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Benefit Cost Analyses of FWPA R&D projects: November 2020

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Forest & Wood Products Australia

Benefit Cost Analyses of FWPA R&D projects: November 2020

Prepared for

Forest & Wood Products Australia

by

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EXECUTIVE SUMMARY

This report presents results from an impact assessment of four projects that were funded by Forest and Wood Products Australia (FWPA) between 2011 and 2018, in conjunction with several other stakeholders. A cost-benefit analysis framework was used to scope and quantify the identified benefits. The evaluation was a desktop study, supported by consultation with key R&D project personnel and a review of the literature.

The four projects that were selected by FWPA for inclusion in this study were:

- Creating a pathway to build timber frame houses in a traditionally double-brick housing market (PNA371),
- Adaptation strategies to manage risk in Australia's plantations (PNC228),
- Life Cycle Assessment of a 5 Storey Residential Building in Parkville (PRA334), and
- Economic contribution of the forestry industry within the Green Triangle (VNA471).

Table ES1 provides a summary of benefits from all four projects categorised into economic, environmental, and social benefits.

Table ES1: A summary of benefits categorised in to economic, environmental, and social benefits

	Benefit
Economic Benefits	• Potential reduction in construction costs in Perth metropolitan area and across Australia (more cost-effective foundations and earthworks) (PNA371 and PRA334) • Avoided rental cost for some buyers and builders due to shorter construction timeframes (PNA371) • Potential avoided industry productivity losses from adoption of improved management strategies (PNC228) • Contribution to medium- and long-term industry sustainability in the face of a changing climate and increased frequency of extreme weather events (PNC228; VNA471). • Reduction in the risk of time lost to construction site related injuries (PRA334). • Potential increase revenue for the timber industry (PRA334).
Environmental Benefits	• Contribution to positive environmental impact due to the use of timber (PNA371). • Potential contribution to reduced anthropogenic climate change causing pollution (PRA334).
Social Benefits	• Contribution to improved housing affordability outcomes (PRA334) • Regional community spillover benefits through improvements in employment and income certainty (PNA371; VNA471). • Potential contribution to avoided welfare issues for plantation owners and their employees (e.g. stress and worries about potential or eventual loss of local employment) (PNC228; VNA471)

The **present value of costs** for total investments in the four projects ranged from $50,294 to $1.98 million and **$42,780 to $841,131** for FWPA's contribution. The **net present value** of the total investment ranged from **$494,837 to $5,715,529** and the benefit cost ratios ranged from **6:1 to 20:1**. The results indicate that all four projects were viable with beneficial outcomes for the levy-paying industry and community at large.

1 BACKGROUND

Forest and Wood Products Australia (FWPA) is a rural research and development corporation (RDC) that is funded by the federal government, member levies and research grants. The research funded by FWPA benefits Australian private entities and society as a whole. The benefits are such that the private sector does not always have sufficient incentive to invest without support from government contributions (CRRDC, 2018). However, the economic, social, and environmental impacts from research and development are not always apparent. This is because benefits are often delayed, and the link between knowledge gained and economic impacts are often not obvious (CRRDC, 2018). Nonetheless, it is important to ensure that government and other stakeholders are provided with evidence of RDCs accomplishments and the returns to the investment to justify funding from the stakeholders. Consequently, the Council of Rural Research and Development Corporations (CRRDC) developed "Cross-RDC impact assessment program-guidelines" to establish a standardised and more comprehensive approach, and to generally strengthen impact assessment undertaken by the RDCs in view of these demands for evidence on the impact of rural R&D.

1.1 This report

FWPA contracted Natural Capital Economics to undertake an economic impact assessment of four randomly selected projects. The sample was selected from projects that were funded and completed between the year 2011 and 2018. The economic assessments will be used for reporting to the FWPA stakeholders (annual reporting), meeting the statutory funding agreement with the Australian Commonwealth Government, and for reporting to the CRRDC.

The primary approach used to assess the impact of the four R&D projects is cost-benefit cost analysis (CBA). The assessment was a desktop study, supported by consultation with key R&D project personnel, literature review, and additional data gathering, as required.

Figure 1 provides an overview of the key steps associated with the project assessment.

Figure 1. Overview of the assessment process

The projects selected for this economic evaluation are listed in Section 1.2 and the detailed descriptions are provided in Section 4.

1.2 Selected R&D projects

There are four projects covered in this economic impact assessment. Table 1 provides a list of these project codes and titles.

Table 1. List of projects included in this assessment

Project code	Title
PNA371	Creating a pathway to build timber frame houses in a traditionally double-brick housing market
PNC228	Adaptation strategies to manage risk in Australia's plantations
PRA334	Life Cycle Assessment of a 5 Storey Residential Building in Parkville
VNA471	Economic contribution of the forestry industry within the Green Triangle

2 ASSESSMENT APPROACH

Our assessment approach was guided by the 2018 Cross-RDC Impact Assessment Guidelines. We reviewed documents supplied by FWPA and published online, and consulted industry stakeholders to identify the research outputs, outcomes and impacts for the four projects that were selected for impact assessment. The following definitions of project outputs, outcomes and impacts from the CRRDC (2018) were adopted in our assessment and documentation of the selected projects.

- Outputs are the findings from a project, and these may include new knowledge, new technology, or markets
- Outcomes are the changes in practices, production or costs as a result of adoption of the research outputs or changes to market structures, institutions, laws and regulations
- Impacts are the aggregated effects of adoption of the research outcomes including changes in production, price and quality or gains in market efficient and spillover benefits and externalities.

Following a detailed assessment of outputs, outcomes and impacts from the projects, we undertook consultation with industry experts and developed conservative assumptions about the magnitudes of industry impacts, attribution of estimated benefits to projects under assessment and also defined the low (pessimistic) and high (optimistic) range for our modelling input data. It is important to note that while some benefits were identified, not all of them were quantified. Data and attribution challenges were the main reasons why some benefits were not quantified. The non-quantified benefits were nonetheless qualitatively discussed to provide a better appreciation of the overall impacts of the projects under assessment.

The benefits that were quantified were then compared with the project costs which were extracted from FWPA supplied documents within a CBA framework. A 5% discount rate, 5% re-investment rate and a 30-year appraisal period were used, as per the CRRDC impact assessment guidelines. The CBA results reported in the form of investment criteria values: present value of costs (PVC), present value of benefits (PVB), net present value (NPV), benefit-cost ratio (BCR) and the modified internal rate of return (MIRR). The investment criteria estimates were calculated for whole of project costs and benefits as well as FWPA's share of benefits based on the share of costs incurred by FWPA.

3 PROJECT INVESTMENT

Table 2 provides a summary of investment by FWPA and others for all four projects under evaluation. All projects received some investment contributions from FWPA and other stakeholders except for project VNA471 which was only funded via FWPA contributions.

Table 2. Project costs (nominal, $)

Project code	FWPA	Others (incl. in-kind contributions	Total
PNA371	235,000	324,471	**559,471**
PNC228	480,393	709,839	**1,190,232**
PRA334	26,400	5,100	**31,500**
VNA471	52,000	-	**52,000**

Source: Project's statement of work and audited financial reports

4 PROJECT DESCRIPTIONS

A logical framework and description of the each of the projects evaluated is provided in the following subsections. Further details for each of the projects is provided in the appendices.

4.1 Description of Project PNA371

Residential house construction in Perth, Western Australia (WA) is traditionally through masonry walls (double-bricks). However, builders had expressed some frustration with this building approach due to high bricklaying costs and shortages of bricks during periods of high demand. These shortages often led to costly construction delays. There was also a diminishing supply of skilled labour for bricklaying as older bricklayers exited the industry and their skills were not being taken up by sufficient younger workers. Builders were seeking solutions on how to overcome obstacles for timber-framed building on reactive soils, to reduce building times, lower their building costs and respond to shortages of skilled labour.

The output - Builders' User Guide - was intended to underpin growth in timber-framed construction in the residential builder market in the Perth metropolitan area as: (1) the logical material and system to substitute for double brick, and (2) the preferred choice when building on reactive clay soil sites. The goal was that timber-framed construction would then continue to gain momentum in the Perth house building market, with builders having the mechanisms in place to effectively market, specify and construct light-weight timber-framed houses. The project also provided guidelines about building boundary walls, this is particularly important given the increasing need for houses to be designed and built with boundary walls in narrow and small lot sites.

Objectives for Project PNA371

The primary objective for this project was to develop a technical transfer package targeting the WA design and construction community, identifying innovative technical solutions for construction of light-weight residential housing on non-standard reactive soils.

Financial and in-kind contributions for Project PNA371

The project costs to FWPA and others (including in-kind contributions) are provided in Table 3. FWPA's contribution was in the form of cash while other investor's contributions where both cash and in-kind. Other investors for the project were James Hardie Building Products, CSR Gyprock, Wespine Industries, TimberLink Australia and ITW Australia (Pryda).

Table 3. PNA371 annual project costs ($), nominal values for financial year ending June (annual cash and in-kind contributions)

Funding source	2016	2017	2018	Total
FWPA (cash contributions)	103,400	98,700	32,900	235,000
Others (cash and in-kind contributions)	141,757	135,457	47,257	324,471
Total	**245,157**	**234,157**	**80,157**	**559,471**

Outputs from Project PNA371

Several outputs were delivered by Project PNA371. These outputs were extracted from the project milestone reports, final report and the PNA371 research team. A summary of these outputs is provided below:

- Two building industry seminars were held in Perth and Bunbury to launch the Builder User Guide and present a summary of the contents to builders, designers and specifiers. The seminars were attended by over 160 participants.
- Further one-on-one consultations were undertaken with industry to promote timber-framed housing solutions and the Builder User Guide (Meachem, pers. comm. 2020).
- Implement a Builder User Guide distribution program over six weeks by post and direct delivery through the steering group members, technical marketing staff, visits to sites and specifier offices.
- Builder User Guide for construction of timber-framed housing in WA. This guide includes:
    - Sales and marketing information on the benefits of timber-framed housing,
    - Design and specification information,
    - Construction guide,
    - Additional support resources,
    - Truss and frame manufacturers information in Perth and regional areas in WA,
    - Typical construction schedules, and
    - Checklist for onsite quality control.
- Undertook a post Builder User Guide release survey to gather feedback.
- Attended a national timber-framing conference in Melbourne.
- Print and electronic versions of the Builder User Guide were distributed to key national suppliers and contacts associated with the WA market (Meachem, pers. comm. 2020).
- A report on the impacts of building on reactive clay soils, distribution of occurrence of reactive soils around the Perth metropolitan area and regional centres, and the cost-effectiveness of light-weight timber-frame construction on reactive soils.

Outcomes and benefits of Project PNA371

Based on the project outputs and activities, the following outcomes were identified for this project:

- Increased use of timber for building houses in the Perth. In 2020, it was estimated that the use of lightweight timber-framed construction had grown by up to 12% from 2-3% since 2015/16. Industry feedback indicates that the Builders User Guide has had a positive impact in the adoption of timber frames, however assignment of a percentage impact is difficult (Meachem, pers. comm. 2020).
- Enhanced ability to build in reactive clay soil sites in a more cost-effective way. A full masonry house in an S1 site class requires more than double the foundation concrete volume than for a timber-framed house. For an M class site the difference is much greater, with a full masonry house requiring 8 times more of the foundation volume concrete than for a timber-framed house.
- Enhanced ability of builders to market, specify and construct light-weight timber-framed houses in WA.
- Increased demand for Australian timber products by the Perth house construction sector.
- Increased demand for building materials that are complementary to timber-frame houses (e.g. plasterboards, nail-plates, fasteners, bracers, and external cladding materials).

- Reduced construction time for residential houses in Perth metropolitan area. It is estimated that construction time will be reduced by up to 6 weeks for 225m^2 single-storey house compared to a double brick house.
- Improved dwelling thermal performance.
- Increased internal floor space by about 9-10m^2 (i.e. 4%) for a standard 250m^2 home.
- Improved structural flexibility that allows future upgrades and modifications

Based on the above outcomes, the following benefits were identified for Project PNA371:

- Potential reduction in construction costs to builders and home buyers in Perth metropolitan area.
    - More cost-effective foundations and earthworks.
- Avoided rental cost for some of the buyers and builders from shorter construction timeframes.
    - A timber-frame clad single-storey house (225m^2) will accelerate the construction by up to 6 weeks relative to a full masonry house.
- Additional internal space created, which is valued at between $950-$2,600 per m^2, based on an average dwelling size of 236.5 m^2 (ABS, 2019b; BuildSearch, 2018).
- Increased revenue for suppliers of timber and complementary building materials for building a timber-frame house.
- Contribution to positive environmental impact due to the use of timber. Timber is an environmentally friendly and renewable building material.

Benefits quantified for Project PNA371

Current and future benefits were assessed to establish the monetary value of the identified benefits. Given the uncertainty around adoption rates, timing of benefits, and level of attribution a conservative approach was used to value the benefits. Furthermore, a sensitivity analysis was undertaken using Monte-Carlo simulations. Three benefits were quantified for Project PNA317, these were:

- Potential reduction in construction costs associated with house earthworks and foundations.
- Avoided rental costs for a proportion of homebuyers, because of faster construction completion.
- Value of additional internal space created from using timber frames compare to conventional double bricks.

Benefits not quantified for Project PNA371

The following benefits were not quantified:

- Potential reduction in house completion time for builders.
- Contribution to positive environmental impact due to the use of timber.
- Increased revenue for suppliers of timber and complementary building materials for building a timber-frame house.

These benefits were not quantified due to the lack of data on specific magnitudes of the impacts. For example, while it is accepted that timber is more environmentally friendly as a construction material, it was not clear how much carbon dioxide is mitigated by using timber rather than conventional masonry works, taking a lifecycle perspective. It is also not clear how a timber house will perform in terms of long-term maintenance requirements compared to a conventional brick house. For example, in another project being evaluated in this report (Project PRA334), a timber framed mid-rise building was found to perform poorly in the Green Star rating. The increased revenue for complementary construction materials was not valued as this is deemed to be offset by the loss of revenue for conventional double brick walled house construction material suppliers.

Valuation of benefit 1: Potential reduction in construction costs associated with house earthworks and foundations

The timber-framed construction method allows a lower volume of foundation concrete and steel across the different site class specifications to be used. Table 4 provides the different concrete volume requirements between a full masonry house (double brick wall) and a brick veneer (timber frame) house for six different site soil classifications. As the classification deteriorates, more concrete is required for the foundation. Further information on the estimated annual number of houses constructed approved at the different soil classifications was estimated in consultation with Timber Insights Pty Ltd.

Table 4. Single storey building's foundation concrete volume requirements

Site Class	Full masonry (m^3)	Brick veneer (m^3)	Difference (m^3)	Proportion of dwellings approved in site class
A	5.1	5	0.1	90%
S1	12	5	7	6%
S2	13	5	8	1%
S3	16	5	11	1%
S4	17	5	12	1%
M	40	5	35	1%

Source: Timber Insights (2017) and Meachem, pers. com. (2020)

Data on annual house construction commencements was estimated using the Australian Bureau Statistics house approvals for the Perth region (ABS, 2020) and dwelling commencement data (ABS, 2019b[1]). House approvals vary from one year to the next. Historical data on house approvals was used for years 2018 and 2019, and a 5-year average to 2018/19 was used for subsequent years within the appraisal period to keep the analysis conservative. A value of $289 per m^3 for avoided foundation concrete costs used (Rawlinsons, 2020). A summary of the assumptions to quantify this benefit is provided in Appendix A.

Valuation of benefit 2: Avoided rental costs for a proportion of homebuyers

Timber-framed houses are typically completed relatively more quickly than the conventional double bricked houses. The Builder User Guide construction schedule estimates that a typical single storey house (225 m^2) can be completed six weeks earlier when a timber frame is used (compared to a double brick wall house). It was therefore assumed that a portion of buyers would receive a financial benefit (rental savings) from having their house completed faster. The 2016 Census data indicates that approximately 26% of households in Perth privately rent their homes. It is assumed that a proportion of new home buyers will come from these renters, but some homes will be built for people currently not renting their homes (e.g. those staying with family, private investors, and developers). Based on

[1] https://www.abs.gov.au/statistics/industry/building-and-construction/building-activity-australia/latest-release#data-download

this understanding it was then assumed that people who may benefit from a shorter construction completion will range between 2.5% and 15%, with the most likely estimate being 5%. A weekly average rental cost of $350 was used in this valuation as per the Housing Industry Forecasting Group (HIFG, 2018). A summary of the assumptions to quantify this benefit is shown in Appendix A.

Valuation of benefit 3: Value of additional internal space from using timber

Timber-framed house have an overall thinner wall compared to double brick wall houses. The Building User Guide indicates that for a 250 m^2 house the gains in internal space can be up to $10m^2$, this is equivalent to a 4% gain. Data from the ABS and from industry groups such as BuildSearch (2018), BMT Quantity Surveyors (2020) indicate that the price per m^2 for building a house ranges from $950 to $2,600. The variability in the price per m^2 is due to the different finish standards of the completed houses. A conservative range of 2% to 4%, with a most likely average value of 3% gain in internal space was used to value this benefit. A summary of the assumptions to quantify this benefit is shown in Appendix A.

4.2 Description of Project PNC228

Australia was experiencing significant changes in climate. The number of days with maximum temperatures has accelerated more in the last two decades and average annual rainfall has declined. It is expected that these trends are likely to continue into the future. Changes in climate and an increased frequency of extreme weather events is expected to impact the short- and long-term productivity of plantations. To improve resilience and reduce the vulnerability of Australian plantations, the National Climate Change and Commercial Forestry Action Plan 2009 – 2012 recommended assessing climate change risks and creating tools to help understand the best way to intervene. There were no tools that were previously available to simultaneously achieve both recommendations. This was recognised as an impediment to climate change adaptation.

This project used modelling to understand how a range of future climate scenarios will affect productivity and wood properties across several plantation locations in Australia. This was followed by an investigation into how different management practises could help mitigate forecast negative impacts. The modelling of climate change and climate variability forms the basis of a decision support tool which can be used by plantation managers to better understand site-specific impacts. For this project to be completed, national assessments of plantation productivity for 2030 and 2050 were updated. Project results were presented with consideration of their level of uncertainty.

Objectives for Project PNC228

There primary objectives for this project were to:

1. Provide forest managers with information on how climate variation will alter stand productivity, wood properties and how indirect climate change hazards will impact productivity, by updating national predictions and discussing these with industry.
2. Develop tools to help industry participants understand the direct and indirect consequences of climate change and climate variability and to provide the knowledge about how to use these tools.
3. Use the tools assess adaptation strategies for climate change and climate variability and to promote industry understanding and uptake.

Financial and in-kind contributions for Project PNC228

The project costs to FWPA and others (including in-kind contributions) are provided in Table 5. Other investors included CO_2 Australia, CSIRO, Forestry Plantations Queensland, Forestry SA, Forestry Tasmania, Norske Skog, State Forests NSW, Treehouse Consulting, University of Tasmanian, WA Plantation Resources and University of Western Sydney who made cash and in-kind contributions.

Table 5. PNC228 annual project costs ($), nominal values for financial year ending June (annual cash and in-kind contributions)

Funding source	2011	2012	2013	2014	Total
FWPA (cash contributions)	101,714	101,714	101,714	175,252	480,393
Others (cash and in-kind contributions)	159,432	159,432	159,432	231,543	709,839
Total	**261,146**	**261,146**	**261,146**	**406,795**	**1,190,232**

Source: Based on final audited financial project report (2015)

Outputs from Project PNC228

Several outputs were delivered by Project PNC228. These outputs were extracted from the project milestone reports, final report and input from the PNC228 research team. A summary of these outputs is provided below:

- Updated the national assessments of plantation productivity for 2030 and 2050.
- Quantified the threats to productivity, carbon stocks and wood products from climatic variability and associated changes in drought, pests and fire.
- Defined uncertainty associated with estimated threats to productivity, carbon stocks and wood products.
- Used a sample of locations to undertake the modelling analysis. Sites where water was likely to become a limiting factor for productivity were prioritised for assessment.
- Determined the adaptive capacity of current management practices, and where new production systems (e.g. new species, new products) may instead be required.
- Identified adaptation strategies for the current plantation estate and the effects of these on productivity and wood properties.
- Developed tools to assist industry decision-making around hazard and productivity management in Australia's plantations.
- Updated the forest productivity model, Carbon BALAnce (CABALA).
- This project delivered nine reports including a final report which gives an overview of the main findings as well as eight region specific reports which break down the findings into greater detail. The reports provide summaries of the key changes expected for production, survival, wood properties and pest and fire hazard expected to take place by 2030. The nine reports from this project are:
- Adaptation strategies to manage risk in Australia's plantations

  - Regional report 1: South west Western Australia eucalypt plantations
  - Regional report 2: South west Western Australia radiata pine plantations
  - Regional report 3: Green Triangle eucalypt plantations
  - Regional report 4: Green Triangle radiata pine plantations
  - Regional report 5: Eastern Victoria/southern NSW eucalypt plantations
  - Regional report 6: Eastern Victoria/southern NSW radiata pine plantations
  - Regional report 7: Tasmania eucalypt plantations

    - Regional report 8: Tasmania radiata pine plantations

- Three face-to-face industry workshops and webinars were held. The first workshop was in March 2012 and focused on co-design of the project deliverables. The remaining workshops were held in 2014 and these focused-on presenting the project results (Pinkard, pers. comm., 2020).
- Published research media article titled "Predicting climate impacts".
- Undertook industry consultation, both in person and via telephone, to assist with the adoption of project outputs. The consultation provided an opportunity for more in-depth discussion of the implications of the research findings for their businesses. The response was positive and particularly in more vulnerable regions such as south west Western Australia (Pinkard, pers. comm., 2020)
- A spatial database for predicting production and survival for five climate models at three time periods (2014, 2030 and 2050). There has been some industry interest in accessing these layers through the CSIRO's data access portal (Pinkard, pers. comm., 2020).
- Held an online presentation to share projects results with the wider industry and stakeholders
- Provided recommended adaptation strategies for management of climate change hazards for the most common plantation species.
    - For *Eucalyptus globulus*, these included: altering initial spacing to manage water stress and fertilising to promote crown development following pest attacks.
    - For *Pinus radiata*, these included: altering initial spacing to manage water stress, reducing the number of thinnings and thinning later to fully utilise the site and reducing the rotation length to minimise exposure to extreme events.
- The impact of a range of these adaptation strategies were explored through modelling to understand their effect on productivity and mortality. This was done for a selection of sites where production is expected to fall by at least 5% by 2030, with more sites being included in regional summaries.
- The results for *E. globulus*, focused on two main strategies to combat drought and control leaf area. The first strategy of reducing the number of stems per hectare (sph) from 1,000 sph to 800 sph resulted in reduced mortality without significantly altering productivity in some cases. Increasing fertiliser was found to potentially improve productivity, but may also increase mortality. At some sites, reducing spacing was found to decrease the mortality risk associated with fertilising, while at other sites it was found to increase it. The results suggest there is a trade-off between risk and productivity to be considered.
- The results for *P. radiata*, focused on two main adaptation strategies to combat drought and control leaf area. These were increasing the initial stocking rate from 1,333 sph to 1,600 sph and reducing the number of thinnings from 3 to 2 thinnings. In most instances, these strategies improved productivity relative to the base case. However, the impact on mortality of these strategies was not able to be captured.
- Regional results indicated that the south west WA was the most vulnerable region (Pinkard, pers. comm., 2020).

Outcomes and benefits of Project PNC228

Based on the project outputs and activities, the following outcomes were identified:

- Increased awareness among industry participants of how changes and variability in climate can affect plantation forests and wood properties.

- Improved industry understanding about the plantation industry's adaptive capacity through changes in management practices and when adaptation is more appropriate than other forms of intervention.
- Enhanced industry understanding of adaptive strategies and their potential benefits.
- Contribution to the improvement of the forest industry's ability to predict and manage climate change impacts and better manage risks to timber quality and plantation productivity.

The following benefits were identified for Project PNC228:

- Potential avoided industry productivity losses from adoption of improved management strategies.
- Contribution to medium- and long-term industry sustainability in the face of a changing climate and an increased frequency of extreme weather events.
- Potential contribution to avoided welfare issues for plantation owners and their employees (e.g. stress and worries about potential or eventual loss of local employment).

Benefits quantified for Project PNC228

The benefit valued for Project PNC228 is the potential avoided loss of productivity plantation products. Given the uncertainty around adoption rates, likelihood of impacts for the mitigation strategies, and level of attribution, a conservative approach was used to value the benefits.

Benefits not quantified for Project PNC228

The following benefits were not quantified:

- Contribution to medium- and long-term industry sustainability in the face of a changing climate and an increased frequency of extreme weather events.
- Potential contribution to avoided welfare issues for plantation owners and their employees.

These benefits were not quantified due to the lack of data on specific magnitudes of the impacts. For example, while it is accepted, that industry sustainability will be improved through efficient and effective management strategies, it is particularly challenging to assign monetary value to this benefit. It is similarly challenging to measure society's welfare improvements without doing a target survey of the community.

Valuation of benefit 1: Potential avoided loss of productivity plantation

Current and future benefits were assessed to establish the monetary value of the identified benefits. This project may provide a benefit by reducing productivity losses to plantations that occur because of climate change. This is achieved through the project outputs which assist plantation managers in implementing adaption strategies, which aim to mitigate negative impacts.

There is uncertainty associated with future climate conditions and their impact on plantations productivity. In some instances, climate change impacts may improve plantation productivity. In addition, not all plantations are expected to be equally impacted by climate change. However, Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES) (2011) suggest that median log availability in softwood plantations will decrease by more than 20% by 2030 and more than 30% by 2050. The same study suggest median log availability in hardwood plantations will fall by more than 8% by 2030 and by more than 14% by 2050. These estimates suggest the study, if successful, can provide considerable benefit to the plantation industry.

However, given the uncertainty around adoption rates, timing of benefits, level of attribution a conservative approach was used to value the benefits. Furthermore, a sensitivity analysis was undertaken using Monte-Carlo simulations. The benefit valued for Project PNC228 is the potential avoided loss of productivity plantation products. The ABARES reports gross value of log production from native vegetation, hardwood plantation and softwood across Australia and at the Australian states and territories level (ABARES, 2019). We relied on this data to estimate the value of potential loss but restricted our estimates to hardwood and softwood products. It was assumed that results for *E. globulus* are representative of all Australian hardwood plantations and the results for *P. radiata* are representative of all softwood plantations. ABARES (2019) reported that the most recent 5-year average gross value for logs harvested from hardwood plantations was $687 million and $1.3 billion for softwood. It was conservatively assumed that a net 5% of the estimated loss for both hardwood and softwood gross value will be avoided across Australia through the adoption of the project findings.

A net value was used as the modelling result indicated that there are certain plantations that may experience increased productivity as climate changes. Also, adoption of the project findings will result in additional costs and possibly more research required to capture these benefits, a conservative attribution of 25% was applied in consultation with industry experts. A summary of the assumptions to quantify this benefit is shown in Appendix B.

4.3 Description of Project PRA334

In Australia, 5 to 6 storey buildings have traditionally been designed and built using 'heavyweight' materials such as steel, pre-cast concrete panels and concrete slab floors. Australand has developed a 'lightweight' method of construction for these types of building. Their approach relies more on timber and incorporates prefabrication to speed up the construction process.

The use of timber, instead of concrete, can have relatively lower negative environmental impacts. A life cycle assessment (LCA) can be used to compare environmental benefits between projects. The LCA method allows benefits and costs from every stage of projects life to be compared rather than a focus on a single stage or aspect.

This study used a LCA to compare the environmental impacts of two multi-storey buildings. These two buildings differed in structure, with the 'study' building incorporating a more 'lightweight' design than is traditionally used. Six environmental impacts were considered for each building over a 60-year time span. These impacts were: climate change, stratospheric ozone depletion potential, acidification potential of land and water, eutrophication potential, photochemical oxidation (smog) and mineral and fossil fuel depletion (abiotic depletion). To ensure a fair comparison, the environmental impacts of each building were presented on a per meter of gross dwellable area (GDA) basis. The GDA of a building includes the area inside each apartment as well as the balcony. The study building was found to reduce the level of impact in 3 of the 6 categories, with most of its environmental advantages coming from its reduced use of materials.

The following sections outlines the project outputs as presented in the project milestone and final reports, as well as from consultations with the project team. The outcomes and benefits were identified from the reports and developed through research and consultation with industry experts.

Objectives for Project PRA334

The primary objective of this study was to compare the potential environmental impacts of two multi-storey buildings in Parkville, Victoria. The 'study' building incorporates the innovative lightweight design approach of Australand, while the 'reference' building relies on more traditional, concrete heavy, methods.

Secondary objectives of this study were:

- To compare the outcomes of this study to the LCA of the Forte building.
- To determining the green star points that may be earned by the study building under the Green Building Council of Australia's Innovation Challenge – Materials Life Cycle Impacts.

Financial and in-kind contributions for Project PRA334

The project costs to FWPA and others (including in-kind contributions) are provided in Table 6. FWPA's contribution was in the form of cash. Other investor contributions came from Australand.

Table 6. PRA334 annual project costs ($), nominal values for financial year ending June (annual cash and in-kind contributions)

Funding source	2014	Total
FWPA (cash contributions)	26,400	26,400
Others (cash and in-kind contributions)	5,100	5,100
Total	**31,500**	**31,500**

Source: Project Statement of Work (2014)

Outputs from Project PRA334

Several outputs were delivered by Project PRA334. These outputs were extracted from the project milestone reports, final report and from consultation with the PRA334 research team. A summary of these outputs is provided below:

- Undertook an environmental impact assessment using six impact categories: climate change, ozone depletion, acidification, eutrophication, photochemical oxidation and abiotic depletion.
- The LCA was undertaken according to ISO14044.
- The study building was found to perform better in most of the environmental impact categories compared to the reference building.
    - Climate change: 2% better, ozone depletion: 17% better, abiotic depletion: 3% better
- In the photochemical oxidation category, the reference building was found to be 9% better than the study building. This is a result of the expected emissions from timber as it degrades in landfill and transport related emissions associated with the material supply chain.
- Performance results for the eutrophication and acidification impact categories were found to be inconclusive.
- The advantages of the study building compared to the reference building were centred around its lightweight design which used about 30% less materials and the use of lower intensity materials.
- The study building did not perform well in terms of Green Star points, with the building performing better against operational performance more than innovation in materials. The study building was awarded a score of 1.6 out of 6. However, the Green Star points were granted under the Green Building Council of Australia's Innovation Challenge program, which was intended to be further refined.
- This project produced a final report, "*A comparative life cycle assessment of two multi storey residential apartment buildings*" which is currently publicly available through ResearchGate. This report has been used to inform several subsequent studies and so far has been cited four times in the academic literature (Crossing pers. com., 2020, and Google Scholar search)

Based on the project outputs and activities, the following outcomes were identified for this project:

- Reduced environmental cost over project's lifecycle
    - Climate change (2.2% lower impact or saving of 89.6 kg CO_2 equivalent per m^2 of GDA over 60 years),
    - Reduced ozone depletion (17.3% lower impact savings of 5.5 mg of CFC-11 equivalent per 1 m^2 over 60 years), and
    - Reduced abiotic depletion (2.5% lower impact or savings of 0.7 kg of SB equivalent per 1 m^2 over 60 years) (Carre pers. Comm., 2020)
- Reduced environmental cost excluding use phase of project
    - Climate change (22.2% lower impact or saving of 107.6 kg CO_2 equivalent per m^2 of GDA over 60 years).
    - Reduced ozone depletion (30.1% lower impact savings of 5.5 mg of CFC-11 equivalent per 1 m^2 over 60 years).
    - Reduced abiotic depletion (32.4% lower impact or savings of 0.9 kg of SB equivalent per 1 m^2 over 60 years) (Carre pers. Comm., 2020)
- Enhanced ability to demonstrate the environmental benefits of using a 'lightweight' timber construction approach instead of a more traditional concrete heavy approach for mid-rise buildings. Over the long term, this would be expected to increase the use of wood in mid-rise construction and reduce the use of concrete.
- Increased awareness and knowledge about the environmental advantages of using a 'lightweight' timber construction approach instead of a more traditional concrete heavy approach. Over the long term this would be expected to increase the use of wood in mid-rise construction. reduce the use of concrete.
- Potential increased demand for Australian timber products to support mid-rise timber buildings.
- Potential increased demand for building materials that are complementary to timber-frame houses (e.g. plasterboards, nail-plates, fasteners, bracers, and external cladding materials).
- Upskilling of domestic trades to better enable the construction of mid-rise timber buildings.
- Enhanced industry knowledge about the benefits (time savings and materials) that can be achieved by using a 'lightweight' timber construction approach that incorporates prefabricate systems instead of the more traditional approach which incorporates precast concrete panels.
- Potential contribution to an increase in the amount of medium-rise housing in outer suburbs where concrete construction is not economically viable.

The following benefits were identified for Project PNC228:

- Reduced anthropogenic climate change causing pollution.
- Lower construction costs through quicker completion times, this was estimated at an average of 6-week construction time saving.
- Reduction in the risk of time lost to construction site related injuries.
- Reduced transport related environmental impacts because of the reduced weight of construction materials.
- Potential increase revenue for the timber industry.
- Potential improved housing affordability for buyers.

Benefits quantified for Project PRA334

Current and future benefits were assessed to establish the monetary value of the identified benefits. Given the uncertainty around adoption rates, timing of benefits, and level of attribution a conservative approach was used to value the benefits. This project is one of many points of evidence on the benefits of using timber frames for mid-rise buildings.[2] FWPA has a *Mid-rise Advisory Program* which promotes and campaigns for the use of timber/wood in mid-rise buildings. Thus, a conservative attribution factor was used to reflect the quantified benefits associated with this project. Furthermore, a sensitivity analysis was undertaken using Monte-Carlo simulations.

Three benefits were quantified for Project PRA334, these are:

- Lower construction costs through quicker completion times.
- Reduction/avoided risk of time lost to construction site related injuries.
- Reduced anthropogenic climate change impact (CO_2 pollution).

Benefits not quantified for Project PRA334

The following benefits were not quantified:

- Reduced transport related environmental impacts because of the reduced weight of construction materials.
- Potential increase revenue for the timber and complementary industries.
- Potential improved housing affordability for buyers.

Some of the benefits outlined in the project file report are acknowledged in this assessment. However, there was limited data on how to meaningful measure and assign monetary value to those benefits. For example while timber construction is likely to achieve a lower environmental impact from the transportation of materials, it is more challenging to establish the magnitude of such a benefit without a detailed study comparing the typical distances and loads involved under the two construction options. The increase in revenue for the timber and complementary industries benefit was not valued as it was assumed that this is essentially a substitute between suppliers in the building sector and thus this benefit is offset by losses in complementary product suppliers.

Valuation of benefit 1: Reduced anthropogenic climate change impact (CO_2 pollution)

The LCA project estimated that the study building led to positive environmental impact outcomes through an emissions reduction of 89.6 kg CO_2 equivalent per m^2 of gross dwellable area (GDA) over 60 years. This estimate was combined with estimated share of the timber framed buildings in the mid-rise residential buildings in Australia.

Data on the average growth in mid-rise apartments and number of units/apartments/flats that commence construction was sourced from the ABS (2019). Historical data indicated that over the last 10 years to 2019, the number of units/apartments/flats in a four to eight storey building has been increasing by average rate of 10% year-on-year (ABS, 2019). This growth factor was interpolated for 10 more years after which it was assumed that the share of the market remains relatively constant. This conservative approach was adopted to avoid overestimating the benefits associated with using the light-weight approach in construction of mid-rise buildings. Conservative 2.5% to 10% (middle value of 5%) was used as an estimated share of timber framed mid-rise buildings given the total volume of all mid-rise buildings. The upper limit (10%) was based on Hardware Journal (2016). An average floor area of 108 m^2 was used to estimate the value of this benefit based on a social cost carbon of $74 as per the Interagency Working Group on the Social Cost of Greenhouse Gases (2016) and the ACT

[2] Other similar studies include Basaglia et al. (2015) and Robertson et al. (2012)

Climate Change Council (2018). A summary of the assumptions to quantify this benefit is shown in Appendix C.

Valuation of benefit 2: Lower construction costs through quicker completion times

While the main goal of this project was to establish the environmental benefits from using light-weight timber materials, there are also some key economic/commercial benefits that were identified for this project. Replacing conventional and heavy weight materials with timber has been reported to achieve cost savings through faster construction completion times. Australand's estimating manager Kase Jong, is reported to have previously estimated that on a per apartment basis, the average savings can be up to 25% and including about a week's worth of time saving per floor level (Jewel, 2014). An average floor area of 108 m^2 valued at $2,752 was then used to estimate the value of reduced construction costs (BMT Quantity Surveyors, 2020; ABS, 2019b). A summary of the assumptions to quantify this benefit is shown in Appendix C.

Valuation of benefit 3: Potential reduction/avoided risk of time lost to construction site related injuries

Preliminary observation indicated that construction of light weight mid-rise building was achieving significant outcomes in the form of avoided lost-time-injury during the construction stage. At the time of the LCA project, Lendlease Australia had completed eight similar timber projects in Australia and they had no reported lost-time injury (LTI) on any of those projects. It is typical for traditional projects in the mid-rise space to have at least one LTI due to the high-risk nature of the construction process (Timber Trader News, 2020). LTI presents a significant cost risk to the construction process through lost productivity, inspection and investigation costs, health and medical costs, among others. An average avoided costs per incidence of $4,582 was used to estimate likely cost savings from avoided LTI (Sun & Zou, 2010). However, after construction of eight buildings using timber frames, Lendlease experienced no LTI. Given that the evidence for valuing this benefit came from a single builder (i.e. Lendlease), it was conservatively assumed that across all constructions in a year, the average number of LTIs is one per conventional mid-rise building and 0.5 for a timber framed equivalent building. A summary of the assumptions to quantify this benefit is shown in Appendix C.

4.4 Description of Project VNA471

The Green Triangle is in the border region of South Australia and Victoria. It is Australia's largest collective plantation and wood processing zone and as a result it is a significant part of the local economy. The plantation and wood processing area is over 6 million ha across South Australia and Victoria.

In 2013, the South Australian part of the Green Triangle was subject to a new Water Allocation Plan (WAP) which was developed as a result of the National Water Initiative (NWI). Its development created concerns for the South Australian forestry industry about the impact of changing water regulations and water use policies. In particular, South Australian based plantations were worried that consequent water allocation changes would impact their businesses through a reduction in their plantation estate, reduction in production capacity, and through reduced ability to optimise the use of their plantation estate. The WAP was adopted in November 2013 and underwent a review in 2019.

The project involved an economic impact assessment of the Green Triangle forestry industry. The assessment was undertaken to determine the expected impacts of the WAP on the economy and involved collation of input data from consultations with the forestry industry.

Three measures we used to measure economic impact. These are total output, value add, and employment impacts. Total output is an indicator of the industry's production, value add is a measure of the wealth generated by the industry and employment is measure of the amount of labour used in the production process. The assessment of economic contribution project takes into consideration that the project was essentially assessment of economic losses as a result of the WAP. The project on its own will not deliver the benefits of avoiding the losses but will rather provide very important information that will potentially influence the decision-making process.

Objectives for Project VNA471

The projects objectives were as follows:

- To understand the economic contribution of the green triangle forestry industry to the South Australian economy.
- To outline the potential consequences of changing business decisions due to the WAP, and thus the impact on the local economy.

Financial and in-kind contributions for Project VNA471

The project costs to FWPA and others (including in-kind contributions) are provided in Table 7. FWPA's contribution was in the form of cash and there were no reported in-kind contributions.

Table 7. VNA471 annual project costs ($), nominal values for financial year ending June (annual cash and in-kind contributions)

Funding source	2018	Total
FWPA (cash contributions)	52,000	52,000
Others (cash and in-kind contributions)	0	0
Total	**52,000**	**52,000**

Source: Project Statement of Work (2018)

Outputs from Project VNA471

Several outputs were delivered by Project VNA471. These outputs were extracted from the project milestone reports, final report and from consultation with the VNA471 research team. A summary of these outputs is provided below:

- Estimated value of the impact of the WAP on the Green Triangle forestry industry.
- Estimated value of the impact of the WAP on forestry industry total output and value add to South Australia.
- Estimated impact of the WAP on regional employment.
- Attendance at two Green Triangle Forum meetings as part of industry consultation. Further consultation via teleconference.

Outcomes and benefits of Project VNA471

Based on the project outputs and activities, the following outcomes were identified for this project:

- Enhanced understanding of the impact of the WAP on the South Australian forestry industry, South Australian Green Triangle forestry industry and the South Australian economy through industry output, value add and annual employment.
- Improved government decision making with regards to water allocations.

- Improved industry confidence leading to beneficial decision making with positive economic outcomes well into the future.

The following benefits were identified for Project PNC228:

- Contribution to potential avoided loss of forestry industry productivity from reduced production output and potential land retirement by plantation owners.
    - Thus leading to contribution to avoided loss in industry economic contribution through value add to the South Australian economy.
- Contribution to avoided loss of employment.
- Potential contribution to community welfare for plantation owners and their employees as well as the general supply chain.

Benefits quantified for Project VNA471

The benefit valued for Project VNA471 is the potential contribution to avoided loss of value add from the South Australia based forestry industry in the Green Triangle.

Benefits not quantified for Project VNA471

The following benefits were not quantified:

- Contribution to avoided loss of employment.
- Potential contribution to community welfare for plantation owners and their employees as well as the general supply chain.

Some of the benefits outlined in the project file report are acknowledged in this assessment. However, there was limited data on how to meaningfully measure and assign monetary value to those benefits. For example, loss of employment in the forestry industry could be offset by employment in other industry. The welfare (e.g. reduced stress) benefits to managers, employees and the community at large are particularly challenging to measure and apply monetary values and thus these are acknowledged but not quantified.

Valuation of benefit 1: Avoided industry losses

Current and future benefits were assessed to establish the monetary value of the identified benefits. Given the uncertainty around adoption rates, timing of benefits, and level of attribution, a conservative approach was used to value the benefits. The benefit valued for Project VNA471 is the potential contribution to avoided loss of value add from the South Australia based forestry industry in the Green Triangle. However, it is important to note that any eventual benefits from this study are only speculative at the time of this impact assessment. This is the case as there is currently a limited understanding of how the outputs from this study will eventually influence government policy. The WAP is due for a review in 2023. Until this time, it is not certain whether the project has influenced policy. Still, it is not clear how influential Project VNA471 will be to the decision making. Ernest & Young (2019)3 undertook an industry consultation with plantation owners in the affected area and found that the average annual loss due to the WAP could be $31.7 million for hardwood and $5.9 million for softwood. Given that the losses are industry reported and that further investments (campaigns and research) will need to be undertaken to deliver the benefits, a very low attribution

[3] "W:\Natural Capital Economics\Work\2020\0920027_BCA_of_FWPA_R&D_Projects\10_Project\3_Input\FWPA project docs\VNA470-1819\VNA471-1819_GreenTriangleForestry_Final_310119.pdf"

factor of 5% was applied to Project VNA471 and the benefits were assumed to commence in 2025, 3 years after the 2023 WAP review to allow for changes in policy and any management practices.

5 SUMMARY INVESTMENT BENEFITS

Table 8 presents a summary of the economic, environmental, and social benefits of investment, broken down by into the triple-bottom line framework, that is, economic, environmental benefits, and social benefits.

Table 8. Categories of benefits from the investment

	Benefit
Economic Benefits	• Potential reduction in construction costs in Perth metropolitan area and across Australia (more cost-effective foundations and earthworks) (PNA371 and PRA334) • Avoided rental cost for some of the buyers and builders from shorter construction timeframes (PNA371) • Potential avoided industry productivity losses from adoption of improved management strategies (PNC228) • Contribution to medium- and long-term industry sustainability in the face of a changing climate and an increased frequency of extreme weather events (PNC228; VNA471). • Reduction in the risk of time lost to construction site related injuries (PRA334). • Potential increase revenue for the timber industry (PRA334).
Environmental Benefits	• Contribution to positive environmental impact due to the use of timber (PNA371). • Potential contribution to reduced anthropogenic climate change causing pollution (PRA334).
Social Benefits	• Contribution to improved housing affordability outcomes (PRA334) • Regional community spillover benefits through improvements in employment and income certainty (PNA371; VNA471). • Potential contribution to avoided welfare issues for plantation owners and their employees (e.g. stress and worries about potential or eventual loss of local employment) (PNC228; VNA471)

The majority of the benefits are economic in nature and they accrue to the levy paying industry through increased revenue/avoided losses, increase market share in the construction industry. The community at large also has the potential to benefit from low construction cost outcomes from lower cost of materials, site preparation costs and faster construction times. Increased use of timber materials rather than the conventional heavy weight (steel and concrete) materials leads to positive outcome for the environment through lower CO_2 emissions. Some projects were assessed to have potential impacts on the welfare of the industry stakeholders (business owners, employees, and complimentary supply chain participants) through improved certainty about employment, incomes leading to reductions in stress.

Across all projects, the levy paying industry is expected to benefit through the capturing of demand that previously accrued to other industries (e.g. concrete, masonry and steel suppliers) and through avoided potential future losses from climate change effects and outcomes from the WAP in South Australia. The CBA estimates were undertaken at a high level (society level) and only the net impacts were quantified. Thus, the benefits quantified are those accruing the whole Australian economy. The counterfactual for our assessment for each project is as follows:

- PNA371 – the construction industry's uptake of timber frames in house construction would remain low, and the identified low-cost benefits to builders and home buyers would not be realised at the estimated adoption rates. It is assumed that this project has contributed to the estimated benefits.

- PNC228 – it is assumed that without this project, the attributed benefits from avoided losses due to climate change would not be realised as estimated, and that this project has provided valuable outputs (spatial maps) and adaptation strategies which will be used to fast-track changes in industry management practices.
- PRA334 – it was assumed that this project will have a modest contribution to industry perception and knowledge about the benefits of light-weight design. The project was also assumed to contribute to current and future research works that advocate for more affordable and relatively environmentally friendly design outcomes. It is acknowledged that other works will be required to realise this benefit and only a conservative attribution factor was assumed.
- VNA471 – the benefits from this project are speculative and dependent on how the report will be utilised and whether it will contribute to any industry benefits through future WAP reviews and changes. A conservative probability of impact and attribution were applied to the estimated benefits, and the counterfactual is that such benefits would not be achieved without inputs from this and other related projects.

5.1 Alignment of benefits with national priorities

The evaluation of the projects and associated benefits indicates that they are aligned with Australian government research priorities. Based on the research priorities presented in Table 9, the projects are considered to contribute as follows:

1. Rural RD&E priority - Advanced technology: e.g. PNA371, PRA334.
2. Rural RD&E priority - Adoption of R&D: e.g. PNA371, PNC228, PRA334, VNA471.[4]
3. Science and Research Priorities: e.g. PNA371, PNC228, PRA334.

Table 9. Australian government research priorities

Australian Government	
Rural RD&E Priorities	**Science and Research Priorities**
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: Department of Agriculture Water and the Environment (2019) and Department of Industry, Science, Energy and Resources (2015).

[4] Note that the adoption of findings from VNA471 will not be known until 2023.

6 RESULTS

The estimation of CBA investment criteria was undertaken by adjusting all past costs to 2018/19-dollar values using the ABS reported Implicit GDP deflator. All future benefits were adjusted to 2018/19 dollars using a 5% discount rate. A 5% re-investment rate was used to calculate the modified internal rate of return (MIRR).

6.1 Impact assessment base results

A base analysis was undertaken over a 30-year appraisal period from the end of each project. Table 10 and Table 11 show a summary of the estimated findings for total investment and FWPA investment only. The present value of FWPA benefits was estimated using the FWPA proportion of total real investment value for each of the projects. FWPA's contribution represented 43% for Project PNA317 and PNC228, 85% for PRA334 and 100% for VNA471.

Table 10. Summary of CBA results for total investment ($) (30 years, 5% discount rate and 5% re-investment criteria)

Investment criteria	PNA371	PNC228	PRA334	VNA471
Present value of costs ($)	616,249	1,976,133	50,294	66,327
Present value of benefits ($)	3,715,639	15,404,065	1,024,840	561,164
Net present value ($)	3,099,390	13,427,932	974,547	494,837
Benefit-cost ratio	6.0	7.80	20.38	8.46
Modified internal rate of return	9.1%	12%	15%	74%

Table 11. Summary of CBA results for FWPA investment (30 years, 5% discount rate and 5% re-investment criteria)

Investment criteria	PNA371	PNC228	PRA334	VNA471
Present value of costs ($)	267,923	841,131	42,781	66,327
Present value of benefits ($)	1,615,428	6,556,660	871,745	561,164
Net present value ($)	1,347,505	5,715,529	828,964	494,837
Benefit-cost ratio	6.0	7.80	20.38	8.46
Modified internal rate of return	9.1%	12%	15%	74%

Impact assessment results at different times

Table 11 provides a summary of the CBA result at different years from the year of last investment. The years covered are 25, 20, 15, 10, 5 and 0 years from last year of investment. The annual undiscounted cashflow charts are provided in Appendix E.

Table 12. Summary of CBA results for total investment at different time periods (5% discount rate and 5% re-investment criteria)

Investment criteria	PNA371	PNC228	PRA334	VNA471
25 years				
Present value of costs ($)	616,249	1,976,133	50,294	66,327
Present value of benefits ($)	3,528,816	14,122,929	905,301	491,486
Net present value ($)	2,912,567	12,146,796	855,007	425,160
Benefit-cost ratio	5.7	7.1	18.0	7.4
Modified internal rate of return	10.0%	12.6%	17.3%	92.4%
20 years				
Present value of costs ($)	616,249	1,976,133	50,294	66,327
Present value of benefits ($)	3,212,699	12,487,839	752,928	402,558
Net present value ($)	2,596,449	10,511,706	702,634	336,232
Benefit-cost ratio	5.2	6.3	15.0	6.1
Modified internal rate of return	10.8%	14.0%	20.0%	122.5%
15 years				
Present value of costs ($)	616,249	1,976,133	50,294	66,327
Present value of benefits ($)	2,677,374	10,401,004	558,702	289,061
Net present value ($)	2,061,125	8,424,871	508,408	222,735
Benefit-cost ratio	4.3	5.3	11.1	4.4
Modified internal rate of return	11.8%	15.9%	23.9%	181.2%
10 years				
Present value of costs ($)	616,249	1,976,133	50,294	66,327
Present value of benefits ($)	1,849,349	7,737,615	338,109	144,207
Net present value ($)	1,233,100	5,761,482	287,815	77,880
Benefit-cost ratio	3.0	3.9	6.7	2.2
Modified internal rate of return	12.0%	18.5%	29.6%	333.6%
5 years				
Present value of costs ($)	616,249	1,976,133	50,294	66,327
Present value of benefits ($)	816,577	4,338,380	159,832	-
Net present value ($)	200,328	2,362,248	109,538	-66,327
Benefit-cost ratio	1.3	2.2	3.2	nc
Modified internal rate of return	6.5%	20.3%	41.3%	nc
0 years				
Present value of costs ($)	616,249	1,976,133	50,294	66,327
Present value of benefits ($)	nc	nc	nc	nc
Net present value ($)	nc	nc	nc	nc
Benefit-cost ratio	nc	nc	nc	nc
Modified internal rate of return	nc	nc	nc	nc

Where: nc means not value not calculated for as no benefits are expected for the project and time period.

6.2 Sensitivity analysis

The key approach to addressing this uncertainty in the analysis was undertaken using Monte Carlo simulations. This approach enables the establishment of confidence intervals around the findings of the analysis and the identification of input parameters that explain the most variability in the economic estimates. Monte Carlo simulations were modelled using 20,000 iterations of the model to investigate the impact of variability in the investment criteria from key input parameters.

Figure 2 shows the Monte Carlo simulations for the estimate benefit-cost ration of project PNA371. This figure shows that there is 90% probability that the benefit cost ratio is between 2.71 and 13.71 given the range of input variables. The top five variables driving this variability in the benefit cost ratio are given at the bottom of Figure 2 and these are: benefit attribution level, assumed increase in internal space, the construction cost per m^2, the discount factor and the assumed average size of the house.

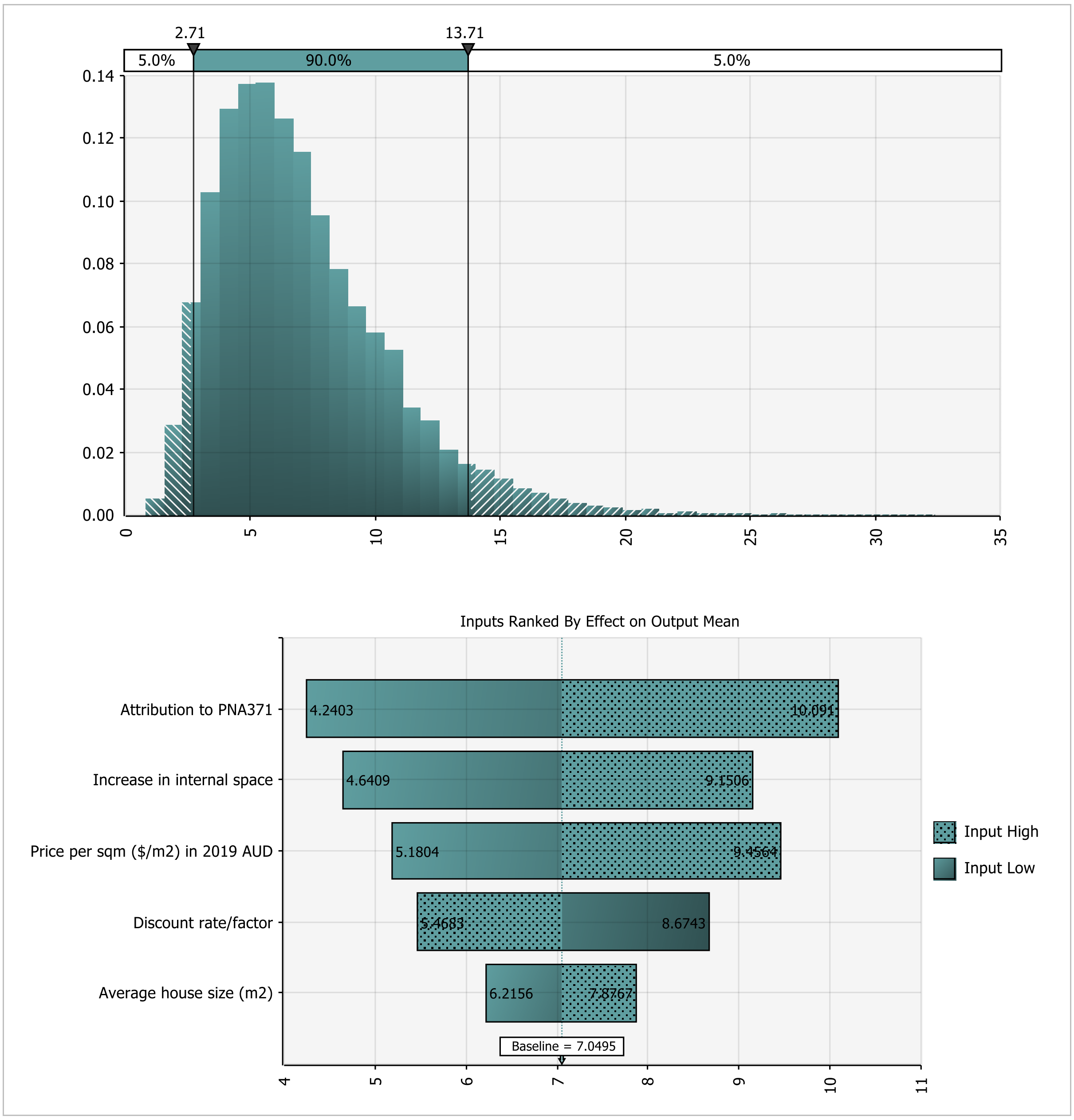

Figure 2. Estimated BCR and top 5 key parameters ranked by their effect on the BCR (PNA371)

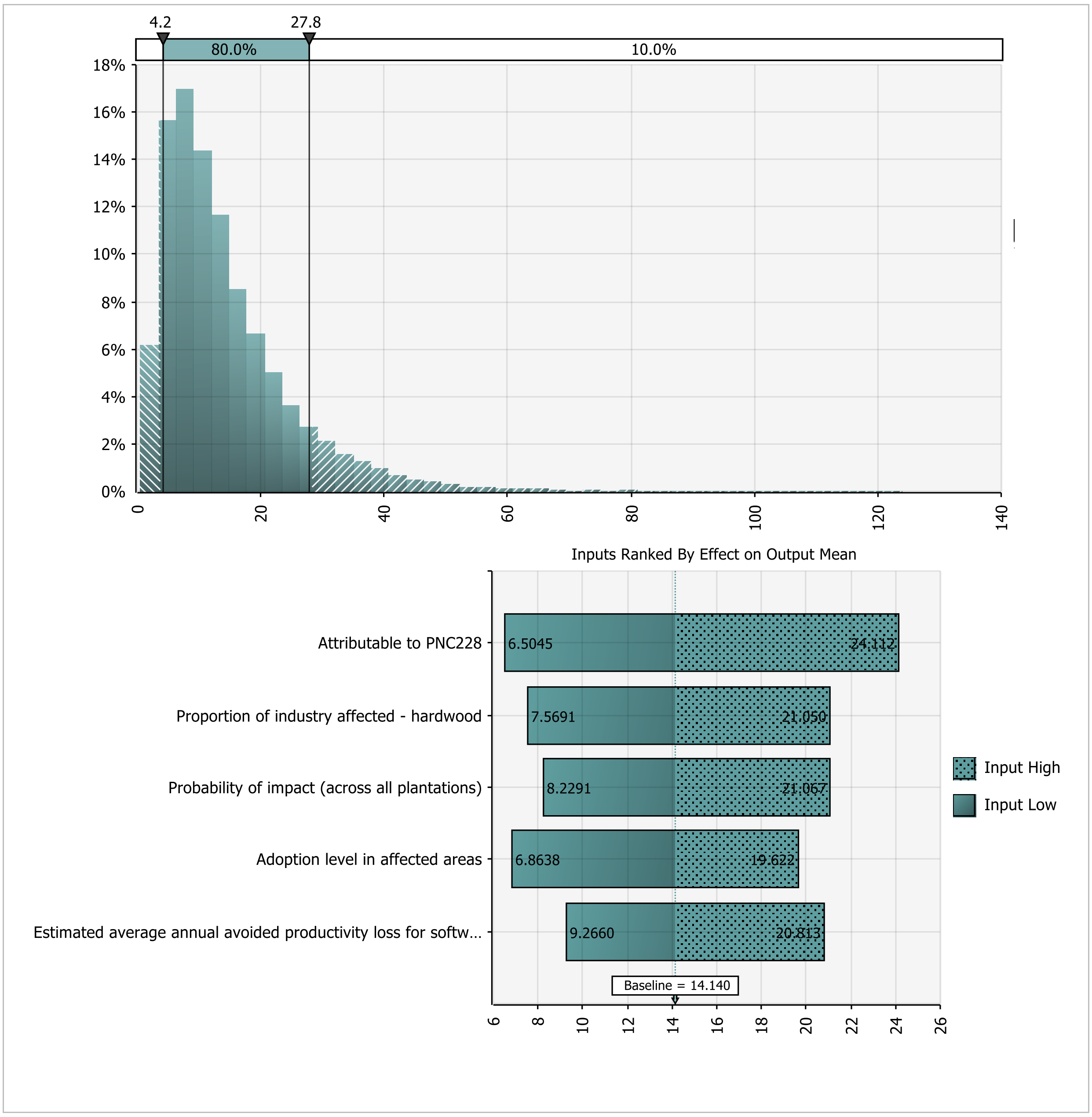

Figure 3. Estimated BCR and top 5 key parameters ranked by their effect on the BCR (PNC228)

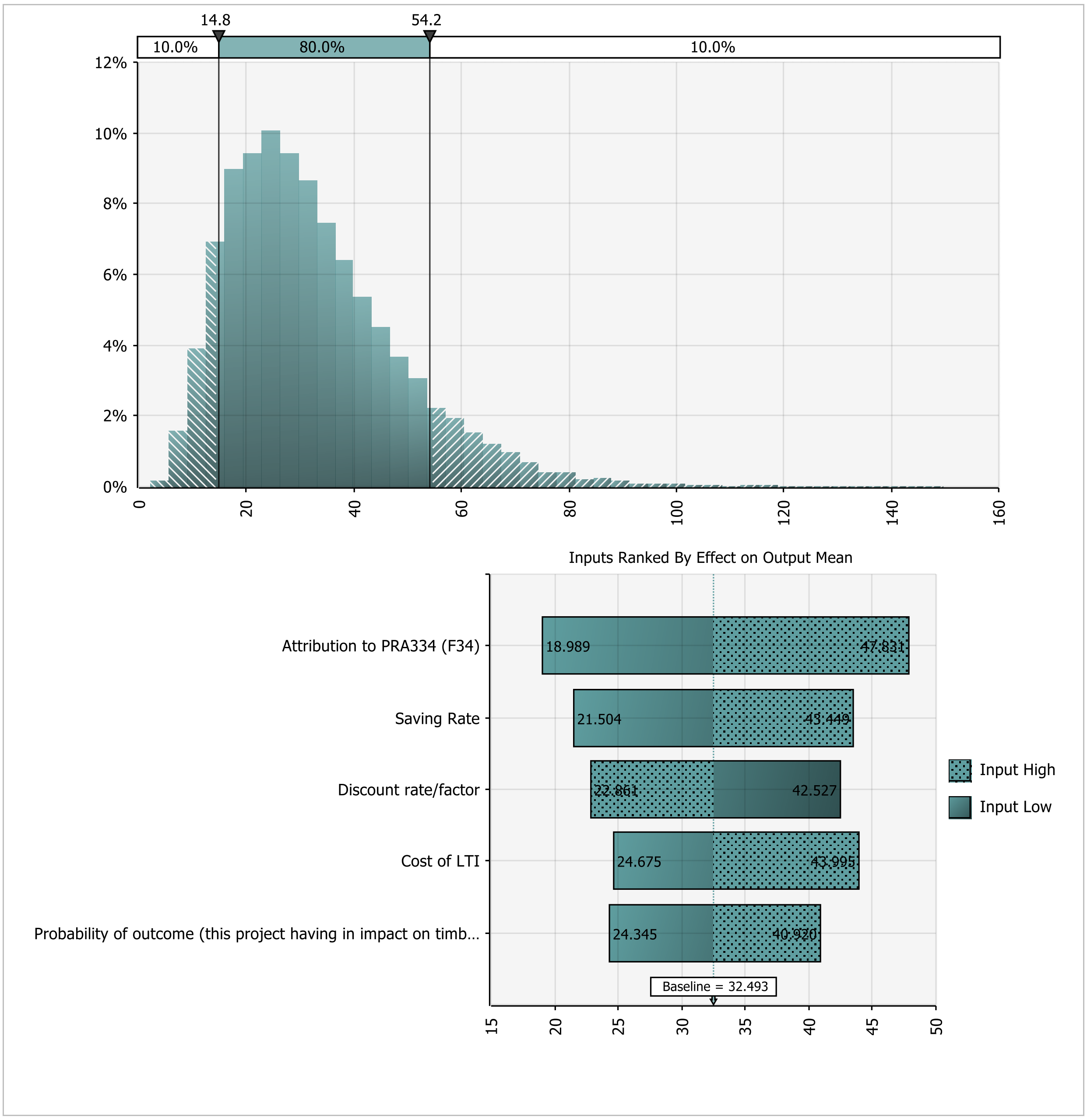

Figure 4. Estimated BCR and top 5 key parameters ranked by their effect on the BCR (PRA334)

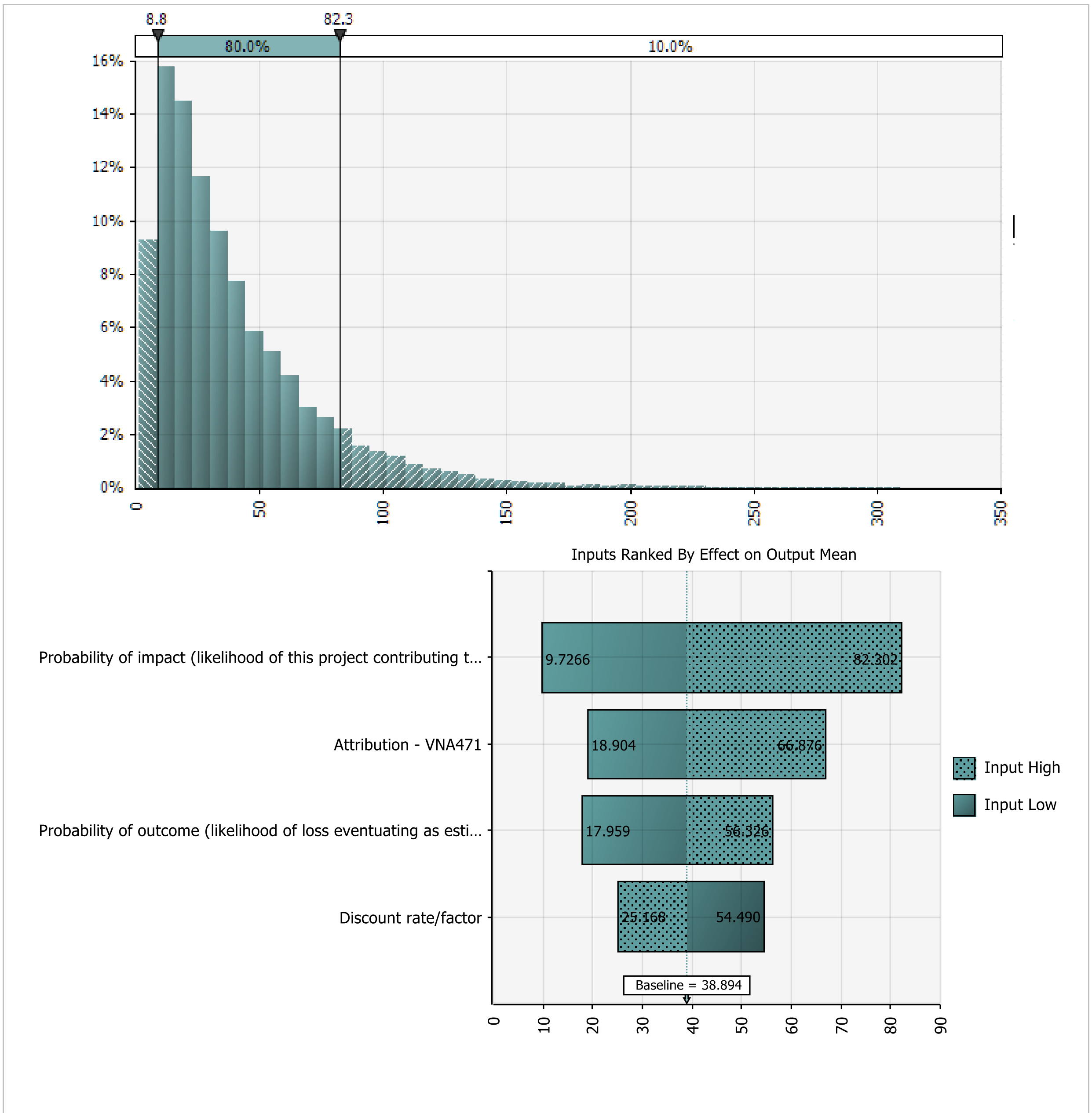

Figure 5. Estimated BCR and top 5 key parameters ranked by their effect on the BCR (VNA471)

6.3 Confidence rating for benefits coverage and assumptions

Table 13 presents the assessment of the level of confidence in the benefits that have been included in the economic assessment. It also provides the level of confidence in the assumptions underpinning the benefits assessment.

In general, we have medium-high confidence in the benefits covered. We have low-medium confidence in the assumptions underpinning the assessment. Where low, medium and high confidence ratings are as defined by Agtrans Research (2016):

- High confidence indicates a good coverage of benefits or reasonable confidence in the assumptions made
- Medium confidence indicates only a reasonable coverage of benefits or some uncertainties in assumptions made

- Low confidence indicates a poor coverage of benefits or many uncertainties in assumptions made

Table 13. Level of confidence in benefits coverage and assumptions

Project	Benefits coverage	Assumptions
PNA371	Medium	Medium-High
PNC228	Medium-high	Low
PRA334	Low-medium	Low
VNA471	Medium	Low

7 CONCLUSIONS

Four FWPA funded projects were analysed to identify and quantify their impacts. All four projects were found to have benefits to the levy paying industry and community at large. Not all benefits identified were quantified and this is an outcome of data challenges.

The CBA results indicate that all four projects were viable. The estimated benefit-cost ratios were 6, 7.8, 20.4 and 8.5 for project PNA371, PNC228, PRA334 and PNA317, respectively. These benefit cost ratios are an outcome of the quantified benefits and the assumptions made. A conservative approach was applied to all valuation. Furthermore, Monte Carlo Simulations were undertaken to investigate the effect of uncertain parameters on the estimated results. Future monitoring and evaluation of impacts and overall adoption will provide more refined estimates of benefits.

Across all projects, the levy paying industry is expected to benefit through the capturing of demand that previously accrued to other industries (e.g. concrete, masonry and steel suppliers) and through avoided potential future losses from climate change effects and outcomes from the Water Action Plan in South Australia. The CBA estimates were undertaken at a high level (society level) and only the net impacts were quantified. Thus, the benefits quantified are those accruing the whole Australian economy.

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APPENDIX A: PATHWAY TO BUILD TIMBER FRAME HOUSES IN A TRADITIONALLY DOUBLE BRICK MARKET (PNA371)

Background

Residential house construction in Perth, Western Australia (WA) is traditionally through masonry walls (double-bricks). However, builders had expressed some frustration with this building approach due to high bricklaying costs and shortages of bricks during periods of high demand. These shortages often led to costly construction delays. There was also a diminishing supply of skilled labour for bricklaying as older bricklayers exited the industry and their skills were not being taken up by sufficient younger workers. Builders were seeking solutions on how to overcome obstacles for timber frame building on reactive soils, to reduce building times, lower their building costs and respond to shortages of skilled labour.

Project Details

The project's principal investigator was Greg Meachem of Timber Insights. The project's commenced in 2015 and the final report was received by FWPA in 2017.

Objectives

There primary objective for this project was to develop a technical transfer package targeting the WA design and construction community identifying innovative technical solutions for construction of light-weight residential housing on non-standard reactive soils.

Costs

The project costs to FWPA and others (including in-kind contributions) are provided in Table 14. FWPA's contribution was in the form of cash while other investor's contributions where both cash and in-kind. Other investors for the project were James Hardie Building Products, CSR Gyprock, Wespine Industries, TimberLink Australia and ITW Australia (Pryda).

Table 14. PNA371 project costs (nominal values in $)

Funding source	2016	2017	2018	Total
FWPA (cash contributions)	103,400	98,700	32,900	235,000
Others (cash and in-kind contributions)	141,757	135,457	47,257	324,471
Total	245,157	234,157	80,157	559,471

Source: Project Statement of Work (2015)

Description

The output Builders' User Guide was intended to underpin growth in timber-framed construction in the residential builder market in the Perth metropolitan area as: (1) the logical material and system to substitute for double brick, and (2) the preferred choice when building on reactive clay soil sites. The goal was that timber-framed construction would then continue to gain momentum in the Perth house building market, with builders having the mechanisms in place to effectively market, specify and construct light-weight timber frame houses. The project also provided guidelines about building boundary walls as a result of an increasing need for houses to be designed and built with boundary walls in narrow and small lot sites.

Outputs

The project reported the following outputs:

- Two building industry seminars were held in Perth and Bunbury to launch the Builder User Guide and present a summary of the contents to builders, designers and specifiers. The seminars were attended by over 160 participants.
- Further one-on-one consultations were undertaken with industry to promote timber-framed housing solutions and the Builder User Guide (Meachem, pers. comm. 2020).
- Implement a Builder User Guide distribution over six weeks by post and direct delivery through the steering group members, technical marketing staff, visits to sites and specifier offices.
- Builder User Guide for construction of timber-framed housing in WA. This guide includes:
    - Sales and marketing information on the benefits of timber-framed housing,
    - Design and specification information,
    - Construction guide,
    - Additional support resources,
    - Truss and frame manufacturers information in Perth and regional areas in WA,
    - Typical construction schedules, and
    - Checklist for onsite quality control.
- Undertook a post Builder User Guide release survey to gather feedback.
- Attended a national timber-framing conference in Melbourne.
- Printed and electronic versions of the Builder User Guide were distributed to key national suppliers and contacts associated with the WA market (Meachem, pers. comm. 2020).
- A report on the impacts of building on reactive clay soils, distribution of occurrence of reactive soils around the Perth metropolitan area and regional centres, and the cost-effectiveness of light-weight timber frame construction on reactive soils.

Outcomes

- Increased use of timber for building houses in the Perth. In 2020, it was estimated that the use of lightweight framed construction had grown by up to 12% from 2-3% since 2015/16. Industry feedback indicates that the Builders User Guide has had a positive impact in the adoption of timber frames, however assignment of a percentage impact is difficult (Meachem, pers. comm. 2020).
- Enhanced ability to build in reactive clay soil sites in a more cost-effective way. A full masonry house in an S1 site class requires more than double the foundation concrete volume, for an M class site the difference is much greater with a full masonry house requiring 8 times more of the foundation volume concrete.
- Enhanced ability of builders to market, specify and construct light-weight timber-framed houses in WA.
- Increased demand for Australian timber products by the Perth house construction sector.
- Increased demand for building materials that are complementary to timber-frame houses (e.g. plasterboards, nail-plates, fasteners, bracers, and external cladding materials).
- Reduced construction time for residential houses in Perth metropolitan area. It is estimated (in the Builder User Guide) that construction time will be reduced by up to 6 weeks for 225m^2 single storey house compared to a double brick house (Timber Insights, 2017).
- Improved dwelling thermal performance.
- Increased internal floor space by about 9-10m^2 (i.e. 4%) for a standard 250m^2 home as reported in the Builder User Guide.[5]

[5] Timber Trader News (2017)

- Contribution to positive environmental impact due to the use of timber. Timber is an environmentally friendly and renewable building material.
- Improved structural flexibility that allows future upgrades and modifications.

Benefits

- Potential reduced construction costs for builders in Perth metropolitan area.
    - More cost-effective foundations and earthworks.
- Potential reduced house completion times for builders.
- Homebuyers cost-savings through shorter construction timeframes
    - A frame clad single-storey house (225m^2) will accelerate the construction by up to 6 weeks relative to a full masonry house (Timber Insights, 2017).
- Increased revenue for suppliers of timber and complementary building materials for building a timber-frame house.
- Additional space for homes valued at between $950-$2,600 per m^2, based on an average dwelling size of 236.5 m^2 (ABS, 2019; BuildSearch, 2018).
- Contribution to positive environmental impact due to the use of timber. Timber is an environmentally friendly and renewable building material

Table 15. Model parameters for use in calculating project benefits

Parameter	Input value (with range in brackets)	Source
Dwelling approvals	Average	ABS (2020) and 5-year historical average for 2020-2044
Estimated annual house construction commencement based on house approvals	83% (+/- 10%)	Estimated proportion of construction commencement based on house approvals and historical construction commencement in WA.
Average dwelling size (m^2)	236.5 (+/-10%)	ABS (2019)[6]
Dwelling cost per m^2	1,255 (950-2,600)	ABS (2019) and BuildSearch (2018)
Estimated construction of timber-framed houses	12% in 2020 and 20% by 2030	NCE assumption. Conservative estimate based on information from Timber trade (2017), Project Milestone Report 6 and Meachem, pers. comm. (2020).
Confidence in the reported and forecasted construction of timber-framed houses	100% to 2020 (reported), then a forecasted confidence of 95% in 2021 to 20% by 2048	NCE conservative estimate. Based on reported construction data, consultation, and a conservative estimate about forecast adoption.
Construction time saving (weeks)	6 (4-8)	Upper limit based on the Builder User Guide (Timber Insights 2017)
Avoided average weekly rent in Perth ($ per week)	350 (295-420)	Housing Industry Forecasting Group (2019).
Average increase in internal space from timber-framed construction (%)	3% (1-4%)	High value based on estimates reported by Timber Trader (2017) for a 250m^2 house.

[6] https://www.abs.gov.au/ausstats/abs@.nsf/Lookup/8752.0Feature+Article2Dec%202018

Parameter	Input value (with range in brackets)	Source
Estimated proportion of houses being built by people who are currently renting their dwelling (exclude developers, investors and those staying rent free e.g. at home)	20% (15-25%)	Conservative assumptions. NCE estimate based on the ratio of renters to homeowners and allowing for the fact that not all new houses will be taken up by people who are currently renting their homes.
Estimated house construction site class A, S1, S2, S3, S4, M	90% for A, 6% for S1 and 1% for each of the remaining four site classes	Meachem, pers. comm. (2020).
Volume of concrete saved when timber-framed approach is used across the different site classes (A, S1, S2, S3, S4, M) in m^3	0.1, 7,8, 11,12, and 35 for A, S1, S2, S3, S4, and M respectively. Only the concrete savings associated with construction in poor class sites (S3 to M) were used to estimate the benefits.	Timber Insights (2017) and NCE conservative estimates.
Cost of reinforced concrete in Perth ($/$m^3$)	289	Rawlinsons Australian Construction Handbook (2020).
Attribution of estimated benefits to project	2.5% (1-5%)	NCE conservative estimate.
First year of benefit	2018	NCE estimate.

APPENDIX B: ADAPTATION STRATEGIES TO MANAGE RISK IN AUSTRALIA'S PLANTATIONS (PNC228)

Background

Australia is experiencing significant changes in climate. The number of days with maximum temperatures has accelerated a lot more in the last two decades and average annual rainfall has declined. It was expected that these trends are likely to continue into the future. Changes in climate and an increased frequency of extreme weather events is expected to impact the short- and long-term productivity of plantations. To improve resilience and reduce vulnerability for Australian plantations, the National Climate Change and Commercial Forestry Action Plan 2009 – 2012 recommended assessing climate change risks and creating tools to help understand the best way to intervene. There were no tools that were previously available to simultaneously achieve both recommendations. This was recognised as an impediment to climate change adaptation.

Project Details

The project's principal investigator was Libby Pinkard from CSIRO. The project commenced in 2011 and was completed in 2014.

Objectives

The objectives of this project were to:

1. Provide forest managers with information on how climate variations would alter stand productivity, wood properties and indirect climate change hazards by updating national predictions and discussing them with industry.
2. Develop tools to help industry participants understand the direct and indirect consequences of climate change and climate variability and to provide the knowledge to use these tools.
3. Use the tools developed to assess adaptation strategies for climate change and climate variability and to promote industry understanding and uptake.

Costs

The project costs to FWPA and others (including in-kind contributions) are provided in Table 16. Other investors included CSIRO, University of Tasmanian and Western Sydney who made both cash and in-kind contributions.

Table 16. PNC228 annual project costs, nominal values for financial year ending June (annual cash and in-kind contributions)

Funding source	2011	2012	2013	2014	Total
FWPA (cash contributions)	101,714	101,714	101,714	175,252	**480,393**
Others (cash and in-kind contributions)	159,432	159,432	159,432	231,543	**709,839**
Total	261,146	261,146	261,146	406,795	**1,190,232**

Source: Based on final audited financial project report (2015)

Description

This project used modelling to understand how a range of future climate scenarios will affect productivity and wood properties across several plantation locations in Australia. This was followed by an investigation into how different management practises could help mitigate forecasted negative impacts. The modelling of climate change and climate variability forms the basis of a decision support tool which can be used by plantation managers to better understand site-specific impacts. For this project to be completed, national assessments of plantation productivity for 2030 and 2050 were required to be updated. Project results were presented with considerations for their level of uncertainty.

The following sections outlines the project outputs as outlined in the project milestone and final reports, as well as from consultations with the project team. The outcomes and benefits were identified from the reports and developed through research and consultation with industry experts.

Outputs

The project reported the following outputs:

- Updated the national assessments of plantation productivity for 2030 and 2050.
- Quantified the threats to productivity, carbon stocks and wood products from climatic variability and associated changes in drought, pests and fire.
- Defined uncertainty associated with estimated threats to productivity, carbon stocks and wood products.
- Used a sample of locations to undertake the modelling analysis, sites where water was likely to become a limiting factor for productivity were prioritised for assessment.
- Determined the adaptive capacity of current management practices, and where new production systems (e.g. new species, new products) may instead be required.
- Identified adaptation strategies for the current plantation estate and the effects of these on productivity and wood properties.
- Developed tools to assist industry decision-making around hazard and productivity management in Australia's plantations.
- Updated the forest productivity model, Carbon BALAnce (CABALA).
- This project delivered nine reports including a final report which gives an overview of the main findings as well as eight region specific reports which break down the findings into greater detail. The reports provide summaries of the key changes expected for production, survival, wood properties and pest and fire hazard expected to take place by 2030. The nine reports from this project are:
    - Adaptation strategies to manage risk in Australia's plantations
    - Regional report 1: South west Western Australia eucalypt plantations
    - Regional report 2: South west Western Australia radiata pine plantations
    - Regional report 3: Green Triangle eucalypt plantations
    - Regional report 4: Green Triangle radiata pine plantations
    - Regional report 5: Eastern Victoria/southern NSW eucalypt plantations
    - Regional report 6: Eastern Victoria/southern NSW radiata pine plantations
    - Regional report 7: Tasmania eucalypt plantations
    - Regional report 8: Tasmania radiata pine plantations
- Three face-to-face industry workshops and webinar were held. The first workshop was in March 2012 and focused on co-design of the project deliverables. The remaining workshops were held in 2014 and these focused-on presenting the project results (Pinkard, pers. comm., 2020).
- Published research media article titled "Predicting climate impacts".[7]

[7] This can be accessed at http://www.internationalinnovation.com/build/wp-content/uploads/2014/10/p70-71_Libby_Pinkard_Intl_Innovation_159_Research_Media.pdf

- Undertook industry consultation, both in person and via phone, to assist with the adoption of project outputs. The consultation was to provide an opportunity for more in-depth discussion of the implications of the research findings for their businesses. The response was positive and particularly in more vulnerable regions such as south west Western Australia (Pinkard, pers. comm., 2020)
- A spatial database for predicting production and survival for five climate models at three time periods (2014, 2030 and 2050). There has been some industry interest in accessing these layers through the CSIRO's data access portal (Pinkard, pers. comm., 2020).
- Held an online presentation to share projects results with the wider industry and stakeholders
- Provided recommended adaptation strategies for management of climate change hazards for the most common plantation species.
    - For *Eucalyptus globulus*, these included: altering initial spacing to manage water stress and fertilising to promote crown development following pest attacks.
    - For *Pinus radiata*, these included: altering initial spacing to manage water stress, reducing the number of thinnings and thinning later to fully utilise the site and reducing the rotation length to minimise exposure to extreme events.
- The impact of a range of these adaptation strategies were explored through modelling to understand their effect on productivity and mortality. This was done for a selection of sites where production is expected to fall by at least 5% by 2030, with more sites being included in regional summaries.
- The results for *P. radiata*, focused on two main adaptation strategies to combat drought and control leaf area. These were increasing the initial stocking rate from 1,333 stems per hectare (sph) to 1,600 sph and reducing the number of thinnings from 3 to 2 thinnings. In most instances, these strategies improved productivity relative to the base case. However, the impact on mortality of these strategies was not able to be captured.
- The results for *E. globulus*, focused on two main strategies to combat drought and control leaf area. The first strategy of reducing the number of stems per hectare from 1,000 sph to 800 sph in some case reduced mortality without significantly altering productivity. On the other hand, increasing fertiliser may improve productivity but it may also increase mortality. At some sites, reducing spacing may decrease the mortality risk associated with fertilising, while at other sites it may increase it, as such, the trade-off between risk and productivity must be considered.
- Regional results indicated that the south west WA was the most vulnerable region (Pinkard, pers. comm., 2020).

Outcomes

- Improved industry understanding about the plantation industry's adaptive capacity through changes in management practices and when adaptation is more appropriate than other forms of intervention.
- Increased awareness among industry participants of how changes and variability in climate can affect plantation productivity and wood properties.
- Enhanced industry understanding of adaptive strategies and their potential benefits.
- Contribution to improved forest industry's ability to predict and manage climate change impacts and better manage risks to timber quality and plantation productivity.

Benefits

- Potential avoided industry productivity losses from adoption of improved management strategies.
- Contribution to medium- and long-term industry sustainability in the face of a changing climate and an increased frequency of extreme weather events.

- Potential contribution to avoided welfare issues for plantation owners and their employees.

Table 17. Model parameters for use in calculating project benefits

Parameter	Low	Most likely	High	Source
Gross value of plantation hardwood ($m) - 5-year average to 2017/18	618	687	756	ABARES (2019), Assumed (+/- 10%)
Gross value of softwood ($m) - 5-year average to 2018/19	1,176	1,307	1,438	ABARES (2019) Assumed (+/- 10%)
Estimated average avoided productivity loss for hardwood plantation (*e. globulus*)[8]	2%	5%	15%	Conservative NCE estimate and consultation with Pinkard pers. comm. (2020)
Estimated average avoided productivity loss for softwood plantation (*p. radiata*)	2%	5%	15%	
Proportion of industry affected – hardwood	10%	30%	50%	
Proportion of industry affected – softwood	10%	30%	50%	
Adoption level in affected areas	10%	50%	60%	
Probability of losses occurring as estimated (across all plantations)[9]	10%	20%	40%	
Attribution of benefit to PNC228	10%	25%	75%	

[8] Likely average loss that could be avoided by implementing some or all the strategies in the report

[9] For those that implement the strategies, what is the average likelihood that the loss will indeed be avoided?

APPENDIX C: LIFE CYCLE ASSESSMENT OF A FIVE STOREY RESIDENTIAL BUILDING IN PARKVILLE (PRA334)

Background

In Australia, 5 to 6 storey buildings have traditionally been designed and built using 'heavyweight' materials such as steel, precast concrete panels and concrete slab floors. Australand has developed a 'lightweight' method of construction for these types of building. Their approach relies more on timber and incorporates prefabrication to speed up the construction process.

The use of timber, instead of concrete, can have relatively lower negative environmental impacts. A life cycle assessment (LCA) can be used to compare environmental benefits between projects. The LCA method allows benefits and costs from every stage of projects life to be compared rather than a focus on a single stage or aspect.

Project Details

The project's principal investigators were Mr Andrew Carre and Dr Edna Crossin of RMIT University. The project was undertaken in 2014 and a final report was received by FWPA in July 2015.

Objectives

The primary objective of this study was to compare the potential environmental impacts of two multi-storey building in Parkville, Victoria. The 'study' building incorporates the innovative lightweight design approach of Australand while the 'reference' building relies on more traditional, concrete heavy, methods.

Secondary objectives of this study were:

- To compare the outcomes of this study to the life cycle assessment of the Forte building.
- To determining the green star points that may be earned by the study building under the Green Building Council of Australia's Innovation Challenge – Materials Life Cycle Impacts.

Costs

The project costs to FWPA and others (including in-kind contributions) are provided in Table 18. FWPA's contribution was in the form of cash, with its funding coming from the Department of Agriculture, Fisheries and Forestry. Other investor contributions came from Australand.

Table 18. PRA334 annual project costs, nominal values for financial year ending June (annual cash and in-kind contributions)

Funding source	2014	Total
FWPA (cash contributions)	26,400	26,400
Others (cash and in-kind contributions)	5,100	5,100

Source: Project Statement of Work (2014)

Description

This study used a LCA to compare the environmental impacts of two multi-storey buildings. These two buildings differed in structure, with the 'study' building incorporating a more 'lightweight' design than is traditionally used. Six environmental impacts were considered for each building over a 60-year time span. These impacts were: climate change, stratospheric ozone depletion potential, acidification potential of land and water, eutrophication potential, photochemical oxidation (smog) and mineral and fossil fuel depletion (abiotic depletion). To ensure a fair comparison, the environmental impacts of each building were presented on a per meter of gross dwellable area (GDA) basis. The GDA of a building includes the area inside each apartment as well as the balcony. The study building was found to have a reduced level of impact in 3 of the 6 categories, with most of its environmental advantages coming from its reduced use of materials.

The following sections outlines the project outputs as outlined in the project milestone and final reports, as well as from consultations with the project team. The outcomes and benefits were identified from the reports and developed through research and consultation with industry experts.

Outputs

The project reported the following outputs:

- Undertook an environmental impact assessment using six impact categories: climate change, ozone depletion, acidification, eutrophication, photochemical oxidation and abiotic depletion.
- The LCA was undertaken according to ISO14044.
- The study building was found to perform better in most of the environmental impact categories by comparison to the reference building.
    - Climate change: 2% better, ozone depletion: 17% better, abiotic depletion: 3% better
- In the photochemical oxidation category, the reference building was found to be 9% better than the study building. This is a result of the expected emissions from timber as it degrades in landfill and transport related emissions associated with the material supply chain.
- Performance results for the eutrophication and acidification impact categories were found to be inconclusive.
- The advantages of the study building compared to the reference building were centred around its lightweight design which used about 30% less materials and the use of lower intensity materials.
- The study building was not well rewarded in terms of Green Star points, with the scheme being found to reward operational performance more than innovation in materials. The study building was awarded a score of 1.6 out of 6. However, the green star points were granted under the Green Building Council of Australia's Innovation Challenge program, which was intended to be further refined.
- This project produced a final report, "*A comparative life cycle assessment of two multi storey residential apartment buildings*" which is currently publicly available through ResearchGate.

Outcomes

- Enhanced ability to demonstrate the environmental benefits of using a 'lightweight' timber construction approach instead of a more traditional concrete heavy approach for mid-rise buildings. Over the long term, this would be expected to increase the use of wood in mid-rise construction and reduce the use of concrete

- Increased awareness and knowledge about the environmental advantages of using a 'lightweight' timber construction approach instead of a more traditional concrete heavy approach. Over the long term this would be expected to increase the use of wood in mid-rise construction. reduce the use of concrete

- Potential increased demand for Australian timber products to support mid-rise timber buildings.

- Potential increased demand for building materials that are complementary to timber-frame houses (e.g. plasterboards, nail-plates, fasteners, bracers, external cladding materials, etc).

- Upskilling of domestic trades to better enable the construction of mid-rise timber buildings

- Enhanced industry knowledge about the benefits (time savings and materials) that can be achieved by using a 'lightweight' timber construction approach that incorporates prefabricate systems instead of the more traditional approach which incorporates precast concrete panels.
- Potential contribution to an increase in the amount of medium-rise housing in outer suburbs where concrete construction is not economically viable.
- Reduced environmental cost over projects lifecycle
    - Climate change (2.2% lower impact or saving of 89.6 kg CO_2 equivalent per m^2 of GDA over 60 years).
    - Reduced ozone depletion (17.3% lower impact savings of 5.5 mg of CFC-11 equivalent per 1 m^2 over 60 years).
    - Reduced abiotic depletion (2.5% lower impact or savings of 0.7 kg of SB equivalent per 1 m^2 over 60 years).
- Reduced environmental cost excluding use phase of project
    - Climate change (22.2% lower impact or saving of 107.6 kg CO_2 equivalent per m^2 of GDA over 60 years).
    - Reduced ozone depletion (30.1% lower impact savings of 5.5 mg of CFC-11 equivalent per 1 m^2 over 60 years).
    - Reduced abiotic depletion (32.4% lower impact or savings of 0.9 kg of SB equivalent per 1 m^2 over 60 years).

Benefits

- Lower construction costs through relatively quicker completion times, this was estimated at an average of 6-week construction time saving.
- Reduction in the risk of time lost to construction site related injuries.
    - Lendlease Australia has completed eight timber projects in Australia and they have not had a lost-time injury (LTI) on any of those projects. Typically, every traditional project in the mid-rise space will have at least one LTI due to the high-risk nature of the construction process.
- Reduced climate change impact with an emissions reduction of 89.6 kg CO_2 equivalent per m^2 of GDA over 60 years.
- Reduced transport impacts because of the reduced weight of construction materials
- Potential increase revenue for the timber industry.
- Potential improved housing affordability for buyers.

Table 19. Model parameters for use in calculating project benefits

Parameter	Input value (with range in brackets)	Source
Number of dwellings commenced (Flats, Units or Apartments - In a four to eight storey block)	27,422 (2016)	Five-year average to 2018 (ABS, 2019)
Annual growth rate in mid-rise apartments	10% (5% - 20%)	NCE conservative estimate based on ABS (2019)

Parameter	Input value (with range in brackets)	Source
Market share of wood in mid-rise buildings (EWP)	5% (2.5% - 10%)	Hardware Journal (2016)
Built costs (4-8 level unit complex, including lift, concrete structure, basement parking) ($/m^2)	2,752 (2,554 - 3,347)	BMT Quantity Surveyors (2020)
Average floor area of new apartments (m$^{2)}$	108.1 (101.8 – 122)	ABS (2019-b)
Value of reduced construction costs (%)	17.5 (10 - 25)	Jewell (2014)
Average number of incidences leading to LTI per build (Heavyweight)	1	Timber Trader News (2020)
Average number of incidences leading to LTI per build (Lightweight)	0.5 (0.25-1)	Timber Trader News (2020)
Cost of LTI ($/incident)	4,582.15 (2,291 – 9,164)	Sun & Zou (2010)
Reduced climate change impact (tonnes CO_2 eq per m^2 of GDA over 60 years)	0.0896	Carre & Crossin (2015)
Social cost of carbon dioxide ($/t$CO_2$)	70 (50 - 150)	ACT Climate Change Council (2018)
Probability of industry uptake	2 (1 - 3)	NCE conservative estimate
Proportion attribution to PRA334 (%)	2 (1 - 3)	NCE conservative estimate

APPENDIX D: ECONOMIC CONTRIBUTION OF THE FORESTRY INDUSTRY WITHIN THE GREEN TRIANGLE (VNA471)

Background

The Green Triangle is in the border region of South Australia (SA) and Victoria. It is Australia's largest collective plantation and wood processing zone and as a result it has a significant impact on the local economy. The plantation and wood processing area is over 6 million ha across South Australia and Victoria.

In 2013, the South Australian part of the Green Triangle was subject to a new Water Allocation Plan (WAP) which was developed as a result of the National Water Initiative (NWI). Its development created concerns for the South Australian forestry industry about the impact of changing water regulations and water use policies. In particular, South Australian based plantations were worried that consequent water allocation changes would impact their businesses through a reduction in their plantation estate, reduction in production capacity, and through reduced ability to optimise the use their plantation estate. The WAP was adopted in November 2013 and underwent a review in 2019.

Objectives

The projects objectives are as follows:

- To understand the economic contribution of the green triangle forestry industry to the South Australian economy.
- To outline the potential consequences of changing business decisions due to the WAP, and thus the impact on the local economy.

Costs

Table 20. VNA471 project costs (nominal values)

Funding source	2014	Total
FWPA (cash contributions)	52,000	52,000
Others (cash and in-kind contributions)	0	0

Source: Project Statement of Work (2018)

Description

The project involved an economic impact assessment of the Green Triangle forestry industry. The assessment was undertaken to determine the expected impacts of the WAP on the economy and involved collation of input data from consultations with the forestry industry.

Three measures we used to measure economic impact. These are total output, value add, and employment impacts. Total output is an indicator of the industry's production, value add is a measure of the wealth generated by the industry and employment is measure of the amount of labour used in the production process. The assessment of economic contribution project takes into consideration that the project was essentially assessment of economic losses as a result of the WAP. The project on its own will not deliver the benefits of avoiding the losses but will rather provide very important information that will potentially influence the decision-making process.

Outputs

- Estimated value of the impact of the WAP on the Green Triangle forestry industry.
- Estimated value of the impact of the WAP on forestry industry total output and value add to South Australia.
- Estimated impact of the WAP on regional employment.
- Attendance at two Green Triangle Forum meetings as part of industry consultation. Further consultation via teleconference.

Outcomes

- Enhanced understanding of the impact of the WAP on the South Australian forestry industry, South Australian Green Triangle forestry industry and the South Australian economy through industry output, value add and annual employment.
- Improved government decision making with regards to water allocations.
- Improved industry confidence leading to beneficial decision making with positive economic outcomes well into the future.

Benefits

- Contribution to potential avoided loss of forestry industry productivity.
- Contribution to potential avoided land retirement by plantation owners.
- Contribution to avoided loss in industry economic contribution through value add to the SA economy.
- Contribution to avoided loss of employment.
- Potential contribution to community welfare for plantation owners and their employees as well as the general supply chain.

Table 21. Summary of assumption used in the benefit valuation

Parameter	Input value (with range in brackets)	Source
Estimated average annual impact of WAP (loss in revenue)	37.6 (+/-20%)	EY (2019) Final report (sum of annual impact for both hardwood and softwood)
Probability of outcome (likelihood of loss eventuating as per EY estimates)	50% (10-75%)	NCE conservative estimate
Probability of impact (likelihood of project contributing to loss avoidance)	5% (2.5-50%)	NCE conservative estimate
Attribution	5% (2.5-15%)	NCE conservative estimate
Potential year of first benefit	2025	NCE estimate, assumes that the information will need to be considered in the 2023 review first.

APPENDIX E: ANNUAL UNDISCOUNTED CASHFLOWS

The following figures show annual undiscounted benefits and cash flow for the total investment over a 30-year appraisal period for each of the four projects. The flow of benefits is an outcome of the historical data, forecasted adoptions and impact levels assumed from each project.

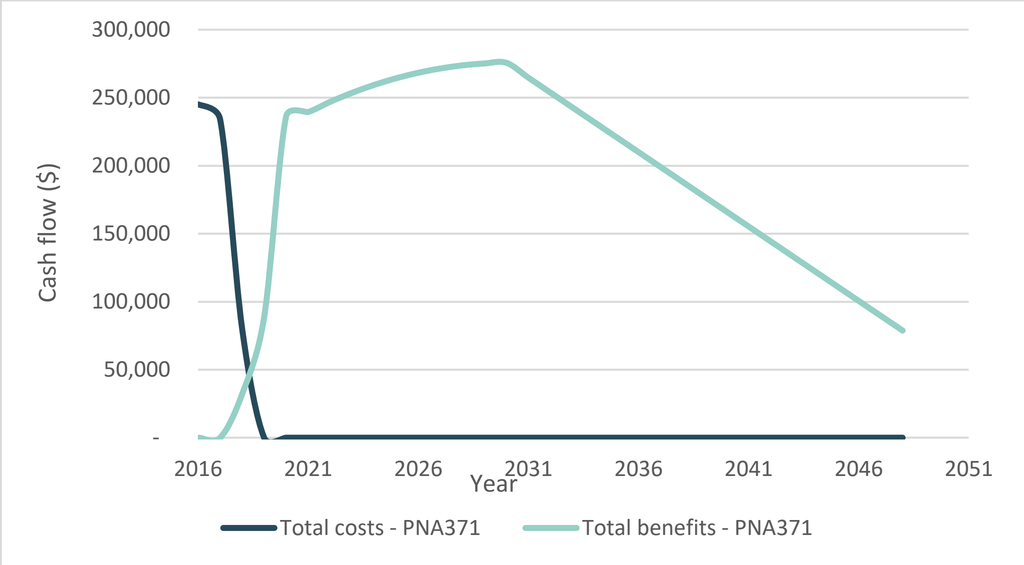

Figure 6. Annual cashflow of undiscounted total benefits and total costs for Project PNA371

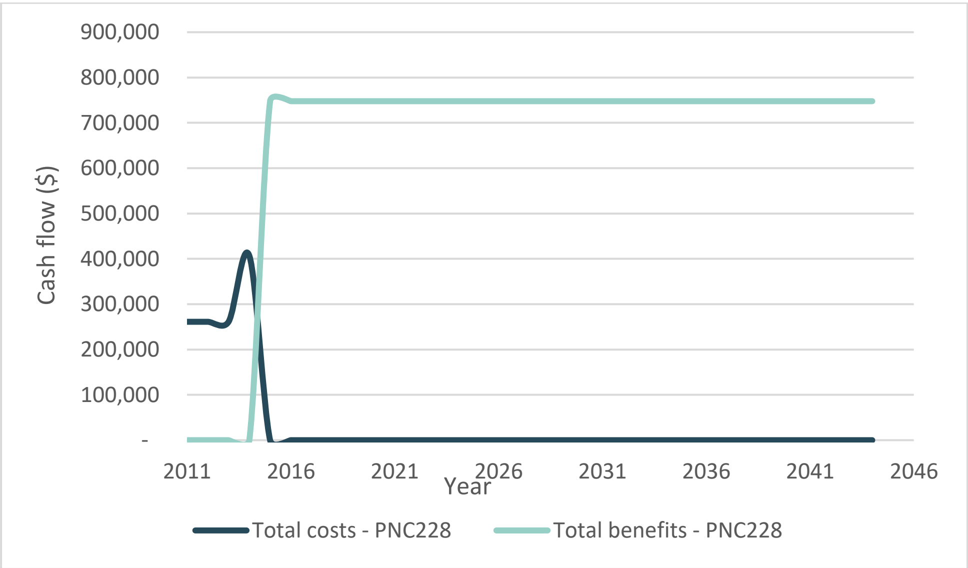

Figure 7. Annual cashflow of undiscounted total benefits and total costs for Project PNC228

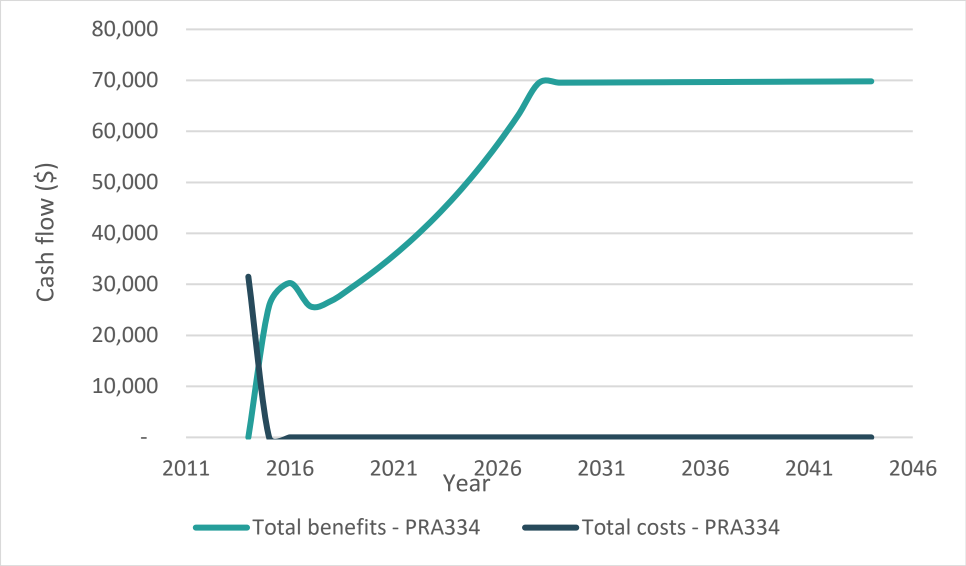

Figure 8. Annual cashflow of undiscounted total benefits and total costs for Project PRA334

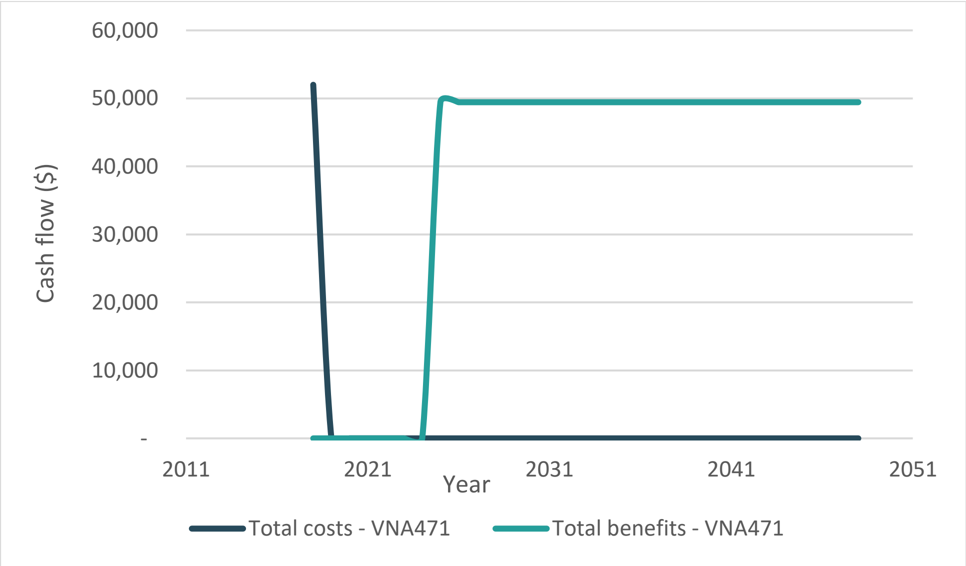

Figure 9. Annual cashflow of undiscounted total benefits and total costs for Project VNA471