CO2CRC	10	2%	n/a	16	1.6
CCSRD&D	0	0%	0%	0	0.0
s22					
LETDF	**23**	**5%**	**39%**	**1,105**	**48.0**
Gorgon	12	2%	42%	1,012	84.3
IDGCC	0	0%	0%	0	0.0
Hazelwood	7	1%	57%	93	13.3
Fairview	1	0%	0%	0	0.0
Other	3	1%	0%	0	0.0
s22					

Source: Deloitte

Notes: The above analysis only includes publically available publications.

Scholarly articles are considered to be publications that appear in peer-reviewed academic or scientific journals.

Limitation of our work

General use restriction

This report is prepared solely for the internal use of Department of Industry, Innovation and Science. This report is not intended to and should not be used or relied upon by anyone else and we accept no duty of care to any other person or entity. The report has been prepared for the purpose of set out in our contract dated 4 April 2019. You should not refer to or use our name or the advice for any other purpose

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EXECUTIVE BOARD
FOR ENDORSEMENT

Title	**Low Emissions Technologies for Fossil Fuels (LETFF) Programs Evaluation Reports**
Purpose/Issue	To present two evaluation reports to the Executive Board for endorsement.
Recommendation(s)	That the Board: 1. **Endorse** the LETFF programs evaluation reports a. Impact evaluation b. Process evaluation s22
Attachment(s)	**A – Impact Evaluation of the LETFF programs** **B – Process evaluation of the Low Emissions Technology Demonstration Fund (LETDF)** s22 s22
Consultation	The LETFF evaluations were overseen by a Reference Group, comprising the general managers of: s22
Prepared by	s22
Sponsored by	s22

Background

The LETFF programs are a Tier One evaluation priority in the department's Evaluation Plan. The impact evaluation was postponed pending completion of ANAO's 2017 audit of two of the four LETFF programs - the Carbon Capture and Storage (CCS) Flagships program s22
s22 . The ANAO recommended the department evaluate the extent to which the programs had achieved their strategic policy objective.

The impact evaluation of the four LETFF programs was undertake in two phases. The Evaluation Unit engaged Deloitte, through separate Panel procurements, to conduct both phases.

- Phase one (evaluability assessment) found that it was not plausible to expect the LETFF programs to have achieved their longer-term objective of demonstrating and deploying LETFF on a commercial-scale.
- Phase two (impact evaluation) therefore evaluated the impact of the LETFF programs against their intended short and medium-term outcomes.

Phase one included a process evaluation of the Low Emissions Technology Demonstration Fund (LETDF) s22 , the two LETFF programs not included in the ANAO audit.

The process evaluation report was circulated to the Programs Assurance Committee on 3 May 2019. The impact evaluation report was circulated to the Programs Committee on 12 August 2019.

According to the *DIIS Evaluation Strategy 2017-21*, all evaluation reports are presented to the Board for endorsement and decision on whether the department will implement the evaluation recommendations (if any) and whether the final report will be publicly released (in its entirety, executive summary or internally only).

Key Issues

In relation to the impact evaluation, Deloitte found that:

- The programs have significantly contributed to increased knowledge, skills and capability, and improved industry understanding of LETFF in Australia. Australia has the research and engineering capability to develop commercial-scale LETFF projects
- The programs were underpinned by clear policy direction and settings, government support and significant funding at commencement, but changing and uncertain policy settings contributed to reduced industry confidence and momentum. The absence of a clear commercial imperative on the part of industry to invest in carbon abatement remains the single largest barrier to commercial development and deployment of LETFF.
- Stakeholders considered the programs to have been successful and that this work would not have progressed without Australian Government support, however achievements and knowledge gained could have been more effectively communicated.
- Australia risks losing the significant gains in knowledge, and skills and capabilities established through the LETFF programs if there is no progression towards the commercialisation and deployment of LETFF.

In relation to the process evaluation, Deloitte found that implementation of both the LETDF and s22 had been generally sound and well-documented.

Neither report made recommendations, but identified lessons learned for future program design and implementation. The Onshore Minerals and Energy Branch endorsed the findings of both evaluations, noting the usefulness of some lessons for strengthening future design.

In line with the department's *Evaluation Strategy 2017-21*, to move towards publishing more evaluation reports externally for transparency reasons, it is recommended that all evaluation reports are made available both internally and externally to the department.

Phase Two of the Impact Evaluation of the Low Emissions Technologies for Fossil Fuels (LETFF) programs

Department of Industry, Innovation and Science

8 August 2019

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Glossary

ACALET R&D	Australian Coal Association Low Emissions Technologies Research and Development
ANAO	Australian National Audit Office
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ARENA	Australian Renewable Energy Agency
CCS	Carbon Capture and Storage
s22	
CO2CRC	Carbon Dioxide Co-operative Research Centre
CSIRO	Commonwealth Scientific and Industrial Research Organisation
GCCSI	Global Carbon Capture and Storage Institute
GHG	Greenhouse Gases
HELE	High Efficiency Low Emissions
IDGCC	Integrated Drying Gasification Combined Cycle
IGCC	Integrated Drying Gasification Combined Cycle
KEQ	Key Evaluation Questions
LETDF	Low Emissions Technology Demonstration Fund
LETFF	Low Emissions Technologies for Fossil Fuels
s22	

Executive summary

In 2004, the Australian Government identified a need to support and promote the development and deployment of low emissions technologies to facilitate a cost-effective transition to a lower carbon economy.

The Department of Industry, Innovation and Science (the Department) has been implementing a range of policies from 2004 to support the research and development of new greenhouse gas (GHG) emissions reduction technologies under the Low Emission Technologies for Fossil Fuels (LETFF) programs.

Deloitte has been engaged by the Department to undertake Phase Two of the LETFF impact evaluation to evaluate the impacts of the LETFF programs on increasing knowledge, skills and capability, and on improving industry understanding in relation to low emissions technologies. The project also sought to answer:

- What factors have helped or hindered the achievement of the above outcomes?
- To what extent would outcomes have been achieved in the absence of the LETFF programs?
- To what extent do factors within and external to the LETFF programs remain a barrier to commercial development and deployment of LETFF?
- What (if any) unintended outcomes, positive and negative, have occurred as a result of the LETFF programs?
- What lessons can be drawn to inform future program development, including the role (if any) of the Commonwealth Government, in relation to supporting the development and implementation of LETFF technologies?

To answer these questions, the impact evaluation adopted a mixed methods approach involving semi-structured interviews with program stakeholders, an online questionnaire, and extensive scan of secondary data including citation analysis and development of case studies.

Contribution to knowledge, skills and industry understanding

The LETFF programs have significantly contributed to increasing knowledge, skills and capability, and improving industry understanding of LETFF in Australia. Overall, Australia has the research and engineering capability to develop commercial scale LETFF projects.

Overall, through the LETFF programs Australia has developed:

- a mature knowledge base with multiple industry participants with knowledge of a range of LETFF, supported by a broad body of research covering multiple technologies
- a moderate level of domestic skills and capability, with more advanced expertise within a number of organisations in relation to specific LETFF, most notably CCS
- a moderate industry understanding of the technical and practical feasibility of some LETFF, notably CCS, under a range of processes and Australian conditions but deployment required to further advance understanding.

A significant body of research has been delivered across the full spectrum of LETFF activities, and the critical research and development and technical barriers are considered to be largely settled for CCS.

Australia’s research skills and capabilities have been deepened with respect to specific LETFF; these skills and local experience are more developed relative to prior to commencement of programs. However, Australia’s research capabilities are considered to be more advanced than industry capabilities. Stakeholders agree that deployment of LETFF is required to further advance Australia’s industry and technical skills and capabilities.

The LETFF programs have resulted in industry developing a detailed ‘end-to-end’ understanding of the engineering and design of LETFF, in particular CCS technologies. Furthermore, there is a

consensus that the coal, energy generation, and oil and gas sectors have an understanding of the practical, technical and financial requirements necessary to deploy CCS. However, the absence of a commercial imperative to invest in emissions abatement remains the overarching barrier to LETFF deployment in Australia.

Factors contributing to the success of the LETFF programs

At commencement, the LETFF programs were underpinned by clear policy direction and settings, support across Commonwealth and State governments, and a significant funding commitment across a suite of programs and projects – factors deemed critical to the achievement of outcomes. Other contributing factors to the achievement of outcomes included:

- establishment of partnerships between government, industry and academic stakeholders
- the direct financial involvement of the coal industry in maintaining an industry-focused research agenda
- establishment of a portfolio of LETFF projects to maximise learnings and the probability of success.

Overall, changing, uncertain and inconsistent domestic policy settings are considered the primary factors hindering achievements and progress across the LETFF programs. Policy uncertainty has resulted in a significant loss of confidence across industry and a loss of momentum in advancing LETFF.

A combination of the unexpected complexity of LETFF, inflexibility of funding agreements, and regulatory uncertainty on the part of the Commonwealth and State governments also hindered achievements and progress across the LETFF programs.

The absence of a clear commercial imperative on the part of industry to invest in carbon abatement remains the single largest barrier to the commercial development and deployment of LETFF.

Success, future research and role of government

Overall, stakeholders overwhelmingly consider the LETFF programs to be successful. There was strong agreement among all stakeholders that the achievements of the LETFF programs would not have been made in the absence of Commonwealth Government support. Furthermore, stakeholders consider that the Commonwealth Government's investment in LETFF programs represents good value for money, and that achievements are commensurate with the investment.

LETFF programs have directly contributed to reducing the technical and commercial barriers to the development and deployment of commercial-scale LETFF projects. However, the achievements and knowledge gained could have been more effectively communicated and disseminated beyond immediate program participants, and achievements could have been more effectively communicated to the broader public. Barriers to knowledge sharing and access to information have contributed to a low level of public understanding and acceptance of LETFF, and in particular CCS, and represent one barrier to the deployment of LETFF.

Australia also risks losing the significant gains in knowledge, and skills and capabilities established through the LETFF programs if there is no progression towards the commercialisation and deployment of LETFF.

The critical underlying research and technical questions to deploying large-scale LETFF (and CCS in particular) have been addressed, however some targeted research would supplement and benefit research done to date. In particular, there is need to undertake site-specific research and testing to support the eventual deployment of LETFF.

Stakeholders consider there remains a critical role for the Commonwealth Government in supporting the development and implementation of LETFF. While there was no clear consensus on the appropriate role for the Commonwealth Government from stakeholders interviewed, a majority of respondents to the online questionnaire considered the Commonwealth Government should continue to provide large-scale grants to support LETFF research and development.

Key lessons for future program design

The impact evaluation has identified the following key lessons to inform future program design and implementation:

- the need to set realistic expectations with respect to program cost and time-horizons, particularly for programs with a focus on deployment of commercial-scale projects incorporating untested technologies
- the need to set realistic expectations with respect to research and development outcomes, noting that only a proportion of projects will succeed in progressing beyond research and pre-commercial feasibility
- ensuring alignment between policy settings and program objectives, and ensuring an appropriate mechanism is in place to trigger a review of program rationale in the event of a fundamental shift in domestic and international policy settings
- enhancing the technical and financial assessment of project feasibility at program commencement, noting that this needs to be balanced with the research and development objectives and any future program
- funding and program governance arrangements should reflect the nature of program activities, in particular stage gates should replace inflexible milestone reporting and payment processes for large projects to enable a more efficient provision of funding
- greater industry engagement in the design of the program, and as part of a formal risk assessment, to ensure program objectives, risks and issues are appropriately understood and reflected in the program design and implementation
- the need to embed monitoring and reporting frameworks to monitor the effects of changes to funding on the achievement of program objectives, and better enable an assessment of how remaining funds can be redistributed within the program or other programs
- the need to embed knowledge-sharing processes and systems to ensure program learnings and outcomes are appropriately captured and disseminated across relevant Commonwealth and State government departments and agencies
- any consideration of future support to further the development and implementation of LETFF, as a first step, should involve a detailed economic cost benefit analysis of LETFF in decarbonising the economy relative to alternative technologies. This analysis should give consideration to fossil fuel demand and the whole-of-lifecycle costs of alternative technologies.

Management response

The Onshore Minerals and Energy Resources Branch endorses the findings of the Impact Evaluation of the Low Emissions Technologies for Fossil Fuel (LETFF) programs. In particular, the Branch notes the evaluation's findings that the LETFF programs have helped to develop a mature knowledge base supported by a broad body of research; a moderate level of skills and expertise; and a moderate industry understanding of the technical and practical feasibility of some LETFF, notably carbon capture and storage (CCS).

The Branch is pleased with the evaluation's finding that stakeholders overwhelmingly consider the LETFF programs to be successful, and the factors identified as being critical to that success (including the establishment of partnerships between government, industry and researchers; the direct financial investment of industry stakeholders; and the establishment of a portfolio of projects to maximise the probability of success); while noting the present risk of losing momentum and knowledge without further progress towards the deployment of LETFF.

The evaluation provides useful insights into the programs' successes, as well as the factors that have hindered achievements across the programs; and stakeholders' views on the need for future government support. These insights, as well as lessons for future program design, will be useful inputs for the design and management of any future programs of a similar scale, duration and complexity.

1 Overview and purpose

1.1 Context

Australia's electricity generation and some industrial sectors (e.g. steel and concrete production) rely heavily on burning fossil fuels, such as coal, natural gas and oil, which release carbon dioxide (CO_2) and other greenhouse gases (GHG) into the atmosphere.

Low emissions technologies have the potential to reduce GHG emissions and Australia's impact on climate change. In 2004, the Australian Government identified a need to support and promote these technologies to facilitate a cost-effective transition to a lower carbon economy. The Department of Industry, Innovation and Science (the Department)[1] has since implemented and overseen the Low Emission Technologies for Fossil Fuels (LETFF) programs. These programs fund research and development of new GHG emission reduction technologies. The LETFF programs comprise the following four programs:

- The Carbon Capture and Storage (CCS) Flagships program

s22

- The Low Emissions Technology Demonstration Fund (LETDF)

s22

These programs commenced against a backdrop of increasing and coordinated global action against climate change. However, they have experienced significant changes in funding, policy and investment conditions. In particular, the repeal of the carbon pricing mechanism has led to uncertainty regarding the future price of carbon, affecting business investment incentives.

The Department has identified the LETFF programs as a Tier One evaluation priority of high strategic importance. The Department previously accepted the recommendation of the Australian National Audit Office (ANAO) audit (2017) to evaluate the LETFF programs. The Department is conducting the evaluation of the LETFF programs in two phases, consisting of:

- Phase One - an assessment of the 'evaluability' of the four LETFF programs, previously conducted by Deloitte Access Economics. (Completed)
- Phase Two - an impact evaluation of the LETFF programs, the scope of which has been informed by the outcomes of Phase One. (Current phase).

1.2 Purpose and scope of Phase Two

The Department has engaged Deloitte to conduct Phase Two of the LETFF impact evaluation (the project). The overarching purpose of this project is to evaluate the impacts of the LETFF programs on increasing knowledge, skills and capability, and on improving industry understanding about low emissions technologies.

The project will also seek to determine whether the Government investments made under the LETFF programs have helped move low emissions technologies closer to commercialisation, and whether the outcomes achieved are commensurate with the level of investment made by the Commonwealth Government.

The findings of this project will inform future LETFF program design, including the potential role of the Commonwealth Government in supporting the further development and implementation of LETFF.

[1] The LETFF programs were originally implemented under the former Department of Resources, Energy and Tourism.

The project covers all components of the LETFF programs with the exception of the CCS Flagships Research Development and Demonstration (RD&D) fund, which is out of scope as impacts are unlikely to have been realised at the time of reporting.

1.3 The LETFF programs

The LETFF programs support low emission fossil fuel technologies by funding programs and initiatives that aim to reduce technical risks and speed up the commercialisation process. Technologies that were supported through the LETFF programs include:

- carbon capture and storage (CCS)
- high efficiency low emissions (HELE) electricity generation
- fugitive methane emission abatement technologies.

A total of $2.8 billion was originally budgeted across all four LETFF programs. However, funding was substantially reduced over time and approximately $750 million has been spent to date.

A summary of the four LETFF programs, including the objectives of each program, is provided in Table 1.1 below. A summary of individual projects delivered under each program is presented in Appendix A.

Table 1.1: Summary of LETFF programs

LETFF Program	Description
The CCS Flagships program	Commenced in 2009 under the Federal Budget's Clean Energy Initiative with a program budget of $1.8 billion. The objective of the program was to promote the dissemination of CCS technologies through supporting a small number of demonstration projects to capture CO_2 emissions from industrial processes and safely store them underground in stable geological formations. Five flagship projects and other small-scale CCS activities have been funded over the course of the program. Two out of the five flagship projects have been deemed 'unsuccessful'. The program also includes the CCS Research, Development and Demonstration (RD&D) Fund with an objective of reducing the technical and commercial barriers to deploying large-scale CCS projects.
s22	
LETDF	Announced in June 2004 under the *Energy White Paper – Securing Australia's Energy Future*. The Fund had a $500 million budget that could be granted to projects ranging from concentrated solar to CCS technology. The aim of the program was to demonstrate the commercial potential of new technologies to contribute to long-term large-scale GHG emissions reductions. The LETDF Program funded six highly complex projects which required a high degree of due diligence. Of these six, two were transferred to other programs, three were unsuccessful and only one – the Gorgon Carbon Dioxide Injection Project, continues to operate.

LETFF Program	Description
s22	

1.4 Summary of Phase One findings

Deloitte was previously engaged to assess the evaluability of the four LETFF programs under Phase One of the impact evaluation of the LETFF, to inform design and resourcing of any future impact evaluation to be undertaken in Phase Two. The evaluability assessment sought to answer three key questions:

- Was it plausible to expect an impact from the programs?
- Would an evaluation be useful, and, if so, to whom?
- Would an evaluation be feasible, based on: program evidence, data availability, baseline measures, and reporting mechanisms?

The evaluability assessment found that, overall, it was reasonable and plausible to expect that the projects and activities delivered under the LETFF programs could achieve intended short-term and, to some extent, medium-term outcomes and impacts. It was not plausible to expect that the LETFF programs could reasonably have achieved the strategic longer-term objectives of demonstrating and deploying LETFF on a commercial scale, thereby reducing GHG emissions.

The evaluation assessment confirmed there was strong stakeholder support and interest for an impact evaluation. It advised that in the absence of delivery of any commercial scale projects, an impact evaluation should focus on the achievement of short and (to some extent) medium-term outcomes to guide future policy focus and direction. It also noted that any future impact evaluation of LETFF programs will require drawing on a range of qualitative evaluation methods, with a focus on stakeholder interviews and questionnaires, documentation review, and case studies.

The evaluability assessment recommended that the Department undertake a targeted impact evaluation of the LETFF programs that focuses on assessing the extent to which the LETFF programs have resulted in changes over the short- and medium-term against the following program outcomes:

- generation of new research, data and modelling relating to the practical and technological use and implementation of LETFF (short-term outcome)
- improved industry knowledge regarding the feasibility and safety of low emissions and abatement technologies, through collaboration and dissemination of findings from pilot and feasibility studies (short-term outcome)
- development of domestic skills and capability in low emissions and abatement technologies (medium-term outcome).

The evaluability assessment recommended a future impact evaluation should also assess:

- whether industry knowledge and understanding of the feasibility and safe development of LETFF would have progressed in the absence of the LETFF programs
- whether changes in policy settings and other external factors have affected the ability of LETFF programs to achieve stated impacts

- implications for future policy development and priority setting, including the role (if any) of the Commonwealth Government in supporting the further development and implementation of LETFF.

1.5 Report structure

This report presents the findings of the impact evaluation of the LETFF programs. The report is structured as follows:

- Chapter 2 outlines the approach to the impact evaluation.
- Chapter 3 presents the contributions made by the LETFF programs to knowledge, skills and industry understanding.
- Chapter 4 discusses factors contributing to the achievements of the LETFF programs.
- Chapter 5 discusses the success of the LETFF programs, including areas of future research and the role of government in supporting the development of LETFF.
- Chapter 6 presents learnings for future program design.

2 Evaluation methodology

The impact evaluation uses a mixed methods approach to assess the extent to which the LETFF programs have contributed to increasing knowledge, skills and capability, and to improving industry understanding of LETFF. This has included semi-structured interviews, an online questionnaire and secondary data analysis, a citation analysis and development of concise case studies.

2.1 Evaluation framework

An evaluation framework has been developed to guide this evaluation. It outlines the key evaluation questions and data sources to be drawn on to address each evaluation question, and was developed in consultation with the Department. The evaluation framework has guided the key lines of enquiry and systematic organisation of analysis to ensure a consistent and robust assessment of the LETFF programs and project activities. The framework is presented in Appendix B.

2.2 Data collection and analysis

2.2.1 Semi-structured interviews

Semi-structured interviews were conducted with key LETFF program stakeholders from the Department, Commonwealth science agencies (e.g. CSIRO and Geoscience Australia), participating State governments, industry grant recipients and representatives, academic and research grant recipients, and expert advisers. All stakeholders engaged had direct involvement in the LETTF programs. Contact details of key stakeholders were provided by the Department.

A total of 18 semi-structured interviews were conducted. An interview guide was developed based on the evaluation framework. Questions were tailored for each stakeholder depending on group and LETFF program(s) they participated in, and mapped to each evaluation question in the framework. Each interview was conducted via telephone and recorded. The interview was subsequently analysed in NVivo, using coding techniques to identify common themes. A summary of stakeholders interviewed is provided in Appendix C.

2.2.2 Online questionnaire

An online questionnaire was developed to gain further insights into stakeholders' perceptions of the impact of the LETFF programs, the factors that may have assisted or hindered the achievements, and the overall success of the LETFF programs. A total of 17 respondents completed the online questionnaire. A summary of the spread of respondents is provided in Appendix C.

The online questionnaire was sent to the same cohort of stakeholders as the semi-structured interviews (via emails provided by the Department). Stakeholders were invited to forward the questionnaire on to their peers and colleagues who had also been directly involved with the LETFF programs. As such, the online questionnaire has not enabled a true triangulation of findings relative to the interviews. However, the questionnaire did provide further richness of insights with respect to the impact of the LETFF programs and supplemented the findings of the interviews.

2.2.3 Program data

The project has involved an examination of departmental documents and data and other publicly available information, to provide insights on impacts achieved by LETFF programs, including:

- final project reports
- research papers, scientific papers, technical papers produced under the LETFF programs
- project specific datasets and models
- broader literature on relevant themes.

A literature scan of research and scientific papers produced under the LETFF was undertaken due to the extensive body of documentation produced. A scan of 496 publically available reports matching key search criteria was undertaken to provide insights into the impact of the LETFF

programs. This ensured an appropriate breadth and depth of documents were reviewed across the LETFF programs.

Key document sources included Department-held documentation, in addition to data, reports and documentation held by:

- s22
- Global CCS Institute (GCCSI) data and documentation
- CO2CRC
- CSIRO
- Geoscience Australia.

2.2.4 Citation analysis

The project has involved a citation analysis of the 496 program publications identified in a literature scan up to 29 May 2019 to gauge the extent to which knowledge transfer has occurred as a result of the LETFF programs. The citation analysis involved:

- cited reference analysis – the number of times that research publications produced by the LETFF programs have been cited in journal articles or scientific publications based on Google Scholar data.
- publication use – the number of times that research publications produced by the LETFF programs have been accessed or requested online (where this data was available).

The results of the citation analysis were then triangulated with semi-structured interviews and results from the online questionnaire.

2.2.5 Case studies

Case studies of individual LETFF projects were developed from across the LETFF programs. This enabled the identification of general findings about the LETFF program. Case studies were developed from primary and secondary data sources, and illustrate the extent to which specific projects have contributed to the achievement of focus outcomes. Two case studies were developed for each program, with the exception of the LETDF program.

Case studies are outlined in Appendix D.

2.3 Limitations of methodology

The focus of this project is an impact evaluation of specific short and medium-term outcomes of the LETFF programs. Specifically, the intent is to assess the impact of the LETFF programs on increasing knowledge, skills and capability, and on improving industry understanding of LETFF. The project has not sought to assess the extent to which the LETFF programs have achieved any other medium or longer-term outcomes.

The qualitative data presented in this report reflect the opinions and perceptions of stakeholders engaged during the evaluation. These opinions and perceptions are presented as originally communicated. Stakeholders engaged in this evaluation have all had direct involvement in the LETFF programs. Stakeholders, by virtue of their involvement in the LETFF programs, may have had an inherent bias in their view of achievements and outcomes.

This evaluation has not engaged any stakeholders external to the LETFF programs, such as representatives of alternative technologies or programs.

The project has been limited by the significant lapse in time since the commencement of the LETFF programs and subsequent implementation. Specific issues that limited this evaluation include:

- the natural turnover of program staff; the Deloitte team was unable to engage with departmental stakeholders who had been involved in the programs at inception
- the natural turnover of participating industry and academic stakeholders; many key project proponent staff and external expert advisors have subsequently left their roles and/or organisations, meaning the Deloitte team was unable to speak to stakeholders from across all projects and activities. As such, only a sample of relevant stakeholders could be reached for the purpose of the evaluation.

3 Contribution to knowledge, skills and industry understanding

Key findings:

- The LETFF programs **have significantly contributed to increasing knowledge, skills and capability, and improving industry understanding of LETFF in Australia.** Overall, Australia has the research and engineering capability to develop commercial scale LETFF projects.
- Australia now has:
  - **a mature knowledge base** with multiple industry participants with knowledge of LETFF, supported by a broad body of research covering multiple technologies
  - **a moderate level of domestic skills and capability**, with more advanced expertise within a number of organisations in relation to specific LETFF, most notably CCS
  - **a moderate industry understanding** of the technical and practical feasibility of specific LETFF under a range of processes and conditions, but further advances in understanding will require deployment.
- A significant body of research has been delivered across the full spectrum of LETFF activities - the critical research and development and technical barriers are considered to be largely settled for CCS.
- Australia's pool of research and technical skills and capabilities is considerably larger, more developed and vastly more experienced relative to prior to commencement of programs.
- Research capabilities are more advanced than industry capabilities. Deployment of LETFF is required to further advance industry skills and capabilities.
- There is a risk of Australia losing the skills and capabilities developed if momentum is not maintained given the global demand for skills and expertise.
- The LETFF programs have resulted in industry developing a detailed 'end-to-end' understanding of the engineering and design of LETFF, in particular CCS technologies.
- There is a consensus that the coal, energy generation, and oil and gas sectors have an understanding of the practical, technical and financial requirements necessary to deploy CCS.
- However, the absence of a commercial imperative to invest in emissions abatement remains the overarching barrier to LETFF deployment in Australia.

3.1 Overall contribution of LETFF programs

Overall, there is consensus among industry, government and academic stakeholders involved in the LETFF programs that these programs have significantly contributed to increasing knowledge, skills and capability, and improving industry understanding about low emissions technologies in Australia.

There is broad stakeholder agreement that the advances in Australia's understanding of LETFF and their implementation – particularly around geological subsurface storage – would not be where it is today in the absence of the LETFF programs (discussed in greater detail in Section 5.2).

Stakeholders highlighted that the LETFF programs have involved an incremental learning process for industry, academia and government. Individual project outcomes have contributed towards a broad portfolio of achievements, rather than one single, flagship success. Even 'failures' have

provided valuable learning opportunities and insights, with most stakeholders indicating the importance of discovering what didn't work to be just as important as knowing what works.

Australia is now considered to be 'deployment ready' from a technological perspective. Australia is considered to have a mature knowledge base, supported by a well-developed body of research, with moderate skills and capability across specific LETFF (particularly CCS), and considerable industry understanding of the practical and technical feasibility of LETFF under a range of Australian conditions. There is strong agreement across all stakeholder groups that the priority for LETFF is to shift to commercial-scale deployment. Figure 3.1 illustrates the shift in the level of knowledge, understanding, and capabilities since the commencement of LETFF as perceived by key stakeholders and reflected in available evidence.

Figure 3.1: Summary of evidence of perceived shift in Australia's LETFF knowledge, understanding and capabilities since 2005

High

Stage	State of knowledge	Understanding of technical and practical feasibility	Local industry skills and capability
5	Deep and broad sector knowledge throughout industry, supported by extensive body of research covering full range of LETFF technologies.	Extensive industry understanding of technical/pract cal feasibility of full range of LETFF technologies under full range of processes and condit ons.	World leading industry skills and capability located w thin a wide number of industry and research organisat ons and across the broad spectrum of LETFF technologies.
4	Broad sector knowledge across major ty industry part cipants, supported by large body of research covering large range of technologies.	Broad industry understanding of techn cal/practical feasibility of LETFF technologies under most industrial processes and condit ons.	Broad local industry skills and capability across a large number of industry and research organisat ons and a across the majority of LETFF technologies.
3	Sector knowledge is moderate, w th multiple industry part cipants having knowledge of LETFF technologies, supported by a moderate body of research covering multiple technologies.	Moderate industry understanding of technical/pract cal feasibility of LETFF technologies under some processes and cond tions.	Moderate local industry skills and capability, with expertise across a moderate number of organisat ons on a moderate range of LETFF technologies.
2	Sector knowledge is thin, w th only select industry part cipants having meaningful knowledge of LETFF technologies, supported by a small body of research focussed on one or two technologies.	Lim ted industry understanding of techn cal/practical feasibility of LETFF technologies under 1 or 2 industrial processes.	Thin but growing local industry skills and capabil ty, w th expertise located across a handful of industry and research institutions.
1	Sector knowledge relating to pract cal, technolog cal and scientif c use and implementation of LETFF technologies is minimal/non-existent.	No industry understanding of techn cal/practical feasibility of LETFF technologies.	Niche local industry skills and capability, with only lim ted expertise.

Low

Source: Deloitte Access Economics

The LETFF programs have contributed to providing Australia with a detailed 'end-to-end' understanding of CCS, with stakeholders agreeing that the major research development questions and technological barriers have been largely settled and overcome. The LETFF programs have contributed to a clear understanding of the 'pathway to deployment' for LETFF and in particular CCS, including:

- the capture, transport, storage and injection technologies involved
- the costs and timeframes involved
- which technologies to deploy and under what conditions
- the locations and suitability of storage sites where technologies can be best deployed.

3.1.2 State of knowledge, capabilities, and understanding prior to commencement

Prior to the commencement of the LETFF programs, stakeholders reported Australia's knowledge and understanding of LETFF as predominantly conceptual and theoretical in nature. Understanding of how LETFF might be practically implemented was very limited, although it was noted that the oil and gas sector had a deeper understanding than other sectors, given the integral nature of drilling

in this sector. Overall, stakeholders reported that Australia, in general, had limited knowledge and understanding of:

- the location, capacity and sub-surface condition of geological resources (both onshore and offshore)
- long-term stability of geological resources and how they would react with CO_2
- different emission capture technologies and application to Australian conditions and industrial processes
- the behaviour of CO_2 plumes under different sub-surface conditions, and how to model the behaviour of CO_2 plumes
- the behaviour of CO_2 during transportation
- the end-to-end engineering and design of capture and storage technologies
- the full life-cycle costs of designing, building and operating commercial-scale LETFF.

Additionally, there was no arrangement in place to structure the existing knowledge base, to direct the advancement of new research, or to provide a knowledge-sharing platform between government, academia and industry. Stakeholders described Australia's knowledge-base as follows:

> *"… we didn't have a good idea of where the basins were. We didn't know much about the capture technologies, we didn't know if there was Enhanced Oil Recovery potential" –* Academic/research stakeholder.

> *"…there was theoretical knowledge, but less knowledge of [how] it [will] actually work in practice. [There was] a gap in the knowledge in terms of the application –* Government stakeholder.

> *"Go back probably 20 years, I would say that the Australian state [of knowledge] was developing. I wouldn't say it was embryonic, I'd say we were better than embryonic, but I think we were developing…. We were by no means near deployment-ready." – Academic/research stakeholder.*

This is not to say that Australia did not have a meaningful understanding of LETFF relative to other developed countries – such as the European Union, the U.S., the U.K., or China. On the contrary, stakeholders interviewed reported Australia's academic and scientific research community had pockets of recognised world-leading skills and expertise. Examples identified by stakeholders include:

> *"Geoscience Australia did some very early work in geological storage… very basic basin work to get some capacity work [back] in the 90s." –* Academic/research stakeholder.

> *"Geoscience Australia had been working toward CCS aspects as well and then we had CSIRO… CSIRO had been working on capture technologies at a small scale across a few sites…. There [were] capture engineers at Monash and Melbourne Universities… so that knowledge was there at a research phase." –* Academic/research stakeholder.

Within industry, however, there was a lack of the technical and practical type skills necessary for deployment and implementation – such as engineering and operational type skills. As noted by some stakeholders:

> *"… it would have been the researchers and not industry in those early days that had the expertise or understanding as well." –* Commonwealth Government stakeholder.

> *"… not as much as the practical engineering because it hadn't been deployed in Australia… not enough for a full industry, which is what we very rapidly found out when the flagship projects were launched there just weren't enough people to do all the work and so what we had is the same people doing a lot of the work…" –* Research stakeholder.

Across industry, there were also certain sectors that were more advanced in their understanding of and engagement with LETFF than others. Stakeholders singled out the Oil and Gas sector, in

particular, as having well-established understanding and capabilities relating to carbon capture and storage (CCS) technologies:

> *"…the Oil and Gas industry in 1999… they were fine. …injecting CO_2 and withdrawing gas from the subsurface, this is their daily bread…these guys have been doing EOR [Enhanced Oil Recovery] for 40 years. They have been injecting CO_2 for 40 years, they know how to do this."* – Academic/research stakeholder.

> *"… [the Oil and Gas industries] were already way up the learning curve both in terms of capture technology and in terms of injection…"* – Industry stakeholder.

In contrast, other emissions-intensive industries had yet to commence investigating the potential of LETFF in detail. In particular, the coal, energy generating, industrial (e.g. steel, concrete, and fertiliser) and agricultural sectors had yet to meaningfully investigate and engage in the development of low-emission, abatement, or monitoring technologies emission abatement and capture technologies. As some stakeholders noted of these sectors:

> *"… there wasn't necessarily much appetite to engage… there wasn't a significant driver… until I suppose the carbon taxes and things came in at that time.… as far as I understand industry weren't totally engaged."* – Commonwealth Government stakeholder.

> *"…the electricity sector has traditionally been happy to produce electricity and run their coal-fired power stations…the big issue for them is that they went from a business of mechanical engineers to a business of chemical engineers [to understand LETFF] and that was a big problem for them. They are low-risk engineers and they had to move into a high risk [investment]."* – Industry stakeholder.

3.1.3 State of knowledge, capabilities, and understanding today

Today, stakeholders report that the breadth and depth of Australia's knowledge, capabilities and understanding of LETFF, in particular CCS, is significantly greater than it was prior to the commencement of the LETFF programs. Overall, stakeholders reported significant improvements in Australia's knowledge and understanding of:

- the 'end-to-end' of the implementation of low-emissions technologies, including:
  - integrating low-emissions technologies with existing production systems
  - proving low-emissions technologies under Australian conditions
  - cost discovery of implementation
  - safety and environmental implications
  - regulatory approvals process
- monitoring and measuring greenhouse gas emissions
- Australia's geological subsurface storage potential and capacity, including:
  - the importance of subsurface storage in the CCS process
  - identification of suitable subsurface storage locations, and their potential capacity
  - dynamic modelling the geological subsurface behaviour of CO_2.

The consensus among stakeholders from across industry, government, and academia is that Australia's knowledge and expertise is now well-past the conceptual and theoretical R&D phase. Australia now possesses the research and technical foundations, including an understanding of the technical challenges, costs, and risks to progress to commercial-scale deployment. Australia is considered to 'hit above its weight' with respect to LETFF on a global stage. As noted by stakeholders:

> *"… in Australia, we have a range of stakeholders that are probably world leaders in terms of understanding the whole value chain of CCS, whether it be understanding capture technologies inside the CSIRO… they are world leaders and they are winning grants from other countries at the moment. I think that monitoring and storage activities … the CO2CRC are world leading … I think we have a much better understanding of the underground storage potential in Australia, both onshore and offshore, more work to be done in that space, but when you compare 10 years ago to now… we have made great progress on the technical front of understanding CCS and I don't disagree with some people who have said we have conquered the technical barriers."* – Commonwealth Government stakeholder.

> *"… we have done all the engineering to the point of construction, so from not even knowing which technology to choose, to now having chosen a technology and done all the upfront engineering, partnering with the technology providers, so that a construction decision can be made with, actually can be made today if we had the money. … That's actually been a dramatic shift"* – Industry stakeholder.

However, the advances in knowledge, skills and capability and understanding have been more concentrated in certain sectors than others. In particular, there was consensus among stakeholders that the advances in knowledge and capabilities in the academic and scientific research community far outweighed advances in the coal, energy generating and industrial sectors. As noted by a stakeholder:

> *"… the skills level of the academic community has indeed increased, but it's the academic skills level and not the industrial deployment skills level…"* – Industry stakeholder.

Despite the gains that have been made over the last 15 years, there are gaps that remain and new gaps have emerged. Overall, stakeholders identified the following gaps:

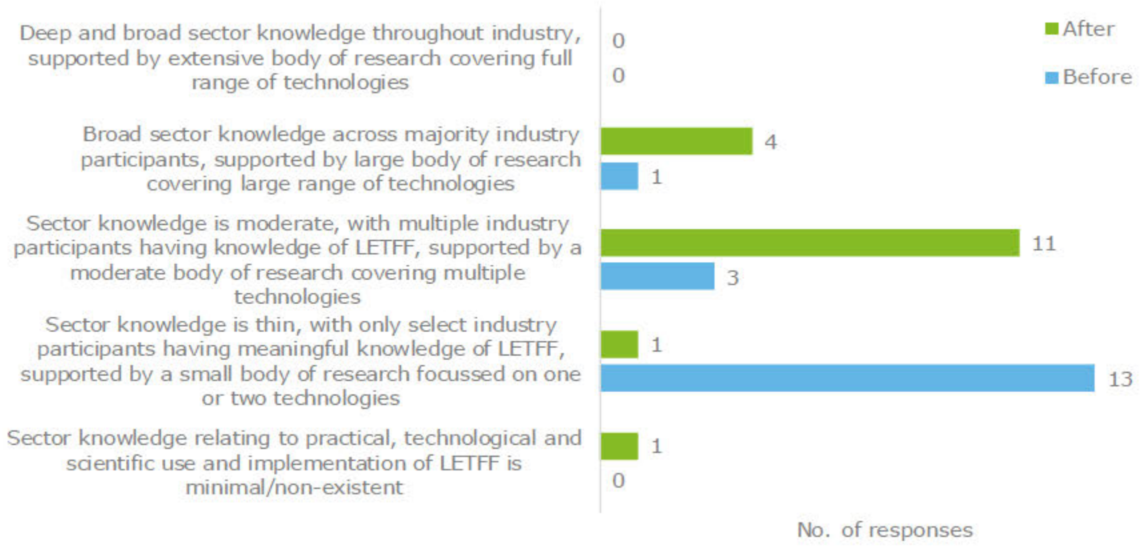
- the need to consolidate the knowledge and understanding of LETFF gained to date
- improving the accessibility, dissemination and communication about LETFF across industry sectors and the broader community
- detailed local and site-specific understanding of suitable onshore and offshore subsurface storage potential and capacity
- demonstration and deployment of LETFF on an industrial-scale, and the absence of an established CCS industry in Australia
- lack of experienced engineering skills and capabilities (mechanical, electrical etc.) for the industrial-scale deployment and operation of LETFF and CCS technologies.

3.2 Generation of new research and knowledge

There was consensus among stakeholders interviewed that Australia's overall state of knowledge progressed from being perceived as 'thin' prior to the commencement of the LETFF programs, to a mature moderate knowledge base underpinned by a well-developed body of research across multiple technologies.

This view was supported by the findings of an online questionnaire of LETFF stakeholders. Chart 3.2 illustrates the perceived change in the overall state of knowledge and understanding with respect to LETFF.

Chart 3.2: Questionnaire responses on overall state of knowledge before and after the commencement of the LETFF programs



Source: Deloitte questionnaire, n = 17

In addition to the improvement and expansion of the domestic skills base, the LETFF programs are attributed with having generated a range of new and original research and technical innovations. These include outputs such as:

- **Data tools** – geological seismic data, atmospheric measurement data, and technical test data
- **Modelling tools** – geological subsurface storage mapping, models of CO_2 subsurface behaviour, energy market modelling, as well as financial models of commercialisation
- Technological **innovations** – digital drill core technology s22
- **Methodological improvements** – improved methods for monitoring greenhouse gas emissions, technical operation methods that improve efficiency or safety, project management methods that improve the up-scaling and commercialisation of technologies
- **Formation of new relationships** – the value of the new relationships formed between industry, government, and the academic and scientific communities, as well as relationships formed between these communities in Australia with other people, communities and institutions overseas.

These provide the foundation tools and resources for industry and government to further invest in LETFF and CCS technologies with greater certainty in regard to the costs associated with deployment and ongoing operation, safety and environmental considerations, and the efficiency of production.

In addition to the above, the LETFF programs have contributed a significant body of **publications,** including academic journal articles, discussion papers, PhD dissertations, conference presentations, government policy documents, and interim and final project reports.

The GCCSI also contributed to the knowledge, skills and industry understanding achieved through the LETFF programs. The GCCSI is an important contributor to research and has an extensive repository of program reports and datasets. It is noted that the Commonwealth Government was instrumental in establishing the GCCSI.

3.2.2 Examples of the types of innovations and knowledge generated

While a rigorous and accurate stocktake of the new research and knowledge generated is beyond the scope of this report, Table 3.3 lists several key innovations developed across the LETFF programs identified by stakeholders.

Table 3.3: Examples of key innovations attributable to LETFF programs/projects

Title (LETFF project)	Description
s22	
Seismic monitoring fibre optic cable technology (CCS Flagships program – Otway Geological Storage and Demonstration Project)	The project involved the development of seismic monitoring fibre optic technology to enhance the performance of seismic monitoring of drills. The technology has effectively replaced traditional geophone technology and significantly reduced the cost of undertaking seismic analysis. *"…with the funding that we have received from the LETFF and a combination of work with experts from Curtin* [University] *and also internationally, we are now at the point where the performance of these fibres is substantially better than these geophones. Now, that all sounds very technical, but what it means is we now have the ability to not have to put major infrastructure down these wells, we can do it through very cheap wells."* – Research stakeholder.
s22	

As reported above, the LETFF programs have generated a significant body of research. An analysis of 496 publically available publications associated with LETFF programs and projects, as well as the results of a citation analysis, are provided in Table 3.4 (below). Although generating published material was not an intended outcome of the LETFF programs, they provide an indication of the knowledge generated and of the understanding that has been disseminated.

s22

The citation analysis indicates the number of times that published materials have been cited in other domestic and international publications, providing an indication as to the extent that learnings and knowledge gained through the LETFF programs have been drawn upon and utilised in other research. Overall, the results indicate that the published material generated through the LETFF programs have been widely disseminated, and gone on to influence and inform a wider body of research and knowledge. This further supports stakeholders' observations of Australia as having world-leading research expertise and of the contribution of Australian expertise and knowledge internationally.

Table 3.4: Summary (broad) of LETFF program and project publications

LETFF program/ project	Publications No.	Publications %	Scholarly articles (as a share of publications) %	No. of citations	Ave. citations per publication
CCS Flagships	65	13%	2%	170	2.6
s22					
LETDF	23	5%	39%	1,105	48.0
s22					

Source: Deloitte Access Economics

Notes: These estimates only include publically available publications; Scholarly articles are considered to be publications that appear in peer-reviewed academic or scientific journals.

Despite the plethora of publically available published materials, many materials and information remain undisclosed. There are many more publications that are held internally by government departments and scientific agencies, industry associations, or are held by 'pay walled' repositories (e.g. the CO2CRC). There is a perception among stakeholders that this acts as a constraint on the transfer of knowledge and the wider dissemination of learnings from one project to another, and is a barrier to the commercialisation of low-emissions technologies and to the establishment of a CCS industry in Australia. s22

s22

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Another stakeholder acknowledged that knowledge of the published information available is dependent on informal personal and community networks. That is, information sharing is about 'who you know':

> *Do we have some nice summary, not that I am aware of … it is not on a central connected basis… The answer is an informal kind of network of people know each other, which is not ideal for information sharing."* – Commonwealth Government stakeholder.

When done right, however, effective information sharing with the wider public is credited with supporting community engagement and enabling the future deployment of LETFF. As one stakeholder remarked:

> *"… the CO2CRC has done a marvellous job in addressing public concerns and public education with their Otway site. It is regarded as one of the world's best practice in that region."* – Research stakeholder.

3.2.3 Summary of the intangible forms of knowledge generated

Stakeholders also identified the importance of the value of less tangible outcomes that were generated as a result of the LETFF programs.

Stakeholders widely acknowledged that the LETFF programs have encouraged collaborations between governments, industry, and the academic and scientific communities within Australia. Stakeholders from each of these communities identified the collaborative nature of the LETFF programs as having an immense benefit for creating networks amongst groups that were unlikely to have otherwise engaged with one another.

For government, the deepening of relationships with industry and the academic and scientific research communities is credited with contributing to improved decision-making, in terms of informing the formulation of regulatory and legislative frameworks. The Gorgon Carbon Dioxide Injection project is an example of where the LETDF facilitated information sharing between the Commonwealth Government and industry partner Chevron, and generated an improved and informed policy outcome. One industry stakeholder noted the role of Chevron in advising and informing the development of the Offshore Petroleum and Greenhouse Gas Storage Act 2006 and the broader regulation of CCS:

> *"a lot of the federal generic legislation in this space comes from lessons learned from Gorgon, and that model has been picked up by a couple of other States."* – Industry stakeholder.

In turn, development of the *Offshore Petroleum and Greenhouse Gas Storage Act 2006* is credited with enabling industry to consider offshore CCS opportunities and promote the role of other LETFF projects, such as CarbonNet. As noted by one stakeholder:

> *"… it's quite ground-breaking… the regulatory framework that the Commonwealth has put in, because obviously that's the lever that* [government] *have responsibility for, so the Offshore Petroleum and Greenhouse Gas Storage Act has really I think incentivised and given industry a mechanism to at least put offshore CCS in their repertoire and that's obviously being exercised now through CarbonNet, they wouldn't have done that without that act."* – Commonwealth Government stakeholder.

The LETFF programs are also credited with establishing valuable international collaborations between Australia and several countries developing low-emissions technologies – such as, the U.S., the U.K., the European Union, Japan, and China. In particular, stakeholders identified the value of the relationships formed through the Australia-China Joint Coordination Group funded through the CCS Flagships program. These relationships enabled Australia to access technology and expertise that would have been extremely costly to develop domestically. In return, Australia provided its expertise of regulatory frameworks, as well as project management methods (e.g. delivering projects safety, on time, and on budget).

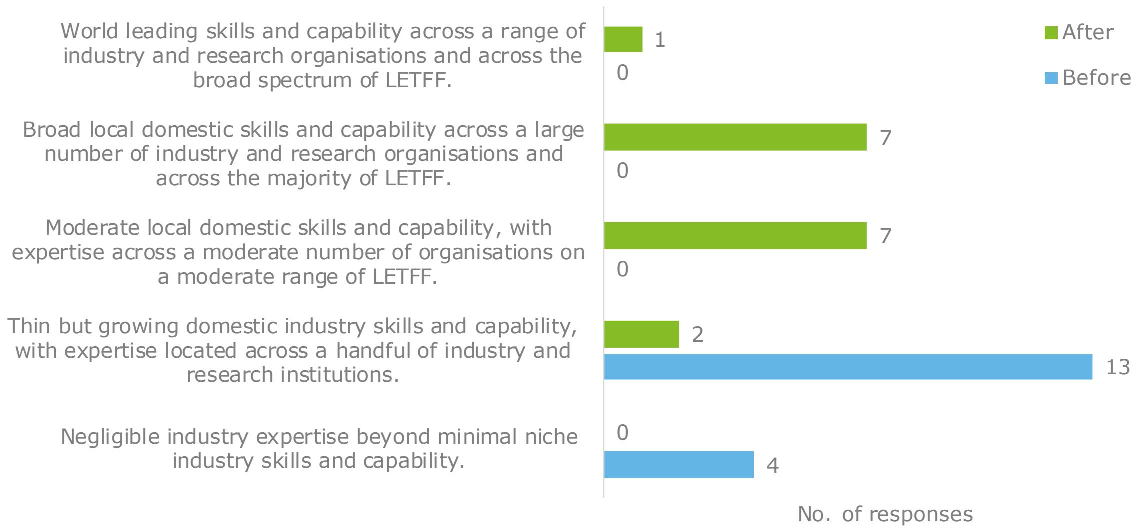
As noted by one stakeholder:

> *"the skills transfer was really quite significant, not just for the Australian government and other stakeholders in regard to accessing Chinese know-how, and how they do it, but the Chinese certainly learned from us too."* – Industry stakeholder.

3.3 Development of greater domestic skills and capabilities

In general, stakeholders interviewed perceived that the LETFF programs had contributed to a considerable increase in skills and capabilities. Australia's overall state of skills and capabilities progressed from being perceived as **'thin but growing'** prior to the commencement of the LETFF programs, to moderate with expertise across a range of industries and research organisations. This is supported by the findings of the online questionnaire (see Chart 3.3).

Chart 3.3: Questionnaire responses on the level of domestic skills and capabilities with respect to low-emissions technologies before and after the commencement of the LETFF programs



Source: Deloitte questionnaire, n = 17

As prefaced earlier, the LETFF programs are considered to have contributed to improving and expanding the capacity of academic and scientific research skills at the key research institutions – such including as, CSIRO, and Geoscience Australia, Melbourne, Monash and Newcastle universities, as well as and CO2CRC, the Global CCS Institute, s22 Australian Petroleum CRC, ACARP and COAL21. Overall, stakeholders agreed that the skills and capabilities developed across academia were far more advanced than industry. As remarked by stakeholders:

> *"… a lot of the money has gone to the research group, so they are far more skilled than the engineering is because they have had the funding to do the research … it's going from being scientists wanting to do the research to now scientists having done the research."* – Industry stakeholder.

> *"… I would say that the scientists are ahead of the engineers because the scientists have just been doing this stuff, but they can't do what engineers do and the engineers need…the time is not for R&D, the time is for doing and the scientists will then have access to real data rather than lab data."* – Industry stakeholder.

However, stakeholders recognised that Australia's technical and engineering capabilities have also developed and improved through the LETFF programs, with Australia now possessing the technical and practical engineering skills necessary for deployment and implementation. There was a common view that commercial deployment is required to enable any further advancement of industry skills and capabilities. As described by one stakeholder:

> *"… we had the engineering infrastructure, but with inexperience in this technology. … at least now the engineering capability is ready to take that next step to implement, but until we have implemented, we haven't really learned all the lessons."* – Industry stakeholder.

Some stakeholders reported that Australia has developed world-leading skills and expertise through the LETFF programs, and those skills are now sought by the other countries:

> *"We actually got a group who we thought were the world's best reservoir engineers come over from University of Texas and … they felt the reservoir engineering capabilities of CO2CRC and our research members, such as CSIRO and Curtin* [University] *are the best in the world"* – Academic/research stakeholder.

> *"… we basically trained up all the CCS specialists in Australia and now they have gone all around the world."* – Research stakeholder.

Within industry, the LETFF programs also contributed to an 'up-skilling' and expansion in the capacity of technical and practical engineering type skills, particularly in the industry sectors that were most engaged in LETFF – that is, the coal mining, and oil and gas sectors. In addition, the LETFF programs prompted a shift in the composition of the types of specialist skills demanded. As industry began to investigate the feasibility of integrating LETFF within existing processes, stakeholders identified increased demand for a range of engineering disciplines across the oil and gas, coal and energy generating sectors. As one stakeholder noted:

> *"We need engineering, so we need design…electrical, we need mechanical, we need ventilation specialists, we need mining specialists… risk specialists…"* – Industry stakeholder.

Within the energy generating sector, there was also an increased demand for specific engineering skill sets that were previously not associated with that industry sector, particularly chemical engineering capabilities.

The composition of skills required also shifted as knowledge and understanding about the importance of geological subsurface storage became a key priority. This resulted in a shift toward and expansion of geotechnical engineering capabilities across industries.

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An exception to this is the dissemination and transfer of technical skills from the academic and scientific research communities to government. A range of stakeholders noted that the Commonwealth Government was able to readily access and draw upon specialist technical and scientific skills, particularly from CSIRO and Geoscience Australia. This supported better informed decision-making.

However, several stakeholders noted the risk of potentially losing the specialist expertise built up over time to other countries – and with it one of key Australia's competitive advantages internationally – in the absence of the eventual deployment of LETFF.

3.4 Industry understanding of low emissions technologies

In general, stakeholders perceived that there was an increase in industry understanding following the commencement of the LETFF programs, albeit from a low base. Overall, stakeholders reported that LETFF programs enhanced industry's understanding with respect to:

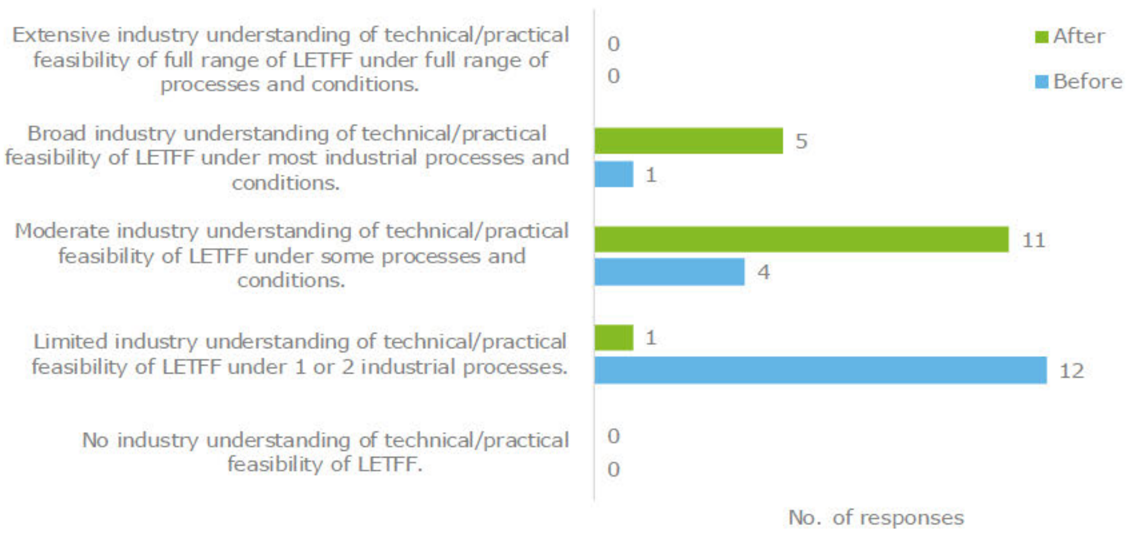
- the appropriateness and effectiveness of particular technologies at an industrial-scale
- the importance of geological subsurface and storage conditions to successful deployment
- greater certainty about the costs, timeframes, and risks involved in commercialisation.

As described by one industry stakeholder:

> *"When you look at all the work we have done to support various demonstrations... I can't help thinking that we are better placed than many of the other countries or most of the other countries when it comes to knowledge to deploy."* – Academic/research stakeholder.

Using the questionnaire responses of stakeholders, Chart 3.4 illustrates that industry understanding is perceived to have gone from being limited to now being at a moderate to broad level of understanding.

Chart 3.4: Questionnaire responses on industry understanding of technical and feasibility of low-emissions technologies before and after the commencement of the LETFF programs



Source: Deloitte questionnaire, n = 17

There is a consensus among stakeholders that the LETFF programs have contributed to industry now having a detailed 'end-to-end' understanding of the engineering and design of LETFF, in particular CCS technologies. Large projects such as CarbonNet and SouthWest Hub, for example, were identified as having provided industry with valuable practical and technical insights about the pathway to large-scale commercialisation, in terms of cost-discovery and the engineering design process involved. As stakeholders noted:

> *"... projects like the CarbonNet project, like the Southwest Hub project really did allow us to get a better understanding of 'yes there is a theoretical capability to put CO_2 in these places, but here are the real commercial understandings and then capabilities that we need to improve on to do that effectively"* – Academic/research stakeholder.

> *"The [projects] that have probably added most to the knowledge set are the ones where, for example, CarbonNet is really testing the whole end-to-end from the technical, regulatory through to the commercialisation."* – Commonwealth Government stakeholder.

More important to industry than any single LETFF project, however, is the combined and cumulative 'end-to-end' understanding that has been gained from the portfolio of LETFF projects –

'successful' and 'unsuccessful' projects. That is, the value of the iterative nature of the journey that industry and government have been on, and the importance of the learnings from each successive step at informing the direction of the next. As two stakeholders remarked:

> *"…as a complete package of knowledge, as they have gone from step to step to step, we know what we need to do now. So, I will call that a great success … if you are only involved at each of the little steps and that's all your involvement is, you can see each one as a failure because it didn't reach the grand scale, but in combination they have honed in on and now we know exactly what we need to do. … We have the luxury of staying with this whole landscape for the last 12 years and taking this whole picture to learn at each of the different steps."* – Industry stakeholder.

> *"… it's quite easy to look at the individual components and say we haven't actually achieved much, but for those that are able to look across the broad suite of projects and programs around capture, storage, transport, understanding where you might drill, understanding what you might retrofit, … there is a view that we have a very compelling understanding now across the implementation of CCS if you put it altogether, which we didn't have before…"* – Government stakeholder.

Even those LETFF projects widely perceived as failures (such as ZeroGen) or those perceived as being challenged and delayed (such as Gorgon), have provided industry with crucial learnings. ZeroGen, for example, despite its perceived failure, is credited with providing industry crucial learnings about the commercial viability of Integrated Gasification Combined Cycle (IGCC) technology (see Box 3.1).

Box 3.1: Learnings from ZeroGen

ZeroGen project: a successful failure
Prior to the commencement of ZeroGen IGCC technology was considered to be the highest efficiency for low-emission coal energy generation:

> *"[IGCC Technology] was at that time seen as being the big technology, that is kind of like the biggest break, and the reasons for that was its high efficiency, it was sort of like the big bang theory. It's the highest efficiency, the biggest one, it's going to make the biggest difference at a cost. So on a CO_2 stored dollar basis, it was going to be the way to go."* – Industry stakeholder

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While industry had a 'desktop-understanding' of Australia's geology and of the potential for subsurface storage sites, very little consideration had been given to the detailed understanding of the potential capacity and suitability of these basins or reservoirs for the purpose of storing CO_2. Understanding the geological subsurface for the safe storage of CO_2 is now considered by industry as one of the key components, along with low-emission and capture technology, to the successful deployment of LETFF on a commercial scale. However, significant gaps in industry understanding of site specific geological conditions and requirements exist. Geological considerations as a critical area of future research is explored further in Section 5.3.

Industry understanding with respect to methane abatement technologies within coal mine sites has not progressed as significantly as that of CCS. Overall, significantly more work is required across the research, design, technical testing and demonstration of methane abatement technology to allow for the technology to progress.

3.5 CCS Flagships Research Development and Development (RD&D) fund

The CCS RD&D fund aims to reduce technical and commercial barriers to the deployment of large-scale carbon capture and storage projects by contributing new knowledge with respect to:

- Australia's understanding of its geological capacity to permanently store carbon dioxide
- enhanced understanding of how CO_2 plumes behave in Australian conditions
- improved knowledge of Australia's CO_2 supply chain requirements
- harnessing international knowledge and expertise and building international relationships that progress global understanding of CCS
- lowering the cost of technology adoption and deployment in Australia.

The CCS RD&D fund has yet to be completed, and is beyond the scope of this evaluation. However, a summary of the intended knowledge to be generated across the CCS RD&D fund is summarised below.

Table 3.7: Summary of intended knowledge to be generated from CCS RD&D fund

Project	Project description	Intended knowledge to be generated
Northern Australia CO_2 Store	This project builds on work carried out by Geoscience Australia's regional assessment of the CO_2 storage potential in the Petrel Sub-Basin (PSB) in NT. The project objective is to de-risk the area of interest within the PSB.	• Detailed subsurface knowledge of the PSB and local geological properties. • Understanding of the geomechanical, geochemical and geophysical properties of the PSB, and behaviour of CO_2 in the PSB. • Detailed assessment of equipment and facilities required to transport CO_2 from Darwin to the PSB storage. • Determination of well numbers to accommodate CO_2 production.

Project	Project description	Intended knowledge to be generated
CTSCo Integrated Surat Basin CCS project	This project delivers aspects of the CCS demonstration project that will enable a Financial Investment Decision for construction and deployment during 2018/2019, including technical, social and permitting aspects.	• Greater understanding of construction and deployment requirements of CO_2 test injection facilities. • Greater understanding of the regulatory pathway for onshore storage of CO_2 in Australia. • Greater understanding of the financial viability of onshore storage of CO_2. • Greater understanding of community engagement with respect to CCS.
Australian Subsurface Carbon Sequestration Simulator	This project works towards improved understanding of how CO_2 behaves during geo-sequestration in the Australian subsurface and how this behaviour can be monitored.	• Improved simulation, forecast and monitoring of CO_2 plume behaviour. • Enhanced geophysical imaging of CO_2 plumes.
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Improving safety and efficiency of CO_2 pipelines	Development of fracture and dispersion models to enhance design and reduce risk associated with CO_2 pipeline construction and development.	• Validated fracture arrest model/software and design requirements. • Validated dispersion model • Updates of Standards and Recommended Practices covering CO_2 pipelines • Development of cost benchmarks for CO_2 pipeline.
Surat Deep Aquifer Appraisal project	Assessment of real optionality for industrial scale CCS deployment linked to south-east Queensland stationary emissions generators.	• Provision of significant technical and cost information into the public (pre-competitive) domain to assist with ultimate de-risking and planning of projects. • Greater understanding of techno-economic and other deployment critical issues. • Enhanced methodologies for community engagement about energy choices (and within that how best to engage on CCS). • Discovery of the degree and criticality (costs, timing risks) to which CCS can be a real mitigation option for GHG abatement in Eastern Australia.

4 Factors contributing to achievement outcomes

Key findings:

- At commencement, the LETFF programs were underpinned by clear policy direction and settings, support across Commonwealth and State governments, and a significant funding commitment across a suite of programs and projects – factors that were critical to the achievement of outcomes.
- Other contributing factors to the achievement of outcomes included:
  - establishment of partnerships between government, industry and academic stakeholders
  - the direct financial involvement of the coal industry in maintaining an industry-focused research agenda
  - establishment of a portfolio of LETFF projects to maximise learnings and the probability of success.
- Changing, uncertain and inconsistent policy settings are considered the **primary factors** hindering achievements and progress across the LETFF programs. This resulted in significant **loss of confidence across industry and a loss of momentum in advancing LETFF**.

  The unexpected complexity of LETFF, inflexibility of funding agreements, regulatory uncertainty and insufficient readiness on the part of the Commonwealth and State governments have also hindered achievements and progress across the LETFF programs.

  The absence of a clear commercial imperative on the part of industry to invest in carbon abatement remains the single largest barrier to the commercial development and deployment of LETFF.
- Knowledge gained throughout the LETFF programs could have been more effectively disseminated to the broader public. Barriers to knowledge sharing and access to information have contributed to a low level of public understanding and acceptance of LETFF, and in particular CCS, and represent a barrier to the deployment of LETFF.

4.1 Factors that contributed to achievement of focus outcomes

There was consensus among stakeholders that the manner in which the LETFF programs were established was a major factor contributing to the achievement of focus outcomes (i.e. knowledge, skills and capability, and improved industry understanding). Specifically, stakeholders noted that, at commencement, the LETFF programs were underpinned by clear policy direction and settings, support across the Commonwealth Government and participating State governments, and a significant funding commitment across a suite of programs and projects.[2] Stakeholders agreed that these factors provided a clear signal of government policy intent and focus to industry, and gave industry the confidence to participate and invest in the programs. As noted by stakeholders:

> *"The greatest assistance was right at the beginning when there was a common urgency, a common understanding that we all needed to do something. And by that, I mean the Federal Government, the State Government, and the industry."* – Industry stakeholder.

[2] The original Commonwealth Government funding commitment across the four LETFF programs was approximately $2.8 billion.

> "[A key factor was] *the early decision to allocate funds to a suite of programs and have sort of a champion in cabinet to push these sort of issues through and make it a priority. I think it then just follows that your domestic stakeholders know that they have got backing through the government in real terms as in funding, but also from a national priority perspective"* – Commonwealth Government stakeholder.

Many stakeholders also identified the partnerships established between government, industry and academic proponents as being critical to the achievement of focus outcomes. This led to meaningful engagement between academic, technical experts, policy makers and industry proponents across the LETFF programs. In turn, these partnerships helped maintain strong technical and research capabilities to support the LETFF programs:

> *"The access that we have had to government and industry to assist with our research program has been probably the most significant factor for us." – Academic/research stakeholder.*

In particular, **the direct financial involvement of the coal industry**[3] is considered to have been critical in maintaining an industry-focused research agenda. Stakeholders considered the industry-led research agenda to be contributing factor to the achievement of focus outcomes. As noted by two stakeholders:

> *"The manner in which the program is set up, means we have to have a combination of government and industry and researchers obviously. It allows us to not just do research for the sake of research, it allows us to understand what the industries' needs are, what the government's needs are, and do the appropriate technology development to meet those users' needs." – Academic/research stakeholder.*

> *"My job is to support demonstration, and this is very, very clear. I am greatly assisted by that because when a researcher comes to me with a good idea…I'm always able to take their idea and hold it up against this lens and say does this help deployment? If it doesn't help deployment I tell them "I'm sorry you have got a fantastic idea, but it doesn't suit my purpose." So, it's not that your idea is bad, it's just that I have a certain purpose and your idea doesn't fit here."* – Academic/research stakeholder.

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4.2 Factors that hindered achievement of focus outcomes

There was consensus among stakeholders that changing, uncertain and inconsistent policy settings were the **primary factors** hindering achievements and progress across the LETFF programs. Specific examples of changing and inconsistent policy settings identified included:

- removal of the carbon price regime following the commencement of the LETFF programs
- lack of a clear national strategy and statement with respect to LETFF, and in particular CCS
- changing and inconsistent policy settings no longer aligning with program objectives

[3] Support was focused through the former Australian Coal Association for Low Emissions Technologies Research and Development (ACALET R&D), now known as COAL21.

- government policy not adopting a technology 'agnostic' approach with respect to emissions abatement, with stakeholders noting that CCS projects were ineligible for funding from the Clean Energy Finance Corporation
- loss of policy direction over time resulting in general policy confusion among industry participants.

These issues **resulted in significant uncertainty and loss of confidence across industry, and a loss of momentum with respect to the advancement of LETFF.** As stakeholders noted:

> *"A lack of clear government policy (both State and Federal) on CCS hinders progression of the demonstration projects required for future large scale CCS to be assessed and ultimately progress."* - Industry stakeholder.

> *"We don't have that clear stable policy framework. We don't have that clear confidence in that framework to allow significant* [Industry] *investment."* – Academic/research stakeholder.

The changing policy settings also contributed to eroding industry engagement within the LETFF programs. Proponents no longer considered the investments to be a priority in the absence of clear policy direction. As one stakeholder noted:

> *"While the project staff were still very committed to the project, they did from time to time run into a bit of pushback from the operations staff at the mine site, because they are no longer quite as keen to have this project running at their site because there wasn't that financial impetus* [any longer]*."* – Commonwealth Government stakeholder.

There is a perception among many stakeholders that an insufficient understanding of the complexity of low emissions technologies at the commencement of the LETFF programs also hindered the achievement of focus outcomes. In particular, there is a perception that the Commonwealth Government lacked the necessary internal scientific and technical capabilities to accurately evaluate and assess the viability of projects proposed prior to the commencement of the LETFF programs. Insufficient understanding of the technical, scientific, engineering, regulatory and environmental challenges underpinning large-scale LETFF across government, industry and academia resulted in:

- unrealistic program and project timelines
- insufficient funding being committed to support development and deployment
- insufficient understanding of project financial and technical risks
- an implicit assumption relating to the commercial feasibility of geological resources.

Overall, this resulted in unrealistic program timeframes, costs and expectations. As noted by stakeholders:

> *"If you look at the CCS Flagships program, in some ways, that was too much too soon. The expectation that you were going to be commercial and up and running in 2013* [for example] *was unrealistic."*– Industry stakeholder.

> *"The challenges with some of this have proven to be … more difficult than first thought. So, Gorgon, for example, has ended up being a much, much larger project than was originally conceived. So, the original intent* [of the LETFF programs] *got the scale completely wrong."* – Commonwealth Government stakeholder.

Stakeholders also identified regulatory uncertainty and insufficient readiness on the part of the Commonwealth and State governments as a factor hindering the achievement of focus outcomes. Governments at both levels were ill-prepared in terms of regulation and legislation for the commercial implementation of technologies – particularly relating to the storage and monitoring of CO_2. Projects involving pilot drilling and site testing (such as CarbonNet in Victoria) required State government regulatory approval (and in the case of CarbonNet also Commonwealth Government approval due to offshore activities) before proceeding. These regulatory approval processes significantly impeded project timelines and presented considerable challenges to project proponents. As summarised by one stakeholder:

> *"It's more in the regulatory space that's been required than people realised. For example, on the CarbonNet project, there were all sorts of Victorian government approvals, but there are also Australian Government approvals because it is eventually going to be in the offshore domain… There are multiple approval processes and I think it's fair to say that's been very challenging."* – Commonwealth Government stakeholder.

A range of stakeholders noted that Commonwealth Government funding agreements, where project funds are tied to specific milestone dates and activities, don't adequately reflect the nature of industrial-scale projects. The inflexible nature of funding agreements were considered to have impeded and slowed project progress and achievement of focus outcomes.

A minority of stakeholders considered that the decision to allocate funding across a portfolio of LETFF programs and projects hindered program achievements. They perceived that greater progress towards the development and deployment of LETFF may have been achieved by focussing on a single or two LETFF projects in total. As one of these stakeholders noted:

> "[The Commonwealth Government] *spread the funding too thinly across several projects. There was only ever sufficient funding allocated for one CCS project. Running a competition* [a grant application process] *encouraging several projects to commence was ineffective and unrealistic"* – Academic/research stakeholder.

4.3 Impact of program design and implementation on achievement of focus outcomes

A majority of respondents to the online questionnaire considered that the level of funding allocated to the LETFF programs (82%) and project selection processes (59%) positively contributed to the achievement of outcomes.

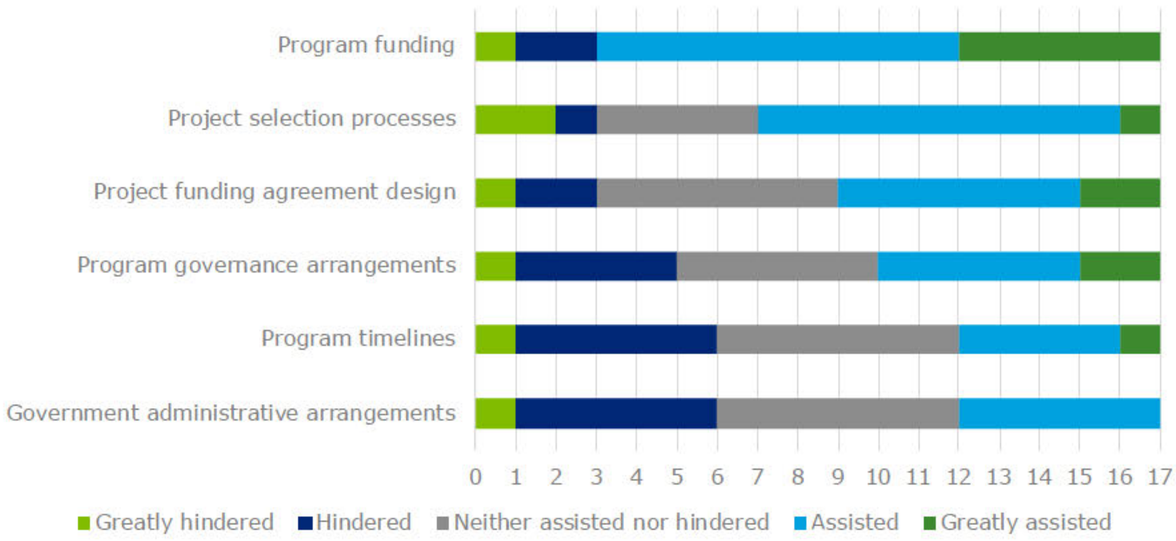
However, responses were more mixed with respect to the impact of program timelines, funding agreement design, administrative arrangements and governance arrangements on the achievement of outcomes (see Chart 4.1).

For example, while almost half (47%) of questionnaire respondents considered the design of funding agreements to have greatly assisted or assisted the achievement of focus outcomes, this view was not shared by all stakeholders. A range of stakeholders interviewed considered funding agreements to be inflexible, and a requirement to tie funding to specific milestones to be incompatible with large-scale industrial development projects. As noted by stakeholders:

> *The way all of these projects are setup, they can only take one step* [at a time]*. And therefore, the project has to wait until you have made a decision. There hasn't been that ability to take the next step after you've learnt something, change the plan a little bit, modify it to suit what you've learnt, take the next step, and having funding continue from there".* – Industry stakeholder.

> *"Here is $100 million go and do your first bit, and here is a $100 million go and do your second bit, and here is $50 million go and do your third bit. That is not the way to run a big project, you know, when BHP decides it is going to develop a mine, that is a $15 billion decision and they don't hand it out, you know, $100 million at a time. So I think the government has to think about a way on how it wants to support large-scale projects like this."* – Academic/research stakeholder.

Chart 4.1: Questionnaire respondents' perception on which aspects of the design of the LETFF programs contributed to the achievement of focus outcomes



Source: Deloitte questionnaire, n = 17

In addition to the above, many stakeholders noted during interviews that the 'removal' or clawback of program funding by the Department from projects deemed infeasible/unsuccessful adversely impacted the achievement of focus outcomes. Many stakeholders considered that this funding should have been reallocated to remaining projects or new funding rounds held to identify 'new' projects, rather than have such funding returned to consolidated revenue. As noted by stakeholders:

> *"The CCS Flagship Demonstration Program was crippled by the withdrawal of Commonwealth funds originally allocated to it."* – Industry stakeholder.

4.4 Barriers to the commercial development and deployment of LETFF

There was consensus among stakeholders interviewed that the absence of a clear commercial imperative on the part of industry to invest in carbon abatement remains the single largest barrier to the commercial development and deployment of LETFF. Key issues identified by stakeholders contributing to the absence of a commercial imperative included:

- lack of a clear, consistent national energy policy that addresses the role of LETFF and provides industry with sufficient long-term confidence to invest
- absence of Commonwealth and State government policy instruments that directly incentivise investment in emissions abatement
- significant cost of deploying commercial-scale CCS projects, noting that LETFF (and CCS in particular) has a particularly high cost relative to alternative emission abatement technologies
- investment risk is perceived to be high given current policy settings and uncertainty
- issue of third party risk remains unaddressed under current policy arrangements, specifically the issue of indemnifying storage and reservoir operators over the longer term.

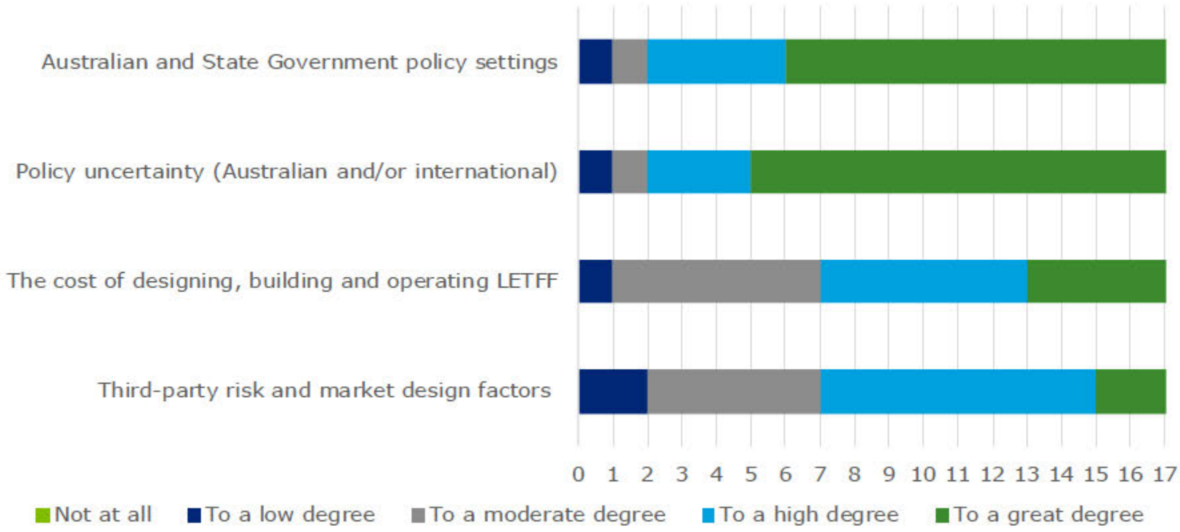
As noted by stakeholders:

> *"The issue with all of this is cost. The investments that are required to do these things* [LETFF] *at scale invariably seem to be much larger and the costs are much larger than originally envisaged."* – Commonwealth Government Stakeholder.

> *"You cannot see* [under current arrangements] *how any of these projects are going to be funded."* – Industry stakeholder.

Responses to the online questionnaire support the above findings. Questionnaire respondents identified existing Australian and State government policy settings (88% of respondents consider policy setting remain a barrier to a high or great degree), domestic and international policy uncertainty (88%), cost of LETFF (59%) and third-party risk (59%) as presenting the greatest barrier to the commercial deployment of LETFF (see Chart 4.2).

Chart 4.2: Questionnaire respondents' perception of the extent to which external factors remain a barrier to the commercial deployment of LETFF



Source: Deloitte questionnaire, n = 17

However, some stakeholders considered that some longer-term commercial drivers were already in place, and highlighted the decision by Chevron and its joint venture partners to invest in the Gorgon Carbon Dioxide Injection project. As one stakeholder noted:

> *"If you want to exploit Australia's offshore gas resources in say 25 years' time, you will have to deal with those emissions I think. I think that's going to be the world we are. So, I think that if you look at it through that lens, there is going to be a commercial driver."* – Commonwealth Government stakeholder.

Many stakeholders also identified the lack of a technologically 'agnostic' approach to emissions abatement as a barrier to the commercial deployment of LETFF. There was a perception among many stakeholders that LETFF was treated inconsistently to alternative technologies. For example, CCS projects are not eligible for funding under the Clean Energy Finance Corporation. As one stakeholder summarised:

> *"It's not about renewables versus CCS or renewables versus coal. It's about having a portfolio of solutions to reach your emissions targets." – Industry stakeholder.*

Stakeholders also identified that barriers to knowledge sharing and access to information may have adversely affected the broader public discourse and perceptions around LETTF. This has contributed to a low level of public understanding and acceptance of LETFF, and in particular CCS, and is considered a barrier to the deployment of LETFF by some stakeholders. All stakeholder groups recognised that the role of LETFF in abating emissions was not well understood by the general public, and that there was a broad public perception that the primary role of LETFF was to extend the 'life' of fossil fuels. There is a perception that this has contributed to hindering the deployment and implementation of LETFF. As noted by stakeholders:

> *"... most of the knowledge is sort of really been distributed amongst people closest to these programs and various industry stakeholders, but in terms of the broader community they have been consulted where they are directly affected, but I don't think the average*

> *Australian knows where the Carbon Capture and Storage is up to in Australia."* – Commonwealth Government stakeholder.
>
> *"… the CCS community and industrial sectors of Australia, we are very good at talking to ourselves about how great CCS is and how we are going to use that as a solution. We are hopeless at talking outside that group, outside of* [our] *comfort zone."* – Academic/research stakeholder
>
> *"I think both government and industry have done a poor job of enunciating the benefits of CCS. I think we are probably behind the eight-ball by now."* – Industry stakeholder.

Stakeholders also recognised that falling domestic demand for fossil fuels was a potential barrier to the deployment of large scale LETFF. While a broad range of emission-intensive industrial processes (such as fertiliser production, agriculture and smelting) have potential to support demand for LETFF deployment, stakeholders agreed that the key sectors (beyond the oil and gas sector) likely to underpin the initial deployment of LETFF were the coal and energy generation sectors. As one stakeholder noted:

> *"I think anything that is going to impact on coal production levels and demand for coal is going to then impact on the operating costs and financial considerations, and so it is going to have even more of a detrimental effect of looking at the capital costs of significant abatement investments."* – Commonwealth Government stakeholder.

5 Success, future research and role of government

Key findings:

- Overall, **stakeholders overwhelmingly consider the LETFF programs to be successful**. The LETFF programs have made significant contributions to increasing knowledge, skills and capability, and improving industry understanding of LETFF in Australia. These achievements **would not have been made in the absence of Commonwealth Government support.**
- Stakeholders consider that the Commonwealth Government's investment in LETFF programs **represents good value for money**, and **achievements are commensurate with the investment**.
- LETFF programs have directly contributed **to reducing the technical and commercial barriers** to the development and deployment of commercial-scale LETFF projects.
- However, the achievements and knowledge gained could have been more effectively communicated or disseminated among industry and the general public.
- Australia risks losing the significant gains in knowledge, and skills and capabilities established through the LETFF programs if Australia does not proceed to the commercialisation and deployment of LETFF.
- The critical underlying research and technical questions to deploying large-scale LETFF (and CCS in particular) have been addressed, however some targeted research would supplement and benefit research done to date.
- Stakeholders consider **there remains a critical role for Government** in supporting the development and implementation of LETFF. While there was no clear consensus from stakeholders interviewed, a majority of respondents to the online questionnaire considered the Commonwealth Government should continue to provide large-scale grants to support LETFF research and development.

5.1 Success of LETFF programs

Overall, stakeholders across all groups consider that the LETFF programs have been successful, and have made a significant contribution to increasing knowledge, skills and capability, and to improving industry understanding about low emissions technologies.

As reported above in Section 3, stakeholders consider that as a result of the LETFF programs Australia now possesses the requisite scientific and engineering knowledge, skills and industry understanding to develop and deploy large, commercial-scale LETFF projects. Through the LETFF programs, the key research and technological barriers to the deployment of LETFF have largely been overcome. Stakeholders noted:

> *"When you put all the projects on the map of Australia, show the different types of geology that we've got around Australia, and the different projects that we've* [delivered] *around Australia, the government has participated in a really good portfolio of projects"* – Industry Stakeholder.

> *"Industry in Australia has gone from not having a clue of what we are doing to now being able to say where we're going to put a drill or drill a hole, where we're going to store CO_2, the technology we're going to use, and to take that next step* [of deployment]*. So, has it* [the LETFF programs] *been successful? In my mind, absolutely."* – Industry stakeholder.

A key element contributing to the success of the LETFF programs has been the critical learnings gained by industry and government across the suite of programs and industry. In particular,

projects deemed 'unsuccessful' have provided valuable insights in progressing Australia's knowledge and understanding of LETFF. For example, the 'unsuccessful' **South West Hub** project yielded the following learnings:

- significant improvements to conducting and analysing seismic data, monitoring and modelling CO_2 plumes
- understanding how basin configuration and structural elements affected containment capabilities of a rock formation.

These areas of research were driven by the fact that the Eneaba Formation did not have the impermeable seal that other potential CO_2 storage sites had (for example sites on the east coast of Australia).

The majority of stakeholders interviewed consider that the Commonwealth Government's investment in LETFF programs represents good value for money, and achievements across the focus outcomes are commensurate with the investment made. In particular, stakeholders noted that the research undertaken has directly contributed to overcoming research and technological gaps and barriers with respect to LETFF. Stakeholders noted:

> *"In the research dimension…I think the returns have been immensely large. So, I think you know, yes, we've done a damn good job of research." – Academic/research stakeholder.*

> *"I think that there has been a pretty good return on investment for most of the projects under the LETFF. I think that there has been a couple of projects that haven't succeeded, but that doesn't always mean that that money hasn't been well spent…you can learn from the failure as well."* – Commonwealth Government stakeholder.

This finding was supported by the results of the questionnaire of LETFF program stakeholders, in which 71% of all respondents agreed or strongly agreed that the LETFF programs have achieved outcomes commensurate with the investment made. The questionnaire found that 71% also agreed or strongly agreed that the LETFF programs have directly contributed to reducing the technical and commercial barriers to deploying large-scale LETFF projects.

However, some stakeholders were more cautious when reflecting on the success of the LETFF programs, noting that Australia still lacks a pipeline of large-scale LETFF projects. As one stakeholder noted:

> *"Yeah, so it's really quite hard to answer* [the question of success] *because I think again from a technical geoscientific perspective, I think that's clearly been a success in terms of that technical scientific knowledge. But for that [approximately $750 million] again we don't really have a pipeline of CCS projects or kind of big things that are going to make a difference to emissions for Australia."* – Commonwealth Government stakeholder.

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Stakeholders also perceive that the knowledge and learnings gained from across the LETFF programs have not been sufficiently communicated to the general public (as reported in Section 4.5 above, this was considered a barrier to commercial deployment by some stakeholders). Overall, stakeholders noted:

- there is a lack of public understanding of the potential role of LETFF in decarbonising the economy and national energy market

- there is a 'poor' public perception of LETFF that does not match the achievements that have been made across the LETFF programs
- LETFF, and CCS in particular, are seen as technologies designed to 'extend the life of fossil fuels'.

Lastly, stakeholders broadly agreed that Australia risks losing the significant gains in knowledge, and skills and capabilities it has established over the last 15 years through the LETFF programs if it does not proceed to the commercialisation and deployment of LETFF. Low emissions technologies such as CCS are increasingly being deployed in the U.S., China and Europe. If Australia does not proceed to deployment, it is likely that the specialised skills developed through the LETFF programs will be lost overseas to where LETFF is being deployed. As one stakeholder noted:

> *"… there are certainly other countries who have skilled up more effectively than Australia has in the last few years and we are at risk of being left behind to some extent. … the US has an extremely comprehensive national CCS approach, Norway, the [and] UK to some extent…. So, we are in danger of losing that capability I believe if we are not careful in what we are doing."* – Academic/research stakeholder.

5.2 Would have achievements been made in the absence of government support?

Overall, there was consensus across all stakeholders interviewed that the achievements made towards increasing knowledge, skills and capability, and on improving industry understanding about low emissions technologies **would not have been made in the absence of Commonwealth Government support**. When asked what progress would have been made without support from the Commonwealth Government, stakeholders noted:

> *"Short answer is zip, nothing. I don't think we would have done much at all. Truly, I don't think we would have done much at all."* – Academic/research stakeholder.

> *"It wouldn't have occurred if it wasn't for the government's investment"* – Industry stakeholder.

> *"We would still be stuck in the theoretical research phase."* – Commonwealth Government stakeholder.

> *"There is no likelihood that we would have achieved what we did without government involvement"* – Academic/research stakeholder.

However, stakeholders did note that the Chevron-led Gorgon Carbon Dioxide Injection project would have occurred in the absence of Commonwealth Government support. Chevron Australia had publicly committed to build the injection project prior to the commencement of the LETDF and the development of the injection project was later included as a development approval condition for the LNG project.

Responses to the online questionnaire supported the outcomes of the stakeholder interviews. The questionnaire showed that 65% of respondents consider that no progress or almost no progress would have been made towards the achievement of the focus outcomes in the absence of Commonwealth Government investment in the LETFF programs (Chart 5.1).

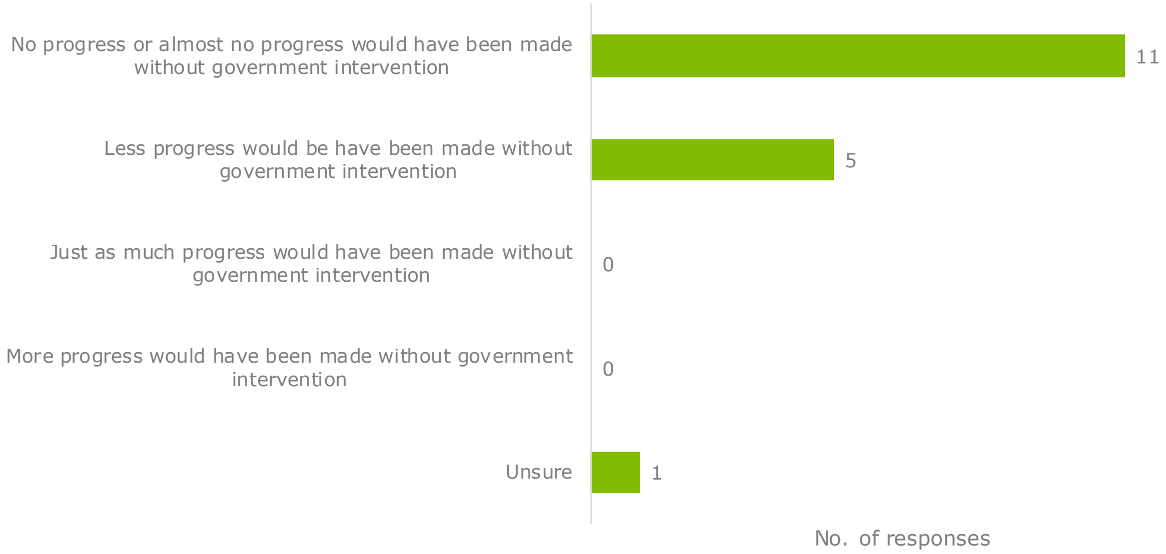
Stakeholders noted that in the absence of a commercial imperative to invest in LETFF (see Section 4.4), there was no incentive on the part of industry to invest in pre-commercial research and development of LETFF. A lack of commercial imperative means that there was no driver to undertake pre-commercial research into capture technologies, CO_2 transportation, storage technologies and CO_2 injection, Australia's geological resources, CO_2 subsurface behaviour, or the safety of LETFF.

By investing in LETFF, the Commonwealth Government was able to successfully leverage significant contributing funding from the coal industry and participating State governments. As one stakeholder noted:

> *"With the current absence of financial incentives for industry to pursue CCS technology, I greatly doubt the funding required to carry out the R&D completed to date would have*

> *existed. The LETFF programs provide the foundation funding (*s22
> s22 *for this research to be proposed and progress."* Academic/research stakeholder.

Chart 5.1: Extent to which questionnaire respondents consider progress would have made in the absence of the LETFF programs



Source: Deloitte questionnaire, n = 17

5.3 Are there critical areas of research that remain unanswered

There is consensus among all stakeholder groups that the critical underlying research and technical questions to deploying large-scale LETFF (and CCS in particular) in Australia have largely been settled as a consequence of the activities delivered under the LETFF programs. Stakeholders agreed that the next critical phase to LETFF in Australia was deployment. As stakeholders noted:

> *"I think we are far, far beyond the research questions. And I think now it's about deployment, and it's about supporting deployment."* – Academic/research stakeholders.

> *"The research is sufficient to take us the next step and let the engineers take the next step so that the researchers can then work on the next problems…I don't think we need more research. I think we need deployment. I don't think there's any gaping holes in research." – Industry stakeholder.*

However, stakeholders did identify a range of future research that would supplement and benefit LETFF research done to date.

In particular, a range of stakeholders across all groups identified the need to undertake **site-specific research and testing to support the eventual deployment of LETFF**. While the LETFF programs have demonstrated proof of concept at the regional level, none of the detailed site-specific research and testing has been undertaken that would be required to support deployment of LETFF. The deployment of LETFF will require a new wave of site-specific research relating to drilling, sub-surface monitoring, seismic analysis and injection testing. Such research and analysis will be critical to project-specific planning, investment, and regulatory decisions. As stakeholders noted:

> *"There will be local specific* [research issues] *related to storage, so there will be groundwater impact concerns mostly, so that will be the Queensland story if they get any further [to deployment]… So, there will be site specific and to a large extent community specific [research requirements]."* – Academic/research stakeholder.

> *"We need to do more detailed analysis on key spots. Because we've got the broader understanding of CCS in Australia, but not the actual real details [of specific sites]." –* Academic/research stakeholder.

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The focus of the LETFF programs had largely been in relation to the capture, transport and storage of emissions from coal mines, liquefied natural gas (LNG) plants and stationary power stations. Some stakeholders noted, however, a need to research **the application of learnings from the LETFF programs to other emission-intensive sectors** including steel, concrete, fertiliser, and agribusiness. As one stakeholder noted:

> *"the industrial applications of CCS that we need to be putting more work into…So, it is other types of CCS technologies that we probably haven't focused on."* – Commonwealth Government stakeholder.

The 'capture' process is one of the most expensive and technically complex aspects of CCS, and can typically account for approximately two-thirds of the total CCS deployment cost.[4] Recognising this, some stakeholders also noted a need to investigate CO_2 capture processes for these emission-intensive industries to assist in making CO_2 capture more commercially feasible.

As reported above, public perception and acceptance of LETFF and CCS in particular is considered a barrier to the eventual commercial deployment of LETFF in Australia. A range of stakeholders identified the need for **further research in effectively engaging with communities at the local level.** Given the nature of CCS (which involves the injection of CO_2), understanding how best to engage local communities level was seen as critical to garnering support and achieving regulatory approval, and ultimately resetting the national conversation. While some research has been undertaken on an ad-hoc, individual project-level, there has been no coordinated, strategic approach across the LETFF programs. The importance of better engagement with local communities was summed up by a stakeholder thus:

> "*…the key is you don't engage them* [local communities] *about CCS, you engage them about the whole gambit of future energy choices, and within the choices and the trade-offs you then bring CCS into that equation, so that they actually see a choice. It is not just, 'Yes CCS' or 'No CCS.'"* – Academic/research stakeholder.

A final area of research identified by a few stakeholders included **the nature of enhanced oil recovery** (EOR). Overall, stakeholders noted that the relative importance of EOR to supporting the commercial viability of CCS projects in Australia was not very well understood. The production of EOR requires significant quantities of CO_2, which is injected into the sub-surface as part of the EOR production process. Overseas, including in the US, EOR is typically most viable where production can integrate with CCS to take advantage of a ready supply of CO_2. While the presence of EOR may not be in all locations that are deemed appropriate for CO_2, there was a view among some stakeholders that further research and investigation was required, particularly given the absence of other commercial imperatives (as reported in Section 4.4 above). As one stakeholder noted:

> *"When you look internationally a lot of the CCS projects have been underpinned by a revenue stream of oil from enhanced oil recovery… there has been this sort of view that EOR or enhanced oil recovery in Australia is not a lot, there is not many prospects. But I*

[4] Estimate based on stakeholder interviews.

> *am not sure that that is underpinned by really good technical and exploratory work. So if we are missing something it is: 'What are the prospects for enhanced oil recovery in Australia?'"* – Academic/research stakeholder.

5.4 Role of Commonwealth Government

There was consensus among all stakeholder interviewed that **there remains a critical role for Government** in supporting the development and implementation of LETFF following the completion of the LETFF programs. Deloitte notes that all stakeholders interviewed as part of this evaluation were directly involved in the LETFF programs, and thus there is likely to be some reported bias in stakeholders' views on the need for continued government support.

However, there was **no clear consensus** among stakeholders interviewed on the most appropriate role for the Commonwealth Government in supporting the development and implementation of LETFF.

Many stakeholders reported that the primary role of the Commonwealth Government should be in setting a clear **national energy and climate policy agenda and framework.** Such a framework would provide industry with sufficient long-term confidence to invest in large-scale LETFF projects. As noted by some stakeholders:

> *"So, absolutely there is a role for government and it links back to that national leadership. I think that we need to have strong policy settings out there that can incentivise investors coming on board for a technology which has some market values in terms of risks." –* Commonwealth Government stakeholder.

> *"The government's role is to set a very clear path forward and then to work with industries and organisations that have a role to play in that path whether it be because they're impacted or because they're contributing to that path."* - Industry stakeholder.

Many stakeholders, in the absence of commercial imperatives on the part of private industry to invest, saw a role for the Commonwealth Government to provide **direct financial support** for the commercial-scale deployment of LETFF. Such stakeholders considered the Commonwealth Government had a critical role in directly financially supporting the first CCS project in Australia. As one stakeholder noted:

> *"I think the investment from the government is to bring opportunities to a point where a private investor can come in and support it. That can be straight-up by supporting the first opportunities for storage and utilisation hubs in Australia." – Industry stakeholder*

Other stakeholders noted the potential role for the Commonwealth Government in **providing ongoing financial support for research and development** where there was a clear, demonstrated need and where industry was unlikely to undertake the activity without support. Specific examples included research related to broader industrial application, safety, and community acceptance. As stakeholders noted:

> *"There is a place for grants. Grants have a benefit…they give [the Commonwealth Government] what we want. So, for example, if we think industrial CCS is somewhere that needs some research and development then we could certainly put a package together. So, there is room for grants in our repertoire."* – Commonwealth Government stakeholder.

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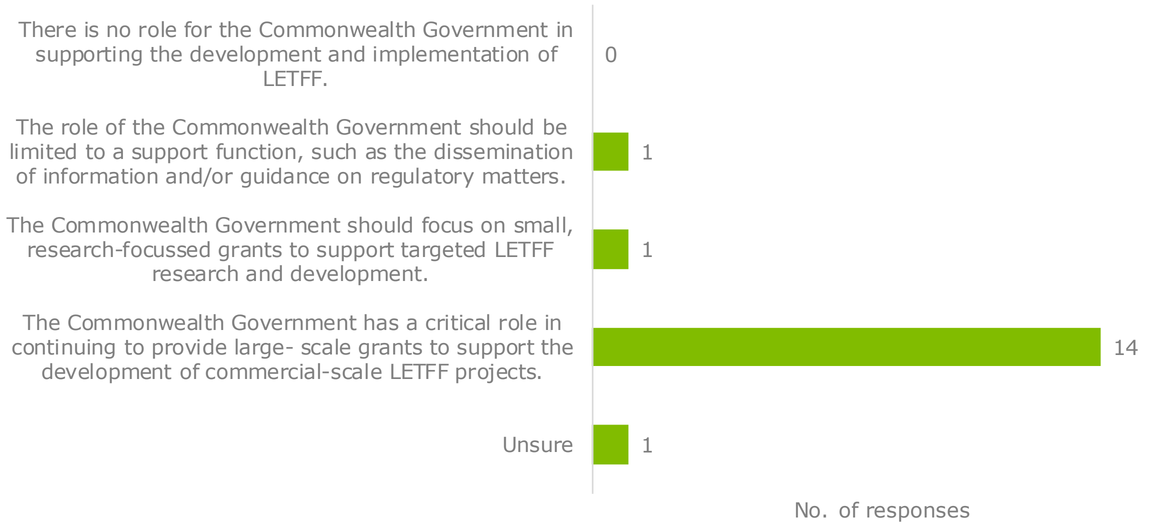
Responses to the online questionnaire were more consistent than stakeholder interviews in their views of what the primary role (if any) should be for the Commonwealth Government going forward with respect to LETFF. The questionnaire found 82% of respondents consider that the Commonwealth Government has a critical role in **continuing to provide large- scale grants** to support the development of commercial-scale LETFF projects (Chart 5.2).

Chart 5.2: Questionnaire responses re what primary role (if any) should the Commonwealth Government adopt in supporting the development and implementation of LETFF



Source: Deloitte questionnaire, n = 17

Some stakeholders interviewed also identified the need for the Commonwealth Government to consolidate the research and knowledge gained to date and ensure it is disseminated to the fullest extent possible.

Despite the majority of stakeholders reporting that the primary role of the Commonwealth Government should be to provide large-scale direct financial support for the deployment of commercial scale CCS projects, **Deloitte considers it is imperative that any future support for LETFF should be informed by a rigorous economic assessment**. Such an economic assessment would specifically involve assessing the role of LETFF in decarbonising the economy and NEM relative to alternative approaches, and give consideration to fossil fuel demand and full life-cycle costs of alternative technologies.

5.5 Unintended outcomes

Many stakeholders reported a perception that the LETFF research agenda is negatively affecting the commercial deployment of LETFF, and in particular CCS. Stakeholders reported that the drive to undertake additional research has resulted in a perception among regulators, industry detractors and the general public that LETFF is not adequately understood and that significant risk remains. As noted by a stakeholder:

> *"I think research has been a drawback for CCS*. [Researchers] *keep telling everybody, "we need to do more research" So, people who are detractors of CCS say, "look it's still an experimental technology." It's not."* – Academic/research stakeholder.

Some stakeholders also reported that the lack of commercial-scale deployment has resulted in a perceived lack of progress among the general public. This, in turn, has resulted in a perception that LETFF is not feasible, and has potentially hindered the sector's ability to achieve a social licence to operate.

6 Learnings for future program design

Key lessons to inform future program design and implementation include:

- setting realistic expectations with respect to program cost and time-horizons
- setting realistic expectations with respect to research and development outcomes
- ensuring alignment between policy settings and program objectives
- enhancing assessment of project feasibility at program commencement
- funding and program governance arrangements should reflect the nature of program activities
- greater industry engagement in the design of the program
- the need for ongoing monitoring of program funding
- embedding engagement processes to share knowledge gained within and across government
- improved understanding of the costs and benefits of LETFF in decarbonising the economy relative to alternative technologies, through a detailed Cost Benefit Analysis, as a first step in any future consideration of LETFF.

6.1 Learning for future program design

The LETFF programs have made a significant contribution to increasing knowledge, skills and capability, and on improving industry understanding with respect to LETFF.

However, there are a range of learnings to be gained from the design and implementation of the LETFF programs to inform future program design. These are discussed in greater detail below:

- **Setting realistic expectations with respect to program cost and time-horizons:** Future programs involving the research, development and deployment of large-scale and complex technologies must set realistic expectations around program costs and time-horizons.

  Program design should not underestimate the scale of research and development required to support the development of industrial-scale projects. This has implications for the level of funding made available, the setting of timelines, and internal program governance arrangement, including the establishment of internal expert panels to provide necessary technical guidance.

- **Setting realistic expectations with respect to research and development outcomes:** Future programs involving the research and development of unproven and untested technologies must set realistic expectations around outcomes realisation. It is critical that future program design explicitly recognise a realistic target in terms of research and development achievements, and that not all projects will proceed beyond the research phase.

- **Ensuring alignment between policy settings and program objectives:** Future program design must consider and reflect existing and likely future policy settings. Furthermore, there is a need to ensure that underlying commercial incentives and imperatives exist to support the achievement of program objectives.

  Future programs should also include a review 'trigger' to revisit the rationale of a program if there is a fundamental shift in domestic and international policy settings that are likely to impact the achievement of program objectives.

- **Enhancing assessment of project feasibility at program commencement:** Future programs should seek to improve technical and financial screening and selection processes to better gauge the feasibility of projects at program commencement. However, this needs to be balanced with the research and development objectives of any future program.

Future programs involving large and complex technologies should embed independent program review boards consisting of recognised domestic (and if appropriate international) experts to periodically assess project progress.

- **Funding and program governance arrangements to reflect the nature of program activities:** Future programs should adopt funding agreements and decision-gates to reflect the nature and needs of industrial development projects. In particular, stage gates should replace inflexible milestone reporting and payment processes. This would ensure approved project funds can be more appropriately accessed over time as the project passes through agreed stage gates.
- **Greater industry engagement in the design of the program:** Future programs should involve greater engagement with industry and academic stakeholders during program design. This would ensure program objectives, risks and issues are appropriately understood and reflected in the program design and implementation. Upfront industry stakeholder engagement should also inform an upfront formal assessment of program risks. This ensures risk mitigation strategies can be fully explored, and if possible, embedded within program design.
- **Monitoring of program funding:** Future programs should embed monitoring and reporting frameworks to monitor the effects of changes to funding on the achievement of program objectives. Such frameworks would enable an assessment of how remaining funds can be redistributed within the program (or other programs) and provide a transparent process for revisiting the project selection process to identify projects that were the next best ranked.
- **Embedding engagement within and across government:** Future programs should embed knowledge-sharing processes to ensure program learnings and outcomes are appropriately disseminated across relevant Commonwealth and State government departments and agencies. Furthermore, program design should consider the required data and information storage and sharing systems to ensure all relevant program documentation is adequately captured and collated in a central location. This mitigates the risks of key learnings and knowledge eroding overtime, and ensures future programs can incrementally build upon the knowledge gained.
- **Undertaking a detailed economic costs benefit analysis:** Any consideration of future support to further the development and implementation of LETFF should, as a first step, involve a detailed cost benefit analysis of LETFF in decarbonising the economy relative to alternative technologies. This analysis should give consideration to fossil fuel demand and the whole-of-lifecycle costs of alternative technologies.

Appendix A: Overview of projects by LETFF program

A summary of the projects delivered under the LETFF programs is presented in the following tables.

Table A.1: Summary of CCS Flagships projects

Project	Description
CarbonNet Project	The project investigates the potential for a large scale CCS network in the Gippsland region of Victoria. The network seeks to cover multiple sources of carbon dioxide captured from industrial plants or power stations.
SouthWest Hub Project	The project aimed to assess the feasibility of storing industrial-generated carbon dioxide deep underground in the Lesueur Sandstone formation. The project involved collecting data and core samples through seismic questionnaires and stratigraphic wells.
ZeroGen Project	The project involved assessing the feasibility of a commercial-scale coal gasification power plant with integrated carbon capture and storage.
Wandoan Integrated Gasification Combined Cycle (IGCC)	A prefeasibility study which involved the following sub-projects: • Stanwell Corporation/Wandoan project which sought to develop an IGCC power station with CCS capabilities. • CTSCo Pty Ltd/Wandoan project which focused on the transportation and storage of carbon dioxide from the IGCC power station through pipelining and geo-sequestration.
Otway Geological Storage and Demonstration Project	A carbon capture and storage demonstration project that aims to address barriers to storage implementation and leverage existing and new datasets arising from the CO2CRC Otway Project to further the technology. The project also involved a monitoring program that test technologies and techniques with the aim of reducing costs.
Australia-China Joint Coordination Group on Clean Coal Technology Projects	The project aimed to build on the growing relationship between Australia and China through the Australia-China Joint Coordination Group on Clean Coal Technology (JCG).

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Table A.3: Summary of LETDF projects

Project	Description
Gorgon Carbon Dioxide Injection Project	Design, construction and operation of facilities to inject and store CO_2 into a deep reservoir unit two kilometres beneath Barrow Island. The CO_2 that is injected into the reservoir unit comes from the process of extracting gas in the Gorgon/Jansz-Io fields.
400MW Integrated Dry-gas Gasification Combined Cycle (IDGCC) Clean Coal Demonstration Project	A project that aimed to increase the burning efficiency of thermal generators by drying brown coal. Reducing the moisture content of brown coal means that less energy is required to convert the coal into electricity.

Project	Description
Hazelwood 2030 Project	A project that aimed to retrofit Low Emission Technologies at the brown coal-fired Hazelwood Power Station in the Latrobe Valley, Victoria. The process involves reducing moisture content of brown coal for an improved burning efficiency. The Hazelwood 2030 project includes CCS facilities – with demonstrated capacity to sequester carbon dioxide at a rate of 0.02mtpa.
Fairview Project	A project that aimed to test the extraction of methane from coal and storing it underground

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Appendix B: Evaluation framework

The evaluation framework, including key evaluation questions and sub-questions, key data collection methods and sources guiding the impact evaluation of the LETFF programs is presented below. The evaluation framework has guided the key lines of enquiry and systematic organisation of analysis to ensure a consistent and robust assessment of the LETFF programs and project activities.

Table B.1: Evaluation framework

Domain	Key evaluation questions	Sub-questions	Data source		
			Interviews	Document review and citation analysis	Questionnaire
Effectiveness	To what extent have the LETFF programs increased knowledge, skills and capability, and improved industry understanding in relation to low emissions technologies for fossil fuels?	To what extent have the LETFF programs generated new research, data and modelling relating to the practical and technical use and implementation of LETFF?	✓	✓	✓
		To what extent have the LETFF programs resulted in the development of greater local (Australian) skills and capabilities in LETFF?	✓	✓	✓
		To what extent have the LETFF programs improved industry understanding of the feasibility and safety of LETFF through collaboration and dissemination of new knowledge?	✓	✓	✓
		To what extent is achievement against the above outcomes commensurate with the investment made by the Commonwealth Government?	✓		✓
	To what extent would knowledge, skills and capability, and industry understanding in relation to LETFF continued to have been developed in the absence of the LETFF programs?	What was the state of knowledge, skills and capability, and industry understanding prior to the commencement of the LETFF programs?	✓	✓	✓
		What is the state of knowledge, skills and capability, and industry understanding following to the commencement of the LETFF programs?	✓	✓	✓
		To what extent has investment from the LETFF programs crowded out industry and research activity that would have occurred in the absence of the LETFF programs?	✓		✓

Domain	Key evaluation questions	Sub-questions	Data source		
			Interviews	Document review and citation analysis	Questionnaire
		How much of the change observed in increased knowledge, skills and capability, and improved industry understanding is because of the LETFF programs?	✓		✓
Efficiency	What factors have helped or hindered the achievement of increased knowledge, skills and capability, and improved industry understanding in relation to LETFFs?	What factors have assisted the achievement of increased knowledge, skills and capability, and improved industry understanding in relation to LETFFs?	✓	✓	✓
		What factors have hindered the achievement of increased knowledge, skills and capability, and improved industry understanding in relation to LETFFs?	✓	✓	✓
		To what extent did the design and implementation of the LETFF programs assist or hinder the achievement of the increased knowledge, skills and capability, and improved industry understanding in relation to LETFFs? Did program design align with known 'best practice' examples elsewhere?	✓	✓	✓
		To what extent did the LETFF programs align with related programs or research (either government or industry)?	✓	✓	✓
		To what extent do these factors remain a barrier to the commercial development and deployment of LETFFs?	✓		✓
	How have external factors affected the ability of the LETFF programs to achieve their intended medium and long-term objectives?	How have Australian Government and international policy settings affected the achievement of medium and long-term objectives?	✓		✓
		How have the relative prices of, and demand for, renewable energy sources affected the achievement of medium and long-term objectives? How have alternative carbon abatement technologies (e.g. bio-sequestration) affected medium and long-term objectives?	✓		✓
		How has the level of demand for fossil fuel-based energy affected the achievement of medium and long-term objectives?	✓		✓
		How have general economic conditions affected the achievement of medium and long-term objectives?	✓		✓
		How have issues such as third-party risk and market design factors affected the achievement of medium and long-term objectives?	✓		✓

Domain	Key evaluation questions	Sub-questions	Data source		
			Interviews	Document review and citation analysis	Questionnaire
Appropriateness	What lessons can be drawn to inform future policy and program development, including the role (if any) of the Commonwealth Government, in relation to supporting the development and implementation of LETFF technologies?	What lessons can be drawn to inform future program design and development?	✓		✓
		Did changes to the LETFF programs since inception influence the efficiency or effectiveness of the programs?	✓		✓
		Are there critical areas of research that have been missed?	✓		✓
		Was there adequate industry engagement on the role of CCS and emission abatement technologies as part of a broad mix of GHG emission mitigation measures?	✓		✓
		What is the role (if any) of the Commonwealth Government in relation to supporting LETFFs?	✓		✓
Unintended impacts	What unintended outcomes have occurred as a result of the LETFF programs?	What (if any) unintended benefits occurred as a result of the LETFF programs?	✓	✓	✓
		What were the unexpected negative impacts of the LETFF programs?	✓	✓	✓

Appendix C: Stakeholder interviews and questionnaire responses

List of stakeholders interviewed

A list of all stakeholders interviewed as part of the evaluation assessment are outlined below. Overall, 19 stakeholders were engaged through 18 interviews as part of the evaluation.

Table C.1: List of stakeholders interviewed

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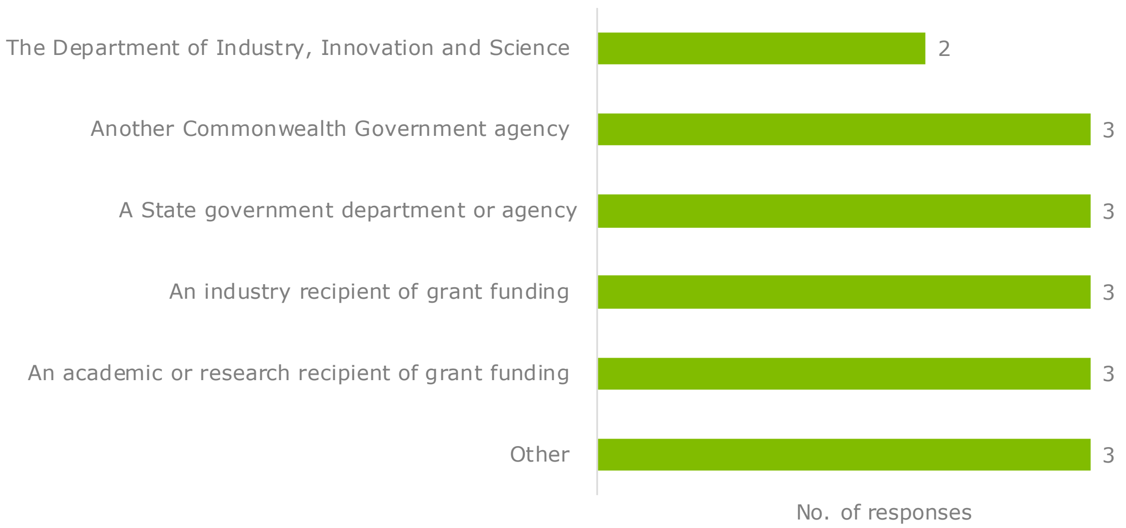
List of respondents to online questionnaire

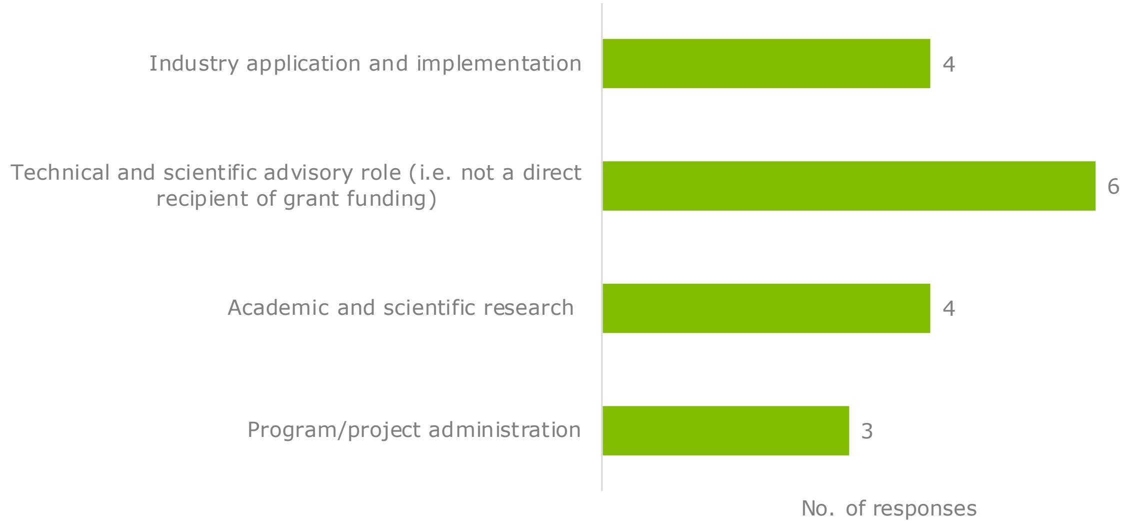
A total of 17 responses to the online questionnaire were received. A summary of the groupings of respondents is provided below.

Chart C.1: Type of organisations that respondent principally worked for during their involvement with the LETFF programs



Source: Deloitte survey, n = 17

Chart C.2: How do respondents describe their involvement with the LETFF programs?



Source: Deloitte survey, n = 17

Appendix D: Case studies

This evaluation has involved the development of concise case studies highlighting the contribution to increased knowledge, domestic skills and capabilities, and improved industry understanding of LETFF made by individual projects delivered under the LETFF programs. The case studies have supported and informed the triangulation of evidence collected across the evaluation. A total of seven case studies have been developed across the LETFF programs:

- **CCS Flagships program:**
  - South West Hub Project
  - Otway Geological Storage and Demonstration project
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- **LETDF:**
  - Gorgon Carbon Dioxide Injection Project
- s22

These concise case studies are presented below.

South West Hub Project

Project Summary and Objectives

The South West Hub project involved testing onshore sandstone formations as a CO_2 reservoir for nearby power plants and industrial sites in Western Australia. Its objectives were to conduct a data study and analysis of the lower Eneaba Formation to determine its suitability for injecting CO_2 underground. In its Extended Case, the facility aimed to capture, transport and store between 5-6Mt of CO_2 annually.

Contribution to Research and Knowledge

The project's unique location was chosen in part due to its proximity to CO_2 emitters, rather than any geological characteristics that make it particularly suitable for CO_2 storage. This aimed to reduce the costs of transporting CO_2 – improving the commerciality of CCS. However, the location led to challenges such as:

- determining how to keep the injected CO_2 underground, since the Eneaba Formation did not have the impermeable seal that other CO_2 storage sites have to contain the CO_2 plume
- determining how to monitor the CO_2 plume underground.

Consequently, most of the new research and knowledge gained came from addressing these challenges. Specific areas of research contributed to by the project included:

- improvements in geosequestration knowledge – including conducting and analysing seismic survey data, as well as conducting geophysical remote sensing of CO_2 sequestration
- geochemical evaluation of the well using a combination of standard and novel techniques – such as chemical tracers to determine the suitability of the area for CO_2 storage
- structural analysis of geological formations, including fault seal first-order analysis.

Stakeholders also reported that the project contributed to a greater understanding of trapping mechanisms, greater confidence in Migration Assisted Trapping (MAT) technology and a greater understanding of geological environments and depositional history at a local level.

Stakeholders also reported that by applying research in the field and conducting demonstrations, they were able to more effectively present comprehensive and compelling business cases to progress CCS technology.

Overall, this evaluation identified 28 technical reports from various public data repositories produced by the project. These reports discuss challenges and the results of geosequestration testing conducted during this project. These reports have cumulatively been cited 25 times in external reports.

Contribution to domestic skills and capabilities

The project made an important contribution to advancing domestic capabilities in the development of behavioural models of CO_2 plume movements within different rock formations. Of the 28 technical reports, eight were written by the University of Western Australia or Curtin University. These reports focused on geophysical data analysis, stability assessments and predicting CO_2 injectivity properties.

Other technical reports also focused on improvements in conducting and analysing seismic survey data like geochemical evaluation and residual trapping. The unique characteristics of the site meant that significant focus was placed on understanding how basin configuration and structural elements affected the containment capabilities of a rock formation.

The project also contributed to the development of domestic research skills, by enabling leading research organisations such as the University of Western Australia and Curtin University to have dedicated staff and students working on CCS research and demonstration projects.

Contribution to industry understanding of low emissions technologies

The Project's location in a low-medium permeability reservoir, without a thicker "continuous impermeable seal" that could effectively contain CO_2 plumes, added to the technical challenges of CCS. These challenges demonstrated that storage proximity to emission sources, while preferable, is neither a necessary nor a sufficient condition. However, a viable geological reservoir is certainly necessary and likely sufficient.

Stakeholders discussed how the South West Hub project was important for the industry to develop a better understanding of both the theoretical capabilities of injecting CO_2 into these types of reservoirs (i.e. without an impermeable seal) and also the commercial aspects that would need to be met before injection can be undertaken effectively.

Whilst challenging, the project was crucial for improving the industry's understanding of geological reservoirs without natural seals, particularly their potential for trapping CO_2. Modelling that was done as a result of the project indicated that geological reservoirs without traditional caps or seals can still store CO_2, potentially doubling the previously estimated storage capacity in south-west Western.

Technical reports and research papers discussing the processes conducted, as well as the challenges associated with geosequestration, were made public – and are found on data repositories such as s22 he Global CCS Institute and WAIMPS.

Otway Geological Storage and Demonstration Project

Project Summary and Objectives

The CO_2 Co-Operative Research Centre's (CO2CRC) Otway Geological Storage and Demonstration Project (the Otway Project) aims to conduct initial site characterisation of the Otway Basin Pilot Project. The project's objective is to demonstrate the deep geological storage of CO_2, and improve understanding of the potential geological storage of various sedimentary basins both onshore and offshore. The project has involved the pilot trial of CO_2 injection and storage to demonstrate proof of concept.

Contribution to Research and Knowledge

The Otway Project has involved partnerships with a range of leading universities and research organisations, including CSIRO, Geosciences Australia and Curtin University, with a specific focus on sub-surface CO_2 storage, monitoring and modelling.

Research and knowledge focused on decreasing the cost of monitoring CO_2 plumes underground, as well as reducing the impact of operating on other stakeholders like land operators or the environment. The Otway Project was seen by stakeholders as critical in demonstrating laboratory-scale technologies in the field as major prototypes. These technologies included new modelling approaches that accurately predict CO_2 plumes and experimental methods for determining tracer partition coefficients. The Otway Project has directly contributed to the following areas of storage and CO_2 monitoring research:

- understanding how geological permeability may change as a function of CO_2, demonstrating a need to monitor water and local mineralogy characteristics
- monitoring the characteristics of injected CO_2 plumes using seismic technology
- analysis and modelling of geophysical data sets (2D, 3D etc.) and downhole pressure and temperature datasets to improve understanding of CO_2 plume behaviour and migration
- an improved understanding of the potential injectivity of reservoirs, their ability to store CO_2 and overall storage capacity
- establishing general methodologies for determining whether a CO_2 storage reservoir is leaking
- improving techniques to monitor sub-surface CO_2 plumes
- improving cost effectiveness of CO_2 monitoring.

The Otway Project has also contributed to the development of a range of new techniques. An example is working with Curtin University to develop fibre optic cable technology to receive acoustic signals. As noted by stakeholder:

> *"Previously when you do seismic monitoring you basically create an acoustic wave through the earth and receive it at a geophone – this has been the traditional way that the Oil and Gas sector has explored. What's been maturing and what Curtin has been heavily involved with is replacing geophones [with fibre optic cables]. You can now use fibre optic to receive that acoustic signal anywhere along that fibre. Now, the quality of what you receive with that fibre versus a mechanical geophone has always been a lot less, so the fibre has never been that great. But with the funding that we have received from the LETFF and combination of work with experts from Curtin and also internationally, we are now at the point where the performance of these fibres is substantially better than these geophones. Now, that all sounds very technical, but what it means is we now have the ability to not have to put major infrastructure down these wells, we can do it through very cheap wells. We can have high resolution on demand, monitoring whenever we want to give assurance of [CO_2] behaviour on the subsurface be it in CCS or be it in Oil and Gas exploration production. It's a massive improvement and a very important technology*.

This evaluation identified ten published technical reports produced through the Otway Project, which have collectively been cited in peer reviewed publications a total of 16 times.

Contribution to domestic skills and capabilities

The Otway Project has involved collaborations with a range of international research organisations and universities – including Silixa (UK), Lawrence Berkeley National Laboratory (US), and the University of Texas. The research and academic institutions partnered with CO2CRC to trial new technologies on site. Through these collaborations, these organisations have assisted in developing and broadening domestic skills and capabilities. Technologies that were trialled include:

- different injection methods
- different storage and monitoring methods such as Distributed Acoustic Sensing (DAS) fibre optic cables and 4-D time-lapse surface seismic methods.

Stakeholders reported that the Otway Project directly contributed to Australia developing world-leading reservoir engineering and monitoring skills and expertise, with CSIRO and Curtin University being identified by international collaborators as world leaders.

A key aspect of the Otway Project was it being "internationalised" by CO2CRC as a preferred test site to trial a range of injection, storage and monitoring techniques for CCS. Stakeholders noted that through these trials and collaborations, Australia has developed skills in these international techniques. Australia was also able to directly develop significant skills and capabilities with respect to the application of a range of CCS technologies, including:

- site management
- managing the regulations around sites
- communications.

Contribution to industry understanding of low emissions technologies

A key aspect of the Otway Project has been its focus as a trial demonstration facility for CCS. This has enabled the project to undertake direct applied research and demonstration in the field, including extensive geoscience and engineering work, to inform future commercial scale deployment of CCS.

The Otway Project has developed a detailed understanding of the process of CO_2 injection under Australian conditions and geology, CO_2 migration and monitoring, and CO_2 stabilization. This has enabled the project to develop an end-to-end visualisation of the injection and storage of CO_2. The project has also significantly contributed to an understanding of monitoring and modelling the behaviour of CO_2 with very advanced modelling techniques. In short, the Otway Project has made a significant contribution in providing industry, government and academia with tangible evidence that CCS works and is safe.

The Otway Project was crucial for demonstrating technologies at a prototype level – such as seismic monitoring through fibre optic rather than mechanical geophones, which are now able to perform at a much higher level.

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Gorgon Carbon Dioxide Injection Project

Project Summary and Objectives

The Gorgon Carbon Dioxide Injection Project was a commercial-scale demonstration project for capturing CO_2 emissions from the natural gas extraction process in the Gorgon field off the coast of Western Australia. The Project involved compressing, dehydrating and transporting the CO_2 by pipeline to the injection site – a saline sandstone reservoir in the Dupuy Formation. It aimed to reduce project emissions by 120Mt over its lifespan at a 3.4-4Mt annual rate, and is the first major project to significantly reduce emissions through underground injection. The Project is expected to begin CO_2 injections in 2019.

Contribution to Research and Knowledge

Research and knowledge gained from the Project may have been limited because CO_2 injections have not started and because of potential commercial-in-confidence issues. The 12 public technical reports identified as part of this evaluation covered key learnings on:

- the acquisition of quality seismic data, through petrographic, petrophysical, biostratigraphical, sedimentological and geochemical reporting – and its significance to improving the accuracy of CO_2 migration simulation models
- the impact on project execution
- well remediation programmes to ensure existing wells near the proposed injection site have been properly secured and do not pose a CO_2 containment risk
- site assessments, research and exploration work.

These technical reports have been cumulatively cited 1,012 times by external papers, demonstrating the significant contribution to enhancing knowledge of LETFF, and particularly CCS, made by the project.

Contribution to domestic skills and capabilities

The Gorgon Project involved the use of technologies, processes and equipment that have previously existed within the oil and gas sector, and as such was able to leverage the existing and significant skills base within the oil and gas sector.

However, the Gorgon Project did bring in monitoring technologies that reduced the cost of monitoring CO_2 plumes. These technologies include surveillance wells, 4D Surface Seismic testing, soil gas verification and pressure sensors on the surface.

This evaluation did not identify any technical reports that were written in partnership with universities or other research-based institutions.

Contribution to industry understanding of low emissions technologies

The Project is seen as a successful example of CCS operations on a commercial scale. While the $60 million allocated from the LETDF was not material to the Gorgon Project's success, it has enabled the development of a successful relationship that was crucial in the following ways:

- key learnings from the Gorgon Project relating to the legal and regulatory aspects influenced how the Australian Government intended to regulate CCS
- it also assisted in developing the Australian Government's Offshore Petroleum and Greenhouse Gas Storage Act.

The Project also led to technical reports associated with pumping CO_2 into reservoirs that are full of water, and its impacts on the reservoir itself. Depending on the type of report, they are either disseminated internally (where there is a commercial advantage) or published in industry journals.

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Appendix E: Literature scan and citation analysis

The results of the citation analysis of publicly available reports relating to the LETFF programs is presented below. This citation analysis covers publications available up until 28 May 2019.

Table E.1: Detailed Analysis of LETFF program/project publications

LETFF program/ project	Publications		Scholarly articles (as a share of publications)	No. of citations	Average citations per publication
	No.	%	%		
CCS Flagships	**65**	**13%**	**2%**	**170**	**2.6**
CarbonNet	20	4%	n/a	65	3.3
SouthWestHub	28	6%	4%	25	0.9
ZeroGen	2	0%	n/a	44	22.0
Wandoan	5	1%	n/a	20	4.0
CO2CRC	10	2%	n/a	16	1.6
CCSRD&D	0	0%	0%	0	0.0
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LETDF	**23**	**5%**	**39%**	**1,105**	**48.0**
Gorgon	12	2%	42%	1,012	84.3
IDGCC	0	0%	0%	0	0.0
Hazelwood	7	1%	57%	93	13.3
Fairview	1	0%	0%	0	0.0
Other	3	1%	0%	0	0.0
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Source: Deloitte

Notes: The above analysis only includes publically available publications.

Scholarly articles are considered to be publications that appear in peer-reviewed academic or scientific journals.

Limitation of our work

General use restriction

This report is prepared solely for the internal use of Department of Industry, Innovation and Science. This report is not intended to and should not be used or relied upon by anyone else and we accept no duty of care to any other person or entity. The report has been prepared for the purpose of set out in our contract dated 4 April 2019. You should not refer to or use our name or the advice for any other purpose

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Deloitte.

Process evaluation of the Low Emissions Technology Demonstration Fund (LETDF) s22

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Department of Industry, Innovation and Science

March 2019

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Glossary

ACALET R&D	Australian Coal Association Low Emissions Technologies Research and Development
ANAO	Australian National Audit Office
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ARENA	Australian Renewable Energy Agency
CCS	Carbon Capture and Storage
s22	
CO_2CRC	Carbon Dioxide Co-operative Research Centre
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DEH	Department of the Environment and Heritage
DITR	Department of Industry, Tourism and Resources
DRET	Department of Resources, Energy and Tourism
GHG	Greenhouse Gases
HELE	High Efficiency Low Emissions
IAP	Independent Assessment Panel
IDGCC	Integrated Drying Gasification Combined Cycle
KEQ	Key Evaluation Questions
LETDF	Low Emissions Technology Demonstration Fund
LETFF	Low Emissions Technologies for Fossil Fuels
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PAC	Program Assurance Committee
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POC	Project Oversight Committee
PSD	Program Summary Database
s22	
SIG Dropbox	Secure Internet Gateway Dropbox solution
SSI	Semi-Structured Interviews
TAC	Technical Advisory Committee
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Executive summary

In 2004, the Australian Government identified a need to support and promote the development and deployment of low emissions technologies to facilitate a cost-effective transition to a lower carbon economy.

The Department of Industry, Innovation and Science (the Department) has been implementing a range of policies from 2004 to support the research and development of new greenhouse gas (GHG) emission reduction technologies under the Low Emission Technologies for Fossil Fuels (LETFF) programs.

Deloitte has been engaged by the Department to assess the evaluability of the s22 LETFF programs. As part of this work, Deloitte also evaluated how well the Low Emission Technology Demonstration Fund (LETDF) s22 s22 have been administered. In 2017, the Australian National Audit Office (ANAO) audited the two remaining LETFF programs, the Carbon Capture and Storage (CCS) Flagships program s22

The evaluation findings draw upon the direct input from ten stakeholder interviews and a detailed review of documentation made available by the Department.

Low Emissions Technology Demonstration Fund (LETDF)

Overall, the administration of the LETDF has been supported by sound and well-documented project selection, technical assessment, progress and milestone reporting and governance processes. In general, these processes have been consistently applied throughout the course of the program. Greater recognition of the technical nature of projects and exploration of possibilities for more flexible contract negotiating processes may have strengthened administrative efficiency of the program.

A summary of evaluation findings relating to the LETDF is provided below.

<table>
<tr><td>Implementation</td><td>

Overall, program processes have been implemented as planned.
The program has evolved significantly over time, with all but one project having been terminated or migrated to another program area.
The implementation of the LETDF would have been strengthened from a strategic review of program rationale and objectives in 2012, when the Gorgon Carbon Dioxide Injection Project became the sole project under the LETDF.
Some gaps in documentation have been identified with respect to the termination and migration of projects to other program areas.
The efficient implementation of the program would have been enhanced by:

policy objectives giving greater recognition of the potential technical complexities of the projects seeking funding. This would have strengthened the project assessment and program timeline setting processes
exploration of possibilities for more flexible contract negotiating processes, which might have supported the finalisation of funding agreements
a single department or agency having clear overarching administrative and management responsibility for the program.

</td></tr>
</table>

Funding allocation	• Overall, the program was well-supported by a robust and transparent project application assessment framework. • Program funding has been significantly lower than originally planned, with only an estimated $88 million (18%) of the original $500 million spent to date under the program. • Developing a framework to monitor the effects of reduced funding on the achievement of stated objectives would have strengthened program administration. • In most cases, project application and assessment processes under the LETDF aligned with and supported stated program objectives. • Assessment and selection processes appear to have been comprehensive, supported by a high degree of rigour and technical expertise, and consistent with stated selection assessment criteria. • Improved precision of project eligibility criteria would have improved consistency in the assessment of project eligibility. • The finalisation of formal funding agreements took significantly longer than anticipated. Greater consideration during the application process of the ability of project proponents to meet financial requirements and implementation timeframes would have improved administrative efficiency and potentially avoided some delays.
Monitoring and reporting	• Program reporting arrangements were, on the whole, appropriate, clearly documented, and consistently followed, and enabled the effective oversight of the LETDF. • Project-level reporting arrangements under the LETDF were clearly defined under respective project funding deeds, and enabled a transparent, consistent and appropriate reporting framework at the project level. • However, the Department did not undertake an evaluation of the appropriateness, efficiency and effectiveness of the LETDF despite a Draft Process Evaluation Plan developed in the early stages of the program.
Governance and risk	• Program governance arrangements were appropriate, clearly documented and well understood by stakeholders. Furthermore, they supported the clear and transparent identification and setting of program priorities. • The LETDF was supported by good risk management practices. Project selection was supported by due diligence assessments, the recruitment and appointment of an expert panel to assess funding applications, and processes to manage potential conflict of interest of panel members. • Risk management arrangements would have been strengthened by the development of a risk management plan at the inception of the program in 2004-05. This would have enabled a formal assessment of potential risks during program development and design, specifically risks associated with the financial viability of project proponents, technical complexity of projects and implementation timeframes – factors that impeded funding agreement negotiations. • Changes to the LETDF governance arrangements were well documented within the updated administrative guidelines.
Accountability	• Program roles, responsibilities and priorities were clearly defined and documented at the outset of the program. • At the project level, the roles and responsibilities were clearly defined for the project proponent and Department (and its representatives) in individual project funding agreements. • Stakeholders considered that the Department managed changes in program personnel well over the course of the program and that such changes did not affect the achievement of program objectives.

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Implications for future program design

The following considerations for future program design have been identified through this process evaluation.

Implementation	• Program alignment to the broader policy environment should be reviewed periodically to ensure outcomes align with the political and investment environment. • Program rationale and objectives should be reviewed periodically, particularly for long-running programs that have experienced significant changes to program activities and/or funding. • Funding agreements should include, to the extent possible, flexible contractual arrangements that appropriately reflect the scale, timing and technical complexity of projects being delivered, while also meeting Government risk management requirements.
Funding allocation	• Processes should be embedded to review and monitor potential effects of material changes in program funding on the achievement of objectives and outcomes. • Future programs should have a focus on increased transparency and documentation around any changes to program funding.
Monitoring and reporting	• For large-scale, long-term projects, with a high degree of uncertainty, there is a need for continuous and ongoing monitoring to ensure programs are continuing to meet their objectives in the context of a changing policy or funding environments. • Evaluation processes should be defined and embedded in formal program monitoring and reporting arrangements at program commencement, and should be fully utilised. • Internal monitoring, reporting and program management tools should be fully utilised.
Governance and risk	• Changes in governance or program administration arrangements should be accurately reported and documented clearly. • Risk management arrangements and relevant documents should be utilised to their full extent over the life of the program. • A formal assessment of potential program risks should be undertaken during program development and design. This ensures risk mitigation strategies can be fully explored, and if possible, embedded within program design.

Limitations

This evaluation of the LETDF s22 programs has been constrained by the significant lapse in time since the inception of each program. Many departmental program staff interviewed were not involved in the inception of either program, and in some instances were unable to comment on implementation and administrative processes underpinning each program. Furthermore, program documentation is often saved in multiple locations and file management systems, resulting in a range of documentation and information gaps.

Management response

The Onshore Minerals and Energy Resources Branch endorses the findings of the Low Emissions Technologies for Fossil Fuel (LETFF) Process Evaluation of the LETDF s22 programs. Overall, the Branch is pleased to receive confirmation that the administration of the programs had been supported by well-documented project assessment; technical assessment; progress and milestone reporting; and governance processes.

The evaluation was thorough and objective and provides useful insight into the management of similar programs in the future. The Branch notes some of the lessons that could strengthen the design stage of future programs including periodically reviewing program alignment with the broader policy environment, particularly for long-running programs; to the extent possible, applying flexible contractual arrangements that appropriately reflect project complexities; and embedding evaluation and risk management processes in formal program monitoring processes at program commencement.

1 Overview and purpose

1.1 Context

Australia has historically relied, and continues to rely, heavily on fossil fuels for electricity generation and in industrial processes. Burning fossil fuels, such as coal, natural gas and oil, releases carbon dioxide (CO_2) and other greenhouse gases (GHG) into the atmosphere.

In 2004, the Australian Government identified a need to support and promote low emissions technologies to facilitate a cost-effective transition to a lower carbon economy. Low emissions fossil fuel technologies have the potential to reduce GHG emissions in the power sector and in industrial processes such as cement, steel and hydrogen production.

To this end, the Department of Industry, Innovation and Science (the Department) has been implementing a range of policies from 2004 to reduce GHG emissions in the context of coordinated global action against climate change. As part of this, the Australian Government provides funding to support the research and development of new GHG emissions reduction technologies under the Low Emission Technologies for Fossil Fuels (LETFF) programs.

The LETFF programs are:

- the Carbon Capture and Storage (CCS) Flagships program (introduced in 2009)

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- the Low Emissions Technology Demonstration Fund (LETDF) (introduced in 2004)

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The Department has identified the LETFF programs as a Tier One evaluation priority of high strategic importance. The Department also accepted the recommendation of the Australian National Audit Office (ANAO) audit (2017) to evaluate the LETFF programs. The Department is conducting the evaluation in two phases:

- Phase One involves an assessment of the 'evaluability' of the four LETFF programs, which will be used to inform the scope of Phase Two
- Subject to Phase One findings, Phase Two will evaluate the impact of the LETFF programs.

Deloitte has been engaged by the Department to undertake Phase One and assess the evaluability of the four LETFF programs. As part of this project, Deloitte has evaluated how well the LETDF s22 have been administered. The ANAO audited the remaining two LETFF programs, the CCS Flagships program s22 in 2017.

This report presents the findings of the process evaluations of the LETDF s22 .

1.2 Purpose and approach of the evaluation

1.2.1 Scope

Deloitte has been engaged by the Department to undertake a process evaluation of how well the LETDF s22 programs have been implemented and administered. This report draws upon direct stakeholder input and a detailed document review to assess the implementation and administration of the programs.

1.2.2 Objectives of process evaluation

The objectives of this evaluation are to assess the:

- extent to which the programs have been implemented as planned
- extent to which funding has been effectively allocated
- extent to which data collection is effectively used to monitor investment performance and drive outcome achievement through a cycle of refinement and improvement
- adequacy of governance structures in place to support governance and reduce risk
- extent to which roles, responsibilities and priorities were appropriately defined and communicated.

1.3 Overview of programs

1.3.1 LETDF overview

The LETDF was announced under the 2004 Energy White Paper – *Securing Australia's Energy Future*. The LETDF aimed to demonstrate that technologies from across the spectrum had the potential to deliver long-term large-scale GHG emissions reductions.

The objective of this program was to demonstrate the commercial potential of new technologies or processes, or to apply overseas technologies or processes to Australian circumstances. The intended outcomes of the program are:[1]

- support for the development and demonstration of low emissions technologies which have the potential to deliver longer term large-scale emission reductions
- support for low emissions technologies that will underpin the value of Australia's resource base and/or promote Australia's leading edge technical capabilities
- the application of overseas technologies to Australian circumstances
- national frameworks to support the introduction of new, low emissions technologies.

The LETDF was announced with $500 million of Commonwealth funding that could be granted to projects ranging from concentrated solar to CCS technology.

1.3.2 Funded projects

Six projects received funding approval under the LETDF. The Gorgon Carbon Dioxide Injection Project is the only remaining project under the LETDF. The other five projects approved for funding have either been migrated to other program areas or terminated.

Table 1.1 below summarises the projects approved for funding under the LETDF. No projects under the LETDF have been completed to date.

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[1] Department of the Environment and Heritage, *Low Emissions Technology Demonstration Fund – Policy Framework,* 2005.

Table 1.1: Projects that received funding approval under LETDF

Project name and description	Approved Funding	Actual Spend	Project Status
Gorgon Carbon Dioxide Injection Project Design, construction and operation of facilities to inject and store CO_2 into a deep reservoir unit two kilometres beneath Barrow Island. The CO_2 that is injected into the reservoir unit comes from the process of extracting gas in the Gorgon/Jansz-Io fields.	$60 million	$60 million	Ongoing, with all funding transferred to project proponent. Project currently being commissioned.
400MW Integrated Dry-gas Gasification Combined Cycle (IDGCC) Clean Coal Demonstration Project A project that aims to increase the burning efficiency of thermal generators by drying brown coal. Reducing the moisture content of brown coal means that less energy is required to convert the coal into electricity.	$100 million	$0 million	Terminated on 27 July 2012 due to inability of proponent to comply with agreement conditions. Funding returned to consolidated revenue.
Hazelwood 2030 Project A project that aims to retrofit Low Emission Technologies at the brown coal-fired Hazelwood Power Station in the Latrobe Valley, Victoria. The process involves reducing moisture content of brown coal for an improved burning efficiency. The Hazelwood 2030 project includes CCS facilities – with demonstrated capacity to sequester carbon dioxide at a rate of 0.02mtpa.	$50 million	$14 million	Terminated by mutual agreement on 15 February 2011 due to technical risks and increases in project costs. $36 million in unspent funds returned to consolidated revenue.
Fairview Project A project that aims to test the extraction of methane from coal and storing it underground	$75 million	$0 million	Terminated with grant offer withdrawn on 2 July 2008 due to competing priority for methane to be extracted and sold internationally, rather than used to generate electricity. $75 million in unspent funds returned to consolidated revenue.
Large Scale Solar Concentrator Power Project A project that aims to develop a 154 MW concentrated solar thermal plant in Mildura, Victoria. s22	$75 million	$0 million	Transferred with funding to ARENA[2] on 1 July 2012.
Total funding	**$410 million**	**$88 million**	

Source: Department of Resources, Energy and Tourism, 2012; Department of Industry, Innovation and Science, 2018.

[2] Australian Renewable Energy Agency

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1.4 Report structure

The report is structured as follows:

- **Chapter 2** describes the evaluation methodology and analytical elements supporting the evaluation.
- **Chapter 3** presents the process evaluation findings of the LETDF.
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2 Evaluation methodology

2.1 Approach to the evaluation

The evaluation uses a mixed methods approach, drawing on stakeholder interviews and detailed documentation analysis, to evaluate how well the LETDF s22 programs have been administered.

2.2 Evaluation framework

2.2.1 Program logic

The process evaluation was guided by program logics of each program, which were developed in consultation with departmental program staff as part of this project.

A program logic provides a theory of how a program will achieve desired outcomes and objectives, by mapping causal links between activities, outputs and outcomes. This logic informs the selection of evaluation questions and the subsequent data requirements for undertaking the evaluation of a program.

Process evaluation questions focus on how and how well programs are implemented. That is, what are the relationships between the stated inputs and activities in supporting and enabling program outputs.

Definitions of the key components of a program logic (as they relate to a process evaluation) include:

- **inputs** – describe the funding and other non-financial resources allocated to the program.
- **activities** – describe the activities and processes involved in delivering funded outputs.
- **outputs** – describe the services, deliverables or units of delivery generated by the program.

The program logics were based on program information supplied by the Department and further refined in workshops with key Department program stakeholders, and presented in Appendix A.

2.2.2 Key evaluation domains and questions

The evaluation has been guided by the following evaluation domains:

- **implementation –** to what extent has the program been implemented as planned?
- **funding allocation –** to what the extent has program funding been effectively allocated?
- **monitoring and reporting** – to what extent has data collection been effectively used to monitor investment performance and drive outcome achievement through a cycle of refinement and improvement?
- **governance and risk –** have adequate governance structures been put place to support governance and reduce program risks?
- **accountability** – to what extent were roles, responsibilities and priorities appropriately defined and communicated?

The key evaluation questions, and supporting sub-questions, are detailed in Appendix B.

2.3 Data and inputs

2.3.1 Document review

A core component of the process evaluation involved the review of departmental and publicly available program documentation.

The Deloitte team was granted access to the Department's internal documentation management system, which included program- and project-level supporting documentation. This information was crucial to understand the administrative processes and challenges faced by each program.

External documents such as previous audits and evaluations undertaken by external parties were also reviewed.

2.3.2 Semi-structured interviews

Semi-structured interviews were conducted with nine key stakeholders across the LETDF s22 programs (Table 2.1), covering departmental program and project management staff, identified in consultation with the Department.

Interview questions were refined throughout the consultation period based on insights gained through completed interviews, whilst ensuring consistency and comparability of results. Interviews were conducted via teleconference and recorded and transcribed to enable a thematic analysis of stakeholders' perceptions and insights against the key evaluation questions.

Table 2.1: LETDF s22 stakeholders interviewed (by program and role)

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3 Implementation of LETDF

The evaluation of the LETDF has been limited by the significant lapse in time since its announcement in 2004 and subsequent implementation. Specific issues that limited this evaluation include:

- the natural turnover of program staff; the Deloitte evaluation team was unable to engage with departmental stakeholders with first-hand knowledge and understanding of the implementation of the program
- administrative and documentation management changes over the course of the LETDF's operation, resulting in a range of documentation gaps.

The process evaluation of the LETDF is detailed in the following sections.

3.1 Implementation

Key findings:

- The program has evolved over time, with only the Gorgon Carbon Dioxide Injection Project remaining under the LETDF.
- Overall, program processes have been implemented as planned.
- Implementation would have been strengthened from a strategic review of program rationale and objectives in 2012, when the Gorgon Carbon Dioxide Injection Project became the sole project under this program.
- There are some gaps in documentation with respect to the termination of projects to other program areas.
- The efficient implementation of the program would have been enhanced by:
  - greater recognition by policy objectives of the **potential technical complexities** of the projects seeking funding - strengthening the project assessment and program timeline setting processes
  - **inclusion of flexible contract negotiating processes**, which would have supported more timely finalisation of funding agreements, which typically required 18 months.
  - a single department or agency having clear overarching **administrative and management** responsibility for the program.

Implications for future programs:

- Program rationale and objectives should be reviewed periodically, particularly for long-running programs that have experienced significant changes to program activities and/or funding.
- Funding agreements should include, to the extent possible, flexible contractual arrangements that appropriately reflect the scale and technical complexity of projects being delivered, while also meeting Government risk management requirements.

3.1.1 Have program objectives and intended outcomes changed over time? What motivated this change? Were changes clearly documented?

The program's intended objectives, outcomes and focus do not appear to have changed over time. This finding was supported by stakeholders who noted that the original intent and focus of the program has remained unchanged.

Under the LETDF, six projects were approved for funding under the first funding round. A review of individual project documentation (including funding applications, assessments, and funding agreements) indicates that individual project objectives and outcomes aligned strongly with stated program objectives and outcomes.

3.1.2 Has the program evolved or changed since its inception? If so, in what ways?

The Gorgon Carbon Dioxide Injection Project is the only remaining project under the LETDF.

The other five projects approved for funding have been either migrated to other program areas or terminated:

- s22
- The IDGCC Clean Coal Demonstration Project, the Hazelwood 2030 Project and the Fairview Project were all terminated by the Commonwealth Government due to an inability to comply with the conditions of their funding agreements.

The migration and termination of projects under the LETDF is discussed in greater detail in Section 3.2.

The LETDF is considered to have changed since its inception, with significantly reduced project activities than originally intended.

Gorgon Carbon Dioxide Injection Project

A review of documentation indicates that the objectives and outcomes of the Gorgon Carbon Dioxide Injection Project have **remained unchanged since inception**. Deloitte notes, however, that the timelines of the project have been extended on multiple occasions due to technical complexities of the CO_2 injection process and logistical issues relating to location of the site (discussed in Section 3.2.5).

Changes to the Gorgon Carbon Dioxide Injection Project timelines were supported with appropriate documentation, including Deeds of Variation, revised project and payment milestones, and other relevant supporting documentation.

Terminated projects

The terminations of the Hazelwood 2030 Project and the Fairview Project were clearly documented, with evidence of executive termination letters and termination deeds, in addition to other supporting material. While Deloitte was able to review some supporting documentation relating to the termination of the IDGCC Clean Coal Demonstration Project, the Department could not provide any formal documentation (such as an executed termination deed or ministerial brief) supporting the termination of the project.

Migrated projects

The Department was unable to provide supporting documentation relating to the formal migration of the CS Energy Callide and the Large Scale Solar Concentrator Power projects to alternate government programs. It is therefore not possible to comment on the manner in which the funding and administrative transfer was managed.

3.1.3 Have program processes been implemented as planned? What are the key enablers and barriers that have impacted implementation?

The original and updated *LETDF Program Administrative Guidelines* outline relevant processes to support the implementation and management of the program.

Overall, Deloitte considers that program *processes* have been implemented as planned:

- **Appointment of an expert panel:** an Expert Panel consisting of independent technical experts was appointed to undertake the eligibility, merit and due diligence assessments of program funding applications. A transparent conflict of interest process supported the management of the panel.
- **Stakeholder engagement:** a detailed stakeholder engagement strategy was developed as part of an implementation plan. Program guidelines, including a customer information guide, outlining the expected obligations of project applicants, assessment criteria, approval processes and timeframes were widely disseminated to stakeholders prior to applications commencing.
- **Funding rounds:** the LETDF was intended to have up to three funding rounds, with subsequent rounds dependent on the outcome of the first round. However, $410 million of the original $500 million funding was committed in the first round. The uncommitted $90 million was returned to consolidated revenue following the 2007 election and no further funding rounds were held.
- **Application and assessment of funding applications:** the Expert Panel, in accordance with relevant guidelines, undertook a comprehensive and rigorous assessment process (outlined in Section 3.2.2).
- **Funding agreements:** funding agreements were established with each project proponent in accordance with the administrative guidelines (discussed in greater detail in Section 3.2.2).

In addition to the above core program processes, a detailed Implementation Plan was developed for the LETDF. It detailed scope, funding, risk management, communications, resources, procurements, and quality assurance processes for the LETDF.[8]

[8] AusIndustry, *Low Emissions Technology Demonstration Fund – Implementation Plan*, 2005.

Standard Operating Procedures (SOPs) were also developed to support AusIndustry's management and administration of the program, which set out specific processes involved in administering the LETDF.[9] Other supporting documents and processes developed as part of the implementation of the LETDF include:

- LETDF Fact Sheet
- LETDF Registration Form
- LETDF Customer Information Guide
- LETDF Grant Application Form
- LETDF Policy Framework
- LETDF Deed of Agreement
- LETDF Variation Application Form
- LETDF Completeness Checklist template
- LETDF Eligibility Assessment templates
- LETDF Completeness and Eligibility Assessment template.

Barriers to implementation

This evaluation has identified some barriers to the efficient implementation of the LETDF. Specifically:

- LETDF policy objectives would have been strengthened by giving greater recognition to the inherent technical complexities of projects seeking funding. Projects under the LETDF were large and complex infrastructure projects, requiring significant lead times for prefeasibility and feasibility design studies, followed by construction and testing activities. An internal review noted that a greater understanding of the nature and the scale of infrastructure development would have assisted program implementation.[10]
- The LETDF was originally administered under a tripartite arrangement between the former Department of the Environment and Heritage (DEH), the Department of Industry, Tourism and Resources (DITR) and AusIndustry (the program delivery division of DITR). A single department or agency having clear program administrative and management oversight would have enhanced program knowledge sharing and file administration. However, Deloitte notes that administrative processes were streamlined following the full transfer of program responsibilities to the former Department of Resources, Energy and Tourism (DRET) in 2008.
- Complicated and rigid contract negotiating processes resulted in significant delays to the finalisation of funding agreements, which typically took around 18 months. This issue is discussed in detail in Section 3.2.2.

3.1.4 Were changes to the implementation of the program appropriately documented, reported and communicated to stakeholders?

The most significant change to the implementation of the program involved the full transfer of administrative and management responsibilities from DEH and DITR to the former DRET following the 2007 Federal election. The transfer of program administrative and management responsibilities are discussed in detail in Sections 3.4 and 3.5.

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[9] See, for example: AusIndustry, *Standard Operating Procedure – Expert Panel merit assessment process*, 2006.
[10] Unknown, *Low Emission Technology Development Fund – Lessons Learnt Review,* 2012.

Overall, changes to the implementation of individual projects were documented appropriately in relevant project reports; for example, progress reports, milestone reports, annual reports and Deeds of Variation. This finding is supported by consultations with stakeholders, who considered that project changes were appropriately documented, reported and communicated.

3.2 Funding allocation

Key findings:

- Overall, the LETDF Program was well-supported by **a robust and transparent project application assessment framework** that included published project selection guidelines, eligibility and merit criteria, and advice and guidance from independent panel of technical experts.
- It is estimated that $88 million (18%) of the original $500 million has been spent to date under the LETDF.
- Program administration would have been strengthened by developing a framework to monitor the effects of reduced funding on the achievement of stated objectives and remaining funds could have been redistributed within other programs.
- Overall, project application and assessment processes under the LETDF aligned with and supported stated program objectives.
- Assessment and selection processes appear to have been comprehensive, supported by a high degree of rigour and technical expertise, and consistent with stated selection assessment criteria.
- Improved precision of project eligibility criteria would have improved consistency in the assessment of project eligibility.
- The finalisation of funding agreements took significantly longer than anticipated. Administrative efficiency would have been improved with greater consideration of the ability of project proponents to meet financial requirements and factors influencing implementation timeframes during the application process.

Implications for future programs:

- Processes should be embedded to review and monitor potential effects of material changes in program funding on the achievement of objectives and outcomes.

3.2.1 Were project application, eligibility criteria and selection guidelines developed to support the program? Were these appropriate and aligned to program objectives?

Overall, the program was well-supported by a sound, robust and transparent project application assessment framework. The framework included published project selection guidelines, eligibility and merit criteria, and advice and guidance from an independent panel of technical experts.

The original *LETDF Programme Administrative Guidelines* (dated 2005) outline in detail the application, assessment and approval processes for the program. This includes guidance and specification on:

- the operational context of the LETDF
- the applications process of the LETDF
- the eligibility and merit assessment process
- the functions and roles of the technical expert panel
- grant approval and notification processes
- the size of grants
- the funding agreement and the process for project variations.

The administrative guidelines were supported by an assessment framework to guide the Expert Panel,[11] a *Customer Information Guide*,[12] and Eligible Expenditure Guidelines.[13]

The *Customer Information Guide* was the primary source of information for potential funding applicants. It provided an overview of the LETDF, the eligibility and merit criteria, the eligible expenditure guide and a guide to assist in completing the application form. A review of it indicates that it was consistent with the overarching program administration guidelines.

Combined, these documents appear to have provided a clear and transparent framework to guide the application, assessment and selection of projects under the LETDF.

Deloitte considers that the application and assessment processes outlined in the *LETDF Programme Administrative Guidelines* and supporting documentation aligned with and supported the stated objectives of the LETDF.

3.2.2 Were program funding decision-making processes appropriately implemented and documented?

Implementation and documentation of funding application processes

As reported above, three funding rounds were originally intended to be held under the LETDF. However, the program was closed after just one funding round.

In total, 30 funding applications were received. Of these, 26 proposals were assessed as 'eligible' with six projects ultimately receiving approval for funding. An internal departmental review noted that the majority of applications were unsuccessful because the technology offered was not considered to be ready for large-scale demonstration.[14] Successful funding grants ranged from $50 million to $100 million.

Stakeholders interviewed were unable to comment on the appropriateness of program funding decision-making processes, due to funding decisions pre-dating their time with the Department and program.

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[11] AusIndustry, *Assessment Framework – Low Emissions Technology Demonstration Fund*, 2005.
[12] AusIndustry, *Low Emissions Technology Demonstration Fund: Customer Information Guide*, 2005.
[13] AusIndustry, *Low Emissions Technology Demonstration Fund: Eligible Expenditure Guidelines*, 2005.
[14] Department of Industry, Innovation and Science, *Low Emissions Technology Development Fund – Lessons Learnt Review (Draft)*, 2012.

However, a review of available documentation indicates the assessment and selection process was comprehensive and consistent with published selection guidelines and eligibility and merit assessment criteria. This finding is consistent with previous reviews and audits of the LETDF[15], which found a high degree of rigour and technical expertise applied to the assessment of project applications.

Documentation reviewed by Deloitte indicates that all project applications underwent technical, due diligence and financial assessments by the appointed panel of external experts, with projects ranked using a numeric scoring system. The funding application assessment process was strengthened by a probity review upon completion.

Some shortcomings within the LETDF assessment framework, however, were identified by an internal Department review. The 2008 review identified that eligibility criteria lacked precision, resulting in some inconsistency in the assessment of project eligibility.[16] This resulted in two applicants appealing their assessment of ineligibility, with a subsequent review process overturning one decision and upholding the other.

Deloitte also considers that the project selection process would have been strengthened with greater scrutiny applied to the financial viability of projects. This finding is consistent with a previous review of the program.[17]

The above issues, particularly financial viability, may have contributed to the large proportion of projects (50%) being terminated. (See Section 3.2.4 for further detail).

Finalisation of funding agreements

All projects experienced substantial delays in negotiating final funding agreements, with an average completion time of 18 months and one project taking almost two years.[18] Factors that contributed to the delays, some of which were outside the control of the Department, included:[19]

- proponents experiencing difficulty in obtaining third party finance
- technical complexity of projects
- certainty of funding (e.g. termination rights and claw back provisions included in the Funding Deeds)
- development approval processes.

In particular, it appears that environmental and regulatory approvals processes required for large, complex projects were not adequately understood. While these issues are outside the direct control of the Department, an internal program review identified that the potential impact of these issues had not been sufficiently considered by the Expert Panel during the project selection stage. For example, the Gorgon Carbon Dioxide

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[15] Australian National Audit Office, *Audit Report No.26 2009-10 - Performance Audit: Administration of Climate Change Programs*, 2010; KPMG, Individual Program Review – *Low Emissions Technology Demonstration Fund*, 2009; Department of Innovation, Industry, Science and Research, *Audit of Low Emissions Technology Demonstration Fund*, 2007.
[16] Department of Innovation, Industry, Science and Research, *Round One Review: Low Emissions Technology Demonstration Fund*, 2008.
[17] Australian National Audit Office, *ANAO Audit Report No. 26 2009-10 Administration of Climate Change Programs,* 2010.
[18] Department of Innovation, Industry, Science and Research, *Round One Review: Low Emissions Technology Demonstration Fund*, 2008.
[19] Australian National Audit Office, *ANAO Audit Report No. 26 2009-10 – Performance Audit: Administration of Climate Change Programs,* 2010.

Injection Project funding agreement was delayed significantly due to a protracted State environmental approvals process.[20]

A more detailed consideration of the financial viability, technical complexity and implementation timeframes for each project would have improved the efficiency in finalising funding agreements.

3.2.3 Were relevant project application and selection guidelines well understood and followed by relevant stakeholders?

Program guidelines outlining the expected obligations of project applicants, assessment criteria, approval processes and timeframes, and a supporting *Statement of Challenges and Opportunities,* were widely disseminated to stakeholders in 2005, well in advance of the deadline for funding applications.

An internal review reported that 30 meetings were held with program registrants between October 2005 and March 2006, and a total of 300 stakeholder queries were submitted to the Department during round one.[21]

The number of project proposals received, and their corresponding financial commitment, suggests that the program was well promoted and communicated to industry.

Furthermore, AusIndustry undertook a customer satisfaction survey following the completion of the first (and only) funding round. The survey found 80% of customers were satisfied with the funding process, including those that were unsuccessful.

Critically, the survey confirmed that the *Customer Information Guide* provided accessible and useful information to funding applicants; almost 90% of surveyed funding applicants were satisfied with the *Customer Information Guide*.[22]

3.2.4 Were there any changes to program funding? What impact did funding changes have on program outputs?

Overall, there were significant changes to LETDF funding. The LETDF had an original budget of $500 million. An initial funding round was completed in March 2006, with $410 million in approved funding offered to six projects.

No further funding rounds were held and the remaining $90 million was returned to consolidated revenue following the 2007 Election.[23]

Further funds from the $410 allocation were also returned to consolidated revenue as two of the projects were transferred to other programs, while three projects were terminated, as noted above.

Overall, it is estimated that $88 million (18%) of the original $500 million has been spent under the LETDF. An overview of the funding and project status of the six projects approved for funding is provided in Table 1.1 in Section 1.

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[20] Department of Industry, Innovation and Science, *Low Emissions Technology Development Fund – Lessons Learnt Review (Draft)*, 2012.
[21] Department of Innovation, Industry, Science and Research, *Round One Review: Low Emissions Technology Demonstration Fund*, 2008.
[22] Department of Innovation, Industry, Science and Research, *Round One Review: Low Emissions Technology Demonstration Fund*, 2008.
[23] Department of Resources, Energy and Tourism, *Low Emission Technology Demonstration Fund (LETDF). Gorgon CO2 Injection Project PSD.*

The changes in project funding appear to have been driven largely by individual project proponents not being able to meet the conditions set out under respective funding agreements. This resulted in a reduction in total program funding, which was not subsequently reallocated to new projects.

3.2.5 How effectively were any changes to program funding managed?

No evidence was identified of a supporting framework being implemented to monitor the effects of reduced funding on the program meeting its objectives. Furthermore, Deloitte could not identify a clear strategy on how the Department might have allocated remaining funds within other LETFF programs, or how it may have revisited the project selection process to identify projects that were the next best ranked.

At a project level, grant payments were attached to the completion of project-specific milestones. Payments were tracked through Milestone Reports that were reviewed by the LETDF team.

Any changes to project funding were administered formally via Deeds of Variation. These required the Ministers' approval before funding could be reallocated at a project-specific scale.

The Gorgon Carbon Dioxide Injection Project funding agreement has been varied on a number of occasions, with the number of milestones increasing from three to eleven over the course of the project. The Gorgon Project has had significant timeline overruns, mainly due to the technical complexity of the project and logistical issues relating to moving equipment to the Barrow Island Class A Nature Reserve site.[24] The project's milestone payments were also extended to reflect increased time required to complete aspects of the carbon dioxide injection process.[25]

A review of supporting project documentation for the Gorgon Carbon Dioxide Injection Project, the Hazelwood 2030 Project and CS Energy Callide Project indicates that changes to project funding and project milestones generally appear to be documented appropriately in line with program reporting requirements. For example, Deloitte was able to identify executed Deeds of Variation, annual reports, revised project and payment milestones, and other project funding-related correspondence from project proponents (e.g. emails, formal letters and minutes).

Both government and industry stakeholder groups noted that funding changes were managed as efficiently and effectively as possible, noting that a lengthy process is generally expected with respect to government contractual agreements that require Ministerial oversight.

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[24] LETFF Interview Transcript – Kim Withers and Selene Ugarte, 2018

[25] Unknown, *Low Emission Technology Development Fund – Lessons Learnt Review,* 2012.

3.3 Monitoring and reporting

Key findings:

- Overall, program-reporting arrangements were appropriate, clearly documented, and consistently followed and enabled the effective oversight of the LETDF.
- Project-level reporting arrangements under the LETDF were found to be clearly defined under respective project funding deeds, and enabled a transparent, consistent and appropriate reporting framework at the project level.
- However, there is no evidence of the Department having undertaken an evaluation of the appropriateness, efficiency and effectiveness of the LETDF despite a Draft Process Evaluation Plan developed in the early stages of the program.

Implications for future programs:

- Evaluation processes should be defined and embedded in formal program monitoring and reporting arrangements at program commencement, and should be fully utilised.
- For large-scale, long-term projects, with a high degree of uncertainty, there is a need for continuous and ongoing monitoring to ensure programs are continuing to meet their objectives in the context of a changing policy or funding environments.

3.3.1 Were effective program oversight and internal reporting arrangements in place? Were reporting arrangements adequately followed and clearly documented?

The *LETDF Program Administrative Guidelines* (dated 2008) specified the monitoring and reporting arrangements required of the Department as part of its administration of the LETDF. The Department was required to prepare monthly and quarterly reports relating to the financial and contractual management of the program and agreed performance indicators for individual projects. The guidelines also included a requirement to monitor and evaluate the appropriateness, efficiency and effectiveness of the LETDF.

Stakeholders noted that a range of standard departmental reporting arrangements supported program reporting, including: an annual risk workbook, preparation of quarterly updates to the Program Assurance Committee (PAC), and regular briefing to departmental executive.

A review of documentation indicates that monthly and quarterly reporting processes were adequately followed by the Department prior to 2012. From 2012, when the Gorgon Carbon Dioxide Injection Project was the sole remaining project under the LETDF, it does not appear that monthly reports were continued. The reduction in reporting burden appears to be appropriate with only one project under administration.

From 2015, quarterly program reporting was managed via the Department’s online Program Summary Database (PSD), which enables the tracking of individual project deliverables, milestones, expenses, and current issues impacting delivery (among other categories of project tracking). A review of the PSD indicates that it has been regularly maintained and updated with respect to the LETDF.

Overall, program reporting arrangements were clearly documented, enabled effective oversight of the LETDF and were adequately followed.

Deloitte has not identified any evidence of the Department having undertaken a formal evaluation of the appropriateness, efficiency and effectiveness of the LETDF prior to this evaluation, despite a Draft Process Evaluation Plan being developed for the program. It is recognised, however, that other audit and review activities of the program have been undertaken. These include:

- internal review of the Round One funding application process in 2008
- external high-level review in 2009
- ANAO audit focussing on administrative processes in 2010
- internal draft "lessons learnt" review in 2012.

3.3.2 Were systems or processes implemented to consistently track the program activities and outputs?

At the program level, stakeholders noted departmental systems were in place to track program activities and outputs over time. These included reporting to the PAC, reporting processes to brief departmental executive, reporting via the PSD and additional tracking documents and frameworks.

Regular program progress reports (typically quarterly) were prepared for the PAC, drawing on information contained within the Department's PSD. The report to the PAC uses traffic light ratings to highlight identified program issues/risks for the particular reporting period, and planned mitigation activities/actions.

The Department also prepared regular approval minutes when approving payments to project proponents. Deloitte confirms these were prepared as required for the Gorgon Carbon Dioxide Injection Program.

Overall, Deloitte considers that appropriate reporting systems were implemented to track program activities.

Given only one project has been active under the LETDF since 2012, program systems essentially reflect project-level reporting arrangements, as discussed in Section 3.3.3 following.

3.3.3 Was there a transparent and appropriate framework for reporting project-level inputs, activities and outputs? Were these processes followed throughout the program?

Project-level reporting arrangements were clearly established under individual project funding agreements. Reporting arrangements included project plans, project milestone reports, project progress reports, annual reports including audited financial statement, and other identified reporting requirements as deemed necessary.

Deloitte reviewed a sample of project reports for the following projects that commenced under the LETDF:

- Gorgon Carbon Dioxide Injection Project
- Large Scale Solar Concentrator Power Project
- Hazelwood 2030 Project
- CS Energy Callide Project.

Deloitte considers that the LETDF was generally supported by a transparent, consistent and appropriate reporting framework at the project level. It is also noted that a previous review of the LETDF considered funding agreements executed under the program to have been well designed.[26]

With the exception of the Gorgon Carbon Dioxide Injection Project, reporting requirements for all projects ceased by July 2012 (as reported above). Deloitte confirms that project reporting processes for the Gorgon Carbon Dioxide Injection Project have continued to date, including annual reports and milestone variation reports as required.

Overall, stakeholders considered the reporting requirements to have been appropriate and clear, and well supported by individual funding agreements.

3.3.4 Did the program or project-level reporting (e.g. format, timing, focus etc) change during the course of the program? What motivated this?

New program-level reporting requirements were introduced in 2008 following the transfer of administrative and management responsibilities to the former DRET. The transfer resulted in the establishment of new *LETDF Program Administrative Guidelines*, which included additional program reporting requirements; specifically, to:

- report financial and delivery performance of the LETDF on a monthly basis
- monitor and evaluate the appropriateness, efficiency and effectiveness of the program
- report on agreed *funding recipient* performance outcome indicators on a one, two and five-year basis.

Stakeholders interviewed noted that there has been no change to project-level reporting arrangements over the course of the program.

This was supported by a review of available documentation that indicates that there have been no material changes to project-level reporting arrangements.

3.3.5 Did findings within the reporting drive a refinement of the approach or individual activities over time?

Project related reporting activities were undertaken as per requirements under individual project funding agreements.

A review of project documentation indicates that significant changes relating to project scope, milestones, reporting and funding were appropriately documented in official variation documents, such as Deeds of Variation and milestone extension reports.

In this respect, findings within project reporting arrangements assisted to refine individual project activities overtime.

At the program level, there is limited evidence of reporting activities driving a refinement in program activities. The Department implemented an issues and risk register in 2010, following the recommendation of an external review of the LETDF in 2009. However, there is no evidence of the register having been updated since 2010.

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[26] Australian National Audit Office, *ANAO Audit Report No. 26 2009-10 – Performance Audit: Administration of Climate Change Programs,* 2010.

3.4 Governance and risk

Key findings:

- Overall, the governance arrangements supporting the LETDF at the commencement of the program were **appropriate, clearly documented and well understood by stakeholders**.
- By setting clear objectives and funding eligibility and assessment criteria, the governance arrangements supported the clear and transparent identification and setting of program priorities.
- The LETDF was supported by good risk management practices. Project selection was supported by due diligence assessments, the recruitment and appointment of an expert panel to assess funding applications, and processes to manage potential conflict of interest of panel members.
- Risk management arrangements would have been strengthened by the development of a risk management plan at the inception of the program in 2004-05. This would have enabled a formal assessment of potential risks during program development and design; specifically, risks associated with the financial viability of project proponents, technical complexity of projects and implementation timeframes – factors that impeded funding agreement negotiations.
- Changes to the LETDF governance arrangements were well documented within the updated administrative guidelines. However, it is unclear if changes were communicated effectively to stakeholders.

Implications for future programs:

- A formal assessment of potential program risks should be undertaken during program development and design. This ensures risk mitigation strategies can be fully explored, and if possible, embedded within program design.

3.4.1 Were program governance and risk management arrangements clearly documented and understood by relevant stakeholders?

Governance arrangements

As reported above, the LETDF was originally administered as a tripartite arrangement between the former DEH and DITR, and AusIndustry.

At the commencement of the program in 2005, the financial governance, delivery and administration arrangements supporting the LETDF were clearly documented and set out in:

- the *LETDF Programme Administrative Guidelines* (2005)[27]
- *Guidelines for the Governance of the LETDF* (2005)[28]

[27] Department of Industry, Tourism and Resources and the Department of the Environment and Water Resources, *Low Emissions Technology Demonstration Fund - Programme Administrative Guidelines*.
[28] Department of Industry, Tourism and Resources and the Department of the Environment and Water Resources, *Guidelines by the Minister for Environment and Heritage and the Minister for Industry, Tourism and Resources for the Governance of the Low Emissions Technology Demonstration Fund*, 2005.

- a Memorandum of Understanding[29] (MoU) between the former DEH and DITR.

These guidelines outlined key management and administrative roles, and functions and responsibilities for the LETDF and were in place at the outset of the LETDF. The guidelines specifically outlined the roles and responsibilities of relevant Ministers, Departments and the Expert Panel.

The LETDF was also supported by a series of Standard Operating Procedures (SOPs) to support AusIndustry's management and administration of the program. These SOPs set out specific steps and processes involved in carrying out the functions required to administer and deliver the LETDF.[30]

The management and administration of the LETDF was further supported by the following documents:

- LETDF Fact Sheet
- LETDF Registration Form
- LETDF Customer Information Guide
- LETDF Grant Application Form
- LETDF Policy Framework
- LETDF Deed of Agreement
- LETDF Variation Application Form
- LETDF Completeness Checklist template
- LETDF Eligibility Assessment templates
- LETDF Completeness and Eligibility Assessment template.

At the project level, governance and risk management arrangements were embedded from a contractual standpoint, with individual funding agreements acting as the primary project governance instrument. The funding agreements outlined the specific reporting requirements for individual proponents, chief among them an annual report with audited financial statement of project expenditure. As noted by an industry stakeholder:

> *I think the big thing for the Government is that they are getting that audited annual report where all the financial statements are fully audited by external financial auditors. It gives a bit of confidence that we are not misappropriating funds here – Industry stakeholder.*

Overall, Deloitte considers **the governance arrangements supporting the LETDF at the commencement of the program were appropriate, clearly documented and well understood by stakeholders**. Furthermore, by setting clear objectives and funding eligibility and assessment criteria, Deloitte considers that the governance arrangements **enabled the clear and transparent identification and setting of program priorities**. However, some shortcomings have been identified (discussed in Section 3.4.3).

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[29] Department of Industry, Tourism and Resources and the Department of the Environment and Water Resources, *Memorandum of Understanding between the Department of the Environment and Heritage and the Department of Industry, Tourism and Resources – Arrangements for Joint Delivery of measures for the low emissions technology demonstration fund*, 2005.
[30] See, for example: AusIndustry, *Standard Operating Procedure – Expert Panel merit assessment process*, 2006.

Risk management arrangements

As noted in the 2010 ANAO audit of climate change programs[31], the LETDF was not supported by a risk management plan at the inception of the program in 2004-05. No formal assessment of the potential program risks was undertaken during program development and design.

Risk assessments aim to identify, assess and provide solutions to minimise adverse risks within a program and maximise value for money. Ideally, risk assessments should be conducted during the design stage of a program – especially for a program with such a high exposure to technologies that have not been developed at a commercial scale in the electricity sector anywhere in the world.

Deloitte considers that the LETDF would have been well served by a formal risk assessment during program development. This would have enabled a deeper consideration of issues such as the financial viability of projects, technical complexity and implementation timeframes which were found to impact the finalisation of funding agreements (see Section 3.2.2).

However, a risk register identifying potential risks was completed in June 2006, and was updated annually until 2010. A risk workbook was also established for the Gorgon Carbon Dioxide Injection Project, which identified key risks associated with project delivery, a risk rating and risk mitigation activities.

Overall, the LETDF was supported by a sound risk management strategy. Examples of good risk management practice include:

- the selection of projects was supported by due diligence assessments
- the recruitment and appointment of an expert panel to assess funding applications
- processes to manage potential conflict of interest of panel members.

3.4.2 Have the governance and risk arrangements changed during the course of the program?

Following the 2007 Federal Election, full administrative and management responsibilities of the LETDF were transferred from DEH and AusIndustry[32] to DRET. The formal transfer to DRET was undertaken on 1 July 2008.

This evaluation was unable to identify formal documentation regarding the transition process and how it was communicated to relevant internal and external stakeholders. As such, Deloitte is unable to comment on the appropriateness and efficacy of the transition process.

As part of the transfer to DRET, a new set of *LETDF Program Administrative Guidelines* (dated 22 July 2008) was established by the Minister for Resources, Energy and Tourism. The updated guidelines streamlined the administrative and management arrangements (previously split across DEH, DITR and AusIndustry) within a single delivery team within the Energy Future Branch in DRET.

As reported above, the new administrative guidelines also included additional program reporting requirements. The new administrative

[31] Australian National Audit Office, *Audit Report No.26 2009-10 - Performance Audit: Administration of Climate Change Programs*, 2010.
[32] AusIndustry was located within the newly formed Department of Innovation, Industry, Science and Research.

guidelines also formalised supporting program documentation, such as the SOPs and other associated documentation.

Deloitte has reviewed the available documentation and considers that changes to the LETDF governance arrangements were clearly documented within the updated administrative guidelines.

3.4.3 Have the governance and risk management arrangements enabled (or hindered) the program in achieving its outputs?

Stakeholders generally considered that the governance and risk management arrangements have not hindered the achievement of program outputs and outcomes.

However, an internal review by the Department in 2012 identified a range of administrative arrangements that may have impeded the ability of LEDTF to meet its stated outputs, and by extension, outcomes. Key issues identified in the internal review included:[33]

- policy objectives not adequately considering the commercial realities of large, complex energy projects which require significant lead times
- a rigid delegated authority which required Ministerial approval for even the smallest funding variation requests
- an assessment framework that placed too much emphasis on the financial challenges of the selected projects, without due appreciation of the environmental and regulatory approvals processes involved.

3.4.4 Have the governance arrangements resulted in any unintended outcomes?

As reported above, issues around termination rights and claw back provisions contributed to significant delays in negotiating funding agreements with project proponents.

3.5 Accountability

Key findings:

- Overall, program roles, responsibilities and priorities were clearly defined and documented at the outset of the program.
- At the project level, the roles and responsibilities were clearly defined for the project proponent and Department (and its representatives) in individual project funding agreements.
- Stakeholders considered that the Department managed changes in program personnel well over the course of the program and that such changes did not affect the achievement of program objectives.

[33] Department of Resources, Energy and Tourism, *Low Emission Technology Development Fund – Lessons Learnt Review (DRAFT)*, 2012.

3.5.1 Were program roles, responsibilities and priorities clearly defined and documented?

Deloitte considers that program roles, responsibilities and priorities were clearly defined and documented at the outset of the program in the *LETDF Programme Administrative Guidelines* (2005), *Guidelines for the Governance of the LETDF* (2005) and MoU between the former DEH and DITR, including:

- the relevant Ministers (the Minister for the Environment and Heritage and Minister for Industry, Tourism and Resources were jointly responsible for the LETDF)
- Departments (DEH and DITR at the time)
- the Expert Panel responsible for the assessment of project applications.

As noted above, project roles and responsibilities were defined project funding agreements. Project priorities were defined in these agreements insofar as the schedule of milestones, reporting and funding related to priority setting.[34]

Program stakeholders agreed that the roles, responsibilities and priorities under the LETDF were well defined.

3.5.2 Were there any changes to the roles and priorities of staff over the course of the program? Were changes documented and communicated effectively?

With the exception of the transfer of the program to the Department, Deloitte has not identified any relevant documentation that relates to changes in the roles and priorities of program staff over the course of the LETDF.

Stakeholders were consistent in the view that changes to departmental staff over the course of the program did not negatively affect the administration of the program. Rather, stakeholders noted that the Department managed staff changes effectively and efficiently, and communicated changes to project proponents in a clear and timely manner.

3.5.3 Did the roles, responsibilities and priorities of program staff present any barriers to the achievement of the program's objectives?

Some stakeholders identified a lack of scientific and technical expertise within the Department, and questioned whether this may have slowed down some program processes. However, while there is no standing technical advisory panel for LETDF, government stakeholders noted their ability to draw upon the expertise of CSIRO and Geosciences Australia as required. Indeed, government stakeholders noted that they did not seek to unnecessarily impede reporting tasks by requesting highly technical reports from project proponents.

Overall, Deloitte has not identified any barriers to the achievement of program objectives stemming from defined roles and responsibilities under the LETDF.

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[34] For example, see: Department of Resources, Energy and Tourism, *Low Emissions Technology Demonstration Fund: Funding Agreement - Chevron Australia Pty Ltd,* 2008.

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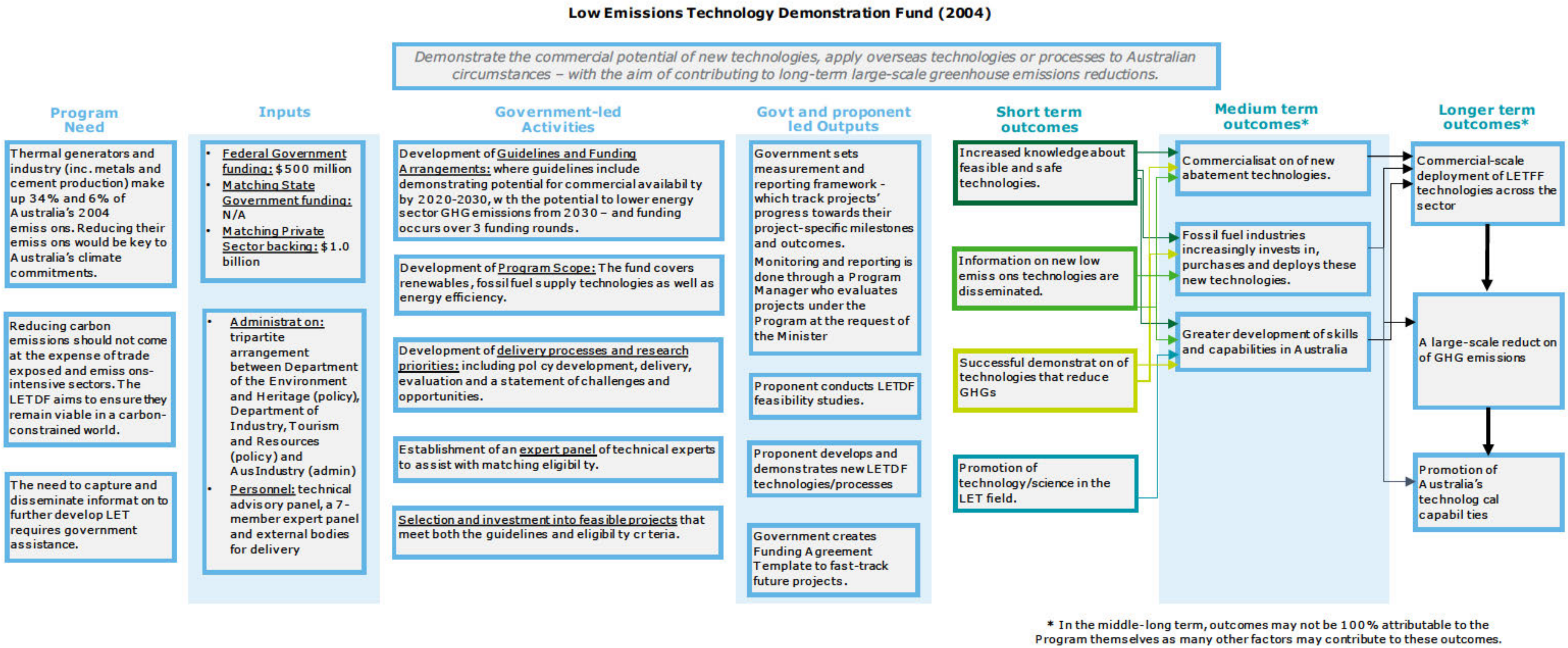
Appendix A Program logic models

Figure A.1: LETDF program logic



Key Assumptions

- Applications are of adequately high quality and there are a sufficient number of applicants
- Projects cover the safety of and effectiveness of emiss ons abatement technologies
- Projects are successful in generating feasible and safe options for emissions abatement
- Industry players – including thermal generators and others choose to deploy these technologies regardless of the presence of a pr ce on carbon
- The relative prices of other technologies do not cause industries reliant on carbon-intensive fuels to become uncompetitive even w th reduced emissions intens ty
- Timelines are sufficient for the goals that the program is trying to achieve.
- Administrat on would be centralised in one Department
- The level of Government funding committed is maintained

External considerations

- The relative prices of other (non coal) energy sources
- Other investments made in reducing emiss ons intensity of the fossil fuel sector (e.g. overseas research)
- The Australian governments' views of a carbon price and other related environmental and climate change policies
- The level of demand for coal-based energy
- Other carbon-intensive industry activ ty (aluminium smelting etc)
- General econom c cond tions and policies relating to economic stimulus

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Appendix B Key Process Evaluation Questions

B.1. Key Process Evaluation Questions

The key evaluation questions and supporting sub-questions, underpinning the process evaluation of the LETDF s22 [redacted] programs are outlined in Table B.1 below.

Table B.1: Key Process Evaluation Questions

Key evaluation question	Evaluation Sub-Questions	Evidence base: Document review	Evidence base: Stakeholder interviews
Implementation: To what extent has the program been implemented as planned?	• Have the program's objectives and intended outcomes changed over time? What motivated these changes? Were these changes clearly documented?	✓	✓
	• Has the program evolved or changed since its inception? If so, how?	✓	✓
	• Have program processes been implemented as planned? What are the key enablers and barriers that have impacted on implementation?	✓	✓
	• Were changes to the implementation of the program appropriately documented, reported and communicated to relevant internal and external stakeholders?	✓	✓
Funding allocation: To what extent has program funding been allocated effectively?	• Were project application, eligibility criteria and selection guidelines developed to support the program? Were these guidelines appropriate and aligned to the objectives of the program?	✓	✓
	• Were project decision-making processes appropriately implemented and documented? Was project selection guided and undertaken in accordance with relevant guidelines?	✓	✓
	• Were relevant project application and selection guidelines well understood and followed by relevant stakeholders?		✓
	• Were there any changes to program funding? What impact did funding changes have on program outputs?	✓	✓
	• How effective were (if any) changes to program funding managed?		✓

Key evaluation question	Evaluation Sub-Questions	Evidence base	
		Document review	**Stakeholder interviews**
Reporting and monitoring framework: To what extent have reporting and monitoring processes been appropriate and effective?	• Were effective program oversight and internal reporting arrangements in place? Were reporting arrangements adequately followed and clearly documented?	✓	✓
	• Were systems or processes implemented to consistently track the program activities and outputs (in particular from the funding recipients)?	✓	✓
	• Was there a transparent and appropriate framework for reporting project-level inputs, activities and outputs? For example Deed of Agreement? Were these processes followed throughout the program?	✓	✓
	• Did the program or project-level reporting (e.g. format, timing, focus etc) change during the course of the program? What motivated this?	✓	✓
	• Did findings within the reporting drive a refinement of the approach or individual activities overtime? Were these changes (e.g. program scope, funding and implementation) appropriately documented and reported?	✓	✓
Governance and risk: To what extent have governance and risk management processes been appropriate and effective?	• Was the program supported by appropriate governance and risk management arrangements (both at the program level and with funding recipients)? Did these arrangements help set program priorities? Are these arrangements clearly documented? Are they clearly understood by relevant stakeholders?	✓	✓
	• Have the governance and risk arrangements changed during the course of the program? If so, have those changes been documented?	✓	✓
	• Have the governance and risk management arrangements enabled (or hindered) the program in achieving its outputs? How?		✓
	• Have the governance arrangements resulted in any unintended outcomes?		✓
Accountability: To what extent were roles, responsibilities and priorities appropriately defined and communicated?	• Were program roles, responsibilities and priorities clearly defined and documented?	✓	✓
	• Were there any changes to the roles and priorities of staff over the course of the program? If so, were these changes documented and communicated effectively to relevant stakeholders?	✓	✓
	• Did the roles, responsibilities and priorities of program staff present any barriers to the achievement of the program's objectives?	✓	✓

Limitation of our work

General use restriction

This report is prepared solely for the internal use of the Department of Industry, Innovation and Science. This report is not intended to and should not be used or relied upon by anyone else and we accept no duty of care to any other person or entity. The report has been prepared for the purpose of set out in our engagement letter dated 21 July 2018. You should not refer to or use our name or the advice for any other purpose.

The evaluation of the LETDF s22 programs has been constrained by the significant lapse in time since the inception of each program. Many departmental program staff interviewed were not involved in the inception of either program, and in some instances were unable to comment on implementation and administrative processes underpinning each program. Furthermore, program documentation is often saved in multiple locations and file management systems, resulting in a range of documentation and information gaps.

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Australian Government
Department of Industry, Innovation and Science

EXECUTIVE BOARD OUTCOMES

Date: 20 August 2019	**Time:** 1:30pm – 2:30pm	**Location:** Executive Boardroom, Level 13, Industry House
Prepared by: s22		
Chair: s22 **Attendees:** s22 **Advisors/Observers:** s22 **Presenters:** Please refer to each specific section.		
Apologies: Nil		

This meeting record is intended to capture key discussion points and all actions and outcomes agreed by the Board.

Item	Description
Standing Items	
1.	s22
Discussion / Decision	
2.	**Low Emissions Technologies for Fossil Fuels (LETFF) Evaluation Reports** *Presenters/Attendees:* s22 s22, s 47C, s47E(d) *Outcomes:* Executive Board: 1. **Noted** the LETFF programs evaluation reports (a. Impact evaluation and b. Process evaluation). 2. **Noted** the management responses as provided by the Senior Responsible Officer (SRO) do not include any objections to the evaluations' findings. s22 *Actions:* • s22
3.	s22

Item	Description
	s22
4.	
Other	
5.	

Item	Description
	s22

Australian Government
Department of Industry, Innovation and Science

Out of Session
Friday, 9 August 2019

DIIS PROGRAMS COMMITTEE FOR INFORMATION

Title	**Low Emissions Technologies for Fossil Fuels (LETFF) Impact Evaluation (Phase two) findings**
Purpose/Issue	To outline the findings of the LETFF impact evaluation (phase two) report produced by Deloitte consultants.
Recommendation(s)	That the Committee **note** the findings of the LETFF impact evaluation (Phase two) report.
Attachment(s)	**A – Impact Evaluation of the LETFF programs** Deloitte's report on the LETFF impact evaluation **B – Background on the LETFF programs evaluation processes** Additional background on the LETFF programs evaluation processes
Consultation	Reference Group members included the s22 s22
Prepared by	s22
Sponsored by	s22

Background

The LETFF programs are classified as a Tier One evaluation priority. The impact evaluation also responds to an ANAO recommendation that the department evaluate the programs to identify the extent to which they achieved their strategic policy objective. The impact evaluation report (**Attachment A**), along with the process evaluation report (provided to PAC on 3 May 2019), are scheduled to be considered by the Executive Board on 20 August 2019 for endorsement and decision on publication. A management response will be added to both reports before they go to the Board. Additional detail on the evaluation approach is at **Attachment B**.

Key Issues

Deloitte found that:

- The LETFF programs have significantly contributed to increased knowledge, skills and capability, and improved industry understanding of LETFF in Australia. Australia now has the research and engineering capability to develop commercial-scale LETFF projects.
- The LETFF programs were underpinned by clear policy direction and settings, government support and significant funding at commencement, but changing and uncertain policy settings contributed to a loss of industry confidence and loss of momentum. The absence of a clear commercial imperative on the part of industry to invest in carbon abatement remains the single largest barrier to commercial development and deployment of LETFF.

- Stakeholders considered the programs to have been successful, that this work would not have been progressed without Australian Government support, and that there remains a critical role for the Australian Government in supporting LETFF development and deployment. However, the achievements and knowledge gained from the LETFF programs could have been more effectively communicated and disseminated.
- Australia risks losing the significant gains in knowledge, and skills and capabilities established through the LETFF programs if there is no progression towards the commercialisation and deployment of LETFF.

Deloitte identified that lessons for future program design and implementation were to:

- set realistic expectations with respect to costs and time to deploy commercial-scale projects incorporating untested technologies
- set realistic expectations with respect to research and development outcomes, noting that only some projects will proceed beyond research and pre-commercial feasibility
- ensure alignment between policy settings and program objectives, with a mechanism to trigger review in the event of significant policy shift
- enhance the technical and financial assessment of project feasibility at commencement, while balancing this with research and development objectives
- ensure funding and governance arrangements reflect the nature of program activities, for example stage gates for large projects
- include greater industry engagement in program design, and as part of formal risk assessment
- embed monitoring and reporting frameworks to monitor the effects of changes to funding on achievement of program objectives and inform redistribution of remaining funds within or between programs
- embed knowledge-sharing processes and systems to ensure learnings and outcomes are captured and disseminated
- if further support for LETFF development and implementation is considered, undertake, as a first step, a detailed economic cost benefit analysis of LETFF in decarbonising the economy relative to alternative technologies.

Deloitte.

Phase Two of the Impact Evaluation of the Low Emissions Technologies for Fossil Fuels (LETFF) programs

Department of Industry, Innovation and Science

8 August 2019

Contents

Charts

Tables

Figures

Glossary

ACALET R&D	Australian Coal Association Low Emissions Technologies Research and Development
ANAO	Australian National Audit Office
s22	
ARENA	Australian Renewable Energy Agency
CCS	Carbon Capture and Storage
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CO2CRC	Carbon Dioxide Co-operative Research Centre
CSIRO	Commonwealth Scientific and Industrial Research Organisation
GCCSI	Global Carbon Capture and Storage Institute
GHG	Greenhouse Gases
HELE	High Efficiency Low Emissions
IDGCC	Integrated Drying Gasification Combined Cycle
IGCC	Integrated Drying Gasification Combined Cycle
KEQ	Key Evaluation Questions
LETDF	Low Emissions Technology Demonstration Fund
LETFF	Low Emissions Technologies for Fossil Fuels
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Executive summary

In 2004, the Australian Government identified a need to support and promote the development and deployment of low emissions technologies to facilitate a cost-effective transition to a lower carbon economy.

The Department of Industry, Innovation and Science (the Department) has been implementing a range of policies from 2004 to support the research and development of new greenhouse gas (GHG) emissions reduction technologies under the Low Emission Technologies for Fossil Fuels (LETFF) programs.

Deloitte has been engaged by the Department to undertake Phase Two of the LETFF impact evaluation to evaluate the impacts of the LETFF programs on increasing knowledge, skills and capability, and on improving industry understanding in relation to low emissions technologies. The project also sought to answer:

- What factors have helped or hindered the achievement of the above outcomes?
- To what extent would outcomes have been achieved in the absence of the LETFF programs?
- To what extent do factors within and external to the LETFF programs remain a barrier to commercial development and deployment of LETFF?
- What (if any) unintended outcomes, positive and negative, have occurred as a result of the LETFF programs?
- What lessons can be drawn to inform future program development, including the role (if any) of the Commonwealth Government, in relation to supporting the development and implementation of LETFF technologies?

To answer these questions, the impact evaluation adopted a mixed methods approach involving semi-structured interviews with program stakeholders, an online questionnaire, and extensive scan of secondary data including citation analysis and development of case studies.

Contribution to knowledge, skills and industry understanding

The LETFF programs have significantly contributed to increasing knowledge, skills and capability, and improving industry understanding of LETFF in Australia. Overall, Australia has the research and engineering capability to develop commercial scale LETFF projects.

Overall, through the LETFF programs Australia has developed:

- a mature knowledge base with multiple industry participants with knowledge of a range of LETFF, supported by a broad body of research covering multiple technologies
- a moderate level of domestic skills and capability, with more advanced expertise within a number of organisations in relation to specific LETFF, most notably CCS
- a moderate industry understanding of the technical and practical feasibility of some LETFF, notably CCS, under a range of processes and Australian conditions but deployment required to further advance understanding.

A significant body of research has been delivered across the full spectrum of LETFF activities, and the critical research and development and technical barriers are considered to be largely settled for CCS.

Australia’s research skills and capabilities have been deepened with respect to specific LETFF; these skills and local experience are more developed relative to prior to commencement of programs. However, Australia’s research capabilities are considered to be more advanced than industry capabilities. Stakeholders agree that deployment of LETFF is required to further advance Australia’s industry and technical skills and capabilities.

The LETFF programs have resulted in industry developing a detailed ‘end-to-end’ understanding of the engineering and design of LETFF, in particular CCS technologies. Furthermore, there is a

consensus that the coal, energy generation, and oil and gas sectors have an understanding of the practical, technical and financial requirements necessary to deploy CCS. However, the absence of a commercial imperative to invest in emissions abatement remains the overarching barrier to LETFF deployment in Australia.

Factors contributing to the success of the LETFF programs

At commencement, the LETFF programs were underpinned by clear policy direction and settings, support across Commonwealth and State governments, and a significant funding commitment across a suite of programs and projects – factors deemed critical to the achievement of outcomes. Other contributing factors to the achievement of outcomes included:

- establishment of partnerships between government, industry and academic stakeholders
- the direct financial involvement of the coal industry in maintaining an industry-focused research agenda
- establishment of a portfolio of LETFF projects to maximise learnings and the probability of success.

Overall, changing, uncertain and inconsistent domestic policy settings are considered the primary factors hindering achievements and progress across the LETFF programs. Policy uncertainty has resulted in a significant loss of confidence across industry and a loss of momentum in advancing LETFF.

A combination of the unexpected complexity of LETFF, inflexibility of funding agreements, and regulatory uncertainty on the part of the Commonwealth and State governments also hindered achievements and progress across the LETFF programs.

The absence of a clear commercial imperative on the part of industry to invest in carbon abatement remains the single largest barrier to the commercial development and deployment of LETFF.

Success, future research and role of government

Overall, stakeholders overwhelmingly consider the LETFF programs to be successful. There was strong agreement among all stakeholders that the achievements of the LETFF programs would not have been made in the absence of Commonwealth Government support. Furthermore, stakeholders consider that the Commonwealth Government's investment in LETFF programs represents good value for money, and that achievements are commensurate with the investment.

LETFF programs have directly contributed to reducing the technical and commercial barriers to the development and deployment of commercial-scale LETFF projects. However, the achievements and knowledge gained could have been more effectively communicated and disseminated beyond immediate program participants, and achievements could have been more effectively communicated to the broader public. Barriers to knowledge sharing and access to information have contributed to a low level of public understanding and acceptance of LETFF, and in particular CCS, and represent one barrier to the deployment of LETFF.

Australia also risks losing the significant gains in knowledge, and skills and capabilities established through the LETFF programs if there is no progression towards the commercialisation and deployment of LETFF.

The critical underlying research and technical questions to deploying large-scale LETFF (and CCS in particular) have been addressed, however some targeted research would supplement and benefit research done to date. In particular, there is need to undertake site-specific research and testing to support the eventual deployment of LETFF.

Stakeholders consider there remains a critical role for the Commonwealth Government in supporting the development and implementation of LETFF. While there was no clear consensus on the appropriate role for the Commonwealth Government from stakeholders interviewed, a majority of respondents to the online questionnaire considered the Commonwealth Government should continue to provide large-scale grants to support LETFF research and development.

Key lessons for future program design

The impact evaluation has identified the following key lessons to inform future program design and implementation:

- the need to set realistic expectations with respect to program cost and time-horizons, particularly for programs with a focus on deployment of commercial-scale projects incorporating untested technologies
- the need to set realistic expectations with respect to research and development outcomes, noting that only a proportion of projects will succeed in progressing beyond research and pre-commercial feasibility
- ensuring alignment between policy settings and program objectives, and ensuring an appropriate mechanism is in place to trigger a review of program rationale in the event of a fundamental shift in domestic and international policy settings
- enhancing the technical and financial assessment of project feasibility at program commencement, noting that this needs to be balanced with the research and development objectives and any future program
- funding and program governance arrangements should reflect the nature of program activities, in particular stage gates should replace inflexible milestone reporting and payment processes for large projects to enable a more efficient provision of funding
- greater industry engagement in the design of the program, and as part of a formal risk assessment, to ensure program objectives, risks and issues are appropriately understood and reflected in the program design and implementation
- the need to embed monitoring and reporting frameworks to monitor the effects of changes to funding on the achievement of program objectives, and better enable an assessment of how remaining funds can be redistributed within the program or other programs
- the need to embed knowledge-sharing processes and systems to ensure program learnings and outcomes are appropriately captured and disseminated across relevant Commonwealth and State government departments and agencies
- any consideration of future support to further the development and implementation of LETFF, as a first step, should involve a detailed economic cost benefit analysis of LETFF in decarbonising the economy relative to alternative technologies. This analysis should give consideration to fossil fuel demand and the whole-of-lifecycle costs of alternative technologies.

1 Overview and purpose

1.1 Context

Australia's electricity generation and some industrial sectors (e.g. steel and concrete production) rely heavily on burning fossil fuels, such as coal, natural gas and oil, which release carbon dioxide (CO_2) and other greenhouse gases (GHG) into the atmosphere.

Low emissions technologies have the potential to reduce GHG emissions and Australia's impact on climate change. In 2004, the Australian Government identified a need to support and promote these technologies to facilitate a cost-effective transition to a lower carbon economy. The Department of Industry, Innovation and Science (the Department)[1] has since implemented and overseen the Low Emission Technologies for Fossil Fuels (LETFF) programs. These programs fund research and development of new GHG emission reduction technologies. The LETFF programs comprise the following four programs:

- The Carbon Capture and Storage (CCS) Flagships program

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- The Low Emissions Technology Demonstration Fund (LETDF)
- s22

These programs commenced against a backdrop of increasing and coordinated global action against climate change. However, they have experienced significant changes in funding, policy and investment conditions. In particular, the repeal of the carbon pricing mechanism has led to uncertainty regarding the future price of carbon, affecting business investment incentives.

The Department has identified the LETFF programs as a Tier One evaluation priority of high strategic importance. The Department previously accepted the recommendation of the Australian National Audit Office (ANAO) audit (2017) to evaluate the LETFF programs. The Department is conducting the evaluation of the LETFF programs in two phases, consisting of:

- Phase One - an assessment of the 'evaluability' of the four LETFF programs, previously conducted by Deloitte Access Economics. (Completed)
- Phase Two - an impact evaluation of the LETFF programs, the scope of which has been informed by the outcomes of Phase One. (Current phase).

1.2 Purpose and scope of Phase Two

The Department has engaged Deloitte to conduct Phase Two of the LETFF impact evaluation (the project). The overarching purpose of this project is to evaluate the impacts of the LETFF programs on increasing knowledge, skills and capability, and on improving industry understanding about low emissions technologies.

The project will also seek to determine whether the Government investments made under the LETFF programs have helped move low emissions technologies closer to commercialisation, and whether the outcomes achieved are commensurate with the level of investment made by the Commonwealth Government.

The findings of this project will inform future LETFF program design, including the potential role of the Commonwealth Government in supporting the further development and implementation of LETFF.

[1] The LETFF programs were originally implemented under the former Department of Resources, Energy and Tourism.

The project covers all components of the LETFF programs with the exception of the CCS Flagships Research Development and Demonstration (RD&D) fund, which is out of scope as impacts are unlikely to have been realised at the time of reporting.

1.3 The LETFF programs

The LETFF programs support low emission fossil fuel technologies by funding programs and initiatives that aim to reduce technical risks and speed up the commercialisation process. Technologies that were supported through the LETFF programs include:

- carbon capture and storage (CCS)
- high efficiency low emissions (HELE) electricity generation
- fugitive methane emission abatement technologies.

A total of $2.8 billion was originally budgeted across all four LETFF programs. However, funding was substantially reduced over time and approximately $750 million has been spent to date.

A summary of the four LETFF programs, including the objectives of each program, is provided in Table 1.1 below. A summary of individual projects delivered under each program is presented in Appendix A.

Table 1.1: Summary of LETFF programs

LETFF Program	Description
The CCS Flagships program	Commenced in 2009 under the Federal Budget's Clean Energy Initiative with a program budget of $1.8 billion. The objective of the program was to promote the dissemination of CCS technologies through supporting a small number of demonstration projects to capture CO_2 emissions from industrial processes and safely store them underground in stable geological formations. Five flagship projects and other small-scale CCS activities have been funded over the course of the program. Two out of the five flagship projects have been deemed 'unsuccessful'. The program also includes the CCS Research, Development and Demonstration (RD&D) Fund with an objective of reducing the technical and commercial barriers to deploying large-scale CCS projects.
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LETDF	Announced in June 2004 under the *Energy White Paper – Securing Australia's Energy Future*. The Fund had a $500 million budget that could be granted to projects ranging from concentrated solar to CCS technology. The aim of the program was to demonstrate the commercial potential of new technologies to contribute to long-term large-scale GHG emissions reductions. The LETDF Program funded six highly complex projects which required a high degree of due diligence. Of these six, two were transferred to other programs, three were unsuccessful and only one – the Gorgon Carbon Dioxide Injection Project, continues to operate.

LETFF Program	Description
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1.4 Summary of Phase One findings

Deloitte was previously engaged to assess the evaluability of the four LETFF programs under Phase One of the impact evaluation of the LETFF, to inform design and resourcing of any future impact evaluation to be undertaken in Phase Two. The evaluability assessment sought to answer three key questions:

- Was it plausible to expect an impact from the programs?
- Would an evaluation be useful, and, if so, to whom?
- Would an evaluation be feasible, based on: program evidence, data availability, baseline measures, and reporting mechanisms?

The evaluability assessment found that, overall, it was reasonable and plausible to expect that the projects and activities delivered under the LETFF programs could achieve intended short-term and, to some extent, medium-term outcomes and impacts. It was not plausible to expect that the LETFF programs could reasonably have achieved the strategic longer-term objectives of demonstrating and deploying LETFF on a commercial scale, thereby reducing GHG emissions.

The evaluation assessment confirmed there was strong stakeholder support and interest for an impact evaluation. It advised that in the absence of delivery of any commercial scale projects, an impact evaluation should focus on the achievement of short and (to some extent) medium-term outcomes to guide future policy focus and direction. It also noted that any future impact evaluation of LETFF programs will require drawing on a range of qualitative evaluation methods, with a focus on stakeholder interviews and questionnaires, documentation review, and case studies.

The evaluability assessment recommended that the Department undertake a targeted impact evaluation of the LETFF programs that focuses on assessing the extent to which the LETFF programs have resulted in changes over the short- and medium-term against the following program outcomes:

- generation of new research, data and modelling relating to the practical and technological use and implementation of LETFF (short-term outcome)
- improved industry knowledge regarding the feasibility and safety of low emissions and abatement technologies, through collaboration and dissemination of findings from pilot and feasibility studies (short-term outcome)
- development of domestic skills and capability in low emissions and abatement technologies (medium-term outcome).

The evaluability assessment recommended a future impact evaluation should also assess:

- whether industry knowledge and understanding of the feasibility and safe development of LETFF would have progressed in the absence of the LETFF programs
- whether changes in policy settings and other external factors have affected the ability of LETFF programs to achieve stated impacts

- implications for future policy development and priority setting, including the role (if any) of the Commonwealth Government in supporting the further development and implementation of LETFF.

1.5 Report structure

This report presents the findings of the impact evaluation of the LETFF programs. The report is structured as follows:

- Chapter 2 outlines the approach to the impact evaluation.
- Chapter 3 presents the contributions made by the LETFF programs to knowledge, skills and industry understanding.
- Chapter 4 discusses factors contributing to the achievements of the LETFF programs.
- Chapter 5 discusses the success of the LETFF programs, including areas of future research and the role of government in supporting the development of LETFF.
- Chapter 6 presents learnings for future program design.

2 Evaluation methodology

The impact evaluation uses a mixed methods approach to assess the extent to which the LETFF programs have contributed to increasing knowledge, skills and capability, and to improving industry understanding of LETFF. This has included semi-structured interviews, an online questionnaire and secondary data analysis, a citation analysis and development of concise case studies.

2.1 Evaluation framework

An evaluation framework has been developed to guide this evaluation. It outlines the key evaluation questions and data sources to be drawn on to address each evaluation question, and was developed in consultation with the Department. The evaluation framework has guided the key lines of enquiry and systematic organisation of analysis to ensure a consistent and robust assessment of the LETFF programs and project activities. The framework is presented in Appendix B.

2.2 Data collection and analysis

2.2.1 Semi-structured interviews

Semi-structured interviews were conducted with key LETFF program stakeholders from the Department, Commonwealth science agencies (e.g. CSIRO and Geoscience Australia), participating State governments, industry grant recipients and representatives, academic and research grant recipients, and expert advisers. All stakeholders engaged had direct involvement in the LETTF programs. Contact details of key stakeholders were provided by the Department.

A total of 18 semi-structured interviews were conducted. An interview guide was developed based on the evaluation framework. Questions were tailored for each stakeholder depending on group and LETFF program(s) they participated in, and mapped to each evaluation question in the framework. Each interview was conducted via telephone and recorded. The interview was subsequently analysed in NVivo, using coding techniques to identify common themes. A summary of stakeholders interviewed is provided in Appendix C.

2.2.2 Online questionnaire

An online questionnaire was developed to gain further insights into stakeholders' perceptions of the impact of the LETFF programs, the factors that may have assisted or hindered the achievements, and the overall success of the LETFF programs. A total of 17 respondents completed the online questionnaire. A summary of the spread of respondents is provided in Appendix C.

The online questionnaire was sent to the same cohort of stakeholders as the semi-structured interviews (via emails provided by the Department). Stakeholders were invited to forward the questionnaire on to their peers and colleagues who had also been directly involved with the LETFF programs. As such, the online questionnaire has not enabled a true triangulation of findings relative to the interviews. However, the questionnaire did provide further richness of insights with respect to the impact of the LETFF programs and supplemented the findings of the interviews.

2.2.3 Program data

The project has involved an examination of departmental documents and data and other publicly available information, to provide insights on impacts achieved by LETFF programs, including:

- final project reports
- research papers, scientific papers, technical papers produced under the LETFF programs
- project specific datasets and models
- broader literature on relevant themes.

A literature scan of research and scientific papers produced under the LETFF was undertaken due to the extensive body of documentation produced. A scan of 496 publically available reports matching key search criteria was undertaken to provide insights into the impact of the LETFF

programs. This ensured an appropriate breadth and depth of documents were reviewed across the LETFF programs.

Key document sources included Department-held documentation, in addition to data, reports and documentation held by:

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- Global CCS Institute (GCCSI) data and documentation
- CO2CRC
- CSIRO
- Geoscience Australia.

2.2.4 Citation analysis

The project has involved a citation analysis of the 496 program publications identified in a literature scan up to 29 May 2019 to gauge the extent to which knowledge transfer has occurred as a result of the LETFF programs. The citation analysis involved:

- cited reference analysis – the number of times that research publications produced by the LETFF programs have been cited in journal articles or scientific publications based on Google Scholar data.
- publication use – the number of times that research publications produced by the LETFF programs have been accessed or requested online (where this data was available).

The results of the citation analysis were then triangulated with semi-structured interviews and results from the online questionnaire.

2.2.5 Case studies

Case studies of individual LETFF projects were developed from across the LETFF programs. This enabled the identification of general findings about the LETFF program. Case studies were developed from primary and secondary data sources, and illustrate the extent to which specific projects have contributed to the achievement of focus outcomes. Two case studies were developed for each program, with the exception of the LETDF program.

Case studies are outlined in Appendix D.

2.3 Limitations of methodology

The focus of this project is an impact evaluation of specific short and medium-term outcomes of the LETFF programs. Specifically, the intent is to assess the impact of the LETFF programs on increasing knowledge, skills and capability, and on improving industry understanding of LETFF. The project has not sought to assess the extent to which the LETFF programs have achieved any other medium or longer-term outcomes.

The qualitative data presented in this report reflect the opinions and perceptions of stakeholders engaged during the evaluation. These opinions and perceptions are presented as originally communicated. Stakeholders engaged in this evaluation have all had direct involvement in the LETFF programs. Stakeholders, by virtue of their involvement in the LETFF programs, may have had an inherent bias in their view of achievements and outcomes.

This evaluation has not engaged any stakeholders external to the LETFF programs, such as representatives of alternative technologies or programs.

The project has been limited by the significant lapse in time since the commencement of the LETFF programs and subsequent implementation. Specific issues that limited this evaluation include:

- the natural turnover of program staff; the Deloitte team was unable to engage with departmental stakeholders who had been involved in the programs at inception
- the natural turnover of participating industry and academic stakeholders; many key project proponent staff and external expert advisors have subsequently left their roles and/or organisations, meaning the Deloitte team was unable to speak to stakeholders from across all projects and activities. As such, only a sample of relevant stakeholders could be reached for the purpose of the evaluation.

3 Contribution to knowledge, skills and industry understanding

Key findings:

- The LETFF programs **have significantly contributed to increasing knowledge, skills and capability, and improving industry understanding of LETFF in Australia.** Overall, Australia has the research and engineering capability to develop commercial scale LETFF projects.
- Australia now has:
  - **a mature knowledge base** with multiple industry participants with knowledge of LETFF, supported by a broad body of research covering multiple technologies
  - **a moderate level of domestic skills and capability**, with more advanced expertise within a number of organisations in relation to specific LETFF, most notably CCS
  - **a moderate industry understanding** of the technical and practical feasibility of specific LETFF under a range of processes and conditions, but further advances in understanding will require deployment.
- A significant body of research has been delivered across the full spectrum of LETFF activities - the critical research and development and technical barriers are considered to be largely settled for CCS.
- Australia's pool of research and technical skills and capabilities is considerably larger, more developed and vastly more experienced relative to prior to commencement of programs.
- Research capabilities are more advanced than industry capabilities. Deployment of LETFF is required to further advance industry skills and capabilities.
- There is a risk of Australia losing the skills and capabilities developed if momentum is not maintained given the global demand for skills and expertise.
- The LETFF programs have resulted in industry developing a detailed 'end-to-end' understanding of the engineering and design of LETFF, in particular CCS technologies.
- There is a consensus that the coal, energy generation, and oil and gas sectors have an understanding of the practical, technical and financial requirements necessary to deploy CCS.
- However, the absence of a commercial imperative to invest in emissions abatement remains the overarching barrier to LETFF deployment in Australia.

3.1 Overall contribution of LETFF programs

Overall, there is consensus among industry, government and academic stakeholders involved in the LETFF programs that these programs have significantly contributed to increasing knowledge, skills and capability, and improving industry understanding about low emissions technologies in Australia.

There is broad stakeholder agreement that the advances in Australia's understanding of LETFF and their implementation – particularly around geological subsurface storage – would not be where it is today in the absence of the LETFF programs (discussed in greater detail in Section 5.2).

Stakeholders highlighted that the LETFF programs have involved an incremental learning process for industry, academia and government. Individual project outcomes have contributed towards a broad portfolio of achievements, rather than one single, flagship success. Even 'failures' have

provided valuable learning opportunities and insights, with most stakeholders indicating the importance of discovering what didn't work to be just as important as knowing what works.

Australia is now considered to be 'deployment ready' from a technological perspective. Australia is considered to have a mature knowledge base, supported by a well-developed body of research, with moderate skills and capability across specific LETFF (particularly CCS), and considerable industry understanding of the practical and technical feasibility of LETFF under a range of Australian conditions. There is strong agreement across all stakeholder groups that the priority for LETFF is to shift to commercial-scale deployment. Figure 3.1 illustrates the shift in the level of knowledge, understanding, and capabilities since the commencement of LETFF as perceived by key stakeholders and reflected in available evidence.

Figure 3.1: Summary of evidence of perceived shift in Australia's LETFF knowledge, understanding and capabilities since 2005

High

Stage	State of knowledge	Understanding of technical and practical feasibility	Local industry skills and capability
5	Deep and broad sector knowledge throughout industry, supported by extensive body of research covering full range of LETFF technologies.	Extensive industry understanding of technical/pract cal feasibility of full range of LETFF technologies under full range of processes and condit ons.	World leading industry skills and capability located w thin a wide number of industry and research organisat ons and across the broad spectrum of LETFF technologies.
4	Broad sector knowledge across major ty industry part cipants, supported by large body of research covering large range of technologies.	Broad industry understanding of techn cal/practical feasibility of LETFF technologies under most industrial processes and condit ons.	Broad local industry skills and capability across a large number of industry and research organisat ons and a across the majority of LETFF technologies.
3	Sector knowledge is moderate, w th multiple industry part cipants having knowledge of LETFF technologies, supported by a moderate body of research covering multiple technologies.	Moderate industry understanding of technical/pract cal feasibility of LETFF technologies under some processes and cond tions.	Moderate local industry skills and capability, with expertise across a moderate number of organisat ons on a moderate range of LETFF technologies.
2	Sector knowledge is thin, w th only select industry part cipants having meaningful knowledge of LETFF technologies, supported by a small body of research focussed on one or two technologies.	Lim ted industry understanding of techn cal/practical feasibility of LETFF technologies under 1 or 2 industrial processes.	Thin but growing local industry skills and capabil ty, w th expertise located across a handful of industry and research institutions.
1	Sector knowledge relating to pract cal, technolog cal and scientif c use and implementation of LETFF technologies is minimal/non-existent.	No industry understanding of techn cal/practical feasibility of LETFF technologies.	Niche local industry skills and capability, with only lim ted expertise.

Low

Source: Deloitte Access Economics

The LETFF programs have contributed to providing Australia with a detailed 'end-to-end' understanding of CCS, with stakeholders agreeing that the major research development questions and technological barriers have been largely settled and overcome. The LETFF programs have contributed to a clear understanding of the 'pathway to deployment' for LETFF and in particular CCS, including:

- the capture, transport, storage and injection technologies involved
- the costs and timeframes involved
- which technologies to deploy and under what conditions
- the locations and suitability of storage sites where technologies can be best deployed.

3.1.2 State of knowledge, capabilities, and understanding prior to commencement

Prior to the commencement of the LETFF programs, stakeholders reported Australia's knowledge and understanding of LETFF as predominantly conceptual and theoretical in nature. Understanding of how LETFF might be practically implemented was very limited, although it was noted that the oil and gas sector had a deeper understanding than other sectors, given the integral nature of drilling

in this sector. Overall, stakeholders reported that Australia, in general, had limited knowledge and understanding of:

- the location, capacity and sub-surface condition of geological resources (both onshore and offshore)
- long-term stability of geological resources and how they would react with CO_2
- different emission capture technologies and application to Australian conditions and industrial processes
- the behaviour of CO_2 plumes under different sub-surface conditions, and how to model the behaviour of CO_2 plumes
- the behaviour of CO_2 during transportation
- the end-to-end engineering and design of capture and storage technologies
- the full life-cycle costs of designing, building and operating commercial-scale LETFF.

Additionally, there was no arrangement in place to structure the existing knowledge base, to direct the advancement of new research, or to provide a knowledge-sharing platform between government, academia and industry. Stakeholders described Australia's knowledge-base as follows:

> *"… we didn't have a good idea of where the basins were. We didn't know much about the capture technologies, we didn't know if there was Enhanced Oil Recovery potential"* – Academic/research stakeholder.

> *"…there was theoretical knowledge, but less knowledge of [how] it [will] actually work in practice. [There was] a gap in the knowledge in terms of the application* – Government stakeholder.

> *"Go back probably 20 years, I would say that the Australian state [of knowledge] was developing. I wouldn't say it was embryonic, I'd say we were better than embryonic, but I think we were developing…. We were by no means near deployment-ready." – Academic/research stakeholder.*

This is not to say that Australia did not have a meaningful understanding of LETFF relative to other developed countries – such as the European Union, the U.S., the U.K., or China. On the contrary, stakeholders interviewed reported Australia's academic and scientific research community had pockets of recognised world-leading skills and expertise. Examples identified by stakeholders include:

> *"Geoscience Australia did some very early work in geological storage… very basic basin work to get some capacity work [back] in the 90s."* – Academic/research stakeholder.

> *"Geoscience Australia had been working toward CCS aspects as well and then we had CSIRO… CSIRO had been working on capture technologies at a small scale across a few sites…. There [were] capture engineers at Monash and Melbourne Universities… so that knowledge was there at a research phase."* – Academic/research stakeholder.

Within industry, however, there was a lack of the technical and practical type skills necessary for deployment and implementation – such as engineering and operational type skills. As noted by some stakeholders:

> *"… it would have been the researchers and not industry in those early days that had the expertise or understanding as well."* – Commonwealth Government stakeholder.

> *"… not as much as the practical engineering because it hadn't been deployed in Australia… not enough for a full industry, which is what we very rapidly found out when the flagship projects were launched there just weren't enough people to do all the work and so what we had is the same people doing a lot of the work…"* – Research stakeholder.

Across industry, there were also certain sectors that were more advanced in their understanding of and engagement with LETFF than others. Stakeholders singled out the Oil and Gas sector, in

particular, as having well-established understanding and capabilities relating to carbon capture and storage (CCS) technologies:

> *"…the Oil and Gas industry in 1999… they were fine. …injecting CO_2 and withdrawing gas from the subsurface, this is their daily bread…these guys have been doing EOR [Enhanced Oil Recovery] for 40 years. They have been injecting CO_2 for 40 years, they know how to do this."* – Academic/research stakeholder.

> *"… [the Oil and Gas industries] were already way up the learning curve both in terms of capture technology and in terms of injection…"* – Industry stakeholder.

In contrast, other emissions-intensive industries had yet to commence investigating the potential of LETFF in detail. In particular, the coal, energy generating, industrial (e.g. steel, concrete, and fertiliser) and agricultural sectors had yet to meaningfully investigate and engage in the development of low-emission, abatement, or monitoring technologies emission abatement and capture technologies. As some stakeholders noted of these sectors:

> *"… there wasn't necessarily much appetite to engage… there wasn't a significant driver… until I suppose the carbon taxes and things came in at that time.… as far as I understand industry weren't totally engaged."* – Commonwealth Government stakeholder.

> *"…the electricity sector has traditionally been happy to produce electricity and run their coal-fired power stations…the big issue for them is that they went from a business of mechanical engineers to a business of chemical engineers [to understand LETFF] and that was a big problem for them. They are low-risk engineers and they had to move into a high risk [investment]."* – Industry stakeholder.

3.1.3 State of knowledge, capabilities, and understanding today

Today, stakeholders report that the breadth and depth of Australia's knowledge, capabilities and understanding of LETFF, in particular CCS, is significantly greater than it was prior to the commencement of the LETFF programs. Overall, stakeholders reported significant improvements in Australia's knowledge and understanding of:

- the 'end-to-end' of the implementation of low-emissions technologies, including:
  - integrating low-emissions technologies with existing production systems
  - proving low-emissions technologies under Australian conditions
  - cost discovery of implementation
  - safety and environmental implications
  - regulatory approvals process
- monitoring and measuring greenhouse gas emissions
- Australia's geological subsurface storage potential and capacity, including:
  - the importance of subsurface storage in the CCS process
  - identification of suitable subsurface storage locations, and their potential capacity
  - dynamic modelling the geological subsurface behaviour of CO_2.

The consensus among stakeholders from across industry, government, and academia is that Australia's knowledge and expertise is now well-past the conceptual and theoretical R&D phase. Australia now possesses the research and technical foundations, including an understanding of the technical challenges, costs, and risks to progress to commercial-scale deployment. Australia is considered to 'hit above its weight' with respect to LETFF on a global stage. As noted by stakeholders:

> *"… in Australia, we have a range of stakeholders that are probably world leaders in terms of understanding the whole value chain of CCS, whether it be understanding capture technologies inside the CSIRO… they are world leaders and they are winning grants from other countries at the moment. I think that monitoring and storage activities … the CO2CRC are world leading … I think we have a much better understanding of the underground storage potential in Australia, both onshore and offshore, more work to be done in that space, but when you compare 10 years ago to now… we have made great progress on the technical front of understanding CCS and I don't disagree with some people who have said we have conquered the technical barriers."* – Commonwealth Government stakeholder.

> *"… we have done all the engineering to the point of construction, so from not even knowing which technology to choose, to now having chosen a technology and done all the upfront engineering, partnering with the technology providers, so that a construction decision can be made with, actually can be made today if we had the money. … That's actually been a dramatic shift"* – Industry stakeholder.

However, the advances in knowledge, skills and capability and understanding have been more concentrated in certain sectors than others. In particular, there was consensus among stakeholders that the advances in knowledge and capabilities in the academic and scientific research community far outweighed advances in the coal, energy generating and industrial sectors. As noted by a stakeholder:

> *"… the skills level of the academic community has indeed increased, but it's the academic skills level and not the industrial deployment skills level…"* – Industry stakeholder.

Despite the gains that have been made over the last 15 years, there are gaps that remain and new gaps have emerged. Overall, stakeholders identified the following gaps:

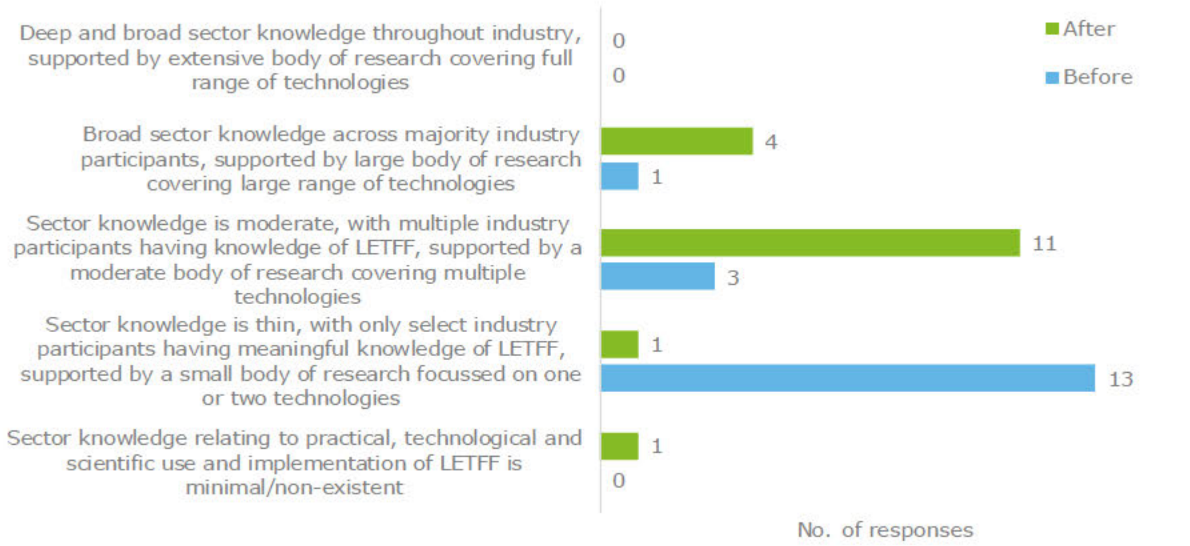
- the need to consolidate the knowledge and understanding of LETFF gained to date
- improving the accessibility, dissemination and communication about LETFF across industry sectors and the broader community
- detailed local and site-specific understanding of suitable onshore and offshore subsurface storage potential and capacity
- demonstration and deployment of LETFF on an industrial-scale, and the absence of an established CCS industry in Australia
- lack of experienced engineering skills and capabilities (mechanical, electrical etc.) for the industrial-scale deployment and operation of LETFF and CCS technologies.

3.2 Generation of new research and knowledge

There was consensus among stakeholders interviewed that Australia's overall state of knowledge progressed from being perceived as 'thin' prior to the commencement of the LETFF programs, to a mature moderate knowledge base underpinned by a well-developed body of research across multiple technologies.

This view was supported by the findings of an online questionnaire of LETFF stakeholders. Chart 3.2 illustrates the perceived change in the overall state of knowledge and understanding with respect to LETFF.

Chart 3.2: Questionnaire responses on overall state of knowledge before and after the commencement of the LETFF programs



Source: Deloitte questionnaire, n = 17

In addition to the improvement and expansion of the domestic skills base, the LETFF programs are attributed with having generated a range of new and original research and technical innovations. These include outputs such as:

- **Data tools** – geological seismic data, atmospheric measurement data, and technical test data
- **Modelling tools** – geological subsurface storage mapping, models of CO_2 subsurface behaviour, energy market modelling, as well as financial models of commercialisation
- Technological **innovations** – digital drill core technology, s22
- **Methodological improvements** – improved methods for monitoring greenhouse gas emissions, technical operation methods that improve efficiency or safety, project management methods that improve the up-scaling and commercialisation of technologies
- **Formation of new relationships** – the value of the new relationships formed between industry, government, and the academic and scientific communities, as well as relationships formed between these communities in Australia with other people, communities and institutions overseas.

These provide the foundation tools and resources for industry and government to further invest in LETFF and CCS technologies with greater certainty in regard to the costs associated with deployment and ongoing operation, safety and environmental considerations, and the efficiency of production.

In addition to the above, the LETFF programs have contributed a significant body of **publications,** including academic journal articles, discussion papers, PhD dissertations, conference presentations, government policy documents, and interim and final project reports.

The GCCSI also contributed to the knowledge, skills and industry understanding achieved through the LETFF programs. The GCCSI is an important contributor to research and has an extensive repository of program reports and datasets. It is noted that the Commonwealth Government was instrumental in establishing the GCCSI.

3.2.2 Examples of the types of innovations and knowledge generated

While a rigorous and accurate stocktake of the new research and knowledge generated is beyond the scope of this report, Table 3.3 lists several key innovations developed across the LETFF programs identified by stakeholders.

Table 3.3: Examples of key innovations attributable to LETFF programs/projects

Title (LETFF project)	Description
s22	
Seismic monitoring fibre optic cable technology (CCS Flagships program – Otway Geological Storage and Demonstration Project)	The project involved the development of seismic monitoring fibre optic technology to enhance the performance of seismic monitoring of drills. The technology has effectively replaced traditional geophone technology and significantly reduced the cost of undertaking seismic analysis. *"…with the funding that we have received from the LETFF and a combination of work with experts from Curtin* [University] *and also internationally, we are now at the point where the performance of these fibres is substantially better than these geophones. Now, that all sounds very technical, but what it means is we now have the ability to not have to put major infrastructure down these wells, we can do it through very cheap wells."* – Research stakeholder.

s22

As reported above, the LETFF programs have generated a significant body of research. An analysis of 496 publically available publications associated with LETFF programs and projects, as well as the results of a citation analysis, are provided in Table 3.4 (below). Although generating published material was not an intended outcome of the LETFF programs, they provide an indication of the knowledge generated and of the understanding that has been disseminated.

s22

The citation analysis indicates the number of times that published materials have been cited in other domestic and international publications, providing an indication as to the extent that learnings and knowledge gained through the LETFF programs have been drawn upon and utilised in other research. Overall, the results indicate that the published material generated through the LETFF programs have been widely disseminated, and gone on to influence and inform a wider body of research and knowledge. This further supports stakeholders' observations of Australia as having world-leading research expertise and of the contribution of Australian expertise and knowledge internationally.

Table 3.4: Summary (broad) of LETFF program and project publications

LETFF program/ project	Publications		Scholarly articles (as a share of publications)	No. of citations	Ave. citations per publication
	No.	%	%		
CCS Flagships	65	13%	2%	170	2.6
s22					
LETDF	23	5%	39%	1,105	48.0
s22					

Source: Deloitte Access Economics

Notes: These estimates only include publically available publications; Scholarly articles are considered to be publications that appear in peer-reviewed academic or scientific journals.

Despite the plethora of publically available published materials, many materials and information remain undisclosed. There are many more publications that are held internally by government departments and scientific agencies, industry associations, or are held by 'pay walled' repositories (e.g. the CO2CRC). There is a perception among stakeholders that this acts as a constraint on the transfer of knowledge and the wider dissemination of learnings from one project to another, and is a barrier to the commercialisation of low-emissions technologies and to the establishment of a CCS industry in Australia. s22

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Another stakeholder acknowledged that knowledge of the published information available is dependent on informal personal and community networks. That is, information sharing is about 'who you know':

> *Do we have some nice summary, not that I am aware of … it is not on a central connected basis… The answer is an informal kind of network of people know each other, which is not ideal for information sharing."* – Commonwealth Government stakeholder.

When done right, however, effective information sharing with the wider public is credited with supporting community engagement and enabling the future deployment of LETFF. As one stakeholder remarked:

> *"… the CO2CRC has done a marvellous job in addressing public concerns and public education with their Otway site. It is regarded as one of the world's best practice in that region."* – Research stakeholder.

3.2.3 Summary of the intangible forms of knowledge generated

Stakeholders also identified the importance of the value of less tangible outcomes that were generated as a result of the LETFF programs.

Stakeholders widely acknowledged that the LETFF programs have encouraged collaborations between governments, industry, and the academic and scientific communities within Australia. Stakeholders from each of these communities identified the collaborative nature of the LETFF programs as having an immense benefit for creating networks amongst groups that were unlikely to have otherwise engaged with one another.

For government, the deepening of relationships with industry and the academic and scientific research communities is credited with contributing to improved decision-making, in terms of informing the formulation of regulatory and legislative frameworks. The Gorgon Carbon Dioxide Injection project is an example of where the LETDF facilitated information sharing between the Commonwealth Government and industry partner Chevron, and generated an improved and informed policy outcome. One industry stakeholder noted the role of Chevron in advising and informing the development of the Offshore Petroleum and Greenhouse Gas Storage Act 2006 and the broader regulation of CCS:

> *"a lot of the federal generic legislation in this space comes from lessons learned from Gorgon, and that model has been picked up by a couple of other States."* – Industry stakeholder.

In turn, development of the *Offshore Petroleum and Greenhouse Gas Storage Act 2006* is credited with enabling industry to consider offshore CCS opportunities and promote the role of other LETFF projects, such as CarbonNet. As noted by one stakeholder:

> *"… it's quite ground-breaking… the regulatory framework that the Commonwealth has put in, because obviously that's the lever that* [government] *have responsibility for, so the Offshore Petroleum and Greenhouse Gas Storage Act has really I think incentivised and given industry a mechanism to at least put offshore CCS in their repertoire and that's obviously being exercised now through CarbonNet, they wouldn't have done that without that act."* – Commonwealth Government stakeholder.

The LETFF programs are also credited with establishing valuable international collaborations between Australia and several countries developing low-emissions technologies – such as, the U.S., the U.K., the European Union, Japan, and China. In particular, stakeholders identified the value of the relationships formed through the Australia-China Joint Coordination Group funded through the CCS Flagships program. These relationships enabled Australia to access technology and expertise that would have been extremely costly to develop domestically. In return, Australia provided its expertise of regulatory frameworks, as well as project management methods (e.g. delivering projects safety, on time, and on budget).

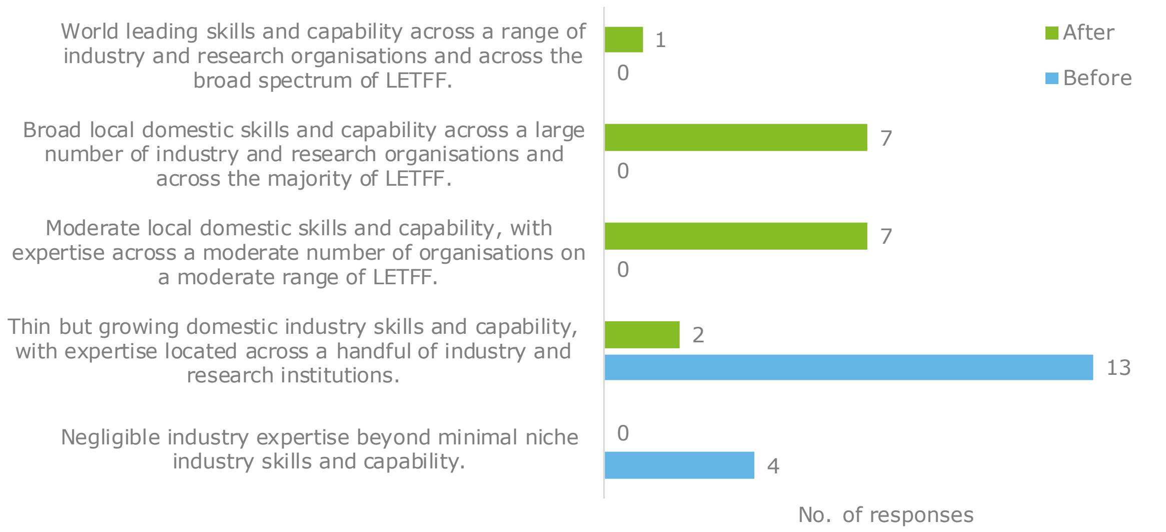
As noted by one stakeholder:

> *"the skills transfer was really quite significant, not just for the Australian government and other stakeholders in regard to accessing Chinese know-how, and how they do it, but the Chinese certainly learned from us too."* – Industry stakeholder.

3.3 Development of greater domestic skills and capabilities

In general, stakeholders interviewed perceived that the LETFF programs had contributed to a considerable increase in skills and capabilities. Australia's overall state of skills and capabilities progressed from being perceived as **'thin but growing'** prior to the commencement of the LETFF programs, to moderate with expertise across a range of industries and research organisations. This is supported by the findings of the online questionnaire (see Chart 3.3).

Chart 3.3: Questionnaire responses on the level of domestic skills and capabilities with respect to low-emissions technologies before and after the commencement of the LETFF programs



Source: Deloitte questionnaire, n = 17

As prefaced earlier, the LETFF programs are considered to have contributed to improving and expanding the capacity of academic and scientific research skills at the key research institutions – such including as, CSIRO, and Geoscience Australia, Melbourne, Monash and Newcastle universities, as well as and CO2CRC, the Global CCS Institute, s22 Australian Petroleum CRC, ACARP and COAL21. Overall, stakeholders agreed that the skills and capabilities developed across academia were far more advanced than industry. As remarked by stakeholders:

> *"… a lot of the money has gone to the research group, so they are far more skilled than the engineering is because they have had the funding to do the research … it's going from being scientists wanting to do the research to now scientists having done the research."* – Industry stakeholder.

> *"… I would say that the scientists are ahead of the engineers because the scientists have just been doing this stuff, but they can't do what engineers do and the engineers need…the time is not for R&D, the time is for doing and the scientists will then have access to real data rather than lab data."* – Industry stakeholder.

However, stakeholders recognised that Australia's technical and engineering capabilities have also developed and improved through the LETFF programs, with Australia now possessing the technical and practical engineering skills necessary for deployment and implementation. There was a common view that commercial deployment is required to enable any further advancement of industry skills and capabilities. As described by one stakeholder:

> *"… we had the engineering infrastructure, but with inexperience in this technology. … at least now the engineering capability is ready to take that next step to implement, but until we have implemented, we haven't really learned all the lessons."* – Industry stakeholder.

Some stakeholders reported that Australia has developed world-leading skills and expertise through the LETFF programs, and those skills are now sought by the other countries:

> *"We actually got a group who we thought were the world's best reservoir engineers come over from University of Texas and … they felt the reservoir engineering capabilities of CO2CRC and our research members, such as CSIRO and Curtin* [University] *are the best in the world"* – Academic/research stakeholder.

> *"… we basically trained up all the CCS specialists in Australia and now they have gone all around the world."* – Research stakeholder.

Within industry, the LETFF programs also contributed to an 'up-skilling' and expansion in the capacity of technical and practical engineering type skills, particularly in the industry sectors that were most engaged in LETFF – that is, the coal mining, and oil and gas sectors. In addition, the LETFF programs prompted a shift in the composition of the types of specialist skills demanded. As industry began to investigate the feasibility of integrating LETFF within existing processes, stakeholders identified increased demand for a range of engineering disciplines across the oil and gas, coal and energy generating sectors. As one stakeholder noted:

> *"We need engineering, so we need design…electrical, we need mechanical, we need ventilation specialists, we need mining specialists… risk specialists…"* – Industry stakeholder.

Within the energy generating sector, there was also an increased demand for specific engineering skill sets that were previously not associated with that industry sector, particularly chemical engineering capabilities.

The composition of skills required also shifted as knowledge and understanding about the importance of geological subsurface storage became a key priority. This resulted in a shift toward and expansion of geotechnical engineering capabilities across industries.

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An exception to this is the dissemination and transfer of technical skills from the academic and scientific research communities to government. A range of stakeholders noted that the Commonwealth Government was able to readily access and draw upon specialist technical and scientific skills, particularly from CSIRO and Geoscience Australia. This supported better informed decision-making.

However, several stakeholders noted the risk of potentially losing the specialist expertise built up over time to other countries – and with it one of key Australia's competitive advantages internationally – in the absence of the eventual deployment of LETFF.

3.4 Industry understanding of low emissions technologies

In general, stakeholders perceived that there was an increase in industry understanding following the commencement of the LETFF programs, albeit from a low base. Overall, stakeholders reported that LETFF programs enhanced industry's understanding with respect to:

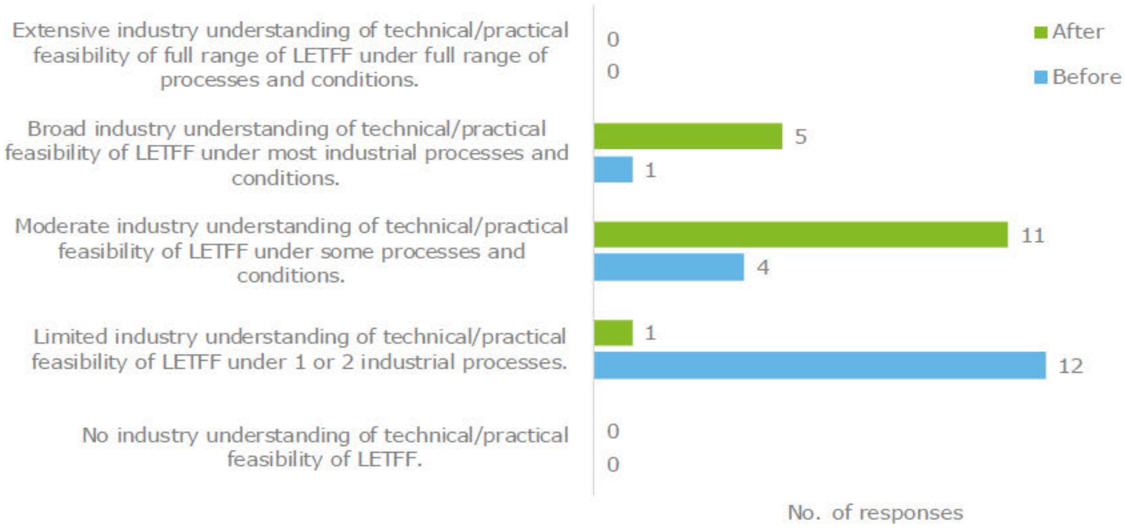
- the appropriateness and effectiveness of particular technologies at an industrial-scale
- the importance of geological subsurface and storage conditions to successful deployment
- greater certainty about the costs, timeframes, and risks involved in commercialisation.

As described by one industry stakeholder:

> *"When you look at all the work we have done to support various demonstrations… I can't help thinking that we are better placed than many of the other countries or most of the other countries when it comes to knowledge to deploy."* – Academic/research stakeholder.

Using the questionnaire responses of stakeholders, Chart 3.4 illustrates that industry understanding is perceived to have gone from being limited to now being at a moderate to broad level of understanding.

Chart 3.4: Questionnaire responses on industry understanding of technical and feasibility of low-emissions technologies before and after the commencement of the LETFF programs



Source: Deloitte questionnaire, n = 17

There is a consensus among stakeholders that the LETFF programs have contributed to industry now having a detailed 'end-to-end' understanding of the engineering and design of LETFF, in particular CCS technologies. Large projects such as CarbonNet and SouthWest Hub, for example, were identified as having provided industry with valuable practical and technical insights about the pathway to large-scale commercialisation, in terms of cost-discovery and the engineering design process involved. As stakeholders noted:

> *"… projects like the CarbonNet project, like the Southwest Hub project really did allow us to get a better understanding of 'yes there is a theoretical capability to put CO_2 in these places, but here are the real commercial understandings and then capabilities that we need to improve on to do that effectively"* – Academic/research stakeholder.

> *"The [projects] that have probably added most to the knowledge set are the ones where, for example, CarbonNet is really testing the whole end-to-end from the technical, regulatory through to the commercialisation."* – Commonwealth Government stakeholder.

More important to industry than any single LETFF project, however, is the combined and cumulative 'end-to-end' understanding that has been gained from the portfolio of LETFF projects –

'successful' and 'unsuccessful' projects. That is, the value of the iterative nature of the journey that industry and government have been on, and the importance of the learnings from each successive step at informing the direction of the next. As two stakeholders remarked:

> *"…as a complete package of knowledge, as they have gone from step to step to step, we know what we need to do now. So, I will call that a great success … if you are only involved at each of the little steps and that's all your involvement is, you can see each one as a failure because it didn't reach the grand scale, but in combination they have honed in on and now we know exactly what we need to do. … We have the luxury of staying with this whole landscape for the last 12 years and taking this whole picture to learn at each of the different steps."* – Industry stakeholder.

> *"… it's quite easy to look at the individual components and say we haven't actually achieved much, but for those that are able to look across the broad suite of projects and programs around capture, storage, transport, understanding where you might drill, understanding what you might retrofit, … there is a view that we have a very compelling understanding now across the implementation of CCS if you put it altogether, which we didn't have before…"* – Government stakeholder.

Even those LETFF projects widely perceived as failures (such as ZeroGen) or those perceived as being challenged and delayed (such as Gorgon), have provided industry with crucial learnings. ZeroGen, for example, despite its perceived failure, is credited with providing industry crucial learnings about the commercial viability of Integrated Gasification Combined Cycle (IGCC) technology (see Box 3.1).

Box 3.1: Learnings from ZeroGen

ZeroGen project: a successful failure
Prior to the commencement of ZeroGen IGCC technology was considered to be the highest efficiency for low-emission coal energy generation:

> *"[IGCC Technology] was at that time seen as being the big technology, that is kind of like the biggest break, and the reasons for that was its high efficiency, it was sort of like the big bang theory. It's the highest efficiency, the biggest one, it's going to make the biggest difference at a cost. So on a CO_2 stored dollar basis, it was going to be the way to go."* – Industry stakeholder

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While industry had a 'desktop-understanding' of Australia's geology and of the potential for subsurface storage sites, very little consideration had been given to the detailed understanding of the potential capacity and suitability of these basins or reservoirs for the purpose of storing CO_2. Understanding the geological subsurface for the safe storage of CO_2 is now considered by industry as one of the key components, along with low-emission and capture technology, to the successful deployment of LETFF on a commercial scale. However, significant gaps in industry understanding of site specific geological conditions and requirements exist. Geological considerations as a critical area of future research is explored further in Section 5.3.

Industry understanding with respect to methane abatement technologies within coal mine sites has not progressed as significantly as that of CCS. Overall, significantly more work is required across the research, design, technical testing and demonstration of methane abatement technology to allow for the technology to progress.

3.5 CCS Flagships Research Development and Development (RD&D) fund

The CCS RD&D fund aims to reduce technical and commercial barriers to the deployment of large-scale carbon capture and storage projects by contributing new knowledge with respect to:

- Australia's understanding of its geological capacity to permanently store carbon dioxide
- enhanced understanding of how CO_2 plumes behave in Australian conditions
- improved knowledge of Australia's CO_2 supply chain requirements
- harnessing international knowledge and expertise and building international relationships that progress global understanding of CCS
- lowering the cost of technology adoption and deployment in Australia.

The CCS RD&D fund has yet to be completed, and is beyond the scope of this evaluation. However, a summary of the intended knowledge to be generated across the CCS RD&D fund is summarised below.

Table 3.7: Summary of intended knowledge to be generated from CCS RD&D fund

Project	Project description	Intended knowledge to be generated
Northern Australia CO_2 Store	This project builds on work carried out by Geoscience Australia's regional assessment of the CO_2 storage potential in the Petrel Sub-Basin (PSB) in NT. The project objective is to de-risk the area of interest within the PSB.	• Detailed subsurface knowledge of the PSB and local geological properties. • Understanding of the geomechanical, geochemical and geophysical properties of the PSB, and behaviour of CO_2 in the PSB. • Detailed assessment of equipment and facilities required to transport CO_2 from Darwin to the PSB storage. • Determination of well numbers to accommodate CO_2 production.

Project	**Project description**	**Intended knowledge to be generated**
CTSCo Integrated Surat Basin CCS project	This project delivers aspects of the CCS demonstration project that will enable a Financial Investment Decision for construction and deployment during 2018/2019, including technical, social and permitting aspects.	• Greater understanding of construction and deployment requirements of CO_2 test injection facilities. • Greater understanding of the regulatory pathway for onshore storage of CO_2 in Australia. • Greater understanding of the financial viability of onshore storage of CO_2. • Greater understanding of community engagement with respect to CCS.
Australian Subsurface Carbon Sequestration Simulator	This project works towards improved understanding of how CO_2 behaves during geo-sequestration in the Australian subsurface and how this behaviour can be monitored.	• Improved simulation, forecast and monitoring of CO_2 plume behaviour. • Enhanced geophysical imaging of CO_2 plumes.
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Improving safety and efficiency of CO_2 pipelines	Development of fracture and dispersion models to enhance design and reduce risk associated with CO_2 pipeline construction and development.	• Validated fracture arrest model/software and design requirements. • Validated dispersion model • Updates of Standards and Recommended Practices covering CO_2 pipelines • Development of cost benchmarks for CO_2 pipeline.
Surat Deep Aquifer Appraisal project	Assessment of real optionality for industrial scale CCS deployment linked to south-east Queensland stationary emissions generators.	• Provision of significant technical and cost information into the public (pre-competitive) domain to assist with ultimate de-risking and planning of projects. • Greater understanding of techno-economic and other deployment critical issues. • Enhanced methodologies for community engagement about energy choices (and within that how best to engage on CCS). • Discovery of the degree and criticality (costs, timing risks) to which CCS can be a real mitigation option for GHG abatement in Eastern Australia.

4 Factors contributing to achievement outcomes

Key findings:

- At commencement, the LETFF programs were underpinned by clear policy direction and settings, support across Commonwealth and State governments, and a significant funding commitment across a suite of programs and projects – factors that were critical to the achievement of outcomes.
- Other contributing factors to the achievement of outcomes included:
  - establishment of partnerships between government, industry and academic stakeholders
  - the direct financial involvement of the coal industry in maintaining an industry-focused research agenda
  - establishment of a portfolio of LETFF projects to maximise learnings and the probability of success.
- Changing, uncertain and inconsistent policy settings are considered the **primary factors** hindering achievements and progress across the LETFF programs. This resulted in significant **loss of confidence across industry and a loss of momentum in advancing LETFF**.

  The unexpected complexity of LETFF, inflexibility of funding agreements, regulatory uncertainty and insufficient readiness on the part of the Commonwealth and State governments have also hindered achievements and progress across the LETFF programs.

  The absence of a clear commercial imperative on the part of industry to invest in carbon abatement remains the single largest barrier to the commercial development and deployment of LETFF.
- Knowledge gained throughout the LETFF programs could have been more effectively disseminated to the broader public. Barriers to knowledge sharing and access to information have contributed to a low level of public understanding and acceptance of LETFF, and in particular CCS, and represent a barrier to the deployment of LETFF.

4.1 Factors that contributed to achievement of focus outcomes

There was consensus among stakeholders that the manner in which the LETFF programs were established was a major factor contributing to the achievement of focus outcomes (i.e. knowledge, skills and capability, and improved industry understanding). Specifically, stakeholders noted that, at commencement, the LETFF programs were underpinned by clear policy direction and settings, support across the Commonwealth Government and participating State governments, and a significant funding commitment across a suite of programs and projects.[2] Stakeholders agreed that these factors provided a clear signal of government policy intent and focus to industry, and gave industry the confidence to participate and invest in the programs. As noted by stakeholders:

> *"The greatest assistance was right at the beginning when there was a common urgency, a common understanding that we all needed to do something. And by that, I mean the Federal Government, the State Government, and the industry."* – Industry stakeholder.

[2] The original Commonwealth Government funding commitment across the four LETFF programs was approximately $2.8 billion.

> "[A key factor was] *the early decision to allocate funds to a suite of programs and have sort of a champion in cabinet to push these sort of issues through and make it a priority. I think it then just follows that your domestic stakeholders know that they have got backing through the government in real terms as in funding, but also from a national priority perspective"* – Commonwealth Government stakeholder.

Many stakeholders also identified the partnerships established between government, industry and academic proponents as being critical to the achievement of focus outcomes. This led to meaningful engagement between academic, technical experts, policy makers and industry proponents across the LETFF programs. In turn, these partnerships helped maintain strong technical and research capabilities to support the LETFF programs:

> *"The access that we have had to government and industry to assist with our research program has been probably the most significant factor for us." – Academic/research stakeholder.*

In particular, **the direct financial involvement of the coal industry**[3] is considered to have been critical in maintaining an industry-focused research agenda. Stakeholders considered the industry-led research agenda to be contributing factor to the achievement of focus outcomes. As noted by two stakeholders:

> *"The manner in which the program is set up, means we have to have a combination of government and industry and researchers obviously. It allows us to not just do research for the sake of research, it allows us to understand what the industries' needs are, what the government's needs are, and do the appropriate technology development to meet those users' needs." – Academic/research stakeholder.*

> *"My job is to support demonstration, and this is very, very clear. I am greatly assisted by that because when a researcher comes to me with a good idea…I'm always able to take their idea and hold it up against this lens and say does this help deployment? If it doesn't help deployment I tell them "I'm sorry you have got a fantastic idea, but it doesn't suit my purpose." So, it's not that your idea is bad, it's just that I have a certain purpose and your idea doesn't fit here."* – Academic/research stakeholder.

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4.2 Factors that hindered achievement of focus outcomes

There was consensus among stakeholders that changing, uncertain and inconsistent policy settings were the **primary factors** hindering achievements and progress across the LETFF programs. Specific examples of changing and inconsistent policy settings identified included:

- removal of the carbon price regime following the commencement of the LETFF programs
- lack of a clear national strategy and statement with respect to LETFF, and in particular CCS
- changing and inconsistent policy settings no longer aligning with program objectives

[3] Support was focused through the former Australian Coal Association for Low Emissions Technologies Research and Development (ACALET R&D), now known as COAL21.

- government policy not adopting a technology 'agnostic' approach with respect to emissions abatement, with stakeholders noting that CCS projects were ineligible for funding from the Clean Energy Finance Corporation
- loss of policy direction over time resulting in general policy confusion among industry participants.

These issues **resulted in significant uncertainty and loss of confidence across industry, and a loss of momentum with respect to the advancement of LETFF.** As stakeholders noted:

> *"A lack of clear government policy (both State and Federal) on CCS hinders progression of the demonstration projects required for future large scale CCS to be assessed and ultimately progress."* - Industry stakeholder.

> *"We don't have that clear stable policy framework. We don't have that clear confidence in that framework to allow significant* [Industry] *investment."* – Academic/research stakeholder.

The changing policy settings also contributed to eroding industry engagement within the LETFF programs. Proponents no longer considered the investments to be a priority in the absence of clear policy direction. As one stakeholder noted:

> *"While the project staff were still very committed to the project, they did from time to time run into a bit of pushback from the operations staff at the mine site, because they are no longer quite as keen to have this project running at their site because there wasn't that financial impetus* [any longer]*."* – Commonwealth Government stakeholder.

There is a perception among many stakeholders that an insufficient understanding of the complexity of low emissions technologies at the commencement of the LETFF programs also hindered the achievement of focus outcomes. In particular, there is a perception that the Commonwealth Government lacked the necessary internal scientific and technical capabilities to accurately evaluate and assess the viability of projects proposed prior to the commencement of the LETFF programs. Insufficient understanding of the technical, scientific, engineering, regulatory and environmental challenges underpinning large-scale LETFF across government, industry and academia resulted in:

- unrealistic program and project timelines
- insufficient funding being committed to support development and deployment
- insufficient understanding of project financial and technical risks
- an implicit assumption relating to the commercial feasibility of geological resources.

Overall, this resulted in unrealistic program timeframes, costs and expectations. As noted by stakeholders:

> *"If you look at the CCS Flagships program, in some ways, that was too much too soon. The expectation that you were going to be commercial and up and running in 2013* [for example] *was unrealistic."*– Industry stakeholder.

> *"The challenges with some of this have proven to be … more difficult than first thought. So, Gorgon, for example, has ended up being a much, much larger project than was originally conceived. So, the original intent* [of the LETFF programs] *got the scale completely wrong."* – Commonwealth Government stakeholder.

Stakeholders also identified regulatory uncertainty and insufficient readiness on the part of the Commonwealth and State governments as a factor hindering the achievement of focus outcomes. Governments at both levels were ill-prepared in terms of regulation and legislation for the commercial implementation of technologies – particularly relating to the storage and monitoring of CO_2. Projects involving pilot drilling and site testing (such as CarbonNet in Victoria) required State government regulatory approval (and in the case of CarbonNet also Commonwealth Government approval due to offshore activities) before proceeding. These regulatory approval processes significantly impeded project timelines and presented considerable challenges to project proponents. As summarised by one stakeholder:

> *"It's more in the regulatory space that's been required than people realised. For example, on the CarbonNet project, there were all sorts of Victorian government approvals, but there are also Australian Government approvals because it is eventually going to be in the offshore domain… There are multiple approval processes and I think it's fair to say that's been very challenging."* – Commonwealth Government stakeholder.

A range of stakeholders noted that Commonwealth Government funding agreements, where project funds are tied to specific milestone dates and activities, don't adequately reflect the nature of industrial-scale projects. The inflexible nature of funding agreements were considered to have impeded and slowed project progress and achievement of focus outcomes.

A minority of stakeholders considered that the decision to allocate funding across a portfolio of LETFF programs and projects hindered program achievements. They perceived that greater progress towards the development and deployment of LETFF may have been achieved by focussing on a single or two LETFF projects in total. As one of these stakeholders noted:

> "[The Commonwealth Government] *spread the funding too thinly across several projects. There was only ever sufficient funding allocated for one CCS project. Running a competition* [a grant application process] *encouraging several projects to commence was ineffective and unrealistic"* – Academic/research stakeholder.

4.3 Impact of program design and implementation on achievement of focus outcomes

A majority of respondents to the online questionnaire considered that the level of funding allocated to the LETFF programs (82%) and project selection processes (59%) positively contributed to the achievement of outcomes.

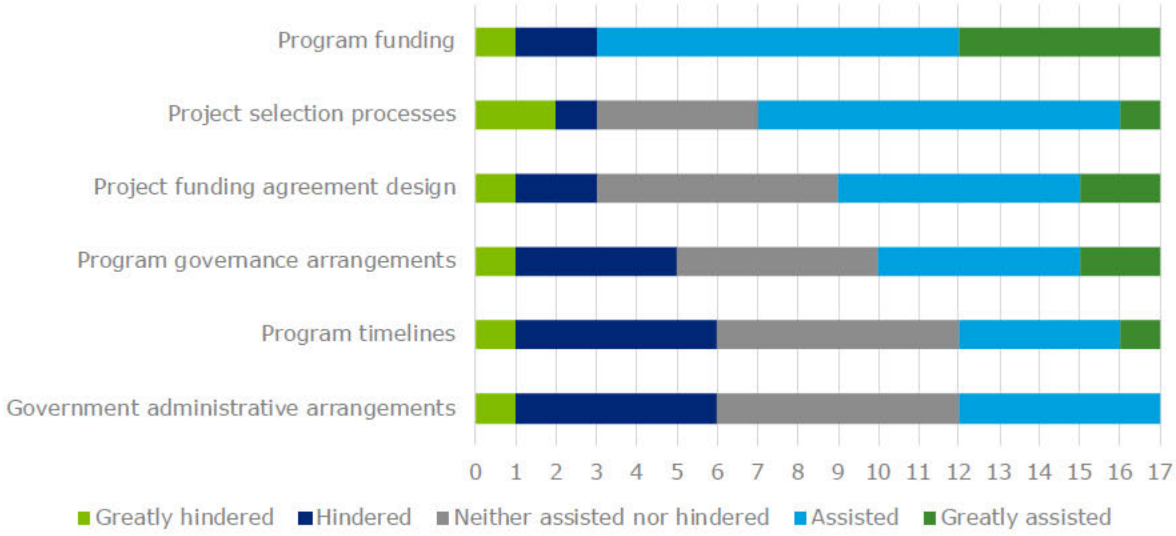
However, responses were more mixed with respect to the impact of program timelines, funding agreement design, administrative arrangements and governance arrangements on the achievement of outcomes (see Chart 4.1).

For example, while almost half (47%) of questionnaire respondents considered the design of funding agreements to have greatly assisted or assisted the achievement of focus outcomes, this view was not shared by all stakeholders. A range of stakeholders interviewed considered funding agreements to be inflexible, and a requirement to tie funding to specific milestones to be incompatible with large-scale industrial development projects. As noted by stakeholders:

> *The way all of these projects are setup, they can only take one step* [at a time]*. And therefore, the project has to wait until you have made a decision. There hasn't been that ability to take the next step after you've learnt something, change the plan a little bit, modify it to suit what you've learnt, take the next step, and having funding continue from there".* – Industry stakeholder.

> *"Here is $100 million go and do your first bit, and here is a $100 million go and do your second bit, and here is $50 million go and do your third bit. That is not the way to run a big project, you know, when BHP decides it is going to develop a mine, that is a $15 billion decision and they don't hand it out, you know, $100 million at a time. So I think the government has to think about a way on how it wants to support large-scale projects like this."* – Academic/research stakeholder.

Chart 4.1: Questionnaire respondents' perception on which aspects of the design of the LETFF programs contributed to the achievement of focus outcomes



Source: Deloitte questionnaire, n = 17

In addition to the above, many stakeholders noted during interviews that the 'removal' or clawback of program funding by the Department from projects deemed infeasible/unsuccessful adversely impacted the achievement of focus outcomes. Many stakeholders considered that this funding should have been reallocated to remaining projects or new funding rounds held to identify 'new' projects, rather than have such funding returned to consolidated revenue. As noted by stakeholders:

> *"The CCS Flagship Demonstration Program was crippled by the withdrawal of Commonwealth funds originally allocated to it."* – Industry stakeholder.

4.4 Barriers to the commercial development and deployment of LETFF

There was consensus among stakeholders interviewed that the absence of a clear commercial imperative on the part of industry to invest in carbon abatement remains the single largest barrier to the commercial development and deployment of LETFF. Key issues identified by stakeholders contributing to the absence of a commercial imperative included:

- lack of a clear, consistent national energy policy that addresses the role of LETFF and provides industry with sufficient long-term confidence to invest
- absence of Commonwealth and State government policy instruments that directly incentivise investment in emissions abatement
- significant cost of deploying commercial-scale CCS projects, noting that LETFF (and CCS in particular) has a particularly high cost relative to alternative emission abatement technologies
- investment risk is perceived to be high given current policy settings and uncertainty
- issue of third party risk remains unaddressed under current policy arrangements, specifically the issue of indemnifying storage and reservoir operators over the longer term.

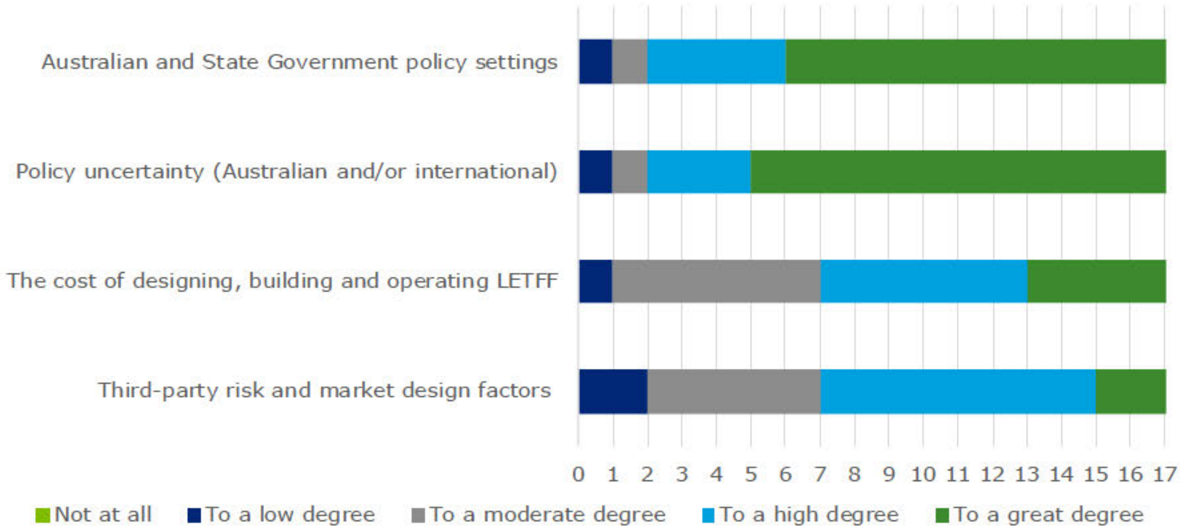
As noted by stakeholders:

> *"The issue with all of this is cost. The investments that are required to do these things* [LETFF] *at scale invariably seem to be much larger and the costs are much larger than originally envisaged."* – Commonwealth Government Stakeholder.

> *"You cannot see* [under current arrangements] *how any of these projects are going to be funded."* – Industry stakeholder.

Responses to the online questionnaire support the above findings. Questionnaire respondents identified existing Australian and State government policy settings (88% of respondents consider policy setting remain a barrier to a high or great degree), domestic and international policy uncertainty (88%), cost of LETFF (59%) and third-party risk (59%) as presenting the greatest barrier to the commercial deployment of LETFF (see Chart 4.2).

Chart 4.2: Questionnaire respondents' perception of the extent to which external factors remain a barrier to the commercial deployment of LETFF



Source: Deloitte questionnaire, n = 17

However, some stakeholders considered that some longer-term commercial drivers were already in place, and highlighted the decision by Chevron and its joint venture partners to invest in the Gorgon Carbon Dioxide Injection project. As one stakeholder noted:

> *"If you want to exploit Australia's offshore gas resources in say 25 years' time, you will have to deal with those emissions I think. I think that's going to be the world we are. So, I think that if you look at it through that lens, there is going to be a commercial driver."* – Commonwealth Government stakeholder.

Many stakeholders also identified the lack of a technologically 'agnostic' approach to emissions abatement as a barrier to the commercial deployment of LETFF. There was a perception among many stakeholders that LETFF was treated inconsistently to alternative technologies. For example, CCS projects are not eligible for funding under the Clean Energy Finance Corporation. As one stakeholder summarised:

> *"It's not about renewables versus CCS or renewables versus coal. It's about having a portfolio of solutions to reach your emissions targets." – Industry stakeholder.*

Stakeholders also identified that barriers to knowledge sharing and access to information may have adversely affected the broader public discourse and perceptions around LETTF. This has contributed to a low level of public understanding and acceptance of LETFF, and in particular CCS, and is considered a barrier to the deployment of LETFF by some stakeholders. All stakeholder groups recognised that the role of LETFF in abating emissions was not well understood by the general public, and that there was a broad public perception that the primary role of LETFF was to extend the 'life' of fossil fuels. There is a perception that this has contributed to hindering the deployment and implementation of LETFF. As noted by stakeholders:

> *"... most of the knowledge is sort of really been distributed amongst people closest to these programs and various industry stakeholders, but in terms of the broader community they have been consulted where they are directly affected, but I don't think the average*

> *Australian knows where the Carbon Capture and Storage is up to in Australia."* – Commonwealth Government stakeholder.
>
> *"… the CCS community and industrial sectors of Australia, we are very good at talking to ourselves about how great CCS is and how we are going to use that as a solution. We are hopeless at talking outside that group, outside of* [our] *comfort zone."* – Academic/research stakeholder
>
> *"I think both government and industry have done a poor job of enunciating the benefits of CCS. I think we are probably behind the eight-ball by now."* – Industry stakeholder.

Stakeholders also recognised that falling domestic demand for fossil fuels was a potential barrier to the deployment of large scale LETFF. While a broad range of emission-intensive industrial processes (such as fertiliser production, agriculture and smelting) have potential to support demand for LETFF deployment, stakeholders agreed that the key sectors (beyond the oil and gas sector) likely to underpin the initial deployment of LETFF were the coal and energy generation sectors. As one stakeholder noted:

> *"I think anything that is going to impact on coal production levels and demand for coal is going to then impact on the operating costs and financial considerations, and so it is going to have even more of a detrimental effect of looking at the capital costs of significant abatement investments."* – Commonwealth Government stakeholder.

5 Success, future research and role of government

Key findings:

- Overall, **stakeholders overwhelmingly consider the LETFF programs to be successful**. The LETFF programs have made significant contributions to increasing knowledge, skills and capability, and improving industry understanding of LETFF in Australia. These achievements **would not have been made in the absence of Commonwealth Government support.**
- Stakeholders consider that the Commonwealth Government's investment in LETFF programs **represents good value for money**, and **achievements are commensurate with the investment**.
- LETFF programs have directly contributed **to reducing the technical and commercial barriers** to the development and deployment of commercial-scale LETFF projects.
- However, the achievements and knowledge gained could have been more effectively communicated or disseminated among industry and the general public.
- Australia risks losing the significant gains in knowledge, and skills and capabilities established through the LETFF programs if Australia does not proceed to the commercialisation and deployment of LETFF.
- The critical underlying research and technical questions to deploying large-scale LETFF (and CCS in particular) have been addressed, however some targeted research would supplement and benefit research done to date.
- Stakeholders consider **there remains a critical role for Government** in supporting the development and implementation of LETFF. While there was no clear consensus from stakeholders interviewed, a majority of respondents to the online questionnaire considered the Commonwealth Government should continue to provide large-scale grants to support LETFF research and development.

5.1 Success of LETFF programs

Overall, stakeholders across all groups consider that the LETFF programs have been successful, and have made a significant contribution to increasing knowledge, skills and capability, and to improving industry understanding about low emissions technologies.

As reported above in Section 3, stakeholders consider that as a result of the LETFF programs Australia now possesses the requisite scientific and engineering knowledge, skills and industry understanding to develop and deploy large, commercial-scale LETFF projects. Through the LETFF programs, the key research and technological barriers to the deployment of LETFF have largely been overcome. Stakeholders noted:

> *"When you put all the projects on the map of Australia, show the different types of geology that we've got around Australia, and the different projects that we've* [delivered] *around Australia, the government has participated in a really good portfolio of projects"* – Industry Stakeholder.

> *"Industry in Australia has gone from not having a clue of what we are doing to now being able to say where we're going to put a drill or drill a hole, where we're going to store CO_2, the technology we're going to use, and to take that next step* [of deployment]*. So, has it* [the LETFF programs] *been successful? In my mind, absolutely."* – Industry stakeholder.

A key element contributing to the success of the LETFF programs has been the critical learnings gained by industry and government across the suite of programs and industry. In particular,

projects deemed 'unsuccessful' have provided valuable insights in progressing Australia's knowledge and understanding of LETFF. For example, the 'unsuccessful' **South West Hub** project yielded the following learnings:

- significant improvements to conducting and analysing seismic data, monitoring and modelling CO_2 plumes
- understanding how basin configuration and structural elements affected containment capabilities of a rock formation.

These areas of research were driven by the fact that the Eneaba Formation did not have the impermeable seal that other potential CO_2 storage sites had (for example sites on the east coast of Australia).

The majority of stakeholders interviewed consider that the Commonwealth Government's investment in LETFF programs represents good value for money, and achievements across the focus outcomes are commensurate with the investment made. In particular, stakeholders noted that the research undertaken has directly contributed to overcoming research and technological gaps and barriers with respect to LETFF. Stakeholders noted:

> *"In the research dimension…I think the returns have been immensely large. So, I think you know, yes, we've done a damn good job of research." – Academic/research stakeholder.*

> *"I think that there has been a pretty good return on investment for most of the projects under the LETFF. I think that there has been a couple of projects that haven't succeeded, but that doesn't always mean that that money hasn't been well spent…you can learn from the failure as well."* – Commonwealth Government stakeholder.

This finding was supported by the results of the questionnaire of LETFF program stakeholders, in which 71% of all respondents agreed or strongly agreed that the LETFF programs have achieved outcomes commensurate with the investment made. The questionnaire found that 71% also agreed or strongly agreed that the LETFF programs have directly contributed to reducing the technical and commercial barriers to deploying large-scale LETFF projects.

However, some stakeholders were more cautious when reflecting on the success of the LETFF programs, noting that Australia still lacks a pipeline of large-scale LETFF projects. As one stakeholder noted:

> *"Yeah, so it's really quite hard to answer* [the question of success] *because I think again from a technical geoscientific perspective, I think that's clearly been a success in terms of that technical scientific knowledge. But for that [approximately $750 million] again we don't really have a pipeline of CCS projects or kind of big things that are going to make a difference to emissions for Australia."* – Commonwealth Government stakeholder.

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Stakeholders also perceive that the knowledge and learnings gained from across the LETFF programs have not been sufficiently communicated to the general public (as reported in Section 4.5 above, this was considered a barrier to commercial deployment by some stakeholders). Overall, stakeholders noted:

- there is a lack of public understanding of the potential role of LETFF in decarbonising the economy and national energy market

- there is a 'poor' public perception of LETFF that does not match the achievements that have been made across the LETFF programs
- LETFF, and CCS in particular, are seen as technologies designed to 'extend the life of fossil fuels'.

Lastly, stakeholders broadly agreed that Australia risks losing the significant gains in knowledge, and skills and capabilities it has established over the last 15 years through the LETFF programs if it does not proceed to the commercialisation and deployment of LETFF. Low emissions technologies such as CCS are increasingly being deployed in the U.S., China and Europe. If Australia does not proceed to deployment, it is likely that the specialised skills developed through the LETFF programs will be lost overseas to where LETFF is being deployed. As one stakeholder noted:

> *"… there are certainly other countries who have skilled up more effectively than Australia has in the last few years and we are at risk of being left behind to some extent. … the US has an extremely comprehensive national CCS approach, Norway, the [and] UK to some extent…. So, we are in danger of losing that capability I believe if we are not careful in what we are doing."* – Academic/research stakeholder.

5.2 Would have achievements been made in the absence of government support?

Overall, there was consensus across all stakeholders interviewed that the achievements made towards increasing knowledge, skills and capability, and on improving industry understanding about low emissions technologies **would not have been made in the absence of Commonwealth Government support**. When asked what progress would have been made without support from the Commonwealth Government, stakeholders noted:

> *"Short answer is zip, nothing. I don't think we would have done much at all. Truly, I don't think we would have done much at all."* – Academic/research stakeholder.

> *"It wouldn't have occurred if it wasn't for the government's investment"* – Industry stakeholder.

> *"We would still be stuck in the theoretical research phase."* – Commonwealth Government stakeholder.

> *"There is no likelihood that we would have achieved what we did without government involvement"* – Academic/research stakeholder.

However, stakeholders did note that the Chevron-led Gorgon Carbon Dioxide Injection project would have occurred in the absence of Commonwealth Government support. Chevron Australia had publicly committed to build the injection project prior to the commencement of the LETDF and the development of the injection project was later included as a development approval condition for the LNG project.

Responses to the online questionnaire supported the outcomes of the stakeholder interviews. The questionnaire showed that 65% of respondents consider that no progress or almost no progress would have been made towards the achievement of the focus outcomes in the absence of Commonwealth Government investment in the LETFF programs (Chart 5.1).

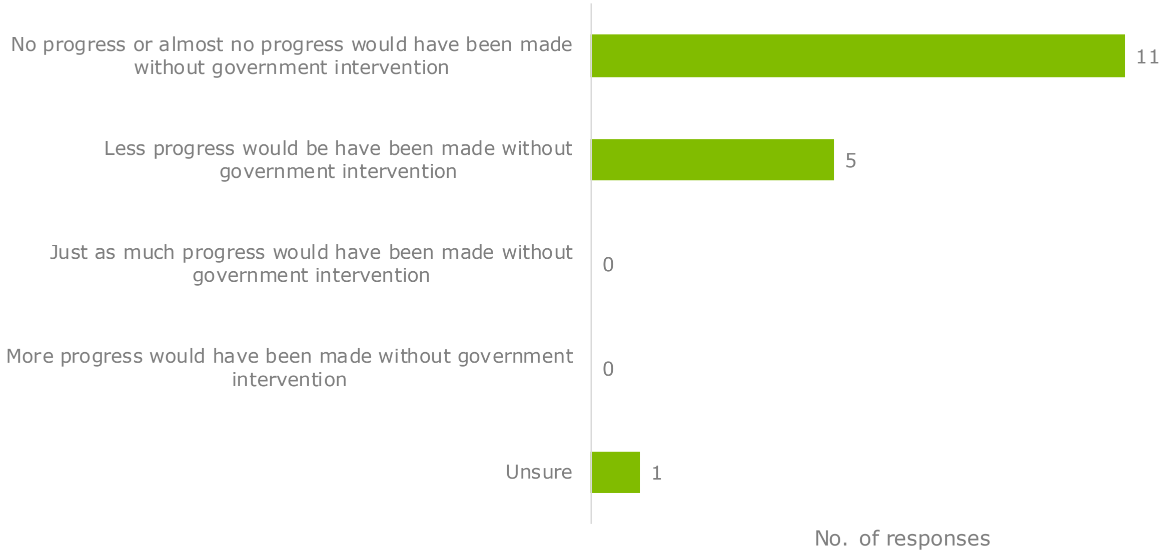
Stakeholders noted that in the absence of a commercial imperative to invest in LETFF (see Section 4.4), there was no incentive on the part of industry to invest in pre-commercial research and development of LETFF. A lack of commercial imperative means that there was no driver to undertake pre-commercial research into capture technologies, CO_2 transportation, storage technologies and CO_2 injection, Australia's geological resources, CO_2 subsurface behaviour, or the safety of LETFF.

By investing in LETFF, the Commonwealth Government was able to successfully leverage significant contributing funding from the coal industry and participating State governments. As one stakeholder noted:

> *"With the current absence of financial incentives for industry to pursue CCS technology, I greatly doubt the funding required to carry out the R&D completed to date would have*

> *existed. The LETFF programs provide the foundation funding (*s22 s22 [redacted]*) for this research to be proposed and progress."* Academic/research stakeholder.

Chart 5.1: Extent to which questionnaire respondents consider progress would have made in the absence of the LETFF programs



Source: Deloitte questionnaire, n = 17

5.3 Are there critical areas of research that remain unanswered

There is consensus among all stakeholder groups that the critical underlying research and technical questions to deploying large-scale LETFF (and CCS in particular) in Australia have largely been settled as a consequence of the activities delivered under the LETFF programs. Stakeholders agreed that the next critical phase to LETFF in Australia was deployment. As stakeholders noted:

> *"I think we are far, far beyond the research questions. And I think now it's about deployment, and it's about supporting deployment."* – Academic/research stakeholders.

> *"The research is sufficient to take us the next step and let the engineers take the next step so that the researchers can then work on the next problems…I don't think we need more research. I think we need deployment. I don't think there's any gaping holes in research." – Industry stakeholder.*

However, stakeholders did identify a range of future research that would supplement and benefit LETFF research done to date.

In particular, a range of stakeholders across all groups identified the need to undertake **site-specific research and testing to support the eventual deployment of LETFF**. While the LETFF programs have demonstrated proof of concept at the regional level, none of the detailed site-specific research and testing has been undertaken that would be required to support deployment of LETFF. The deployment of LETFF will require a new wave of site-specific research relating to drilling, sub-surface monitoring, seismic analysis and injection testing. Such research and analysis will be critical to project-specific planning, investment, and regulatory decisions. As stakeholders noted:

> *"There will be local specific* [research issues] *related to storage, so there will be groundwater impact concerns mostly, so that will be the Queensland story if they get any further [to deployment]… So, there will be site specific and to a large extent community specific [research requirements]."* – Academic/research stakeholder.

> *"We need to do more detailed analysis on key spots. Because we've got the broader understanding of CCS in Australia, but not the actual real details [of specific sites]." –* Academic/research stakeholder.

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The focus of the LETFF programs had largely been in relation to the capture, transport and storage of emissions from coal mines, liquefied natural gas (LNG) plants and stationary power stations. Some stakeholders noted, however, a need to research **the application of learnings from the LETFF programs to other emission-intensive sectors** including steel, concrete, fertiliser, and agribusiness. As one stakeholder noted:

> *"the industrial applications of CCS that we need to be putting more work into…So, it is other types of CCS technologies that we probably haven't focused on." –* Commonwealth Government stakeholder.

The 'capture' process is one of the most expensive and technically complex aspects of CCS, and can typically account for approximately two-thirds of the total CCS deployment cost.[4] Recognising this, some stakeholders also noted a need to investigate CO_2 capture processes for these emission-intensive industries to assist in making CO_2 capture more commercially feasible.

As reported above, public perception and acceptance of LETFF and CCS in particular is considered a barrier to the eventual commercial deployment of LETFF in Australia. A range of stakeholders identified the need for **further research in effectively engaging with communities at the local level.** Given the nature of CCS (which involves the injection of CO_2), understanding how best to engage local communities level was seen as critical to garnering support and achieving regulatory approval, and ultimately resetting the national conversation. While some research has been undertaken on an ad-hoc, individual project-level, there has been no coordinated, strategic approach across the LETFF programs. The importance of better engagement with local communities was summed up by a stakeholder thus:

> "…*the key is you don't engage them* [local communities] *about CCS, you engage them about the whole gambit of future energy choices, and within the choices and the trade-offs you then bring CCS into that equation, so that they actually see a choice. It is not just, 'Yes CCS' or 'No CCS.'"* – Academic/research stakeholder.

A final area of research identified by a few stakeholders included **the nature of enhanced oil recovery** (EOR). Overall, stakeholders noted that the relative importance of EOR to supporting the commercial viability of CCS projects in Australia was not very well understood. The production of EOR requires significant quantities of CO_2, which is injected into the sub-surface as part of the EOR production process. Overseas, including in the US, EOR is typically most viable where production can integrate with CCS to take advantage of a ready supply of CO_2. While the presence of EOR may not be in all locations that are deemed appropriate for CO_2, there was a view among some stakeholders that further research and investigation was required, particularly given the absence of other commercial imperatives (as reported in Section 4.4 above). As one stakeholder noted:

> *"When you look internationally a lot of the CCS projects have been underpinned by a revenue stream of oil from enhanced oil recovery… there has been this sort of view that EOR or enhanced oil recovery in Australia is not a lot, there is not many prospects. But I*

[4] Estimate based on stakeholder interviews.

> *am not sure that that is underpinned by really good technical and exploratory work. So if we are missing something it is: 'What are the prospects for enhanced oil recovery in Australia?'"* – Academic/research stakeholder.

5.4 Role of Commonwealth Government

There was consensus among all stakeholder interviewed that **there remains a critical role for Government** in supporting the development and implementation of LETFF following the completion of the LETFF programs. Deloitte notes that all stakeholders interviewed as part of this evaluation were directly involved in the LETFF programs, and thus there is likely to be some reported bias in stakeholders' views on the need for continued government support.

However, there was **no clear consensus** among stakeholders interviewed on the most appropriate role for the Commonwealth Government in supporting the development and implementation of LETFF.

Many stakeholders reported that the primary role of the Commonwealth Government should be in setting a clear **national energy and climate policy agenda and framework.** Such a framework would provide industry with sufficient long-term confidence to invest in large-scale LETFF projects. As noted by some stakeholders:

> *"So, absolutely there is a role for government and it links back to that national leadership. I think that we need to have strong policy settings out there that can incentivise investors coming on board for a technology which has some market values in terms of risks."* – Commonwealth Government stakeholder.

> *"The government's role is to set a very clear path forward and then to work with industries and organisations that have a role to play in that path whether it be because they're impacted or because they're contributing to that path."* - Industry stakeholder.

Many stakeholders, in the absence of commercial imperatives on the part of private industry to invest, saw a role for the Commonwealth Government to provide **direct financial support** for the commercial-scale deployment of LETFF. Such stakeholders considered the Commonwealth Government had a critical role in directly financially supporting the first CCS project in Australia. As one stakeholder noted:

> *"I think the investment from the government is to bring opportunities to a point where a private investor can come in and support it. That can be straight-up by supporting the first opportunities for storage and utilisation hubs in Australia." – Industry stakeholder*

Other stakeholders noted the potential role for the Commonwealth Government in **providing ongoing financial support for research and development** where there was a clear, demonstrated need and where industry was unlikely to undertake the activity without support. Specific examples included research related to broader industrial application, safety, and community acceptance. As stakeholders noted:

> *"There is a place for grants. Grants have a benefit…they give [the Commonwealth Government] what we want. So, for example, if we think industrial CCS is somewhere that needs some research and development then we could certainly put a package together. So, there is room for grants in our repertoire."* – Commonwealth Government stakeholder.

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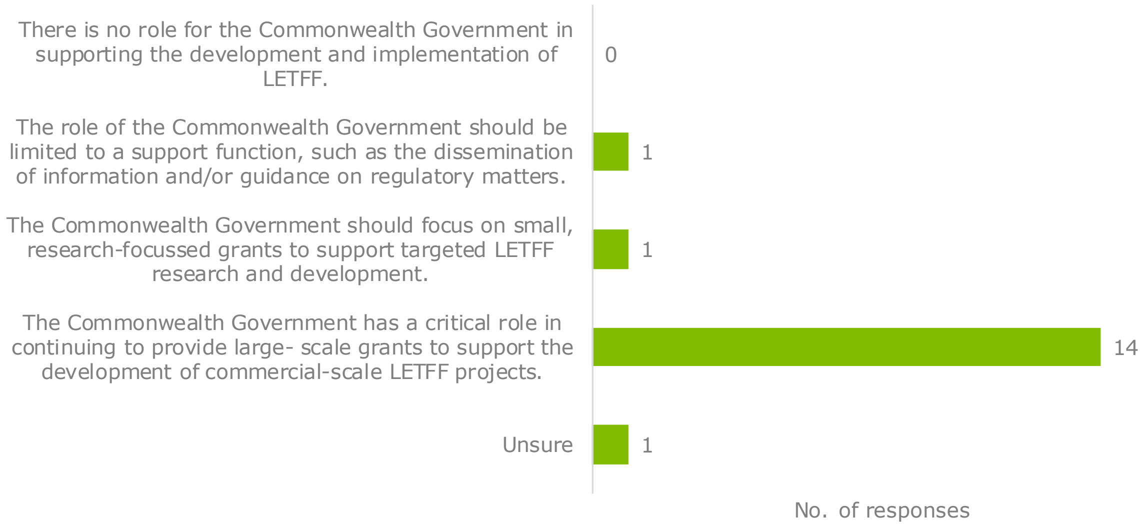
Responses to the online questionnaire were more consistent than stakeholder interviews in their views of what the primary role (if any) should be for the Commonwealth Government going forward with respect to LETFF. The questionnaire found 82% of respondents consider that the Commonwealth Government has a critical role in **continuing to provide large- scale grants** to support the development of commercial-scale LETFF projects (Chart 5.2).

Chart 5.2: Questionnaire responses re what primary role (if any) should the Commonwealth Government adopt in supporting the development and implementation of LETFF



Source: Deloitte questionnaire, n = 17

Some stakeholders interviewed also identified the need for the Commonwealth Government to consolidate the research and knowledge gained to date and ensure it is disseminated to the fullest extent possible.

Despite the majority of stakeholders reporting that the primary role of the Commonwealth Government should be to provide large-scale direct financial support for the deployment of commercial scale CCS projects, **Deloitte considers it is imperative that any future support for LETFF should be informed by a rigorous economic assessment**. Such an economic assessment would specifically involve assessing the role of LETFF in decarbonising the economy and NEM relative to alternative approaches, and give consideration to fossil fuel demand and full life-cycle costs of alternative technologies.

5.5 Unintended outcomes

Many stakeholders reported a perception that the LETFF research agenda is negatively affecting the commercial deployment of LETFF, and in particular CCS. Stakeholders reported that the drive to undertake additional research has resulted in a perception among regulators, industry detractors and the general public that LETFF is not adequately understood and that significant risk remains. As noted by a stakeholder:

> *"I think research has been a drawback for CCS*. [Researchers] *keep telling everybody, "we need to do more research" So, people who are detractors of CCS say, "look it's still an experimental technology." It's not."* – Academic/research stakeholder.

Some stakeholders also reported that the lack of commercial-scale deployment has resulted in a perceived lack of progress among the general public. This, in turn, has resulted in a perception that LETFF is not feasible, and has potentially hindered the sector's ability to achieve a social licence to operate.

6 Learnings for future program design

Key lessons to inform future program design and implementation include:

- setting realistic expectations with respect to program cost and time-horizons
- setting realistic expectations with respect to research and development outcomes
- ensuring alignment between policy settings and program objectives
- enhancing assessment of project feasibility at program commencement
- funding and program governance arrangements should reflect the nature of program activities
- greater industry engagement in the design of the program
- the need for ongoing monitoring of program funding
- embedding engagement processes to share knowledge gained within and across government
- improved understanding of the costs and benefits of LETFF in decarbonising the economy relative to alternative technologies, through a detailed Cost Benefit Analysis, as a first step in any future consideration of LETFF.

6.1 Learning for future program design

The LETFF programs have made a significant contribution to increasing knowledge, skills and capability, and on improving industry understanding with respect to LETFF.

However, there are a range of learnings to be gained from the design and implementation of the LETFF programs to inform future program design. These are discussed in greater detail below:

- **Setting realistic expectations with respect to program cost and time-horizons:** Future programs involving the research, development and deployment of large-scale and complex technologies must set realistic expectations around program costs and time-horizons.

  Program design should not underestimate the scale of research and development required to support the development of industrial-scale projects. This has implications for the level of funding made available, the setting of timelines, and internal program governance arrangement, including the establishment of internal expert panels to provide necessary technical guidance.

- **Setting realistic expectations with respect to research and development outcomes:** Future programs involving the research and development of unproven and untested technologies must set realistic expectations around outcomes realisation. It is critical that future program design explicitly recognise a realistic target in terms of research and development achievements, and that not all projects will proceed beyond the research phase.

- **Ensuring alignment between policy settings and program objectives:** Future program design must consider and reflect existing and likely future policy settings. Furthermore, there is a need to ensure that underlying commercial incentives and imperatives exist to support the achievement of program objectives.

  Future programs should also include a review 'trigger' to revisit the rationale of a program if there is a fundamental shift in domestic and international policy settings that are likely to impact the achievement of program objectives.

- **Enhancing assessment of project feasibility at program commencement:** Future programs should seek to improve technical and financial screening and selection processes to better gauge the feasibility of projects at program commencement. However, this needs to be balanced with the research and development objectives of any future program.

Future programs involving large and complex technologies should embed independent program review boards consisting of recognised domestic (and if appropriate international) experts to periodically assess project progress.

- **Funding and program governance arrangements to reflect the nature of program activities:** Future programs should adopt funding agreements and decision-gates to reflect the nature and needs of industrial development projects. In particular, stage gates should replace inflexible milestone reporting and payment processes. This would ensure approved project funds can be more appropriately accessed over time as the project passes through agreed stage gates.
- **Greater industry engagement in the design of the program:** Future programs should involve greater engagement with industry and academic stakeholders during program design. This would ensure program objectives, risks and issues are appropriately understood and reflected in the program design and implementation. Upfront industry stakeholder engagement should also inform an upfront formal assessment of program risks. This ensures risk mitigation strategies can be fully explored, and if possible, embedded within program design.
- **Monitoring of program funding:** Future programs should embed monitoring and reporting frameworks to monitor the effects of changes to funding on the achievement of program objectives. Such frameworks would enable an assessment of how remaining funds can be redistributed within the program (or other programs) and provide a transparent process for revisiting the project selection process to identify projects that were the next best ranked.
- **Embedding engagement within and across government:** Future programs should embed knowledge-sharing processes to ensure program learnings and outcomes are appropriately disseminated across relevant Commonwealth and State government departments and agencies. Furthermore, program design should consider the required data and information storage and sharing systems to ensure all relevant program documentation is adequately captured and collated in a central location. This mitigates the risks of key learnings and knowledge eroding overtime, and ensures future programs can incrementally build upon the knowledge gained.
- **Undertaking a detailed economic costs benefit analysis:** Any consideration of future support to further the development and implementation of LETFF should, as a first step, involve a detailed cost benefit analysis of LETFF in decarbonising the economy relative to alternative technologies. This analysis should give consideration to fossil fuel demand and the whole-of-lifecycle costs of alternative technologies.

Appendix A: Overview of projects by LETFF program

A summary of the projects delivered under the LETFF programs is presented in the following tables.

Table A.1: Summary of CCS Flagships projects

Project	Description
CarbonNet Project	The project investigates the potential for a large scale CCS network in the Gippsland region of Victoria. The network seeks to cover multiple sources of carbon dioxide captured from industrial plants or power stations.
SouthWest Hub Project	The project aimed to assess the feasibility of storing industrial-generated carbon dioxide deep underground in the Lesueur Sandstone formation. The project involved collecting data and core samples through seismic questionnaires and stratigraphic wells.
ZeroGen Project	The project involved assessing the feasibility of a commercial-scale coal gasification power plant with integrated carbon capture and storage.
Wandoan Integrated Gasification Combined Cycle (IGCC)	A prefeasibility study which involved the following sub-projects: • Stanwell Corporation/Wandoan project which sought to develop an IGCC power station with CCS capabilities. • CTSCo Pty Ltd/Wandoan project which focused on the transportation and storage of carbon dioxide from the IGCC power station through pipelining and geo-sequestration.
Otway Geological Storage and Demonstration Project	A carbon capture and storage demonstration project that aims to address barriers to storage implementation and leverage existing and new datasets arising from the CO2CRC Otway Project to further the technology. The project also involved a monitoring program that test technologies and techniques with the aim of reducing costs.
Australia-China Joint Coordination Group on Clean Coal Technology Projects	The project aimed to build on the growing relationship between Australia and China through the Australia-China Joint Coordination Group on Clean Coal Technology (JCG).

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Table A.3: Summary of LETDF projects

Project	Description
Gorgon Carbon Dioxide Injection Project	Design, construction and operation of facilities to inject and store CO_2 into a deep reservoir unit two kilometres beneath Barrow Island. The CO_2 that is injected into the reservoir unit comes from the process of extracting gas in the Gorgon/Jansz-Io fields.
400MW Integrated Dry-gas Gasification Combined Cycle (IDGCC) Clean Coal Demonstration Project	A project that aimed to increase the burning efficiency of thermal generators by drying brown coal. Reducing the moisture content of brown coal means that less energy is required to convert the coal into electricity.

Project	Description
Hazelwood 2030 Project	A project that aimed to retrofit Low Emission Technologies at the brown coal-fired Hazelwood Power Station in the Latrobe Valley, Victoria. The process involves reducing moisture content of brown coal for an improved burning efficiency. The Hazelwood 2030 project includes CCS facilities – with demonstrated capacity to sequester carbon dioxide at a rate of 0.02mtpa.
Fairview Project	A project that aimed to test the extraction of methane from coal and storing it underground

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Appendix B: Evaluation framework

The evaluation framework, including key evaluation questions and sub-questions, key data collection methods and sources guiding the impact evaluation of the LETFF programs is presented below. The evaluation framework has guided the key lines of enquiry and systematic organisation of analysis to ensure a consistent and robust assessment of the LETFF programs and project activities.

Table B.1: Evaluation framework

Domain	Key evaluation questions	Sub-questions	Data source		
			Interviews	Document review and citation analysis	Questionnaire
Effectiveness	To what extent have the LETFF programs increased knowledge, skills and capability, and improved industry understanding in relation to low emissions technologies for fossil fuels?	To what extent have the LETFF programs generated new research, data and modelling relating to the practical and technical use and implementation of LETFF?	✓	✓	✓
		To what extent have the LETFF programs resulted in the development of greater local (Australian) skills and capabilities in LETFF?	✓	✓	✓
		To what extent have the LETFF programs improved industry understanding of the feasibility and safety of LETFF through collaboration and dissemination of new knowledge?	✓	✓	✓
		To what extent is achievement against the above outcomes commensurate with the investment made by the Commonwealth Government?	✓		✓
	To what extent would knowledge, skills and capability, and industry understanding in relation to LETFF continued to have been developed in the absence of the LETFF programs?	What was the state of knowledge, skills and capability, and industry understanding prior to the commencement of the LETFF programs?	✓	✓	✓
		What is the state of knowledge, skills and capability, and industry understanding following to the commencement of the LETFF programs?	✓	✓	✓
		To what extent has investment from the LETFF programs crowded out industry and research activity that would have occurred in the absence of the LETFF programs?	✓		✓

Domain	Key evaluation questions	Sub-questions	Data source		
			Interviews	**Document review and citation analysis**	**Questionnaire**
		How much of the change observed in increased knowledge, skills and capability, and improved industry understanding is because of the LETFF programs?	✓		✓
Efficiency	What factors have helped or hindered the achievement of increased knowledge, skills and capability, and improved industry understanding in relation to LETFFs?	What factors have assisted the achievement of increased knowledge, skills and capability, and improved industry understanding in relation to LETFFs?	✓	✓	✓
		What factors have hindered the achievement of increased knowledge, skills and capability, and improved industry understanding in relation to LETFFs?	✓	✓	✓
		To what extent did the design and implementation of the LETFF programs assist or hinder the achievement of the increased knowledge, skills and capability, and improved industry understanding in relation to LETFFs? Did program design align with known 'best practice' examples elsewhere?	✓	✓	✓
		To what extent did the LETFF programs align with related programs or research (either government or industry)?	✓	✓	✓
		To what extent do these factors remain a barrier to the commercial development and deployment of LETFFs?	✓		✓
	How have external factors affected the ability of the LETFF programs to achieve their intended medium and long-term objectives?	How have Australian Government and international policy settings affected the achievement of medium and long-term objectives?	✓		✓
		How have the relative prices of, and demand for, renewable energy sources affected the achievement of medium and long-term objectives? How have alternative carbon abatement technologies (e.g. bio-sequestration) affected medium and long-term objectives?	✓		✓
		How has the level of demand for fossil fuel-based energy affected the achievement of medium and long-term objectives?	✓		✓
		How have general economic conditions affected the achievement of medium and long-term objectives?	✓		✓
		How have issues such as third-party risk and market design factors affected the achievement of medium and long-term objectives?	✓		✓

Domain	Key evaluation questions	Sub-questions	Data source		
			Interviews	Document review and citation analysis	Questionnaire
Appropriateness	What lessons can be drawn to inform future policy and program development, including the role (if any) of the Commonwealth Government, in relation to supporting the development and implementation of LETFF technologies?	What lessons can be drawn to inform future program design and development?	✓		✓
		Did changes to the LETFF programs since inception influence the efficiency or effectiveness of the programs?	✓		✓
		Are there critical areas of research that have been missed?	✓		✓
		Was there adequate industry engagement on the role of CCS and emission abatement technologies as part of a broad mix of GHG emission mitigation measures?	✓		✓
		What is the role (if any) of the Commonwealth Government in relation to supporting LETFFs?	✓		✓
Unintended impacts	What unintended outcomes have occurred as a result of the LETFF programs?	What (if any) unintended benefits occurred as a result of the LETFF programs?	✓	✓	✓
		What were the unexpected negative impacts of the LETFF programs?	✓	✓	✓

Appendix C: Stakeholder interviews and questionnaire responses

List of stakeholders interviewed

A list of all stakeholders interviewed as part of the evaluation assessment are outlined below. Overall, 19 stakeholders were engaged through 18 interviews as part of the evaluation.

Table C.1: List of stakeholders interviewed

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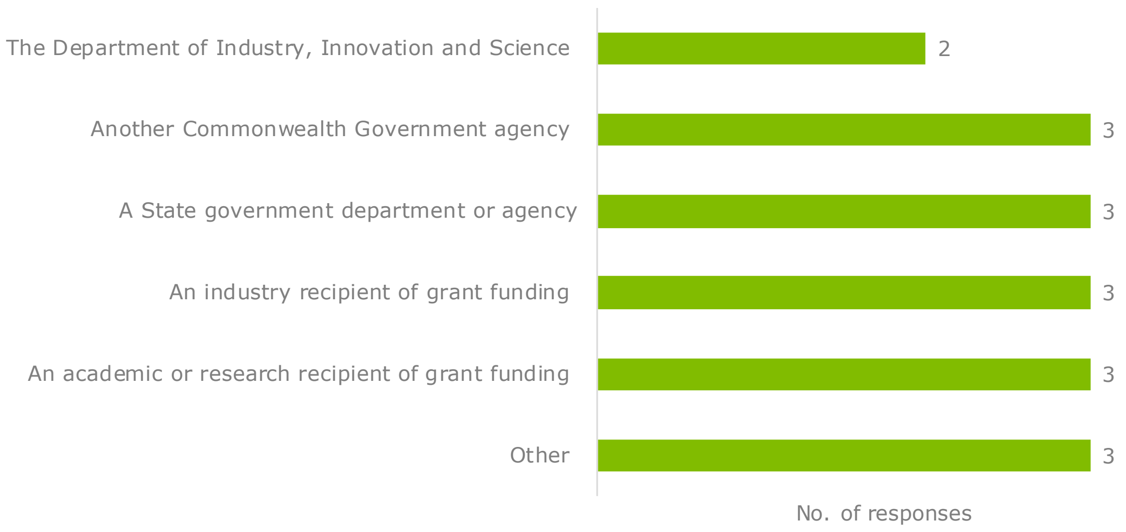
List of respondents to online questionnaire

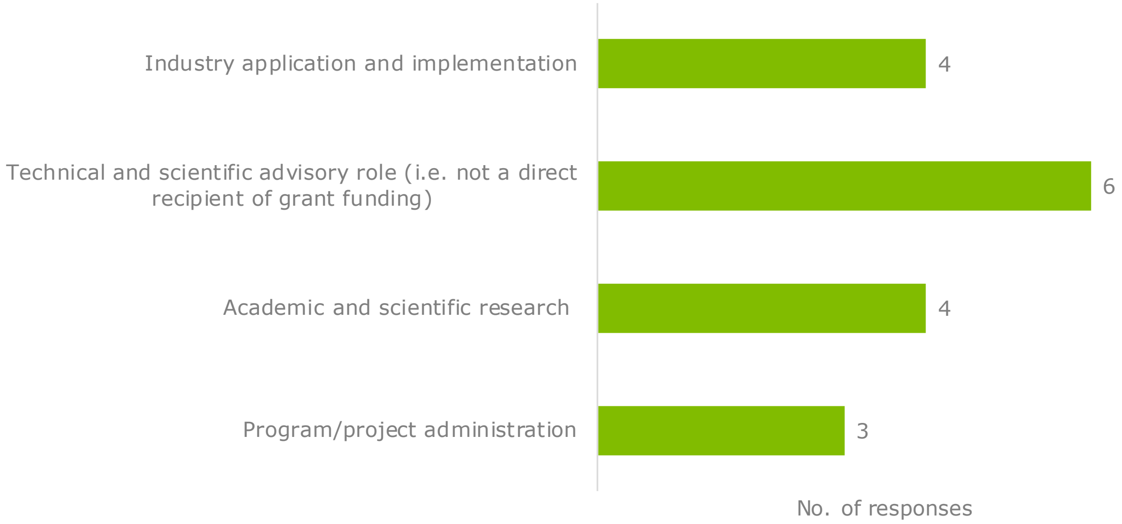
A total of 17 responses to the online questionnaire were received. A summary of the groupings of respondents is provided below.

Chart C.1: Type of organisations that respondent principally worked for during their involvement with the LETFF programs



Source: Deloitte survey, n = 17

Chart C.2: How do respondents describe their involvement with the LETFF programs?



Source: Deloitte survey, n = 17

Appendix D: Case studies

This evaluation has involved the development of concise case studies highlighting the contribution to increased knowledge, domestic skills and capabilities, and improved industry understanding of LETFF made by individual projects delivered under the LETFF programs. The case studies have supported and informed the triangulation of evidence collected across the evaluation. A total of seven case studies have been developed across the LETFF programs:

- **CCS Flagships program:**
  - South West Hub Project
  - Otway Geological Storage and Demonstration project

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- **LETDF:**
  - Gorgon Carbon Dioxide Injection Project

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These concise case studies are presented below.

South West Hub Project

Project Summary and Objectives

The South West Hub project involved testing onshore sandstone formations as a CO_2 reservoir for nearby power plants and industrial sites in Western Australia. Its objectives were to conduct a data study and analysis of the lower Eneaba Formation to determine its suitability for injecting CO_2 underground. In its Extended Case, the facility aimed to capture, transport and store between 5-6Mt of CO_2 annually.

Contribution to Research and Knowledge

The project's unique location was chosen in part due to its proximity to CO_2 emitters, rather than any geological characteristics that make it particularly suitable for CO_2 storage. This aimed to reduce the costs of transporting CO_2 – improving the commerciality of CCS. However, the location led to challenges such as:

- determining how to keep the injected CO_2 underground, since the Eneaba Formation did not have the impermeable seal that other CO_2 storage sites have to contain the CO_2 plume
- determining how to monitor the CO_2 plume underground.

Consequently, most of the new research and knowledge gained came from addressing these challenges. Specific areas of research contributed to by the project included:

- improvements in geosequestration knowledge – including conducting and analysing seismic survey data, as well as conducting geophysical remote sensing of CO_2 sequestration
- geochemical evaluation of the well using a combination of standard and novel techniques – such as chemical tracers to determine the suitability of the area for CO_2 storage
- structural analysis of geological formations, including fault seal first-order analysis.

Stakeholders also reported that the project contributed to a greater understanding of trapping mechanisms, greater confidence in Migration Assisted Trapping (MAT) technology and a greater understanding of geological environments and depositional history at a local level.

Stakeholders also reported that by applying research in the field and conducting demonstrations, they were able to more effectively present comprehensive and compelling business cases to progress CCS technology.

Overall, this evaluation identified 28 technical reports from various public data repositories produced by the project. These reports discuss challenges and the results of geosequestration testing conducted during this project. These reports have cumulatively been cited 25 times in external reports.

Contribution to domestic skills and capabilities

The project made an important contribution to advancing domestic capabilities in the development of behavioural models of CO_2 plume movements within different rock formations. Of the 28 technical reports, eight were written by the University of Western Australia or Curtin University. These reports focused on geophysical data analysis, stability assessments and predicting CO_2 injectivity properties.

Other technical reports also focused on improvements in conducting and analysing seismic survey data like geochemical evaluation and residual trapping. The unique characteristics of the site meant that significant focus was placed on understanding how basin configuration and structural elements affected the containment capabilities of a rock formation.

The project also contributed to the development of domestic research skills, by enabling leading research organisations such as the University of Western Australia and Curtin University to have dedicated staff and students working on CCS research and demonstration projects.

Contribution to industry understanding of low emissions technologies

The Project's location in a low-medium permeability reservoir, without a thicker "continuous impermeable seal" that could effectively contain CO_2 plumes, added to the technical challenges of CCS. These challenges demonstrated that storage proximity to emission sources, while preferable, is neither a necessary nor a sufficient condition. However, a viable geological reservoir is certainly necessary and likely sufficient.

Stakeholders discussed how the South West Hub project was important for the industry to develop a better understanding of both the theoretical capabilities of injecting CO_2 into these types of reservoirs (i.e. without an impermeable seal) and also the commercial aspects that would need to be met before injection can be undertaken effectively.

Whilst challenging, the project was crucial for improving the industry's understanding of geological reservoirs without natural seals, particularly their potential for trapping CO_2. Modelling that was done as a result of the project indicated that geological reservoirs without traditional caps or seals can still store CO_2, potentially doubling the previously estimated storage capacity in south-west Western.

Technical reports and research papers discussing the processes conducted, as well as the challenges associated with geosequestration, were made public – and are found on data repositories such as s22 the Global CCS Institute and WAIMPS.

Otway Geological Storage and Demonstration Project

Project Summary and Objectives

The CO_2 Co-Operative Research Centre's (CO2CRC) Otway Geological Storage and Demonstration Project (the Otway Project) aims to conduct initial site characterisation of the Otway Basin Pilot Project. The project's objective is to demonstrate the deep geological storage of CO_2, and improve understanding of the potential geological storage of various sedimentary basins both onshore and offshore. The project has involved the pilot trial of CO_2 injection and storage to demonstrate proof of concept.

Contribution to Research and Knowledge

The Otway Project has involved partnerships with a range of leading universities and research organisations, including CSIRO, Geosciences Australia and Curtin University, with a specific focus on sub-surface CO_2 storage, monitoring and modelling.

Research and knowledge focused on decreasing the cost of monitoring CO_2 plumes underground, as well as reducing the impact of operating on other stakeholders like land operators or the environment. The Otway Project was seen by stakeholders as critical in demonstrating laboratory-scale technologies in the field as major prototypes. These technologies included new modelling approaches that accurately predict CO_2 plumes and experimental methods for determining tracer partition coefficients. The Otway Project has directly contributed to the following areas of storage and CO_2 monitoring research:

- understanding how geological permeability may change as a function of CO_2, demonstrating a need to monitor water and local mineralogy characteristics
- monitoring the characteristics of injected CO_2 plumes using seismic technology
- analysis and modelling of geophysical data sets (2D, 3D etc.) and downhole pressure and temperature datasets to improve understanding of CO_2 plume behaviour and migration
- an improved understanding of the potential injectivity of reservoirs, their ability to store CO_2 and overall storage capacity
- establishing general methodologies for determining whether a CO_2 storage reservoir is leaking
- improving techniques to monitor sub-surface CO_2 plumes
- improving cost effectiveness of CO_2 monitoring.

The Otway Project has also contributed to the development of a range of new techniques. An example is working with Curtin University to develop fibre optic cable technology to receive acoustic signals. As noted by stakeholder:

> *"Previously when you do seismic monitoring you basically create an acoustic wave through the earth and receive it at a geophone – this has been the traditional way that the Oil and Gas sector has explored. What's been maturing and what Curtin has been heavily involved with is replacing geophones [with fibre optic cables]. You can now use fibre optic to receive that acoustic signal anywhere along that fibre. Now, the quality of what you receive with that fibre versus a mechanical geophone has always been a lot less, so the fibre has never been that great. But with the funding that we have received from the LETFF and combination of work with experts from Curtin and also internationally, we are now at the point where the performance of these fibres is substantially better than these geophones. Now, that all sounds very technical, but what it means is we now have the ability to not have to put major infrastructure down these wells, we can do it through very cheap wells. We can have high resolution on demand, monitoring whenever we want to give assurance of [CO_2] behaviour on the subsurface be it in CCS or be it in Oil and Gas exploration production. It's a massive improvement and a very important technology*.

This evaluation identified ten published technical reports produced through the Otway Project, which have collectively been cited in peer reviewed publications a total of 16 times.

Contribution to domestic skills and capabilities

The Otway Project has involved collaborations with a range of international research organisations and universities – including Silixa (UK), Lawrence Berkeley National Laboratory (US), and the University of Texas. The research and academic institutions partnered with CO2CRC to trial new technologies on site. Through these collaborations, these organisations have assisted in developing and broadening domestic skills and capabilities. Technologies that were trialled include:

- different injection methods
- different storage and monitoring methods such as Distributed Acoustic Sensing (DAS) fibre optic cables and 4-D time-lapse surface seismic methods.

Stakeholders reported that the Otway Project directly contributed to Australia developing world-leading reservoir engineering and monitoring skills and expertise, with CSIRO and Curtin University being identified by international collaborators as world leaders.

A key aspect of the Otway Project was it being "internationalised" by CO2CRC as a preferred test site to trial a range of injection, storage and monitoring techniques for CCS. Stakeholders noted that through these trials and collaborations, Australia has developed skills in these international techniques. Australia was also able to directly develop significant skills and capabilities with respect to the application of a range of CCS technologies, including:

- site management
- managing the regulations around sites
- communications.

Contribution to industry understanding of low emissions technologies

A key aspect of the Otway Project has been its focus as a trial demonstration facility for CCS. This has enabled the project to undertake direct applied research and demonstration in the field, including extensive geoscience and engineering work, to inform future commercial scale deployment of CCS.

The Otway Project has developed a detailed understanding of the process of CO_2 injection under Australian conditions and geology, CO_2 migration and monitoring, and CO_2 stabilization. This has enabled the project to develop an end-to-end visualisation of the injection and storage of CO_2. The project has also significantly contributed to an understanding of monitoring and modelling the behaviour of CO_2 with very advanced modelling techniques. In short, the Otway Project has made a significant contribution in providing industry, government and academia with tangible evidence that CCS works and is safe.

The Otway Project was crucial for demonstrating technologies at a prototype level – such as seismic monitoring through fibre optic rather than mechanical geophones, which are now able to perform at a much higher level.

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Gorgon Carbon Dioxide Injection Project

Project Summary and Objectives

The Gorgon Carbon Dioxide Injection Project was a commercial-scale demonstration project for capturing CO_2 emissions from the natural gas extraction process in the Gorgon field off the coast of Western Australia. The Project involved compressing, dehydrating and transporting the CO_2 by pipeline to the injection site – a saline sandstone reservoir in the Dupuy Formation. It aimed to reduce project emissions by 120Mt over its lifespan at a 3.4-4Mt annual rate, and is the first major project to significantly reduce emissions through underground injection. The Project is expected to begin CO_2 injections in 2019.

Contribution to Research and Knowledge

Research and knowledge gained from the Project may have been limited because CO_2 injections have not started and because of potential commercial-in-confidence issues. The 12 public technical reports identified as part of this evaluation covered key learnings on:

- the acquisition of quality seismic data, through petrographic, petrophysical, biostratigraphical, sedimentological and geochemical reporting – and its significance to improving the accuracy of CO_2 migration simulation models
- the impact on project execution
- well remediation programmes to ensure existing wells near the proposed injection site have been properly secured and do not pose a CO_2 containment risk
- site assessments, research and exploration work.

These technical reports have been cumulatively cited 1,012 times by external papers, demonstrating the significant contribution to enhancing knowledge of LETFF, and particularly CCS, made by the project.

Contribution to domestic skills and capabilities

The Gorgon Project involved the use of technologies, processes and equipment that have previously existed within the oil and gas sector, and as such was able to leverage the existing and significant skills base within the oil and gas sector.

However, the Gorgon Project did bring in monitoring technologies that reduced the cost of monitoring CO_2 plumes. These technologies include surveillance wells, 4D Surface Seismic testing, soil gas verification and pressure sensors on the surface.

This evaluation did not identify any technical reports that were written in partnership with universities or other research-based institutions.

Contribution to industry understanding of low emissions technologies

The Project is seen as a successful example of CCS operations on a commercial scale. While the $60 million allocated from the LETDF was not material to the Gorgon Project's success, it has enabled the development of a successful relationship that was crucial in the following ways:

- key learnings from the Gorgon Project relating to the legal and regulatory aspects influenced how the Australian Government intended to regulate CCS
- it also assisted in developing the Australian Government's Offshore Petroleum and Greenhouse Gas Storage Act.

The Project also led to technical reports associated with pumping CO_2 into reservoirs that are full of water, and its impacts on the reservoir itself. Depending on the type of report, they are either disseminated internally (where there is a commercial advantage) or published in industry journals.

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Appendix E: Literature scan and citation analysis

The results of the citation analysis of publicly available reports relating to the LETFF programs is presented below. This citation analysis covers publications available up until 28 May 2019.

Table E.1: Detailed Analysis of LETFF program/project publications

LETFF program/ project	Publications		Scholarly articles (as a share of publications)	No. of citations	Average citations per publication
	No.	%	%		
CCS Flagships	**65**	**13%**	**2%**	**170**	**2.6**
CarbonNet	20	4%	n/a	65	3.3
SouthWestHub	28	6%	4%	25	0.9
ZeroGen	2	0%	n/a	44	22.0
Wandoan	5	1%	n/a	20	4.0
CO2CRC	10	2%	n/a	16	1.6
CCSRD&D	0	0%	0%	0	0.0
s22					
LETDF	**23**	**5%**	**39%**	**1,105**	**48.0**
Gorgon	12	2%	42%	1,012	84.3
IDGCC	0	0%	0%	0	0.0
Hazelwood	7	1%	57%	93	13.3
Fairview	1	0%	0%	0	0.0
Other	3	1%	0%	0	0.0
s22					

Source: Deloitte

Notes: The above analysis only includes publically available publications.

Scholarly articles are considered to be publications that appear in peer-reviewed academic or scientific journals.

Limitation of our work

General use restriction

This report is prepared solely for the internal use of Department of Industry, Innovation and Science. This report is not intended to and should not be used or relied upon by anyone else and we accept no duty of care to any other person or entity. The report has been prepared for the purpose of set out in our contract dated 4 April 2019. You should not refer to or use our name or the advice for any other purpose

Deloitte.

s22

Minister for Industry, Science and Technology Min ID: MS19-001173

For Information

Subject: s22

Timing: Routine

Recommendation:	
1. s22	**Noted / Please discuss**
2. That you **note** the key findings from the s22 program evaluation reports as outlined in this brief.	
s22 ………………………………………… **Date:** / /2019	
Comments:	

Key Points:

s22

d. Impact evaluation of the Low Emissions Technologies for Fossil Fuels (LETFF) programs

2. These evaluations were undertaken in line with the department's *Evaluation Strategy 2017-21*, which outlines the department's approach to evaluation, and our methods and prioritisation processes. The strategy is available on the Office of the Chief Economist's website and is also at Attachment A.

3. s22
LETFF reports were prepared by consultants.

4. The evaluations were overseen by reference groups representing policy, program and evaluation areas, chaired by the AID. The reference groups had oversight of the process and reviewed the draft findings, recommendations and final evaluation report. Feedback was also sought from the department's Program Assurance Committee, and the departmental Executive Board endorsed the reports' findings and recommendations for implementation s22
s22

5. Attachment B summarises key points from each evaluation. The evaluation reports are provided at Attachments C to F.

s22

s22

s22

8. The department will brief s22 separately about the results of the LETFF evaluation, as the LETFF programs are part of his portfolio responsibilities.

s22

Consultation: Relevant line areas and other internal and external stakeholders were consulted in the development of each evaluation report.

s22

MLO Version: / /2019

ATTACHMENTS

A: Evaluation Strategy 2017-2021

B: Key points for the evaluation reports

s22

F: Impact evaluation of the LETFF programs

ATTACHMENT B

KEY POINTS FROM THE EVALUATION REPORTS

s22

s22

Impact evaluation of Low Emissions Technologies for Fossil Fuels (LETFF) programs

LETFF programs include four separate programs launched since 2004:

- the Carbon Capture and Storage (CCS) Flagships program;

s22

- Low Emissions Technology Demonstration Fund (LETDF); and

s22

The LETFF programs are a Tier One evaluation priority in the department's Evaluation Plan.

The department engaged Deloitte to carry out the impact evaluation. Deloitte found that:

- The programs have significantly contributed to increased knowledge, skills and capability, and improved industry understanding of LETFF in Australia. Australia has the research and engineering capability to develop commercial-scale LETFF projects.
- The programs were underpinned by clear policy direction and settings, government support and significant funding at commencement, but changing and uncertain policy settings contributed to reduced industry confidence and momentum. The absence of a clear commercial imperative on the part of industry to invest in carbon abatement remains the single largest barrier to commercial development and deployment of LETFF.

- Stakeholders considered the programs to have been successful and that this work would not have progressed without Australian Government support, however achievements and knowledge gained could have been more effectively communicated.
- Australia risks losing the significant gains in knowledge, and skills and capabilities established through the LETFF programs if there is no progression towards the commercialisation and deployment of LETFF.

The report did not make recommendations, but identified lessons learned for future program design and implementation. The Onshore Minerals and Energy Branch endorsed the findings of both evaluations, noting the usefulness of some lessons for strengthening future design.

Australian Government

Department of Industry, Innovation and Science

Minister for Resources and Northern Australia

For Information

Min ID: MS19-001206

Subject: s22

Timing: Routine – by 24 October 2019

Recommendations: That you

s22

2. **Note** the key findings from the report as outlined in this brief.

Noted/Please discuss

s22

Date: 14 / 11 /2019

Comments:

Key Points:

s22

2. This evaluation was undertaken in line with the department's *Evaluation Strategy 2017-21*, which outlines the department's approach to evaluation, and our methods and prioritisation processes. The strategy is available on the Office of the Chief Economist's website and is also at Attachment A.
3. The report was prepared by Deloitte.
4. The evaluation was overseen by a reference group representing Resources and Industry Growth divisions and AusIndustry - Support for Business, chaired by AID Insights and Evaluation Branch. The reference group had oversight of the process and reviewed the draft findings, recommendations and final evaluation report. Feedback was also sought from the department's Program Assurance Committee, and the departmental Executive Board endorsed the report's findings and recommendations for implementation s22
5. Attachment B summarises key points from the evaluation. The evaluation report is provided at Attachment C.

s22

Sensitivities:

8. There are potential sensitivities around content that relates to past domestic policy settings being a hindering factor behind achievements and progress across the LETFF programs; as well as stakeholders views that the Government should have a role in supporting the development and implementation of LETFF.

Consultation: Relevant line areas and other internal and external stakeholders were consulted in the development of the evaluation report. The Department of the Environment and Energy has been informed of its planned release.

s22

MLO Version: 10/10/2019

ATTACHMENTS

A: Evaluation Strategy 2017-2021
B: Key points for the evaluation report
C: Impact evaluation of the LETFF programs