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An Impact Assessment FRDC Investment in 2013-753: A New Refrigeration System Reference Design and Demonstration Prototype

Agtrans Research

November 2017

FRDC Project No **2016-134**

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2017

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In submitting this report, the researcher has agreed to FRDC publishing this material in its edited form.

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Acknowledgments

Agtrans Research and Consulting would like to thank Patrick Hone (Executive Director) and Nicole Stubing (Project Manager) of the Fisheries Research and Development Corporation for facilitating contact with relevant project personnel and for their guidance and feedback throughout the Impact Assessment process.

Crispian Ashby, Programs Manager, Fisheries Research and Development Corporation
Peter Brodribb, Managing Director and Refrigeration Engineer, Expert Group Pty Ltd
Andre Prendergast, General Manager, Austral Fisheries Pty Ltd

Abbreviations

CRC	(Seafood) Cooperative Research Centre
CRRDC	Council of Rural Research and Development Corporations
DAWR	Australian Government Department of Agriculture and Water Resources
FRDC	Fisheries Research and Development Corporation
HCFCs	Hydro-Chloro-Fluoro-Carbons (deplete the ozone layer and are potent greenhouse gases)
HFCs	Hydro-Fluoro-Carbons (do not deplete the ozone layer but are potent greenhouse gases)
NPF	Northern Prawn Fishery
OH&S	Occupational Health and Safety
PVB	Present Value of Benefits
RD&E	Rural Research, Development and Extension

Executive Summary

What the report is about

This report presents the results of an impact assessment of a Fisheries Research and Development Corporation (FRDC) investment in a new refrigeration system reference design and demonstration prototype for fishing vessels. The project was funded by FRDC and Tropic Ocean Prawns Australia Pty Ltd over the period February 2014 to March 2015.

Methodology

The project was analysed qualitatively within a logical framework that included activities/outputs, outcomes and impacts. Impacts were categorised into a triple bottom line framework. Principal impacts were then valued. Benefits were estimated for a range of time frames up to 30 years from the year of last investment in the project. Past and future cash flows in 2016/17 dollar terms were discounted to the year 2016/17 using a discount rate of 5% to estimate the investment criteria.

Results/key findings

The major impact identified was of a financial nature. However, some environmental and social impacts were also identified but not valued. It is expected that fishers in the Northern Prawn Fishery (NPF) will be the primary beneficiary of the investment.

Investment Criteria

Total funding from all sources for the project was $0.82 million (present value terms). The value of benefits was estimated at $5.92 million (present value terms). This gave an estimated net present value of $5.10 million, and a benefit-cost ratio of 7.2 to 1. These investment criteria are likely to be underestimates as any additional impacts on vessels operating in fisheries other than the NPF were not valued.

Conclusions

Investment in this project has delivered a new refrigeration system reference design, a working prototype on a commercial NPF vessel and training in new system operation and maintenance. The new refrigeration system addressed an immediate industry need (how to maintain operations post phase out of refrigeration gas HCFC-22) and was so successful that it won both a Queensland and National Seafood Industry Research and Development award.

The analysis provided a good example of how a ‘tactical’ FRDC investment can successfully address an immediate industry need.

Keywords

Impact assessment, refrigeration, fishing vessels, HCFC phase out, Montreal Agreement, ozone depleting gas, greenhouse gas

Introduction

The Fisheries Research and Development Corporation (FRDC) required a series of impact assessments to be carried out annually on a number of investments in the FRDC research, development and extension (RD&E) portfolio. The assessments were required to meet the following FRDC evaluation reporting requirements:

- Reporting against the FRDC 2015-2020 RD&E Plan and the Evaluation Framework associated with FRDC's Statutory Funding Agreement with the Commonwealth Government.
- Annual Reporting to FRDC stakeholders.
- Reporting to the Council of Rural Research and Development Corporations (CRRDC).

The first series of impact assessments included 20 randomly selected FRDC investments worth a total of approximately $6.31 million (nominal FRDC investment). The investments were selected from an overall population of 136 FRDC investments worth an estimated $24.98 million (nominal FRDC investment) where a final deliverable had been submitted in the 2015/16 financial year.

The 20 investments were selected through a stratified, random sampling process such that investments chosen spanned all five FRDC Programs (Environment, Industry, Communities, People and Adoption), represented approximately 25% of the total FRDC RD&E investment in the overall population (in nominal terms) and included a selection of small, medium and large FRDC investments.

Project 2013-753: *Seafood CRC: A New Refrigeration System Reference Design and Demonstration Prototype for Fishing Vessels* was selected as one of the 20 investments and was analysed in this report.

General Methods

The impact assessments followed general evaluation guidelines that are now well entrenched within the Australian primary industry research sector including Research and Development Corporations, Cooperative Research Centres, State Departments of Agriculture, and some Universities. The approach includes both qualitative and quantitative descriptions that are in accord with the impact assessment guidelines of the CRRDC (CRRDC, 2014).

The evaluation process involved identifying and briefly describing project objectives, activities and outputs, outcomes, and impacts. The principal economic, environmental and social impacts were then summarised in a triple bottom line framework.

Some, but not all, of the impacts identified were then valued in monetary terms. Where impact valuation was exercised, the impact assessment uses Cost-Benefit Analysis as its principal tool. The decision not to value certain impacts was due either to a shortage of necessary evidence/data, a high degree of uncertainty surrounding the potential impact, or the likely low relative significance of the impact compared to those that were valued. The impacts valued are therefore deemed to represent the principal benefits delivered by the project. However, as not all impacts were valued, the investment criteria reported for individual investments potentially represent an underestimate of the performance of that investment.

Background and Rationale

Background

Modern fishing fleets and fish product supply chains are dependent on reliable and effective cooling systems. The Northern Prawn Fishery (NPF) is particularly reliant on refrigeration. Refrigeration equipment on NPF vessels must operate in confined spaces, under heavy load, and in high ambient temperatures. The refrigeration system has to provide for the snap freezing of tonnes of sensitive product using equipment operating on a moving vessel with heavy vibration and exposure to corrosive salt spray and water.

In addition to challenging mechanical and environmental conditions, NPF vessel refrigeration has been entirely reliant on the ozone depleting greenhouse gas HCFC-22. In 2013, HCFC-22 was on the verge of complete phase out. With the loss of HCFC-22, the NPF was going to be without a refrigeration solution and there was no easy 'off the shelf' technology available for its replacement.

The NPF is a valuable fishery spanning Queensland, the Northern Territory and Western Australia where 52 refrigerated prawn trawl vessels generated a gross value of production of $107 million in 2015 (ABARES 2016a).

Furthermore, workable refrigeration solutions post the phase out of HCFC-22 are also relevant to other fisheries where vessels process their catch on-board, for example, other prawn and fin-fish fisheries. For fin-fish, FRDC advise that on-board processing equates to approximately 15% of Australia's total fin-fish catch (Nicole Stubing, Projects Manager, FRDC pers. comm., May 2017).

Rationale

In 2013 the tactical FRDC research Project 2013-227 confirmed that the main refrigerant gas used in the Australian fishing fleet, HCFC-22, was being phased out under the terms of the Montreal Protocol (Expert Group 2013). This earlier project reported that for the majority of refrigeration applications a raft of solutions was available that could be used to replace HCFC-22, including 'natural refrigerants' such as ammonia. However, ammonia and other 'natural refrigerants' are poisonous and not suitable for the confined spaces found on fishing vessels. Leaking refrigeration systems on fishing vessels filled with poisonous refrigerants would be a major occupational health and safety (OH&S) issue.

Consequently, FRDC Project 2013-227 in examining a range of solutions for the fishing vessel refrigerant problem, made the following recommendations:

1. Although it is not ideal, the only alternative available to the fishing industry to maintain operations over the next decade is to switch to refrigeration plants that contain refrigerant HFC-404A (a greenhouse gas that does not deplete the ozone layer and is not currently being phased out).
2. There is a critical need to develop a new refrigeration system reference design and standard that focuses on adaptability to HFC-404A and newer refrigerants, while also enhancing refrigeration containment, reducing the volume of gas used in the refrigerant system and improving energy efficiency.
3. This task is too complex for one operator to take on board alone and industry needs to act collectively as the majority of operators are facing this decision at the same time.

Further support for investment in developing a new system was that the NPF was then operating vessels with refrigeration systems at or near the end of their economic life.

Project Details

Summary

Project Code: 2013-753

Title: *Seafood CRC: A new refrigeration system reference design and demonstration prototype for fishing vessels*

Research Organisation: The Expert Group (a specialist refrigeration engineering company)

Principal Investigator: Peter Brodribb

Period of Funding: February 2014 to March 2015.

Objectives

The objectives of the project were:

1. To develop a technical design standard for a new refrigeration system, using HFC-404A, or newer refrigerants, that can be used by refrigeration equipment suppliers as a basis for replacement of aging freezers on fishing vessels, particularly the NPF trawler fleet.
2. To make the new design freely available to Australian fishing vessel owners, thereby reducing the cost of freezer replacement.
3. To provide training to vessel crews on the operation and maintenance of the new system.

Logical Framework

Table 1 provides a description of the project in a logical framework.

Table 1: Logical Framework for Project 2013-753

Activities and Outputs	• The emphasis on the NPF was due to the length of time trawlers spent at sea and the very difficult equatorial conditions experienced. • Completion of a workshop with NPF representatives to develop a better understanding of the technical, operational and maintenance issues surrounding on-vessel refrigeration systems. • Preparation and delivery of a technical standard and evaporator design for a new refrigeration system that operates using HFC-404A and makes provision for emerging 'fourth generation' refrigerants. • Construction of a prototype, its evaluation and refinement on a commercial vessel in the Northern Prawn Fishery (Tropic Ocean Prawns Australia', 'Gulf Bounty'). • Demonstration of an improved hydraulic deck snap/chilled water system that when combined with a hold based fixed plate snap freezer, shortens freezing time, increases vessel refrigeration capacity, shortens trawl time/operating cost during the banana prawn season and improves total catch quality. • Demonstration of improved refrigerant gas containment design, with less refrigerant charge required for the same amount of freezing capacity and with a significant life time fuel cost/operating cost saving, as well as environmental benefits. • Demonstration of a leak detection system that uses a hand-held leak detector. Weekly use of this system will deliver fewer leaks, less inhalation by crew members, refrigerant cost savings and will avoid catastrophic system failure.

	• Preparation of final technical documentation including operator guidelines for use as a training aid and a preventative maintenance manual. • Development and delivery of a new refrigeration system implementation plan with the plan to be executed by the NPF Industry Pty Ltd (the NPF industry association). The plan included communication with the Western Australian Fishing Industry Council, the Queensland Seafood Industry Association and the Australian Council of Prawn Fisheries. • Inspection of the prototype by refrigeration companies (e.g. CASCO Refrigeration Services) that specialise in vessel fit out and by commercial fishers. Fit out specialists and fishers were able to discuss technical details pertaining to the new refrigeration system with project engineers from the Expert Group. • Delivery of a commercial large-scale trial that demonstrated the technical and economic superiority of the new refrigeration system. The new system had a capital cost of between \$300,000 and \$400,000 which was comparable to the replacement cost of existing technology nearing the end of its economic life. • All project documentation was made freely available to the industry and new refrigeration system training was provided to industry representatives.
Outcomes	• The availability of a new refrigeration system with comparable capital costs and lower operating costs that is able to meet industry's freezing requirements post phase out of the ozone depleting refrigerant HCFC-22. • A reduction in emissions of ozone depleting gas. However, this outcome would have been achieved through regulation in the absence of the project. • Receipt of both a Queensland and National Seafood Industry Research and Development Award for the new refrigeration system. • The new refrigeration system is not yet in use and adoption in the NPF is assumed to start in 2019. Modification of the prototype is required before it can be used in fin fisheries and there are no current plans for this investment (Crispian Ashby, Programs Manager, FRDC, pers. comm., June 2017). • There may be opportunities to utilise the technology in future in vessels servicing other Australian prawn fisheries.

Impacts	• Potential for lower operating costs delivered from an improvement in refrigeration fuel use efficiency on NPF and fin-fish vessels.
	• Potential for lower operating costs delivered from a reduced trawl time for NPF vessels during the banana prawn season.
	• Potential improved prawn quality in the NPF as a result of quicker freezing.
	• There are potentially broader impacts of the new refrigeration system for fisheries other than the NPF including:
	  o Prawn fisheries in Western Australia, South Australia and the Torres Strait
	  o The processed fin-fish catch across a range of fisheries
	• No net change in carbon emissions when HFCs replace HCFCs (HCFCs produce more potent greenhouse gases but these are assumed to be offset by reduced leakage/discharge to the environment).
	• OH&S benefit of less time for crew spent climbing into and out of the hold with the addition of deck based processing (currently no deck-based snap freezing occurs).
	• OH&S benefit of a check system to prevent inhalation of leaking refrigerants.

Project Investment

Nominal Investment

Table 2 shows the annual investment for the project funded by FRDC and other investors. ‘Other’ investors included Tropic Ocean Prawns Australia, owners of the ‘Gulf Bounty’ who were required to contribute to the fit out of their vessel with the new refrigeration system prototype.

Table 2: Annual Investment in the Project 2013-753 (nominal $)

Year ended 30 June	**FRDC ($)**	**OTHER ($)**	**TOTAL ($)**
2015	447,336	106,731	554,067
2016	49,099	72,626	121,725
Totals	496,435	179,357	675,792

For the FRDC investment, the cost of managing the FRDC funding was added to the FRDC contribution for the project via a management cost multiplier (1.115). This multiplier was estimated based on the share of ‘employee benefits’ and ‘supplier’ expenses in total FRDC expenditure reported in the FRDC’s Cash Flow Statement (FRDC, 2016). This multiplier then was applied to the nominal investment by FRDC shown in Table 2.

For the other investment, the management and administration costs for the project are already built into the nominal amounts shown in Table 2.

Real Investment and Extension Costs

For the purposes of the investment analysis, the investment costs of all parties were expressed in 2016/17 dollar terms using the Gross Domestic Product deflator index. No additional costs of extension were included.

Impacts

Table 3 provides a summary of the types of impacts categorised into economic, environmental and social impacts.

Table 3: Triple Bottom Line Categories of Impacts from Refrigeration System Design

Economic	• Potential for lower operating costs delivered from an improvement in refrigeration fuel use efficiency for NPF vessels. • Potential for lower operating costs delivered from a reduced trawl time for NPF vessels during the banana prawn season. • Potential improved prawn quality in the NPF as a result of quicker freezing. • Potential for use in prawn fisheries other than the NPF. • Potential for applications in the processed fin-fish catch.
Environmental	• No net change in carbon emissions when HFCs replace HCFCs (HCFCs are more potent greenhouse gases but assumed to be offset by reduced leakage / discharge to the environment).
Social	• OH&S benefit from less time for crew spent climbing into and out of the hold with the addition of deck based processing (currently no deck-based snap freezing occurs). • OH&S benefit of a check system to prevent inhalation of leaking refrigerants.

Public versus Private Impacts

Key impacts identified in this evaluation are private and industry related (a new refrigeration system with lower operating costs that is able to meet industry's freezing requirements post HCFC-22 phase out). Public impacts identified include gains in on-vessel OH&S with savings in public health costs. OH&S gain is also a private benefit, helping industry to reduce work hours lost to injury.

Distribution of Private Impacts

The benefits of a new refrigeration system will be captured by the commercial fishers operating in the NPF and potentially other fisheries. Reductions in commercial fisher costs will be shared along the supply chain with wholesalers, retailers, exporters and consumers all sharing some of the benefits.

Impacts on other Australian Industries

Australian companies such as CASCO Refrigeration Services which will manufacture and install the new refrigeration system will benefit from the project's success. No impacts on other Australian rural industries were identified. The situation facing the NPF and commercial fin-fishers who process at sea is unique – reliance on a soon to be phased out ozone depleting gas that cannot be easily substituted in a commercial fishing environment.

Impacts Overseas

The new refrigeration system reference design will be relevant to overseas fishing fleets and the design is now in the public domain. Parts of the New Zealand fishing industry have expressed interest in the project findings (Peter Brodribb, Managing Director, Expert Group, pers. comm., June 2017).

Match with National Priorities

The Australian Government's Science and Research Priorities and Rural Research, Development and Extension (RD&E) priorities are reproduced in Table 4. Investment in refrigeration system design contributes to Rural RD&E Priorities 1 and 4 and to Science and Research Priorities 1 and 6 with potential for some minor contribution to priority 8.

Table 4: Australian Government Research Priorities

Australian Government	
Rural RD&E Priorities (est. 2015)	**Science and Research Priorities (est. 2015)**
1. Advanced technology 2. Biosecurity 3. Soil, water and managing natural resources 4. Adoption of R&D	1. Food 2. Soil and Water 3. Transport 4. Cybersecurity 5. Energy and Resources 6. Manufacturing 7. Environmental Change 8. Health

Sources: DAWR (2015) and OCS (2015)

Valuation of Impacts

Impacts Valued

Analyses were undertaken for total benefits that included future expected benefits. A degree of conservatism was used when finalising assumptions, particularly when some uncertainty was involved. Sensitivity analyses were undertaken for those variables where there was greatest uncertainty or for those that were identified as key drivers of the investment criteria.

Two impacts were valued – improvement in refrigeration fuel use efficiency on NPF vessels and reduced trawl time during the banana prawn season on NPF vessels.

Impacts Not Valued

The economic impacts identified but not valued included:

- Improved prawn quality as a result of quicker freezing on NPF vessels. This impact is somewhat speculative at this point in time. As the prawn price is largely based on overall supply and demand rather than marginal changes in quality, an analysis of price data would have been confounded by such factors. Also, even if a quality premium were established, the contribution of quicker freezing would have been difficult to establish.
- Lower operating costs and improved quality for the processed fin-fish catch. No trial data were available with which to determine refrigeration fuel use efficiency, reduction in catch time or improvement in product quality. The NPF prototype would need to be modified before it could be used for fin-fish (Crispian Ashby, Program Manager, FRDC pers. comm., June 2017).
- Potential for cost impacts of the new refrigeration system if adopted in other prawn fisheries such as the Torres Strait, and in Western Australia and South Australia. No data were available for estimating any potential benefits for these fisheries. The assumptions made for operating cost savings for the NPF boats may not apply to the vessels used in the other fisheries in the south and west, as fleet structure and operating conditions would vary.

The environmental impacts identified but not valued included:

- No net change in carbon emissions when HFCs replace HCFCs – future predictions on the use of HFCs were not readily available.

The social impacts identified but not valued included:

- OH&S benefit of less time spent climbing into and out of the hold with the addition of deck based processing. Data on accidents pre- and post-implementation of the new refrigeration system were currently not available.
- OH&S benefit of a check system to prevent inhalation of leaking refrigerants. Data on the link between leakage of refrigeration gas from existing systems and the health of fishing crews were not available.

Valuation of Benefit 1: Improvement in Refrigeration Fuel Use Efficiency on NPF vessels

Improvement in fuel use efficiency on NFP vessels as a result of adopting the new refrigeration system reference design was quantified using data provided in the final 2013-753 project report and data from ABARES 2016b. Assumptions were reviewed during discussions with Andrew Prendergast General Manager Austral Fisheries Pty Ltd and the Principal Investigator.

Diesel fuel is consumed on a fishing vessel in the NFP to power the main engine (69% of total diesel consumption) and on-board generators (31% of total diesel consumption). Three quarters of on-board generator consumption of diesel is used to power the refrigeration system. The new refrigeration system prototype delivers a 10% improvement in refrigeration fuel use (Expert Group 2015).

Fuel is the single largest cost of operating a vessel in the NPF and the average cost of fuel on a vessel in the NPF in 2014 was $527,944 (the most recent year for which data were available). There were 52 vessels operating in the NPF in 2014 (ABARES 2016b).

Specific assumptions for valuing Benefit 1 are provided in Table 5.

Valuation of Benefit 2: Reduced Trawl Time during the Banana Prawn Season on NPF Vessels

The new refrigeration system offers additional harvest capacity and operating cost savings during the banana prawn harvest season. Vessels in the NPF split their fishing time between banana prawn season (32% of total time) and tiger prawn season (68% of total time). Other prawn species are caught during the banana prawn and tiger prawn seasons. During the banana prawn season, refrigeration capacity limits harvest efficiency, increasing trawl time and vessel operating cost (Expert Group 2015).

It has been assumed that the adoption of the new refrigeration system will increase harvest efficiency, reduce trawl time and vessel operating cost during the banana prawn season by 5%.

Total trawl time cost and banana prawn and tiger prawn harvesting costs combined, are estimated from ABARES 2016b at $1,235,188 per annum and include crew costs, repairs and maintenance and fuel after allowing for improved refrigeration efficiency estimated in Benefit 1. However, only a proportion of the total cost can be attributed to the banana prawn effort. Specific assumptions are provided in Table 5.

Adoption of the New Refrigeration System in the NPF

There has been no commercial uptake of the new refrigeration system since the implementation plan was delivered in 2016. Delay in adoption has been caused by an unforeseen increase in the availability of HCFC-22. Gas from decommissioned refrigeration systems used in other industries has been captured and recycled, stabilising and even lowering the cost of a HCFC-22 re-gas. Low cost stocks of HCFC-22 are also being sourced from South East Asia and Papua New Guinea (Peter Brodribb, Managing Director, Expert Group, pers. comm., June 2017).

However, current buoyant supplies of HCFC-22 are not expected to last in the medium term and 35 year-old ‘end of life’ vessel refrigeration systems will fail in the next few years. This analysis assumes that the first installations of the new refrigeration system designed as part of project 2013-753 will be made by 2019 and that the fleet is fully converted to some form of new refrigeration system by 2027.

No additional capital cost is incurred by installing the new refrigeration system designed as part of project 2013-753. Vessel owners faced with an old and worn out refrigeration system simply make a decision to install the new refrigeration system design or an alternative design. Capital costs for both options are similar at between $300,000 and $400,000 per vessel (Expert Group 2015).

Not all vessels operating in the NPF will install the new refrigeration system designed as an output of project 2013-753. Fleet managers in the NPF report that both old and new vessels are being fitted with alternative systems including systems based around the refrigerant R507. Systems based around R507 are long term proven but do not offer the same operating cost savings (Andrew Prendergast, General Manager, Austral Fisheries, pers. comm., June 2017).

Consequently, the analysis assumes that half of the 52 vessel NPF fleet adopts the new refrigeration system design and half adopts another system. The adoption profile assumed in the analysis is summarised in Table 5.

Counterfactual

If this project had not been funded, all NPF vessels would have adopted alternative refrigeration systems based on refrigeration gas R507 that operates its supply lines under high pressure and consumes more fuel and without any corresponding reduction in trawl time/operating cost.

Attribution

Project 2013-227 as well as Project 2013-753 contributed to the benefits valued. In recognition of this preceding research, only 87% of the quantified benefits has been attributed to project 2013-753. This proportion was based on the proportion of total investment in the two projects that was contributed by Project 2013-753.

Summary of Assumptions

A summary of key assumptions made for valuation of the impacts is shown in Table 5.

Table 5: Summary of Assumptions

Variable	Assumption	Source/comment
COUNTERFACTUAL: All NPF vessels would have adopted alternative refrigeration systems and forgone operating cost savings.		
Benefit 1: Improvement in Refrigeration Fuel Use Efficiency NPF Vessels		
Fuel cost of refrigeration on a NPF vessel.	$122,747 per annum.	Total cost of diesel on a NPF vessel was $527,944 in 2014, (ABARES 2016b), 31% used on generators ($163,663) and 75% of this used for refrigeration ($122,747) (Expert Group 2015).
Improvement in refrigeration fuel use efficiency with adoption of new refrigeration system reference design.	10%	Expert Group 2015.
Benefit 2: Reduced Trawl Time During the Banana Prawn Season on NPF Vessels		
Cost of vessel operation in the NPF.	$1,235,188 per annum.	ABARES 2016b and includes crew costs, repairs and maintenance and fuel after allowing for improved refrigeration efficiency.
Share of vessel operating cost incurred during the banana prawn season.	32%	Expert Group 2015.
Reduction in banana prawn operating cost attributable to new refrigeration system.	5%	Consultant assumption after reviewing relevant literature.
Adoption of the New Refrigeration System in the NPF		

Number of vessels in the NFP adopting the refrigeration system reference design.	26	Consultant assumption made after discussions with Andrew Prendergast, General Manager, Austral Fisheries Pty Ltd.
Ramp up in adoption of the refrigeration system reference design.	2017 = 0 2018 = 0 2019 = 2 2020 = 4 2021 = 7 2022 = 11 2023 = 15 2024 = 19 2025 = 22 2026 = 24 2027 = 26 2028 = 26	Consultant assumption made after discussions with Andrew Prendergast, General Manager, Austral Fisheries.
Probability of assumed level of adoption occurring	75%	Consultant assumption
Attribution		
Attribution of the above benefits to Project 2013-753	87%	Consultant assumption based on relevant cost of this project's contribution to the two contributing R&D projects (2013-753 and 2013-227).

Results

All benefits after 2016/17 were expressed in 2016/17 dollar terms. All costs and benefits were discounted to 2016/17 using a discount rate of 5%. A reinvestment rate of 5% was used for estimating the Modified Internal Rate of Return. The base analysis used the best available estimates for each variable, notwithstanding a level of uncertainty for many of the estimates. All analyses ran for the length of the project investment period plus 30 years from the last year of investment in Project 2013-753 investment (2015/16).

Investment Criteria

Tables 6 and 7 show the investment criteria estimated for different periods of benefits for the total investment and the FRDC investment. The present value of benefits (PVB) attributable to FRDC investment only, shown in Table 7, has been estimated by multiplying the total PVB by the FRDC proportion of real investment (76%). The balance of benefits is attributable to Tropic Ocean Prawns Australia.

Table 6: Investment Criteria for Total Investment in Project 2013-753

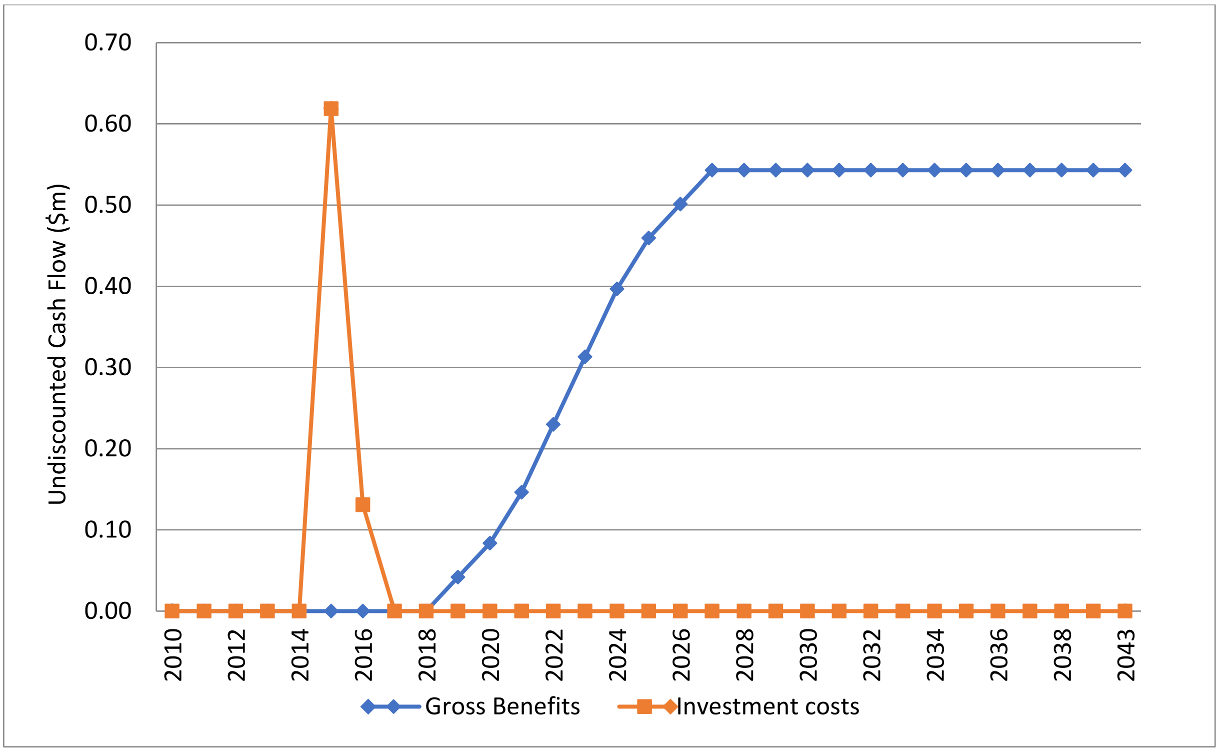
Investment Criteria	**Years after Last Year of Investment**						
	0	**5**	**10**	**15**	**20**	**25**	**30**
Present Value of Benefits ($m)	0.00	0.23	1.56	3.08	4.26	5.19	5.92
Present Value of Costs ($m)	0.82	0.82	0.82	0.82	0.82	0.82	0.82
Net Present Value ($m)	-0.82	-0.59	0.74	2.26	3.44	4.37	5.10
Benefit-Cost Ratio	0.00	0.28	1.90	3.75	5.20	6.34	7.23
Internal Rate of Return (%)	negative	negative	13.38	19.12	20.56	21.02	21.18
Modified Internal Rate of Return (%)	negative	negative	12.79	15.41	14.52	13.40	12.41

Table 7: Investment Criteria for FRDC Investment in Project 2013-753

Investment Criteria	**Years after Last Year of Investment**						
	0	**5**	**10**	**15**	**20**	**25**	**30**
Present Value of Benefits ($m)	0.00	0.17	1.18	2.32	3.22	3.92	4.47
Present Value of Costs ($m)	0.62	0.62	0.62	0.62	0.62	0.62	0.62
Net Present Value ($m)	-0.62	-0.45	0.56	1.70	2.60	3.30	3.85
Benefit-Cost Ratio	0.00	0.28	1.90	3.74	5.18	6.31	7.20
Internal Rate of Return (%)	negative	negative	13.26	18.97	20.41	20.87	21.04
Modified Internal Rate of Return (%)	negative	negative	12.75	15.38	14.50	13.38	12.40

The annual undiscounted benefit and cost cash flows for the total investment for the duration of Project 2013-753 investment plus 30 years from the last year of investment are shown in Figure 1.

Figure 1: Annual Cash Flow of Undiscounted Total Benefits and Total Costs



Source of Benefits

Estimates of the relative contribution of each benefit valued, given the assumptions made, are shown in Table 8.

Table 8: Contribution to Total Benefits from Each Source

Source of Benefits	Contribution to PVB ($m)	Share of Benefits (%)
Benefit 1:	2.27	38.3
Benefit 2:	3.65	61.7
Total	5.92	100.0

Sensitivity Analyses

A sensitivity analysis was carried out on the discount rate. The analysis was performed for the total investment and with benefits taken over the life of the investment plus 30 years from the last year of investment in Project 2013-753. All other parameters were held at their base values. Table 9 presents the results. Results are moderately sensitive to the discount rate employed.

Table 9: Sensitivity to Discount Rate
(Total investment, 30 years)

Investment Criteria	Discount rate		
	0%	5% (base)	10%
Present value of benefits ($m)	13.03	5.92	3.11
Present value of costs ($m)	0.75	0.82	0.89
Net present value ($m)	12.28	5.10	2.22
Benefit-cost ratio	17.39	7.23	3.48

The project benefits are both dependent on operating cost savings in the NPF. A second sensitivity analysis tests refrigeration operating cost savings and trawl time savings (Table 10). Even at an operating cost saving of half that assumed in the base analysis (refrigeration saving of 5% and trawl time saving of 2.5%) the project delivers a strong positive benefit-cost ratio of 3.6 to 1.

Table 10: Sensitivity to Operating Cost Savings
(Total investment, 30 years)

Investment Criteria	**Lower Operating Costs**		
	Refrig. saving 5% Trawl saving 2.5%	**Refrig. saving 10% Trawl saving 5% (base)**	**Refrig. saving 20% Trawl saving 10%**
Present value of benefits ($m)	2.96	5.92	11.84
Present value of costs ($m)	0.82	0.82	0.82
Net present value ($m)	2.14	5.10	11.02
Benefit-cost ratio	3.61	7.23	14.46

Confidence Ratings and other Findings

The results produced are highly dependent on the assumptions made, some of which are uncertain. There are two factors that warrant recognition. The first factor is the coverage of benefits. Where there are multiple types of benefits it is often not possible to quantify all the benefits that may be linked to the investment. The second factor involves uncertainty regarding the assumptions made, including the linkage between the research and the assumed outcomes.

A confidence rating based on these two factors has been given to the results of the investment analysis (Table 11). The rating categories used are High, Medium and Low, where:

- High: denotes a good coverage of benefits or reasonable confidence in the assumptions made
- Medium: denotes only a reasonable coverage of benefits or some uncertainties in assumptions made
- Low: denotes a poor coverage of benefits or many uncertainties in assumptions made

Table 11: Confidence in Analysis of Project

Coverage of Benefits	**Confidence in Assumptions**
Medium	High

Coverage of benefits was assessed as medium. The most important benefit (two types of operating cost savings from the new refrigeration system) was valued. However, other benefits identified were not valued in the analysis (e.g. application of the new refrigeration system to the fin-fish fisheries or other prawn fisheries as relevant data were not available).

Confidence in assumptions was rated as high. Principal assumptions around operating cost savings were sourced from the project final report and reviewed with industry personnel.

Conclusions

Investment in this project has delivered a new refrigeration system reference design, a working prototype on a commercial NPF vessel and training in new system operation and maintenance. The new refrigeration system addressed an immediate industry need (how to maintain operations post phase out of refrigeration gas HCFC-22) and was so successful that it won both a Queensland and National Seafood Industry Research and Development award.

Investment in this project totalled $0.82 million (present value terms) and produced aggregate total expected benefits of $5.92 million (present value terms). This gave a net present value of $5.10 million, a benefit-cost ratio of 7.2 to 1, an internal rate of return of 21% and a modified internal rate of return of 12%. These investment criteria are likely to be underestimates as any additional impacts on vessels operating in fisheries other than the NPF were not valued.

The analysis provided a good example of how a ‘tactical’ FRDC investment can successfully address an immediate industry need.

Glossary of Economic Terms

Cost-benefit analysis:	A conceptual framework for the economic evaluation of projects and programs in the public sector. It differs from a financial appraisal or evaluation in that it considers all gains (benefits) and losses (costs), regardless of to whom they accrue.
Benefit-cost ratio:	The ratio of the present value of investment benefits to the present value of investment costs.
Discounting:	The process of relating the costs and benefits of an investment to a base year using a stated discount rate.
Internal rate of return:	The discount rate at which an investment has a net present value of zero, i.e. where present value of benefits = present value of costs.
Investment criteria:	Measures of the economic worth of an investment such as Net Present Value, Benefit-Cost Ratio, and Internal Rate of Return.
Modified internal rate of return:	The internal rate of return of an investment that is modified so that the cash inflows from an investment are re-invested at the rate of the cost of capital (the re-investment rate).
Net present value:	The discounted value of the benefits of an investment less the discounted value of the costs, i.e. present value of benefits - present value of costs.
Present value of benefits:	The discounted value of benefits.
Present value of costs:	The discounted value of investment costs.

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