An Impact Assessment of Investment by the Antarctic Climate & Ecosystems CRC in the 'Climate Futures for Tasmania' Initiative

Final Report

to

The Antarctic Climate & Ecosystems Cooperative Research Centre

March 2018

By

Agtrans Research

AGTRANS RESEARCH
Suite 36, Benson House, 2 Benson Street,
Toowong, Brisbane, Australia
PO Box 385, Toowong Qld 4066
Telephone: (07) 3870 4047 or (07) 3870 9564
Facsimile: (07) 3371 3381
E-mail: info@agtrans.com.au

Contents

Acknowledgments

Agtrans Research wishes to thank the following personnel for their contributions to the impact assessment process (in alphabetical order):

Barry White	Brisbane Consultant
Bryce Graham	Manager, Water Management and Assessment Branch, Department of Primary Industries, Parks, Water and Environment
Chris Irvine	Senior Planning and Education Officer, Tasmanian State Emergency Services
Deidre Wilson	Assistant Deputy Secretary, AgriGrowth, Department of Primary Industries, Parks, Water and Environment
Greg Carson	Water Operations Advisor, Hydro Tasmania
Guy Westmore	Plant Biosecurity and Diagnostics Branch, Biosecurity Tasmania
Jan Davis	Managing Director, Agribusiness Tasmania
Katrina Graham	Environment and Climate Change, Hobart City Council
Mark Kelleher	Chief Executive Officer, Antarctic Climate & Ecosystems CRC
Nathan Bindoff	Project Leader, Climate Futures for Tasmania, Antarctic Climate & Ecosystems CRC
Paul Smart	Technical and Extension Officer, Wine Tasmania
Phil Gee	Managing Director, Sugden & Gee Pty Ltd
Richard Rawnsley	Dairy Centre Leader, Tasmanian Institute of Agriculture
Robert Musk	Resources and Planning Manager, Sustainable Timber Tasmania
Snow Barlow	Emeritus Professor of Horticulture and Viticulture, University of Melbourne) and formerly Director of the National Climate Change Research Strategy for Primary Industries
Sophie Muller	Director, Tasmanian Climate Change Office
Ted Lefroy	Professor and Director, Centre for Environment, University of Tasmania

Glossary of Economic Terms

Benefit-cost ratio	The ratio of the present value of investment benefits to the present value of investment costs.
Discounting	The process of relating the costs and benefits of an investment to a base year using a stated discount rate.
Internal Rate of Return	The discount rate at which an investment has a net present value of zero, i.e. where present value of benefits = present value of costs.
Investment criteria	Measures of the economic worth of an investment such as Net Present Value, Benefit-Cost Ratio, Internal Rate of Return, and Modified Internal Rate of Return.
Net Present Value	The discounted value of the benefits of an investment less the discounted value of the investment costs, i.e. present value of benefits - present value of costs.
Present Value of Benefits	The discounted value of benefits.
Present Value of Costs	The discounted value of investment costs.

Acronyms & Abbreviations

APSIM	Agricultural Production Systems Simulator
AWI	Alfred Wegener Institute for Polar and Marine Research
ACE CRC	Antarctic Climate and Ecosystems Cooperative Research Centre
AAD	Australian Antarctic Division
ABS	Australian Bureau of Statistics
BCR	Benefit-Cost Ratio
BoM	Bureau of Meteorology
BTE	Bureau of Transport Economics
CEO	Chief Executive Officer
CFT	Climate Futures for Tasmania
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CRC	Cooperative Research Centre
CBA	Cost-Benefit Analysis
DPEM	Department of Police, Fire and Emergency Management (Tasmania)
DPIPWE	Department of Primary Industries, Parks, Water and Environment (Tasmania)
SEWPAC	Department of Sustainability, Environment, Water, Population and Communities
DEE	Department of the Environment and Energy
FFDI	Forest Fire Danger Index
GCM	Global Climate Model
GDP	Gross Domestic Product
GOS	Gross Operating Surplus
HDD	Heat Degree Days
A2	High Emissions Scenario
IPCC	Intergovernmental Panel on Climate Change
IRR	Internal Rate of Return
LISTmap	Land Information System Tasmania Map
LPH	Landscape and Policy Hub
B1	Low Emissions Scenario
NCCARF	National Climate Change Adaptation Research Facility
NERP	National Environmental Research Program
NPV	Net Present Value
R&D	Research and Development
RDC	Research and Development Corporation
RD&E	Research, Development and Extension
SEACI	South Eastern Australia Climate Initiative
SES	State Emergency Services
SST	Sustainable Timber Tasmania
TAS	Tasmania
TFS	Tasmanian Fire Services
TIAR	Tasmanian Institute of Agricultural Research
TSNDRA	Tasmanian State Natural Disaster Risk Assessment
TWWHA	Tasmanian Wilderness World Heritage Area
UTAS	University of Tasmania

Executive Summary

The Antarctic Climate and Ecosystems Cooperative Research Centre (ACE CRC) is Australia's longest continually funded CRC. Originally established in 1991 as the 'CRC for the Antarctic and Southern Ocean Environment' established and supported under the Australian government's Cooperative Research Centres (CRCs) Programme. It was refunded in 1997 as the 'CRC for Antarctica and the Southern Ocean', and in 2003 and 2010 as the 'Antarctic Climate and Ecosystems CRC'.

In 2008, the Tasmanian and Commonwealth governments, with the ACE CRC and other partners, funded the Climate Futures for Tasmania (CFT) project. The CFT project (hereafter referred to as the CFT Initiative) provided the first, fine-scale climate projections ever produced for the State of Tasmania. The CFT researchers downscaled six global climate models under both high (A2) and low (B1) emissions scenarios that allowed the Initiative to generate local-scale climate projections at a resolution of approximately 10 kilometres for the period 1961 to 2100.

The CFT Initiative was funded as an integrated assessment of the high resolution, dynamically downscaled climate models with operationally meaningful models. The Initiative addressed the need for relevant, locally specific information about expected changes to climate that reflected the highly variable topography of Tasmania and the many regional variations at a finer scale resolution than was available from global climate models (GCMs) and national scale climate models.

The five-year funding period for the current iteration of the ACE CRC is due to end by 30 June 2019. In October 2017, the ACE CRC contracted Agtrans Research to conduct an Impact Assessment of investment in the CFT Initiative. The impact assessment was funded to demonstrate the impact of a significant RD&E investment by the ACE CRC and partners. This assessment will also be provided as a cross-disciplinary impact study for the University of Tasmania Excellence in Research Australia 2018 submission.

The scope of this assessment has been limited to ACE CRC investment in 17 key CFT research, development and extension (RD&E) outputs completed as at 30 June 2017. The approach followed general impact assessment guidelines that are now well entrenched within the Australian primary industry research sector. The assessment used a logical framework approach to describe the CFT inputs and then qualitatively identified and described the key outputs and outcomes of the CFT investment. Economic, environmental and social impacts then were identified and described.

A 'key users survey' was undertaken as part of the impact assessment approach to determine the primary outcomes of the CFT investment. The impact assessment team contacted a number of key personnel identified as being associated with the outcomes of the CFT Initiative. Responses received then were collated and examined, and the results analysed to identify and describe the key outcomes and impacts for the CFT impact assessment.

Following the qualitative descriptions completed using the logical framework, cost-benefit analysis (CBA) was carried out for those impacts identified that could be valued in monetary terms. The CBA focused on economic impacts where clear, logical pathways existed from the CFT Initiative outputs through to actual or potential future impacts, and for which there were sufficient data available in the background literature to make reasonable assumptions.

Thirteen impacts were identified and described in the impact assessment. Of the thirteen impacts identified, six were not valued in monetary terms. The key reasons for some impacts not being valued include insufficient resources/time the envisaged difficulty in assembling appropriate data, and/or complexity of developing reliable specific assumptions. Nevertheless, many of the impacts not valued would contribute significantly to the total value of the CFT Initiative. In particular, the improved protection afforded the cultural heritage value of the Tasmanian Wilderness World Heritage Area is potentially a significant omission and further economic analysis of this impact could be warranted. Further, because of the usefulness of climate futures information to general economic and community well-being, there are likely other impacts that have not been covered by the 13 impacts identified in this assessment.

For the seven impacts identified that were valued in monetary terms, all investment costs and benefits were expressed in 2016/17 dollars using the GDP Implicit Price Deflator. All costs and benefits were discounted to the 2016/17 year using a discount rate of 5%. The base analysis used the best estimates of each variable, notwithstanding a high level of uncertainty for some of the estimates. Investment criteria were estimated for the total investment in the CFT projects over the years 2007/08 to 2016/17.

The investment in the CFT Initiative for the period 2008-2017, based on the best bet assumptions made and sensitivity analyses of key variables, has been estimated to produce a present value of benefits of between $21.5 million and $86.5 million (present value terms) from total investment costs of approximately $16.4 million (present value terms). This produced a net present value of between $5.1 million and $70.0 million and a benefit-cost ratio of between 1.3 and 5.3 to 1. The best estimate benefit-cost ratio of approximately 2.6 to 1 is within the range of benefit-cost ratios for other CRCs and other climate RD&E programs that have been estimated over the past ten years by Agtrans Research.

While there is no doubt that the CFT Initiative has produced important and relevant information, the estimation of attribution to the CFT regarding changes in preparedness planning, strategy development and operational decision making was challenging, particularly in relation to the specific impacts subjected to valuation. The magnitude of the attribution factors varies somewhat between impacts and each has been based on the strength of evidence available. In most cases the approach taken has been to conservatively attribute only marginal or small changes to estimate each of the CFT impacts.

A changing climate will affect most sectors and industries, as well as all types of communities. The CFT investment has contributed significantly to preparedness for future climate change in Australia, and particularly in Tasmania. The CFT Initiative has created greater awareness, understanding and knowledge that otherwise would not have occurred in its absence. The survey of representatives of various sectors where impacts have been identified has provided a high level of supporting information to the difficult assumptions that necessarily had to be made for the cost-benefit analysis. However, there were still some assumptions that had to be made with limited evidential support.

The data assembled from the key user survey was not only useful in supporting best-bet assumptions for the cost-benefit analysis, but also contributed to the description of the pathway to impact via definition of outputs, outcomes and impacts from the various CFT investments. For example, users were asked to rate five key characteristics of the CFT outputs (finer scale of prediction and time lines, increased confidence for future planning, sector specific relevance of CFT outputs, meaningful communication of CFT outputs, and more specific information on future risk profiles). The sector specific relevance of the CFT outputs was the highest rated characteristic. The survey results indicated that sector specific information and the ability to improve communication of climate futures research were characteristics of significant value to key users of the CFT outputs. In fact, the enabling functions of public and private sector engagement and communication were considered critical factors in ensuring delivery of the overall impact of the Initiative.

The conservative assumptions made in the CBA, combined with only a medium coverage of impacts, and the omission of the value of current projects that are underpinned by methods developed within the CFT, are likely to have resulted in an underestimate of the investment criteria.

Nevertheless, the best estimate of the net present value of $26.6 million is an outstanding result and should be viewed positively by the ACE CRC, its research and funding partners, industry and other key stakeholders.

1. Introduction

1.1 Background

The Antarctic Climate and Ecosystems CRC

The Antarctic Climate and Ecosystems Cooperative Research Centre (ACE CRC) is Australia's longest continually funded CRC. Originally established in 1991 as the 'CRC for the Antarctic and Southern Ocean Environment' established and supported under the Australian government's Cooperative Research Centres (CRCs) Programme. It was refunded in 1997 as the 'CRC for Antarctica and the Southern Ocean', and in 2003 and 2010 as the 'Antarctic Climate and Ecosystems CRC' (ACE CRC, 2015a).

The current iteration of the ACE CRC is a collaborative partnership of seven core members and many other important participants. The seven core members comprise the University of Tasmania (UTAS), The CSIRO Division of Marine and Atmospheric Research (CSIRO), The Australian Antarctic Division of the Australian Department of the Environment (AAD), The Australian Bureau of Meteorology (BoM), The Alfred Wegener Institute for Polar and Marine Research based in Germany (AWI), The Australian Department of the Environment and Energy (DEE), and the National Institute of Water and Atmospheric Research in New Zealand (NIWA) (ACE CRC, 2015b).

The ACE CRC is housed in the UTAS Waterfront Building in Hobart and is Australia's primary research, development and extension (RD&E) agency that works to understand the role of the Antarctic region in the global climate system, and the implications for marine ecosystems. The aim of the ACE CRC is to provide governments and industry with accurate, timely and actionable information on climate change and its likely impacts (ACE CRC, 2015c).

The Climate Futures for Tasmania Project

In 2008, the ACE CRC and partners funded the Climate Futures for Tasmania (CFT) project. The CFT project (hereafter referred to as the CFT Initiative) provided the first, fine-scale climate projections ever produced for the State of Tasmania. The CFT researchers downscaled six global climate models under both high (A2) and low (B1) emissions scenarios that allowed the Initiative to generate local-scale climate projections at a resolution of approximately 10 kilometres for the period 1961 to 2100 (ACE CRC, 2015d).

Between 2010 and 2012, the ACE CRC published seven key CFT reports that presented the local-scale climate data as well as specific climate impact information for key sectors likely to be affected by climate change such as Tasmanian agriculture, water and catchments, and extreme tide and sea-level events.

The CFT Initiative is an ongoing part of the ACE CRC's RD&E investment and has continued to produce useful and important climate change information by building on the original climate modelling work. Outputs of the Initiative include additional sector specific climate impact and risk reports, climate change decision support tools and other information. Apart from the inherent value of these outputs, the management of the process of engagement and communication with information users was a key contributor to the overall impact of the Initiative.

The CFT Initiative Impact Assessment Report

The five-year funding period for the current iteration of the ACE CRC is due to end by 30 June 2019 (ACE CRC, 2015e). As this funding period comes to an end, the CRC is required to report on its overall performance and the impact of RD&E projects funded by the ACE CRC and its partners.

Also, the ACE CRC, its collaborators and other participants, have expressed some interest in developing a business plan to seek future funding from alternative sources (outside of the CRC Programme) in order to continue the important and unique RD&E work conducted by the CRC after the current funding period concludes.

In October 2017, the ACE CRC contracted Agtrans Research to conduct an Impact Assessment of investment in the CFT Initiative. The impact assessment was funded to demonstrate the impact of a significant RD&E investment by the ACE CRC and partners. This report will also be provided as a cross-disciplinary impact study for the University of Tasmania Excellence in Research Australia 2018 submission.

1.2 Rationale for the CFT Investment

Global climate models (GCMs) provide the best estimates of global change to Australia's climate to the end of the 21st century. However, generally, climate information from GCMs has a resolution of 200 to 300 kilometres. For example, the CSIRO Mk3.5 climate model uses a T63 horizontal resolution (Gordon, et al., 2010) which is equivalent to approximately 210 kilometres (National Centre for Atmospheric Research Staff, 2017). At this resolution, Tasmania is usually represented by one or two grid cells. In each grid cell, climate variables such as temperature and rainfall (and even topography) have just a single value. This means that GCMs do not allow decision-makers to understand regional detail of climate change at local scales (ACE CRC, 2010).

Tasmania is Australia's second smallest State/Territory by area and is surrounded by the ocean. The state also has a varied topography leading to significant differences in local climate. The CFT Initiative was funded as an integrated assessment of the high resolution, dynamically downscaled climate models with operationally meaningful models. The Initiative addressed the need for relevant, locally specific information about expected changes to climate that reflected the highly variable topography of Tasmania and the many regional variations at a finer scale resolution than was available from GCMs and national scale climate models (NCCARF, 2013).

1.3 Structure of this Report

The following report addresses an impact assessment of the ACE CRC's investment in the CFT Initiative. Section 2 describes the general approach and methods used to conduct the assessment. Section 3 outlines the scope of the investment being assessed and specifies the costs of the CFT Initiative in terms of both cash and in-kind contributions. Section 4 describes the reports for the key outputs of the CFT Initiative from 2007/08 to 2016/17 as well as the findings of a key user survey undertaken as part of the assessment. This section also describes, in broad terms, the outcomes of the CFT investment (i.e. how the outputs of the RD&E have been used and on which sectors of the Tasmanian economy the outputs are likely to have had an impact). Sections 5 and 6 describe the impacts identified and the categorisation and valuation/non-valuation of those impacts. Section 7 reports the results of the quantitative assessment (cost-benefit analysis (CBA)) including investment criteria such as Net Present Value (NPV), Benefit-Cost Ratio (BCR), and Internal Rate of Return (IRR), as well as the results of some sensitivity analyses undertaken on key CBA assumptions. Section 8 presents a discussion of the results and findings of the impact assessment and Section 9 provides a conclusion for the report.

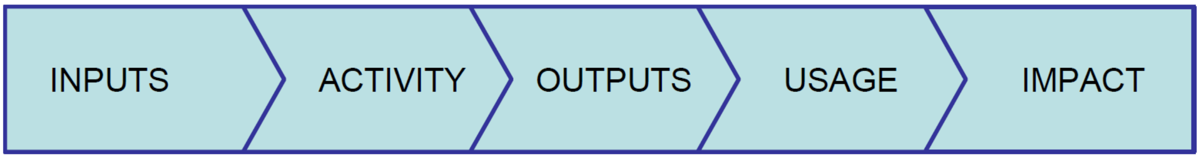
2. Method/Approach

The approach followed general impact assessment guidelines that are now well entrenched within the Australian primary industry research sector including Research and Development Corporations (RDCs), CRCs, State Government Departments and some universities. The impact assessment used CBA as a primary tool. The assessment entailed both qualitative and quantitative approaches.

2.1 Impact Assessment Approach

The assessment used a logical framework approach to describe the CFT inputs and then qualitatively identified and described the key outputs and outcomes of the CFT investment. Economic, environmental and social impacts then were identified and described. This framework can be expressed diagrammatically as shown in Figure 1 below.

Figure 1: Measurement along the input to impact chain – the logical framework



Source: (Deloitte - Insight Economics, 2007)

Following the qualitative descriptions completed using the logical framework, CBA was carried out for those impacts identified that could be valued in monetary terms. The CBA focused on economic impacts where clear, logical pathways existed from the CFT Initiative outputs through to actual or potential future impacts, and for which there were sufficient data available in the background literature to make reasonable assumptions.

All assumptions made for the impact valuations were described and recorded as part of the impact assessment reporting process. Results of the CBA then were reported and include investment criteria such as the NPV, BCR, and IRR.

The impact valuations and results may be found in Sections 6 and 7 of this report.

2.2 CFT Key Users Survey

A 'key users survey' was undertaken as part of the impact assessment approach to determine the primary outcomes of the CFT investment. The ACE CRC provided Agtrans Research with a list of 275 potential contacts related to the CFT Initiative. Professor Nathan Bindoff (leader of the CFT Initiative) then was asked to identify a short-list of key personnel who may be able to answer questions about the outcomes and impacts of the CFT investment.

Nineteen key contact personnel were initially identified through this process. The impact assessment team then attempted to contact each of the identified personnel (by phone and/or email) to describe the impact assessment project and gain their cooperation to participate in a short, written user survey.

Those that were contacted and responded positively were then sent an email containing a series of six key questions pertaining to the outputs, outcomes and impacts of the CFT investment. An example of the survey questionnaire sent to participants may be found in the appendix of this report (Appendix 1).

Responses received then were collated and examined, and the results analysed to identify and describe the key outcomes and impacts for the CFT impact assessment. The responses (and non-responses) to the survey questions also were used to identify gaps in the impact assessment teams' information and understanding of the CFT outcomes and impacts (both actual and potential) so that further investigation (including contacting additional key personnel) could be undertaken.

The findings of the ‘key users survey’ are reported in detail in Section 4.2.

3. The CFT Investment

3.1 Scope of the Assessment

The CFT Initiative is an ongoing investment by the ACE CRC. The scope of the impact assessment for the CFT Initiative was discussed and agreed upon at an initial meeting (teleconference) between Agtrans personnel and key ACE CRC personnel (CEO Mark Kelleher and CFT Project Leader Professor Nathan Bindoff). It was decided that the scope of the assessment would be limited to investment in 16 key CFT RD&E outputs completed as at 30 June 2017. The decision was based on the breadth of the past and ongoing CFT RD&E investment, number and type of RD&E outputs, potential availability of reliable data for the quantitative analyses, time and resource constraints, and the complexity of the analysis in terms of linking outputs to actual and potential future impacts.

3.2 Nominal Investment

Table 1 shows the estimated annual investment by key RD&E output for the CFT Initiative over the 10-year period from 2007/08 to 2016/17. The detail of the investment data available for the CFT outputs was variable. The assessment team was provided with the start and end year for each output, the total cash and in-kind investment costs for outputs 1 to 7, and the total cash costs only for outputs 8 to 16.

ACE CRC personnel then estimated a cash to in-kind ratio of 1:1.5 for CFT RD&E. Thus, a 1.5x in-kind multiplier was applied to the original investment costs for outputs 8 to 16. The total calculated investment for each output was then divided equally between the years of RD&E activity to provide an estimate of the total annual investment costs for the CFT Initiative.

Table 1: Investment by the ACE CRC and Partners in the CFT Initiative for the Years Ending June 2008 to June 2017 (nominal $)

No.	CFT Output	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Totals
(1)	General Climate Impacts Technical Report	2,504,333	2,504,333	2,504,333	0	0	0	0	0	0	0	7,513,000
(2)	Extreme Events Technical Report	Included in (1)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
(3)	Impacts on Agriculture Technical Report	Included in (1)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
(4)	Climate Modelling Technical Report	Included in (1)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
(5)	Water and Catchments Technical Report	Included in (1)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
(6)	Extreme Tide and Sea-Level Events Technical Report	Included in (1)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
(7)	Severe Wind Hazard and Risk Technical Report	Included in (1)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
(8)	NERP Landscape and Policy Hub	0	0	211,250	211,250	211,250	211,250	211,250	211,250	0	0	1,267,500
(9)	ClimateAsyst®	0	112,500	112,500	112,500	112,500	0	0	0	0	0	450,000
(10)	Future Fire Danger	0	0	0	0	37,500	37,500	37,500	37,500	0	0	150,000
(11)	Tasmanian State Natural Disaster Risk Assessment	0	0	0	0	0	0	0	0	225,000	0	225,000
(12)	The Potential Impact of Climate Change on Victorian Alpine Resorts	0	0	0	0	0	0	0	37,500	37,500	42,000	117,000
(13)	The Impact of Climate Change on Weather Related Fire Risk in the TWWHA	0	0	0	0	0	0	0	0	172,500	172,500	345,000
(14)	An Assessment of the Viability of Prescribed Burning as a Management	0	0	0	0	0	0	0	195,000	0	0	195,000

	Tool Under a Changing Climate											
(15)	Local Government Area Climate Profiles	0	0	0	0	0	0	0	3,000	3,000	0	6,000
(16)	Projecting Volunteer Resources Under Extreme Climate Futures	0	0	0	0	0	0	0	130,500	0	0	130,500
	Totals	**2,504,333**	**2,616,833**	**2,828,083**	**323,750**	**361,250**	**248,750**	**248,750**	**614,750**	**438,000**	**214,500**	**10,399,000**

Talia: Note that previous output no 15 has been deleted as Mark/Nathan thought it was a duplication; This may cause a problem for total budget; However, I suggest we move the deleted $42,000 for previous no 15 to no 12 and then, overall, there will be no change to the totals? I have already made this change in track.

3.3 Program Management & Extension Costs

No additional costs were included for program management and extension. The CFT investment was assumed to include project management and the Initiative incorporated a high degree of extension and stakeholder involvement throughout the related RD&E activities.

3.4 Real Investment

For the purposes of the CBA, the total annual investment costs were expressed in 2016/17 dollar terms using the Implicit Price Deflator for Gross Domestic Product (ABS, 2017a).

4. Description of Outputs & Outcomes

4.1 Outputs

From 2008 to 2017, the CFT Initiative produced 16 key outputs from related RD&E activities. A brief description of each output follows. The first seven outputs represent the primary CFT technical reports from the initial CFT Initiative RD&E between 2008 and 2010. Further outputs were produced as the research continued beyond 2012.

(1) General Climate Impacts Technical Report

The CFT General Climate Impacts Technical Report (Grose, et al., 2010) was the first of seven reports from the CFT Initiative. The report covers the past and present climate of Tasmania, and the projected changes to the general climate up to the year 2100.

The General Climate report also describes the large-scale climate mechanisms at work, projected changes to those climate mechanisms, and presents some details of the modelling used to examine projected changes in the Tasmanian climate to the end of the 21st century.

The focus of the research was on changes in the mean state of climate variables (primarily temperature and rainfall), and changes in the spatial pattern of the Tasmanian climate. A summary of the report also was produced and may be found at:
https://web.archive.org/web/20150406012906/http://www.dpac.tas.gov.au/__data/assets/pdf_file/0019/134209/CFT_Summary_-_General_Climate_Impacts.pdf

Data from this report, and others produced by the CFT Initiative, were made available to the Tasmanian state government, Tasmanian regional councils, emergency services, farmers, infrastructure managers and planners, energy and water authorities, community groups and researchers, to assist them in planning for the future and adapting to a changing climate.

(2) Extreme Events Technical Report

The second in the series of seven primary CFT research reports was the Extreme Events Technical Report (White, et al., 2010). The Extreme Events report covers projected changes to the frequency, magnitude and duration of temperature and precipitation extremes across Tasmania up to the year 2100.

The report describes past and current extreme events in the Tasmanian region, the likely drivers of projected changes in extreme events, and assesses aspects of the performance of climate models in terms of their ability to simulate these extremes.

A summary of the report also was produced and may be found at:
https://web.archive.org/web/20150406013441/http://www.dpac.tas.gov.au/__data/assets/pdf_file/0014/151412/CFT_-_Extreme_Events_The_Summary.pdf

The extreme events research was delivered with the goal of better informing the Tasmanian government so that government and other stakeholders could work in partnership to assist communities around the State to minimise the adverse effects of climate change by better preparing for, and responding to, extreme weather events.

(3) Impacts on Agriculture Technical Report

The CFT Impacts on Agriculture Technical Report (Holz, et al., 2010) (report three of seven) provides a brief summary of the projections of future climate, climate extremes and hydrology from the dynamically downscaled GCMs used to conduct the CFT climate modelling. This information is followed by a discussion about some agriculturally significant climate indices such as growing degree days, chill hours, drought and frost indices.

The research reported used biophysical models such as DairyMod (Johnson, et al., 2008) and APSIM (Keating, et al., 2003) to evaluate the impact of a changing climate on pastures and crops. The report also reports on impacts on land use and land use changes through an evaluation of potential responses to climate change along altitudinal gradients.

The research also investigated and reported the potential for Queensland fruit fly infestations (through CLIMEX modelling) as an example of an impact on agricultural biosecurity. The Impacts on Agriculture report did not address impacts on agriculture from changes in climate extremes and changes in runoff and river flows, nor the direct impact of extremes on livestock and impacts on forestry.

A summary of the report also was produced and may be found at:
https://web.archive.org/web/20150406013241/http://www.dpac.tas.gov.au/__data/assets/pdf_file/0004/140197/CFT_-_Impacts_on_Ag_Summary.pdf

The report was targeted at improving the understanding of the negative and positive impacts of a changing climate on agriculture, and the potential benefits and costs of adaptation strategies, to enable policy makers to take advantage of opportunities, and to plan for and potentially offset transformations to existing industries and farming systems.

(4) Climate Modelling Technical Report

The CFT Climate Modelling Technical Report (Corney, et al., 2010) (report four of seven) describes the CFT Initiative's climate modelling program and regional, dynamic downscaling of GCMs using multiple greenhouse gas emission scenarios.

The report focuses on the performance of the climate simulations in reproducing the Tasmanian climate and assesses the likelihood that they can accurately project future climate change for the Tasmanian region.

A summary of the report also was produced and may be found at:
https://web.archive.org/web/20150406013036/http://www.dpac.tas.gov.au/__data/assets/pdf_file/0016/151126/CFT_-_Climate_Modelling_Summary.pdf

The CFT climate modelling report complemented climate analyses and projections completed at the continental scale for the Fourth Assessment Report from the Intergovernmental Panel on Climate Change (IPCC, 2007), at the national scale in the Climate Change in Australia report and data tool

(Climate Change in Australia, 2016), as well as work done in the south-east Australia region as part of the South Eastern Australia Climate Initiative (SEACI, 2012). The work also complemented projections done specifically on water availability and irrigation in Tasmania by the Tasmanian Sustainable Yields Project lead by CSIRO (CSIRO, 2009).

(5) Water and Catchments Technical Report

The CFT Water and Catchments Technical Report (Bennett, et al., 2010) (report five of seven) analysed changes to surface water yields in Tasmania to the year 2100. Only changes caused by anthropogenic climate change were considered.

The report describes the methods and results of hydrological modelling designed to complement information presented in other CFT technical reports (e.g. the Climate Modelling Technical Report, General Climate Impacts Technical Report, Impacts on Agriculture Technical Report, etc.).

A summary of the report also was produced and may be found at:
https://web.archive.org/web/20150406013406/http://www.dpac.tas.gov.au/__data/assets/pdf_file/0006/140199/Water_and_Catchments_Summary.pdf

(6) Extreme Tide and Sea-Level Events Technical Report

The CFT Extreme Tide and Sea-Level Events Technical Report (McInnes, et al., 2012) (report six of seven) describes the development of spatial maps of extreme sea level associated with particular recurrence intervals along the Tasmanian coast under climate conditions projected to the year 2100. The research used dynamic modelling of storm surge and a statistical combination of surge and tidal information.

The maps provided a basis for the investigation of possible impacts of future climate change due to sea-level rise and changes in weather conditions. The report also includes information about the nature of extreme sea levels around Tasmania and the weather conditions most commonly responsible for elevated sea levels.

The Extreme Tide and Sea-Level report was intended to be helpful in supporting evidence-based policy and decision making for the management of Tasmanian coasts.

(7) Severe Wind Hazard and Risk Technical Report

The CFT Severe Wind Hazard and Risk Technical Report (Cechet, et al., 2012) (report seven of the CFT's primary seven RD&E reports) describes new modelling and analysis techniques used to develop a revised understanding of the regional wind hazard across the Tasmanian region.

The downscaled climate modelling enabled the development of wind hazard maps for the current Tasmanian climate as well as for the projected future climate under two different climate change scenarios to the year 2100. Regional wind hazard was assessed by utilising the downscaled simulations and applying statistical-parametric models to derive estimates of wind hazard from two different weather phenomena – thunderstorms and synoptic storms.

The research was undertaken to improve the current understanding of severe winds for the Tasmanian region detailed in the Australian and New Zealand wind loading standard (AS/NZS 1170.2:2011 (R2016)) (Holmes, Kwok, & Ginger, 2012). The wind risk assessment determined the annualised loss due to severe wind hazard in urban areas across Tasmania.

(8) National Environmental Research Program (NERP) Landscape and Policy Hub

The NERP Landscape and Policy Hub (found at https://www.nerplandscapes.edu.au/) was created to answer the question:

‘What would a whole of landscape approach to biodiversity conservation look like?’ (NERP, 2015)

The CFT Initiative’s role in the Landscape and Policy Hub (LPH)was to generate fine-scale resolution climate projections for the Tasmanian Midlands and Australian Alps as case studies, and to work with LPH researchers and land managers to apply these unique regional climate projections to the conservation of biodiversity.

CFT researchers, in consultation with land managers and LPH researchers, generated a range of tools, techniques and policy pathways (including ecological indices that can be used with multi-model projections of future climate in Tasmania and the Australian Alps) to improve decision-making at a regional level for planners and environmental managers.

The research aimed to increase the capacity of researchers, planners and managers to explore the likely implications of climate change on priority species, communities and threatening processes (NERP, 2013).

(9) ClimateAsyst®

ClimateAsyst® is a climate change analysis, risk assessment and communication tool developed with pitt&sherry (an engineering consulting business) that can be used by State and local government, emergency services, planners, developers, engineers, farmers, and the general public to assist in the management and planning of Tasmania's built assets and infrastructure in a changing climate.

ClimateAsyst® enables analysis of a broad range of climate change variables that were provided through the CFT research and through coastal inundation mapping developed by the Tasmanian government. CFT project information included projected temperature related variables (such as annual average temperatures, frost/heat days, and growing degree days) and projected rainfall changes (including the effects of climate on long term average and seasonal rainfall, short duration rainfall events, and humidity and evaporation variables).

The CFT project variables are present in ClimateAsyst® as a 10 kilometre grid based on model outputs. The projections can be manipulated through choice of projection period. The CFT information can be presented either as modelled projected values of the calculated difference between selected projection periods (as a number or a percentage change) (Rand, 2014).

The ClimateAsyste® tool may be found at: http://www.pittsh.com.au/climateasyst/

(10) Future Fire Danger Technical Report

The CFT Future Fire Danger Technical Report (Fox-Hughes, et al., 2015) was initiated by the Tasmanian State Emergency Service as a result of findings of the 2012 Tasmanian State Natural Disaster Risk Assessment report (DPEM, 2012) that identified bushfires as one of the top two most significant hazards in Tasmania, along with flooding.

The CFT research provided information about relevant processes at an appropriate temporal and spatial scale for Tasmania that enabled seasonal and annual changes in fire danger to be identified. The research also allowed the identification of changes in the synoptic climatology associated with fire weather in different regions of Tasmania under future climate conditions to 2100.

The Future Fire Danger report summarises the key findings of models projecting the cumulative Forest Fire Danger Index (the sum of the daily maximum Forest Fire Danger Index (FFDI) across one year incorporating a single fire season), the synoptic drivers of particularly dangerous fire days, and trends in soil moisture.

(11) Tasmanian State Natural Disaster Risk Assessment

The Tasmanian State Natural Disaster Risk Assessment (TSNDRA) (White, CJ, et al., 2016) was an assessment of the state level risks associated with Tasmanian bushfires, storms, severe weather events, earthquakes, landslips, coastal inundation, heatwaves, and human influenza pandemic.

The report aims to contribute to disaster resilience by increasing the community's understanding and awareness of emergency risks affecting the state. The report may be used by stakeholders and practitioners through the emergency management sector to inform emergency management planning.

(12) The Potential Impact of Climate Change on Victorian Alpine Resort

The Potential Impacts of Climate Change on Victorian Alpine Resorts Report (Harris, Remenyi, & Bindoff, 2016) is written in two parts. Part I of the report (The Impact of Investing in Snowmaking) reviews the Australian and international research on the economic viability of snow-making under climate change and assesses the viability of snow-making in relation to its impact on visitor numbers.

Part II of the report (Climate Change in the Australian Alps Region) includes an overview of the projected changes in key climate variables (e.g. mean temperature, precipitation, and snow over the Alps region) with regional insights from the CFT modelling. Part II also includes an assessment of the changes projected to occur in key climate variables up to 2100 at each of the six Victorian alpine resorts (Falls Creek, Lake Mountain, Mt Baw Baw, Mt Buller, Mt Hotham, and Mt Stirling) as well as an assessment of shifts in the timing and duration of the ski season based on natural snowfall and an analysis of variability in snow-making conditions.

The report was produced to provide input into Victorian alpine resort climate change adaptation strategies and planning to ensure long-term, sustainable operations into the future.

(13) The Impact of Climate Change on Weather Related Fire Risk in the Tasmanian Wilderness World Heritage Area (TWWHA)

The Impact of Climate Change on Weather Related Fire Risk in the TWWHA Reports (Love, PT, et al., 2016a) and (Love, PT, et al., 2016b) reports on potential impacts of climate change in terms of increased fire risk to the TWWHA through an analysis of future lightning potential, the FFDI and the Moorland Fire Danger Index. The report also incorporates data on dryness thresholds, subregional variation and seasonal climate changes within the TWWHA.

The research was conducted to help identify ways to improve how Tasmania prepares for, and responds to, bushfires in the TWWHA. The Tasmanian government prepared a formal response to the report (Tasmanian Climate Change Office, 2017) and supported most of the recommendations stemming from the research, including the introduction of comprehensive fire management planning, development of a Bushfire Risk Assessment Model, and an investigation of bushfire response operational capability.

(14) An Assessment of the Viability of Prescribed Burning as a Management Tool Under a Changing Climate

A report was produced describing research conducted to assess the viability of prescribed burning as a management tool under a changing climate with Tasmania as a case study (Harris, et al., 2017). The research investigated the changing opportunities for prescribed burning in Tasmania in the near future (2021-2040) and towards the end of the century (2081-2100) under a high emissions (A2) scenario.

The report presents the findings of an assessment of monthly changes in the climate variables that determine when prescribed burning can be applied, including rainfall, temperature, fuel moisture and atmospheric stability.

The findings reported may be used by decision-makers to better plan for and manage bushfire risk using prescribed burning in the future. The timing and resourcing of prescribed burning may be affected, with a narrower window of suitable weather conditions for burning meaning that alternative methods to mitigate bushfire risk may be required.

(15) Local Government Area Climate Profiles

The ACE CRC (through the CFT Initiative) was engaged to produce a Climate Change Snapshot for Hobart City Council in 2012 (ACE CRC, 2012a). The snapshot summarised the CFT Initiative's climate model outputs to produce data directly relevant to council operations (e.g. engineering projects, asset risk management etc.) and was produced to provide input into more detailed information for regional planning and risk management through the Regional Climate Adaptation Strategy (Graham, Green, & Heyward, 2013) and, more specifically, the City of Hobart Corporate Climate Adaptation Policy (Hobart City Council, 2014), and the City of Hobart Climate Change Adaptation Plan (Graham, Green, & Heyward, 2012).

Following the development of the Hobart City Council Climate Change Snapshot, a series of individual Local Government Area Climate Profiles (ACE CRC, 2012b) were produced for the 29 local government areas in Tasmania. These profiles provide local-level climate information to assist councils, resource managers and businesses to better understand the expected climate changes in their area and adapt accordingly. The local profiles include information on past and current climate, as well as forecast changes to temperature, rainfall, runoff, and extreme events.

(16) Projecting Volunteer Resources Under Extreme Climate Futures

The CFT researchers investigated the potential impacts of climate change on emergency service volunteer resources in Tasmania. The project used a five-stage process to match current emergency service volunteer profile data with CFT climate hazard projections (Tasmania SES, 2016).

The research determined the expected requirements of the emergency services volunteer workforce given the projected frequency and severity of future climate hazards such as fire danger, heat stress, and rainfall runoff intensity in the context of projected demographic changes in Tasmanian municipalities.

4.2 Survey of Key Personnel: Usage of CFT Outputs

A number of key personnel were contacted to gain feedback on the usage of the CFT outputs. Nineteen people were listed by ACE CRC as key contacts from whom to seek feedback in the form of a written questionnaire. The written questionnaire included six questions about the relevance of the CFT outputs to the sector represented by the contact (see Appendix 1).

An attempt was made to contact all 19 to seek their cooperation in the provision of comment on usage of CFT information. Additional feedback was sought for the forestry, wine, and biodiversity sectors in addition to the original 19 personnel contacted. Nine responses to the questionnaire were recorded.

The responses indicated the use of the CFT reports has produced a number of outcomes and influenced significantly many investment and planning decisions across many Tasmanian government (state and local) entities as well as private sector institutions and industries.

Because of the comments varying considerably due to the diversity of sector representation, the responses to each question are not easily or meaningfully aggregated. The list of respondents and their individual responses to each question are reported on Appendix 2.

However, aggregation was possible for response to question 3, and this result is posted below.

Question 3: Please rate on a scale of 1 to 5, the characteristics of the CFT research outputs that you consider are of most value (with 1 being little to no value and 5 being extremely valuable).

Characteristics of CFT Outputs	**Ratings**	**Average Rating**
Finer scale of prediction and time lines	3, 4, 4, 5, 5, 5, 5, 3, 5, 1	4.0
Increased confidence for future planning	5, 5, 4, 4, 4, 5, 5, 4, 5, 2	4.3
Sector specific relevance of CFT outputs	5, 3, 5, 4, 4, 5, 5, 5, 5, 5	4.6
Meaningful communication of CFT outputs	4, 3, 4, 3, 4, 5, 5, 5, 5, 4	4.2
More specific information on future risk profiles	4, 3, 4, 3, 4, 5, 5, 5, 5, 3	4.1

The aggregated response showed that all average ratings were greater than 4 out of 5; the highest average rating (4.6) was for the sector specific relevance of the CFT outputs.

4.3 Outcomes

The following generalised outcomes are based on a synthesis of the direct responses from the surveyed sector participants as well as some information exchanges with sector representatives that occurred when analysing potential impacts later in the assessment process.

It is evident that the CFT outputs have been used by a wide variety of sectors and personnel across Tasmania. They have been used, in conjunction with other research and reports, in various policy and planning decisions. Their use has resulted in improved public and private sector resource allocation outcomes that take into account preparedness associated with future climate change. Many of these decisions have been partly driven by increased confidence from improved spatial and temporal future Tasmanian climate information delivered by the CFT. More specific outcomes related directly to the impacts identified are explored in more detail in Sections 5 and 6.

The following generalised outcomes are presented by sector below.

4.3.1 Infrastructure

A number of CFT reports and tools have been used as an input to decision making associated with infrastructure investment. The CFT outputs have and will be used in infrastructure policy, determining where critical infrastructure can or cannot be built, identifying the risk factors associated with building infrastructure in certain locations, and improving estimates of the useable life of existing infrastructure.

For example, the finer scale climate predictions have been used as inputs into the following:

- LISTmap,
- Hydro Tasmania's private research,
- Infrastructure planning and development of regulations in various Tasmanian Government Departments,
- Local council infrastructure planning, and
- The design and planning of infrastructure in the private sector.

4.3.2 Natural Disaster Management

The CFT Initiative produced several future fire and flood predictions on temporal and spatial scales for Tasmania that were more detailed then previously available. These predictions were used to improve natural disaster preparedness planning and mitigation, and operational management of natural disaster events when they occur.

For example, CFT outputs were used in several government planning documents and reports such as:

- The 2016 Tasmanian State Natural Disaster Risk Assessment (White et al., 2016)
- Mitigating Natural Hazards through Land Use Planning and Building Control – Coast Hazards in Tasmania (report and planning documents) (Department of Premier and Cabinet, 2016)
- Tasmanian Coastal Adaptation Pathways Project
- LISTmap (see https://www.thelist.tas.gov.au/app/content/home), and
- Various Tasmanian SES and Tasmanian Fire Service (TFS) studies and plans.

The government planning documents, tools, and reports identified above (as well as other CFT influenced documents) have led to significant changes in regulations associated with improved planning for natural disasters and natural disaster mitigation.

4.3.3 Agriculture

The CFT information has been used by agricultural industries and individual agricultural producers to guide enterprise planning, and priorities and decisions regarding land use and risk management. The use of the CFT outputs has resulted in both short-term and long-term increases in the productivity of land, labour and capital resources and in higher farm incomes.

For example, there has been increased confidence in investment in dairy farming due to the CFT outputs, specifically the finer scale modelling. There also has been increased confidence across agriculture and horticulture that irrigation investments will be worthwhile. Similarly, the area of cool climate wine grapes in Tasmania has expanded; one of the factors contributing to this increased area has been the confidence given to investors by the future climate predictions delivered by the CFT.

In a related area, the CFT outputs have helped inform predictions of when and where potential pests and diseases may enter Tasmania because of the changing climate. For example, the CFT outputs have been used as inputs to additional climate models such as CLIMEX, to determine the likely spatial and temporal dimensions of a potential fruit fly infestation. The improved modelling has updated the spatial and temporal distribution of the potential entry and spread of insects such as the Queensland fruit fly.

4.3.4 Forestry

The CFT Initiative has improved knowledge of local scale climate predictions and increased awareness of the scope and extent of different climate change factors for the plantation forestry industry. Because of the CFT outputs, the forestry industry in Tasmania has been able to make improved predictions of the viability and productivity of tree varieties for specific locations based on future climate scenarios.

4.3.5 Public health

Due to the CFT information, there is a greater awareness of the potential effect of climate change on public health. The specific and localised climate information delivered by the CFT research, can be used by the Tasmanian and local governments to improve communication of associated health risks to communities, and to adequately prepare for extreme heat event days. This will be particularly relevant to vulnerable groups within specific community locations, including the aged, disabled, and children. The CFT information may also be relevant to the location and design of servicing infrastructure for vulnerable groups.

4.3.6 Improved weather forecasting

CFT data has been used in weather forecasting and improving trend data for weather forecasts. This will lead to more accurate weather forecasts as underlying assumptions become more robust. The improved forecasts can be used by a number of stakeholders in the Tasmanian community. The CFT also has been an input into a current CFT project ‘Reanalysis for Tasmania 2016-2018’ (See Table 2, Section 4.4).

4.4 Legacy of the 2008-2017 CFT Investment

A number of ongoing and new projects have evolved from the initial CFT Initiative investment (2008-2017). Most of these projects are being undertaken by the CFT research team at the ACE CRC and many build on, and enhance, former CFT outputs. A summary list of the new projects is provided in Table 2.

Table 2: Current projects and products under development by the Climate Futures team at the ACE CRC, and their applicability and coverage of the relevant climate indices, extremes and regions of Tasmania (as of 16 December 2017)

Product (or tool)	**Sector or risk area**	**Region**	**Provider**	**Status**	**Climate models and ancillary models**	**Summary**	**Gap Analysis and opportunity**
Australia's Wine Future	Agriculture	Australia	Climate Futures /ACE CRC	Active	CCAM Simulations hosted in CMIP5 simulations	Providing high resolution climate information to the wine regions of Australia, assessing historical and future changes in the frequency and intensity of large scale climate drivers and identifying weather risks particularly important to grape growing. Further outputs to include regionally relevant adaptation options to improve the sustainability of each wine region as climate conditions continue to change.	High resolution regional climate projections produced can be utilised in further studies. Projections only for high emissions scenario RCP 8.5
Reanalysis for Tasmania	General	Tasmania	Climate Futures /ACE CRC, Bureau of Meteorology	Active. Initial analysis delivered 10/2016. First tranche of final data product due 4/2018.	ACCESS-C/ ACCESS-R	Producing a consistent reconstruction of the state of the atmosphere through time at horizontal resolution of 1.5 km. It will provide a high-resolution meteorological and climatological dataset that will allow users to compare weather parameters such as wind, rainfall or temperature (or derived quantities such as fire danger) through time and space to inform emergency	Unprecedented quality gridded weather data complements climate projections for understanding of current climate and validation of regional climate models

						management and disaster risk activities.	
TWWHA Climate Change and Bushfire Research Initiative	Emergency services management	Tasmanian Wilderness World Heritage Area	Climate Futures /ACE CRC	Active	CCAM Simulations hosted in CMIP3 simulations	Updating the FIRESCAPE-SWTAS fire regime and vegetation dynamics model. The updated model will have improved fire dynamics over an expanded spatial area and will test the effectiveness of the Parks and Wildlife prescribed burning strategy under climate change projections.	Expertise acquired will provide capability to assess future lightning fire ignition efficiency, as raised in preceding TWWHA fire danger report
NESP Earth Systems and Climate Change Hub	General	Australia	CSIRO, BoM, ANU, UTas, Monash, UNSW, Melbourne	Active	Providing guidance for next generation of regional climate models for Australia	Partnership of earth system and climate change research institutions prioritising research on past and present climate, how climate may change in the future and building the utility of climate change information. Research will be used to generate data, information, products, tools and services for a range of end users, including government, the private sector, non-government organisations, and Australian communities of interest.	Engagement with this body will enhance potential for leverage by coordination with other state and national regional climate change projects
Victorian Extreme Heat Vulnerability Assessment	Extremes	Victoria	SGS, Climate Futures /ACE CRC	Proposal submitted	Review of all modelling available	Systematic assessment of the vulnerability of Victoria's economy to heat to enable Victorian governments, and other key stakeholders, to	Climate analysis methodology and decision-making framework developed

						understand current and future risks from extreme heat to Victoria's economy and incorporate this knowledge into decision making.	can be applied to Tasmania. High resolution climate data will assess only high emissions scenarios (RCP 8.5, SRES A2).
Queensland Climate Resilient Councils	General	Queensland	Ethos Urban, Climate Planning, Climate Futures /ACE CRC	Invited to respond to RFT. Proposal under development	Review of all modelling available	Multi-sectoral climate change strategy guideline for Queensland local governments to strengthen internal council decision-making processes to better respond to climate change.	Strategy guideline and information delivery model could be adapted for Tasmanian local government.

Source: Bindoff NL, Love PT, Grose MR, Harris RMB, Remenyi TA, White CJ (2017), *Review of climate impact change work undertaken, research gaps and opportunities in the Tasmanian context: Technical report*, Antarctic Climate & Ecosystems Cooperative Research Centre, Hobart, Australia.

A brief description of two of the current/future CFT RD&E projects follow. These projects demonstrate a significant legacy of the 2008-2017 CFT investment and will add to and/or increase the impacts identified (described in Sections 6 and 7) for the 2008-2017 investment assessed.

The first example is associated with wine grape management in Australia. The second is associated with weather/climate forecasting and natural disaster management. It should be noted that the brief description of these projects has been included only to highlight the legacy of the CFT 2008-2017 investment. Impacts emanating from these ongoing and new investments are beyond the scope of the current impact assessment.

1) Australia's Wine Future

This project builds on the original CFT Initiative work and its impact relevant to the Tasmanian wine industry (described later in this report). The 'Australia's Wine Future' project commenced in July 2016 and is financially supported by Wine Australia. The formal project code and title is UT 1504 - Australia's Wine Future: Adapting to short-term climate variability and long-term climate change. The project is addressing future weather and climate risks in different Australian wine regions that will provide high relevance data for varietal choice and various management options to address future climate risks. The high resolution regional climate projections will have high relevance to maintaining grape yield and quality through both preparedness and operational activities.

2) Meteorological and Climatological Data Sets

This project builds on an early CFT research linking long-term climatic and meteorological (weather) data to better understand weather in Tasmania. The new project is entitled 'Reanalysis for Tasmania 2016-2018' and is funded by the Tasmania's State Emergency Services with contributions from the ACE CRC (under the CFT Initiative), the Bureau of Meteorology, and various emergency services agencies.

This project focuses on increasing horizontal resolution for climate modelling to a 1.5 km grid (Climate Futures, 2018). The project is generating data that will allow greater understanding of Tasmania's weather as well as weather in other locations in Australia, particularly in areas that currently are poorly served by weather observations such as the TWWHA (ACE CRC, 2017). In this regard, enhanced improved weather forecasting could be utilised by many sectors and communities, particularly in response to natural hazards such as bushfires.

5. Impacts

5.1 Introduction

A summary of the types of actual and anticipated impacts of the CFT investment (2008-2017) is provided in the following section. The impact summary is based largely on the information from the individual survey respondents reported in Section 4.2 and the aggregation and interpretation of their actual and anticipated usage responses in Section 4.3.

According to the respondent survey the use of the CFT reports has produced a number of outcomes and influenced significantly a number of investment and planning decisions across a wide spectrum of both Tasmanian government (state and local) and private sector institutions. Many of these improved decisions will influence operational income and investment costs in the longer term. Hence, the majority of the impacts from the CFT outputs will be largely concentrated in the future, rather than in the short-term.

5.2 Identification and Description of Impacts

There were thirteen impacts identified and briefly described in the impact assessment. These are summarised in the following table (Table 3). The table identifies also whether the impact is valued in monetary terms or not in this assessment.

Table 3: Summary of Impacts Identified and whether Valued in this Assessment

Impact No.	Impact Title	Impact Valued in this Assessment
1	More efficient and effective capital investment in infrastructure development	Yes
2	More efficient and effective water allocation polices	No
3	More efficient and effective natural disaster management	Yes
4	Increased future operating surpluses in agriculture and horticulture	Yes
5	Increased wine grape expansion and profitability	Yes
6	Increased community well-being from improved weather forecasting	No
7	Potentially improved policies and preparedness for pests and diseases affecting agricultural production	No
8	Improved decisions regarding public health	No
9	More efficient and effective future biodiversity conservation management	Yes
10	More effective forest industry investment	Yes
11	Higher value use of land from improved land use planning	No
12	Improved business planning for Victorian Alpine resorts	No
13	Improved preparedness, prevention and operational capacity for fire management in the TWWHA	Yes

Brief descriptions of each of these impacts follow.

1. More efficient and effective capital investment in infrastructure development

Capital investment in Tasmanian infrastructure has been, and is still, being positively influenced by the CFT information and products. This applies to more efficient and effective investment by State and local government, as well as investment by the private sector. The impact involves a range of infrastructure types including transport (e.g. roads, bridges, ports), water resources (e.g. water treatment, wastewater, sewerage and irrigation), energy (hydroelectricity, wind generation).

2. More efficient and effective water allocation polices

More effective and efficient water availability and location forecasts have allowed improved planning for lower cost and equitable water allocation policies for Tasmania (human, hydroelectricity, and irrigation).

3. More efficient and effective natural disaster management

More efficient and effective Tasmanian natural disaster management (for example, more accurate hazard location and severity forecasts, improved preparedness, long-term prevention, and mitigation effectiveness). The natural disaster impact includes floods, bushfires and severe storms.

4. Increased future operating surpluses in agriculture and horticulture

An increase in investment efficiency, enterprise planning, risk management, and operating surplus in agriculture and horticulture, excluding increased wine grape profitability.

5. Increased wine grape expansion and profitability

Higher profitability will accrue to new investors in Tasmanian wine grape production partly from the more favourable future Tasmanian climate for cool climate grape varieties.

6. Increased community well-being from improved weather forecasting

Weather forecasts can be improved by the greater understanding of climate drivers delivered by the CFT investment.

7. Improved policies and preparedness for pests and diseases affecting agricultural production

Potential for improved management of risk for the potential introduction of Queensland fruit fly to Tasmania and hence contribution to continued maintenance of freedom of the fruit fly free status of Tasmanian horticultural production.

8. Improved decisions regarding public health

More specific and localised climate information delivered by CFT research, can be used by the Tasmanian state and local governments to improve communication of climate associated health risks (e.g. heat waves) to vulnerable communities.

9. More efficient and effective future biodiversity conservation management

The CFT Initiative contributed to the NERP Landscapes and Policy Hub. The LPH has, in turn, enhanced biodiversity conservation management.

10. More effective forest industry investment

Spatial and temporal information on future climate parameters has been used to improve forestry species planting decisions.

11. Higher value use of land from improved land use planning

Improved land use planning to accommodate more specific future climate changes will affect a range of industry and community investments by encouraging higher use values.

12. Improved business planning for Victorian Alpine resorts

Improved information on changes to the timing and duration of the snow season from natural snowfall and the future conditions for snowmaking will have contributed to improved planning and management for one or more of the six Alpine resorts in Victoria

13. Improved preparedness, prevention and operational capacity for fire management in the TWWHA

The CFT predictions on future dry lightning strikes and other hazardous climate conditions (e.g. extreme heat days) will contribute to improved preparedness and management of fire risks that will minimise biodiversity and heritage damage in the future.

5.3 Impacts Not Valued

Of the thirteen impacts identified, six were not valued in monetary terms. The key reasons for some impacts not being valued include insufficient resources/time the envisaged difficulty in assembling appropriate data, and/or complexity of developing reliable specific assumptions.

The non-valuation of some impacts has resulted in a conservative overall value of the CFT impacts. On the other hand, some of the impacts categorised as not being valued may well have been included in the valued impacts. Some specific reasons for not valuing impacts are provided below.

Impact 2: More efficient and effective water allocation polices

This impact has not been valued as it may, at least in part, be included in the increase in gross operating surplus for agriculture (Impact 4) due to a potential increase in the area of irrigated land.

Impact 6: Increased community well-being from improved weather forecasting

Weather forecasts can be improved a by a greater understanding of climate drivers. While some progress was made in this regard from the 2008-2017 CFT investments, a current ACE CRC project (‘Reanalysis for Tasmania 2016-2018, see Table 2) is generating data that will allow greater understanding of Tasmania’s weather at a high resolution. While the initial focus is on natural hazard management, improved regional weather forecasting could be utilised by many sectors and communities including farmers. The impact from improved weather forecasting has not been valued in the current evaluation as most of the impact will be delivered by the current ‘Reanalysis’ project that lies beyond the scope of the CFT investment being assessed in this report.

Impact 7: Improved policies and preparedness for pests and diseases affecting agricultural production

A new strategic plan for maintaining Tasmania’s freedom from fruit fly was released in 2017. The localised climate information produced by the CFT research demonstrated the ability of the pest risk projection system CLIMEX to map fruit fly’s potential distribution as climate change progresses (Biosecurity Tasmania, 2017). However, CLIMEX has not been used to date in operational management of fruit fly, including the 2018 fruit fly incursion into Tasmania (Guy Westmore, pers. comm.,2018).

Future data collection by Biosecurity Tasmania is envisaged to help model appropriate parameters for both Queensland fruit fly and Mediterranean fruit fly within Tasmania. This will provide a scientific basis for long term policy and decision making (Biosecurity Tasmania, 2017). Enhanced modelling capacity would be helpful in the development of strategies and policies regarding management of future incursions. Such strategies could help to protect the $37 million per annum of Tasmanian exports destined for fruit fly-sensitive markets in Asia.

This potential future impact has not been valued as it would most likely require assumptions concerning changes in probabilities of variables such as the reduction of risk of fruit fly entry, establishment, spread, and eradication that may be associated with enhanced strategies and policies. Time and resources did not allow development of such assumptions.

Impact 8: Improved decisions regarding public health

More specific and localised climate information delivered by CFT projects, can be used by the Tasmanian and local governments to prepare for public health risks associated with climate change. Increased preparedness of the public health sector may reduce costs of future health services, some infrastructure and potentially save lives and improve quality of life. Such impacts have not been valued due to a requirement for significant additional information (including non-market valuations) and the time and resources available.

Impact 11: Higher value use of land from improved land use planning

CFT information has been used by Tasmanian government agencies and local councils to inform land use planning. Much of this use has been via LISTmap. In addition, the State Government of Tasmania has used LISTmap in land use planning regulations, subsequently adhered to by local councils. For example, the township of Burnie has used inputs from The List (as directed by State Government), for land use planning (Burnie City Council, 2010). This will affect the location and type of infrastructure that can be built as per the land use planning regulations, resulting in better adapted infrastructure and more efficient use of capital.

The wide range of actual and potential impacts stemming from improved land use planning has resulted in this impact not being valued. However, some of the impacts of improved land use planning will have been captured in the capital infrastructure efficiency dividend (Impact 1); also, some planning impacts in the agricultural sector may have been included in the impact valued associated with a productivity increase affecting the gross operating surplus for Tasmanian agriculture (Impact 4) and reduced costs for natural disaster management (Impact 3).

Impact 12: Improved business planning for Victorian Alpine resorts

As any affected decisions would be likely to include both supply and demand side responses that may vary by individual resort, the amount and type of information required would have been prohibitive to obtain given time and resources available.

6. Impacts Valued

Of the thirteen impacts identified, seven were valued in monetary terms. The associated CBA refers to the costs and benefits to Australia and impacts therefore are not limited to Tasmania. However, many of the impacts valued will accrue to Tasmanian interests rather than those in the mainland.

6.1 Valuation of Impact 1: More efficient and effective capital investment in infrastructure development

Introduction

The CFT Initiative has produced more spatially accurate rainfall maps, and river flood and flow predictions. This has allowed policymakers, planners, and organisations to make improved investment decisions. Such improved decisions may reflect a lower likelihood of new infrastructure being damaged or being built in a less suitable location than with the CFT information. While there would have been some gains in infrastructure efficiency due to preparedness for climate change without the CFT investment, use of the CFT information has led to an additional increase in the efficiency of infrastructure investment.

Gains from the availability and use of the CFT research will vary with different infrastructure sectors. The sectors to which capital infrastructure spending applies and where the CFT information has been used include:

- Hydroelectricity and wind generation
- Bridges, railways, and harbours
- Roads, highways, and subdivisions

- Water infrastructure including water treatment, sewerage and irrigation

Hydroelectricity and wind generation

Hydro Tasmania has taken note of the outputs that related to water availability and have used the CFT outputs in their research for future infrastructure plans (Greg Carson, pers. comm., 2017). The CFT reports helped confirm and refine Hydro Tasmania's assumptions of water flows and potential energy forecasts, strengthening the confidence held in the allocation of their infrastructure investments. While the CFT outputs have not been used directly in hydroelectricity investment decisions (Greg Carson, pers. comm., 2017), they have provided an input to other reports and business cases associated with major infrastructure and planning decisions. Wind generation may also be affected by the CFT outputs, with improved climate predictions improving investment decisions for wind generation.

As water flows are an input into electricity generation, the increased confidence in energy predictability provided by the CFT research may lead to more accurate energy supply forecasts that will be utilised by various industry sectors.

The increased confidence for decision-making resulting from the CFT research has led to hydroelectricity infrastructure being planned and built in more suitable areas compared to the situation without the CFT. The result is that the infrastructure now built will be more cost efficient, compared to what would have been built otherwise (i.e. less subject to damaging floods, more efficient power generation etc.). The capital expenditure used in the valuation includes investment by Hydro Tasmania in wind generation.

It can be assumed that the capital investment made post-2010 would have been less than that required to achieve the same effectiveness and outcomes in the absence of the CFT information. Hence, a proportion of the investment required under the counterfactual scenario (climate change assumed but no CFT information) would have been saved.

Specific assumptions regarding the annual capital investment in hydroelectricity and wind generation are provided in Table 4. Assumptions for the proportion of hydroelectricity capital investment affected by the CFT information, and the efficiency dividend assumed for use of the CFT information are provided in Table 5.

Bridges, railways, and harbours

The downscaled future climate predictions available from the ClimateAsyst® tool have been used by engineers to better plan new infrastructure that will mitigate future extreme climate scenarios. For example, planning for new infrastructure such as bridges can incorporate designs according to their ability to withstand extreme future climate scenarios. It has been noted that rainfall predictions based on CFT models have been used in engineering decision making (Phil Gee, pers. comm., 2017).

The more efficient planning of infrastructure is assumed to save capital investment over what would have been required to deliver the same outcome without the CFT information. An example would be a bridge whose design has taken into account increased river flows/flooding from CFT modelling compared to a bridge that may have been designed without the CFT information. For example, the bridge may have been overcapitalised or undercapitalised resulting in a shorter life or higher maintenance costs. Specific assumptions on capital investment for this infrastructure type is provided in Table 4 and the extent of the assumed impact is provided in Table 5.

Roads, highways, and subdivisions

The rationale for gains from investments in roads, highways and subdivisions from use of the CFT information available is the same as for bridges, railways, and harbours. The required assumptions on capital investment and the impact of the CFT information are provided in Tables 4 and 5.

Water infrastructure

The CFT outputs have been an input into water infrastructure decision making throughout Tasmania and have been integrated into Tasmanian State Government strategic decision making (Sophie Muller, pers. comm., 2017). The CFT outputs have provided additional information on future water availability scenarios. This information has increased confidence in planning infrastructure investment by both Government bodies and the private sector. Relevant CFT information includes the potential likelihood and severity of floods at a finer scale (spatial and temporal) than was previously available, increasing the robustness and effectiveness of planned infrastructure development.

Run-off predictions from flood mapping have been accommodated with regard to the location of irrigation infrastructure. The predicted run-offs have provided a critical input into future predictions of irrigation water availability. CFT predictions show that some irrigation inflows (for example the Central Highlands) may be less than current inflows (and pre-CFT predictions of future inflows), while other irrigation inflows may increase (higher than pre-CFT predictions). This has improved irrigation infrastructure planning and led to more efficient infrastructure development.

Water infrastructure as defined in this assessment includes capital investment in water treatment and sewerage infrastructure as well as in irrigation. The CFT information related to water (such as rainfall, flow, and runoff forecasts) has increased efficiency in water infrastructure investment compared to what most likely would have occurred without the CFT. In part due to the CFT information, water assets are less likely to have to be re-built, improved, or replaced at some earlier future date when planned with the CFT information. As for the other infrastructure types, the assumptions for estimating the value of impacts are provided in Tables 4 and 5.

It should be noted that the indicative efficiency dividend assumed (shown in Table 5) is the same for all water infrastructure investments. The dividend for irrigation of 1% may be an underestimate as irrigation infrastructure design can rely heavily on rainfall and flow predictions to ascertain whether a proposed infrastructure investment is likely to be viable. Therefore, the finer scale flow predictions derived from the CFT investment, may be associated with a larger efficiency dividend than for the other water sectors. In the statistical series used for determining annual capital investment, irrigation was included with the other water sectors.

Proportion of capital investment subject to efficiency dividend

It is assumed that an average of 20% of all types of total annual infrastructure expenditure will have benefitted in some way from improved climate mitigation action due to the CFT information. Some of this affected investment will likely benefit to a significant degree while some may only benefit marginally.

Efficiency dividend

Due to the difficulty of breaking down each infrastructure investment by specific type and sector, the gains have been estimated using a broad assumption of a likely efficiency dividend applied to a proportion of public, private, and hydroelectricity infrastructure spending that will be affected by climate change. The efficiency dividend for the 20% of infrastructure investment affected has been assumed conservatively at 1%. This has been assumed for all four types of investment considered (hydroelectricity, bridges, roads and water).

Commencement, application and longevity of efficiency dividend

The efficiency dividend is assumed to commence in 2010/11 and gradually increase to its 1% maximum by 2014/15. For all infrastructure, it is assumed that the full 1% CFT efficiency dividend will then apply for 10 years. After this time, it is assumed that without the CFT information, there would have been increased precision in climate modelling (due to technological progress, and increased data points). Hence, after 10 years of the 1% full impact, a diminishing factor is applied to the efficiency dividend resulting in no impact after 2035.

Table 4: Breakdown of infrastructure spending per sector per annum
($ million, adjusted to 2016/2017 dollars)

Year ending 30 June	Hydroelectricity and wind generation	Bridges, railways, and harbours		Roads, highways, and subdivisions		Water infrastructure	
		Public	Private	Public	Private	Public	Private
2011	$64.30	$45.55	$1.68	$225.70	$40.55	$105.58	$34.75
2012	$186.10	$56.36	$0.91	$163.73	$60.25	$143.83	$28.93
2013	$164.00	$65.19	$7.33	$133.37	$41.85	$158.84	$48.29
2014	$118.70	$89.30	$5.45	$182.24	$36.95	$138.38	$14.97
2015	$100.70	$76.72	$2.29	$201.52	$86.81	$160.18	$24.30
2016	$109.10	$66.16	$3.92	$171.15	$57.92	$155.08	$5.95
2017	$131.20	$126.43	$3.75	$214.51	$75.06	$142.37	$17.16
2018 – 2047(a)	$124.74	$84.76	$4.55	$180.56	$59.68	$150.97	$22.13

(a) Based on a 5-year average, 2013-2017
Sources: Hydro Tasmania (2011, 2015, 2016, 2017), ABS (2018)

Table 5: Assumptions for estimating value of CFT impact (including counterfactual, applicability, efficiency dividend and its level by year, commencement and longevity)

Variable	**Assumption[(a)]**	**Source**
Counterfactual		
Existing climate change scenarios available pre-CFT used in capital expenditure decisions	Existing climate change scenarios available pre-CFT used in capital expenditure decisions	Agtrans Research
Applicability: Percentage of annual infrastructure capital investment where information on climate change is applicable (both CFT and counterfactual)	20%	
Efficiency dividend assumed due to CFT		
Full efficiency dividend assumed for annual existing infrastructure capital investment due to CFT	1%	Agtrans Research
Application of efficiency dividend by year		
Proportion of full efficiency applied in 2011	10%	Agtrans Research
Proportion of full efficiency dividend applied in 2012	20%	
Proportion of full efficiency dividend applied in 2013	40%	

Proportion of full efficiency dividend applied in 2014	80%	
Proportion of full efficiency dividend applied in 2015 -2025	100%	
Proportion of full efficiency dividend applied in 2026	90%	
Proportion of full efficiency dividend applied in 2027	80%	
Proportion of full efficiency dividend applied in 2028	70%	
Proportion of full efficiency dividend applied in 2029	60%	
Proportion of full efficiency dividend applied in 2030	50%	
Proportion of full efficiency dividend applied in 2031	40%	
Proportion of full efficiency dividend applied in 2032	30%	
Proportion of full efficiency dividend applied in 2033	20%	
Proportion of full efficiency dividend applied in 2034	10%	
Proportion of full efficiency dividend applied in 2035 onwards	0%	

(a) All values in Tables 4 and 5 have been adjusted to 2016/17 dollar terms

6.2 Valuation of Impact 3: More efficient and effective natural disaster management

The natural disasters covered in the valuation of this impact include floods, bushfires and severe storms.

Floods

The SES routinely use the finer scale rainfall grids produced by the CFT in flood and floodplain studies (Chris Irvine, pers. comm., 2017). The usage of the reports mentioned above has increased preparedness for flood events due to increased knowledge of where flood events are likely to occur and increased the accuracy of predictions of hazard severity and frequency. The increase in knowledge and improved predictions have allowed the SES and other emergency services generally to be better prepared, and improved usage of available resources including staffing and volunteer management when dealing with natural disasters.

For example, due to the improved flood mapping, the SES has been able to identify potential new areas that will be subject to increased flooding. One result has been improved planning regulations so new buildings are not built in risky flood zones.

Bushfires

Due to the CFT outputs such as more localised wind, rainfall and temperature predictions, the TFS has been more adequately prepared to predict and manage bushfire risk compared to the situation without the CFT outputs. The CFT outputs on bushfire risk and precise mapping have already affected land-use planning such as where new buildings can be constructed. In addition, areas that are now deemed to be low risk from bushfires have had updated zoning changes (TFS, 2017).

As the CFT-based maps provide an updated risk of bushfires spatially, backburning operations can be better targeted than previously. The improved backburning operations can lighten the fuel load, leading to less intense bushfire events.

Severe Storms

As for floods and bushfires, the provision of climate predictions on a finer spatial scale than hitherto has allowed improved community and agency preparedness for, and mitigation activities against, severe storms.

As the incidence of future natural disasters will likely increase due to climate change (Deloitte Access Economics, 2014) there is likely to be an increase in the cost of future disaster events. As the CFT information was a large contributor to the outcomes, the cost of preparing for, mitigating, and managing natural disasters is expected to be lower than if the CFT outputs had not been produced. For all three types of natural disasters listed above, it is assumed that CFT has led to an efficiency dividend in the cost of preparedness as well as lowering the overall cost of natural disasters when they do occur.

For all three types of natural disasters addressed, the CFT has also improved land use planning in mitigating these disasters and this outcome is captured in the impact valuation. Overall, if the CFT investment had not occurred, information on the potential flood, fire, and storm risk factors would have been more generic, and would not have been specific to each region and sub-region within Tasmania (Chris Irvine, pers. comm., 2017). In addition, the CFT information improved confidence in strategic direction changes regarding natural disaster management, many of which may have been made anyway in response to future climate change.

There are a range of costs incurred by individuals and communities due to flood, bushfire and severe storm events. Actions taken by individual households and local government may reduce these costs. The reduction in future costs of these events may be increased by use of CFT outcomes as identified earlier.

Through improved planning and mitigation, there should be lowered demand for emergency management services to deal with flood events (Chris Irvine, pers. comm., 2017). As a result, spending by the SES and community services will be more efficient as they can direct their resources to more appropriate operations.

There is expected to be more efficient use of resources by those fighting and managing bushfires because of the CFT. An example is backburning. The CFT outputs allow backburning operations to be more efficient, as without the CFT, backburning operations would cost more to perform to gain the same outcome as with the CFT investment.

The impacts of the CFT on severe storms are assumed similar to those for flooding and bushfires. The improved mapping and predictions will lead to more efficient responses to severe storm events and improve SES planning.

Base Damage Costs

A previous Australian study on bushfires includes a state by state breakdown of the projected cost of bushfires to 2050 (Deloitte Access Economics, 2014). The predicted costs for Tasmania from this study are used as a starting point for the valuation of the CFT impact on bushfires. It is assumed that these predictions have not considered CFT information, as they are based on past historical costs of bushfires, pre-CFT. For floods and severe storms, past natural disaster costs for Tasmania (available pre-1999, averaged per year) are used as the starting point to estimate future flood and severe storm damage (BTE, 2001). It is expected that floods and severe storm costs will increase into the future (with and without CFT) but no future prediction trend has been estimated, as it is unknown how large the future costs will be, and timelines cannot be predicted with any certainty.

Both sets of data on damage costs use insurance data from past natural disasters. Data for floods and severe storms includes only natural disasters that incurred a cost of over $10 million. As insurance costs do not take into account all economic costs, a multiplier was then used to determine the total economic loss[1] from each of the three types of natural disasters.

As the $10 million cut off ignores disasters under the $10 million threshold, the Bureau of Transport Economics (BTE) study (2001) sampled the total cost of natural disasters (nationally) for seven years. Natural disasters under $10 million contributed only on average 9% of total disaster costs, so disasters under $10 million costs were ignored (BTE, 2001).

Infrastructure

Infrastructure damage is included in the total cost of natural disasters. However, the impact of the CFT on capital expenditure on infrastructure is valued separately within this assessment. Infrastructure costs from natural disasters would have already been included in the value used in valuing this impact.

Hence, an adjustment was made to exclude infrastructure damage from the total cost of natural disasters. This was affected by decreasing the cost of natural disasters by 5.35%. The 5.35% figure was derived from BTE (2001) and represented the total infrastructure cost component for the five in-depth studies of natural disasters, divided by total cost of the five natural disasters.

Cost Reduction Attributed to the CFT

The impact of the CFT information has been valued by estimating a cost reduction of 1% compared to the without CFT scenario.

Period of impact

It is assumed the period of full impact will last for 10 years from 2015-2026, Before 2016 there will be a ramp up of benefits while the CFT information works its way through policy, and a ramp down after 2025 due to similar information being produced by other providers (such as the CSIRO) at this time (without the CFT).

Summary of assumptions

A summary of the foregoing assumptions is provided in Table 6.

Table 6: Assumptions for Valuing Impacts on Natural Disasters

Variable	**Assumption**	**Resource**
Counterfactual		

[1] The BTE report (2001) defines economic costs as “Economic costs are focused on the additional resources used by the Australian community because of a disaster”.

Existing climate change scenarios available pre-CFT used in natural disaster planning		Agtrans Research
Annual Economic Costs of Disasters to Tasmanian society		
Annual flood costs to Tasmania	$6.70 million (1998 dollars)	BTE (2001)
Baseline 2014 bushfire costs to Tasmania	$40.00 million (2011 dollars) per year	Deloitte Access Economics (2014)
Growth rate of bushfire costs 2014-2020	1.98% per annum	
Growth rate of bushfire costs 2020- 2030	2.39% per annum	
Growth rate of bushfire costs 2030 -2040	2.51% per annum	
Growth rate of bushfire costs 2040-2047	2.34% per annum	
Annual severe storm costs to Tasmania	$1.10 million (1998 dollars)	BTE (2001)
Reduction in Natural Disaster Costs to account for infrastructure impact already valued in Impact 1	5.35%	Agtrans Research based on BTE (2001)(a)
Efficiency dividend assumed for the economic costs of natural disasters		
Efficiency dividend assumed on the cost of flood, fire, and storm costs	1%	Agtrans Research
Proportion of natural disasters where CFT is assumed to have an impact	50%, based on assumption that the impact of some natural disasters cannot be alleviated	
First year of Impact	2011	Agtrans Research, based on when CFT outputs were first mentioned in Tasmanian Government Emergency Plans
Ramp up of benefits	10%, 20%, 40%, 80%,100% in years 2011, 2012, 2013, 2014, 2015	Agtrans Research
Last year of full impact	2025	
Impact decay function	90%, 80%, 70%, 60%, 50%, 40%, 30%, 20%, 10%, 0% of full impact for years 2026- 2035 onwards	
Last year of impact	2034	

(a) Based on the average proportion of infrastructure costs compared to total natural disaster costs.

6.3 Valuation of Impact 4: Increased future operating surpluses in agriculture and horticulture

Agriculture as defined here to include crops, livestock industries and horticulture. The wine grape industry has been excluded from this impact as the impact of the CFT on wine grape production has been estimated separately (Impact 5).

The potential impacts have been valued by using historical Tasmanian statistics on the gross operating surplus (GOS) of the agriculture, forestry and fisheries sector in Tasmania from 2010 to 2017. GOS is similar to profit as costs are subtracted from the value of outputs; however, there is no allowance for fixed capital investment.

Assumptions were then developed on the agricultural component of the broader GOS estimate for agriculture, fishing and forestry, and a time series for the Tasmanian agricultural GOS estimated; in turn, this allowed the gain in GOS to be estimated for each year.

The CFT contribution to the growth in agricultural GOS was then estimated by applying a very small attribution factor (maximum of 0.0% to 0.5% in any one year). The sequence of attribution factors was as follows: the first year of impact was assumed to be 2011 where only a very small factor was applied; this factor increased to a maximum in 2015, remained constant for five years and then declined gradually to zero in 2025. This pattern was adopted to reflect both short term and longer-term management and investment decisions. The phase out of the attribution was to reflect other factors that may have occur in the next eight years that may override the information and decisions that may have been made by paying attention solely to the CFT.

An attempt to value such impacts has been made with assumptions presented in Tables 7 and 8. Note that conservative assumptions for the attribution to the CFT have been made and are presented in Table 8.

Table 7: Gross Operating Surplus Changes for Agriculture, Fisheries and Forestry

Year	Tasmanian Ag., Fish and Forestry: GOS (nominal $m)	Tasmanian Ag., Fish and Forestry: GOS (2016/17 $m)	Increase over Previous Year (2016/17 $m)
2009-10	1,298	1,458	n/a
2010-11	1,477	1,561	103
2011-12	1,508	1,565	4
2012-13	1,599	1,662	96
2013-14	1,783	1,827	166
2014-15	1,822	1,880	53
2015-16	1,982	2,055	175
2016-17	2,335	2,335	280

Source: ABS 5220.0 Australian National Accounts: State Accounts

Table 8: Attribution of GOS Changes to CFT from 2011 to 2024

Year	Increase in GOS over previous year to Tasmanian Ag., Fish and Forestry (2016/17 $)	Proportion of GOS Contributed by Agriculture[(a)] (%)	GOS increase contributed by agriculture (2016/17 $)	Increase in agriculture GOS attributed to CFT (%)	Increase in Agriculture GOS due to CFT (2016/17 $)
2010-11	103,033,700	55	56,668,535	0.1	56,669
2011-12	3,967,300	55	2,182,015	0.2	4,364
2012-13	96,216,900	55	52,919,295	0.3	158,758
2013-14	165,519,200	55	91,035,560	0.4	364,142
2014-15	52,899,500	55	29,094,725	0.5	145,474
2015-16	175,394,400	55	96,466,920	0.5	482,335
2016-17	279,666,000	55	153,816,300	0.5	769,082
AVERAGE: PAST FIVE YEARS			84,666,560		
2017-18			84,666,560	0.5	423,333
2018-19			84,666,560	0.5	423,333
2019-20			84,666,560	0.4	338,666
2020-21			84,666,560	0.3	254,000
2021-22			84,666,560	0.2	169,333
2022-23			84,666,560	0.1	84,667
2023-24			84,666,560	0.0	0

(a) Based on proportion of gross value derived from agriculture to that derived from agriculture, forestry, and fisheries; Proportions derived from: http://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/7503.02015-16?OpenDocument

6.4 Valuation of Impact 5: Increased wine grape expansion and profitability

Wine grape production in Tasmania is distributed across seven Tasmanian regions (North West, Tamar Valley, North East, East Coast, Coal Valley, Derwent Valley, and Huon Valley/Dentrcasteaux Channel). Table 9 shows that the total area of vines in Tasmania compared to total Australian area/production up until 2012 is very small. However, the table shows also that the Tasmanian area of wine grapes has increased over the past 6 years by an average of 127 ha per annum from 2012 up until 2018. Tasmania has over 160 individual wine producers and there are 230 working vineyards covering more than 1,880 ha (Wine Tasmania, 2017).

Table 10 shows additional statistics (measures of success) for the Tasmanian wine industry produced by Wine Tasmania.

Table 9: Total Area Statistics for Wine Grapes in Australia and Tasmania

Year	**Total Australian vineyard area (ha)**	**Tasmanian vineyard area (ha)**
2009-10	156,632	1,388
2010-11	n/a	n/a
2011-12	148,509	1,320
2012-13	n/a	n/a
2013-14	n/a	n/a
2014-15	135,177	1,505
2015-16	n/a	n/a
2016-17	n/a	1,880
2017-18	n/a	2,080

n/a: Not collected
Source: ABS, Wine Tasmania

Table 10: Measures of Success for the Tasmanian Wine Grape Industry

Measure	2015/16	2016/17	2017/18	2018/19
Availability of Tasmanian wine (rolling five-year average)	723,000 9LE* (624,000 9LE)	1,108,000 9LE (733,000 9LE) +17%	+ 5%	+5%
Average value of Tasmanian wine grapes	$2,565/T (Aus - $463/T)	$2,707/T (Aus - $526/T)	+3%	+3%
Average value of Tasmanian wine (domestic - off-premise)**	$22.36/bottle (Aus-$10.87/bottle)	+$22.62/bottle (Aus - $11.48/bottle)	+5%	+5%
Average value of Tasmanian wine (export)	$13.72/L (Aus - $5.22/L)	$13.66/L (Aus - $5.48/L)	+3%	=3%
Visits to Tasmanian cellar doors	18% of visitors (207,000)	21% of visitors (262,332) +22.5%	23% of visitors	25% of visitors
Visits to Wine Tasmania website	81,500	117,800 +40%	125,000	135,000
Membership support	95% production	96% production	97% production	98% production
Tasmanian Sustainability Program Participation	N/A	17	30	50

N/A Not available
* 9 litre equivalents (9LE)
** Note, this is based on available off-premise data, and does not capture the retail value of Tasmanian wine, such as sales through cellar door and direct.
Source: Wine Tasmania (2017)

The following extract from the latest Strategic Plan for Wine Tasmania (2017) supports the growth of the Tasmanian wine industry over the past few years.

"Over the past five years, vineyard plantings in Tasmania have grown by more than 25% and an estimated 200+ hectares is being planted in 2017/18. Tasmania is bucking the national trend in production growth, with the most recent Vineyard Census reporting that overall yield decreased by 11% in the cool and temperate regions of Australia in 2012/13, in contrast to Tasmania's growth of 14% over the same period. In addition to the significant increase in vineyard plantings, expansion by existing wine producers and external investors has included new processing facilities (wineries), packaging / bottling, cellar door, restaurant and tourism infrastructure. Tasmania's total wine production represents less than 0.5% of the total national wine grape production, but 10% of the premium wine segment. The Tasmanian wine sector continues to be an important and growing contributor to trade and the economy, regional employment, tourism and the overall Tasmanian brand. It directly employs 1,400 full time equivalent positions throughout the island's regions and attracted 249,850 interstate / international visitors to its cellar." (Wine Tasmania, 2017)

There has been growing demand for cool climate grape varieties and styles such as Pinot Noir and Chardonnay (together these varieties make up two thirds of Tasmanian grape varieties), as well as Sauvignon Blanc, Riesling and Pinot Gris. Wine Australia's 2016 vintage reports show Tasmanian Pinot Noir grapes are fetching an average of $3,000 per tonne, double the value of cool climate Pinot grapes in the Adelaide Hills, NSW Riverina and Victoria's Yarra Valley (Smith, 2017).

Brown Brothers were aware of the opportunity in Tasmania for cool climate wine production in Tasmania well before 2010. This awareness was driven by Snow Barlow and others around 2005 as well as by formal consultations between Snow Barlow and the Brown Brothers Board in about 2007, and also by consultations with the Victorian Department of Primary Industries. This awareness precipitated the 2010, $32 million purchase of Gunn's wine assets in Tasmania, including 380 ha of wine grapes. The opportunity was created by climate change and rising temperatures for their Victorian cool climate vineyards of wine grapes on the Australian mainland (Snow Barlow, pers. comm., 2017).

Since that time, other mainland-based wine producers have increased grape and wine production in Tasmania in response to seeking wines suited to cool climates and market demand. In addition, existing Tasmanian grape growers and wine producers have increased production and new vineyards are being established by other Tasmanian landholders to diversify from other agricultural enterprises such as sheep production on the east coast.

The early Brown Brothers move to Tasmania in 2010 by purchasing Gunns cannot be attributed to the CFT outputs although the CFT Initiative kicked off in 2007/08 and potentially may have provided some additional confirmation of the opportunity before the CFT reports were released. However, a small part of the later increase in Tasmanian wine grape plantings can be directly attributed to the CFT outputs. The information provided by the CFT has given increased confidence to investors post-2010 regarding spatial temperature and frost predictions.

Further, use of the CFT information in subsequent Tasmanian projects has strengthened the link between wine grape expansion and the CFT. For example, a study by Smart and Wells (2014) produced HDD maps (heat degree days, an index of temperature from links between air temperature and topography), allowing warmer sites to be identified.

Frost distribution maps were also produced of these areas, showing where the risk of frost damage is likely to constrain vineyard development. Frost temperatures were shown to vary greatly in response to topography, with one frost event producing temperatures of lower than -8°C, while 500 m away temperatures were not below freezing (Smart & Wells, 2014). The relationship between HDD and ripening date was used to produce maps of expected average harvest date within these three regions; this was viewed as assisting growers and potential investors to better interpret the HDD maps. Vineyard suitability maps were produced from the frost and HDD maps, identifying areas with both higher HDD levels, and also lower frost levels (Smart & Wells, 2014).

It is assumed that much of the increase in Tasmanian wine grape area would have happened without the CFT investment. This would have been largely due to the increasing market demand for cool climate grape types, the realisation that climate change will reduce or was reducing cool climate grape quality in the mainland, and the competitive price for wine grape land in Tasmania. These reasons supporting the counterfactual have been identified by Wine Tasmania.

Against this counterfactual scenario, it is assumed that the impact of the CFT information may have influenced only a proportion of the increase in area of Tasmanian wine grapes post 2010. A proportion of 25% of the observed area of expansion in the past six years has been attributed to the CFT. This proportion has been assumed to have been driven by the increased confidence gained by prospective investors provided by the detailed spatial temperature, frost and rainfall predictions for Tasmania generated by the CFT initiative.

This assumption is supported by the outcome response by one of the survey respondents as to significant use of the CFT outputs “Enterprise suitability mapping for the wine sector. The wine sector has made strategic investment decisions as a result of the climate modelling that underpins the mapping work”.

The growth in Tasmanian wine grape area has emanated from a number of sources. Estimates of the proportion of each contributing source are provided in Table 11.

Table 11: Scenarios for Expanded Wine Grape Area in Tasmania post-2012

Scenario	New wine grape area by type of investor	Estimated percentage
A	Mainland domiciled wine grape producers with no former grape areas in Tasmania	10%
B	Mainland or Tasmanian domiciled wine grape producers and wineries with existing grape areas/wineries in Tasmania	80%
C	Tasmanian domiciled sheep and wool producers	10%

The impact of the increased area of grapes is valued through the increase in profits likely to have been made by those investing in new grape areas. The assumptions used to estimate the profit increase can vary according to the type of investor. Some of the issues assumed to affect the profit increase include the competing opportunities for investment, the cost of capital required for new grape areas in Tasmania, and the opportunity cost of land where new wine grapes are grown.

Estimation of the profit increase has relied to a large extent on a web-based tool produced by the Tasmanian Department of Primary Industries, Parks, Water and Environment. The tool is entitled ‘Profitability and Gross Margin Analysis for Wine Grapes (Chardonnay and Pinot Noir) that was last updated in May 2017. The tool contains also a capital investment routine.

The profitability increase for each scenario above has been estimated separately through the cash flows generated. The individual cash flows generated for each scenario were then aggregated by weighting them by the scenario area weights provided in Table 11. The use of cash flows was required due to new plantings occurring each year across six years, the time period from planting to mature yields and the cost of capital.

A general set of assumptions that apply to all three scenarios are provided in Table 12 with specific scenario assumptions provided in Tables 13 to 15.

Table 12: General Assumptions for Estimating Profitability Increase

Variable	**Assumption**	**Source**
Increased areas of wine grapes in Tasmania post 2012/13	Average of 127 ha per year for 6 years from 2012/13	Derived from ABS and Wine Tasmania statistics (1,880-1320)/6 = 127 ha per annum
Value of cool climate grapes in Tasmania (Chardonnay and Pinot Noir)	$2,519 net per tonne ($3,200 gross less $681 harvesting, freight and levies)	Based on Tasmanian DPIWPE (2017a)
Yield of cool climate grapes in Tasmania	8t/ha in year 6 with partial yields in years 3, 4 and 5 (2.4, 4,0 and 4.8 tonnes /ha)	
Capital investment per ha	$92,560 per ha in year 1 less residual capital per ha of $79,716 per ha after 15 years	Based on Tasmanian DPIWPE (2017a); includes land, irrigation and other infrastructure, land preparation, planting material, and planting.
Proportion of wine grape area expansion in Tasmania from 2012/13 to 2017/18 in Tasmania that can be attributed to CFT	25% for all Scenarios A to C	The attribution assumes the major drivers of the increased area of cool climate wine grapes in Tasmania have been: • Increased market demand for cool climate grape types • Climate change will reduce or is reducing grape quality in mainland Australian viticulture areas • Low Tasmanian viticulture land prices • The CFT information including spatial and timescale specific information, and the provision of confidence in the general suitability of the future climate for cool climate grape types

Table 13: New Investors from the Mainland without pre-2012 grape areas in Tasmania

Variable	**Assumption**	**Source**
Simple average value of cool climate Pinot Noir grapes and Chardonnay grapes purchased from Adelaide Hills SA region	Chardonnay: $1,390 per tonne Pinot Noir: $1,561 per tonne Average $1,476 per tonne	Based on SA Winegrape Crush Survey, Wine Australia, 2017
Value of cool climate grapes in Tasmania (Chardonnay and Pinot Noir)	$2,519 net per tonne ($3,200 gross less $681 harvesting, freight and levies)	Based on Tasmanian DPIWPE (2017a)
Yield of cool climate grapes in Tasmania and Mainland	8t/ha in year 6 with partial yields in years 3, 4 and 5 (2.4, 4,0 and 4.8 tonnes /ha)	
Increase in price for Tasmanian production (Australian mainland versus Tasmania)	$1,043 per tonne	($2,519-$1,476)
Increase in gross revenue per ha for Tasmania over mainland at mature yield	$8,344 per ha; increases in years 3, 4 and 5 are proportionally less	8 x $1,043; assumes the same yield in both locations
Annual yields, capital and variable and overheads costs	Assumed similar between South Australian and Tasmanian vineyards	Agtrans Research
Capital investment per ha	$92,560 per ha in year 1 less residual capital per ha of $79,716 per ha after 15 years	Based on Tasmanian DPIWPE (2017a); includes land, irrigation and other infrastructure, land preparation, planting material, and planting.
Annualised cost of capital utilised	$5,531 per ha per annum for 15 years @ 6%	Break even analysis
Assumption 1 re capital	Assumes vineyard in SA is sold for same value as new investment so indicative gain is all of $8,344 per ha in years of mature yield	Agtrans Research
Assumption 2 re capital	Assumes new planting in SA would have occurred anyway so only change is a new location chosen and indicative gain remains at $8,344 per ha at mature yield	

Assumption 3 re capital	Increase in gross revenue is reduced by annualised cost of capital, so indicative gain is $8,344-$4,764 = $3,580 per ha at mature yield	
The average net cash flow is estimated as a simple average for the three assumptions above	Indicative gain is the simple average for equal weighting for the three assumptions of $6,756 per ha at mature yield	

Scenario B is assumed to differ from Scenario A in that benefits are not estimated in relation to an alternative investment in the mainland. Rather, the investment is an independent decision to expand production from current plantings in Tasmania. It is assumed that such investors may not have to purchase additional land or possibly, due to existing infrastructure, can avoid some capital expenditure in expanding their wine grape area.

Table 14: Mainland or Tasmanian domiciled wine grape producers and wineries with existing grape areas/wineries in Tasmania

Variable	**Assumption**	**Source**
Gross margin per ha	$4,489 per ha at mature yield	Based on Tasmanian DPIWPE (2017a); capital investment includes land, irrigation and other infrastructure, land preparation, planting material, and planting.
Capital investment per ha is lower compared to Scenario A as it is assumed some land and some infrastructure is already available	$65,016 per ha in year 1 less residual capital per ha of $56,841 per ha after 15 years	
Annualised cost of capital utilised	$3,855 per ha per annum @6% for 15 years	Break even analysis
Profit per ha at mature yield allowing for capital servicing	$634 per ha	$4,489-$3,855

It is assumed that new investment by Tasmanian sheep and wool producers will not have to purchase additional land but will forego profits being made from the enterprise being replaced. The average annual gross margin foregone from the land used for grapes is assumed to be $370 per ha, based on a simple average of enterprises based on wool, store lambs and prime lambs.

Table 15: Tasmanian sheep and wool producers developing new grape areas

Variable	Assumption	Source
Gross margin per ha	$4,489 per ha	Based on Tasmanian DPIWPE (2017a)
Increase in gross margin at mature yield	$4,119 per ha	$4489-$370
Capital investment per ha is lower compared to Scenario A as it is assumed land is already available; however, the earnings foregone from the existing land use constitutes an opportunity cost to the new land use	$67,516 per ha in year 1 less residual capital per ha of $54,716 per ha after 15 years	Based on Tasmanian DPIWPE (2017a); capital investment includes, irrigation and other infrastructure, land preparation, planting material, and planting (does not include land).
Opportunity cost of land	$370 per ha	DPIWPE (2017b) Livestock Gross Margins; average of margins for store lambs, prime lambs and wool
Annualised cost of capital utilised at 6%	$4,171 per annum per ha for 15 years	Break-even analysis

6.5 Valuation of Impact 9: More efficient and effective future biodiversity conservation management

CFT contributed to the Landscapes and Policy Hub of the NERP. The LPH was one of five Hubs funded under the NERP.

The purpose of the LPH was to focus on biodiversity at the scale of landscapes and whole regions. The research process included two case study regions where researchers addressed social and institutional issues, climate change, biogeography, economics, wildlife, fire and freshwater ecology, and communication and integration. From the research in the two case study regions (The Australian Alps and the Tasmanian Midlands), the LPH developed a range of tools, techniques and policy pathways, and presented a set of recommendations for more effective management of biodiversity at the regional scale.

As an example, an extract from one of many impact statements for the Hub reads:

"*Working in collaboration with biodiversity conservation practitioners, the hub developed a modelling tool to aid large–scale planning for wildlife conservation in the Tasmanian Midlands. This dataset comprises climate–niche models for all of Tasmania's terrestrial vertebrates (about 230 species) and shows how suitable their climate–niche space may change over the next 100 years. The modelling tool can generate maps for the 230 species in any given year, from 1950–2100, in the form of shape files (or a format that can be converted to shape files). These maps represent the most comprehensive set of projected fauna distributions in any jurisdiction. There is great interest* *in this data set amongst conservation planners in the public and private sector as the data can be used in other analyses or combined with other spatial data such as land cover maps for more refined estimation of likely future distributions of taxa of interest.*"

The final report of the LPH (2011-2015) was compiled in 2015 (Gaynor & Lefroy, 2015).

An evaluation of the strategies used by the LPH was produced by Charles Sturt (Mitchell, et al., 2015). The evaluation in 2015 reported expectations that the LPH research would make a difference to biodiversity conservation with 59% of respondents stating their expectation had been met somewhat, but that it was too soon to tell if the research had made a difference to biodiversity conservation.

However, 38 testimonials to the LPH were published in April 2015 (Gaynor, The Hub Happenings, 2015). These clearly show the potential from many perspectives. Four selected examples follow:

'One of the most successful aspects of the hub was its effort to identify who the agencies they need to engage with, learn about their issues, then respond by working out how the researchers can help develop tools to deal with those issues. So, while this has not yet translated across to all those working in the field, the tools have certainly helped at the strategic planning level, and the tools are focused on real management problems. I have every confidence that the tools will help later at the field level.' - ***John Wright,*** Parks Victoria

'The way the research is woven together and presented, with the wheel, and in multiple ways of the case study areas, the steps and the tools, is really useful. It is accessible in a modern electronic world, as opposed to a final report with a dusty cover that we put on a shelf unused, this final report has potential to have much greater reach with a legacy that goes far beyond these researchers and this bit of work. Life at Large sets a context of Australia doing world class, integrated research.' - ***Carolyn Cameron,*** Federal Department of the Environment

'I will use GAP CloSR to assist staff, especially in Assessments Branch and Strategic Approaches to make more informed decisions in impacts of development on species, especially in the context of dispersal ability or lack thereof.' - ***Anonymous***

'The wealth of data is outstanding already and has delivered sound results. The accumulation data may benefit much future research.' – ***Landowner***

Impacts of the LPH are expected to be associated with more effective biodiversity management in Australia in the future through improved regional research and policies by governments and programs and an associated increase in effective expenditure by Community Groups, Landcare, Catchment Management Authorities, individual farmers and farm groups.

Although the impacts are difficult to value, an attempt has been made with the contributing assumptions presented in Table 16. Conservative assumptions for some uncertain estimates have been made. Note that the biodiversity management expenditure estimate is for terrestrial species (land based) and therefore excludes marine and aquatic species.

Also, While the CFT made a modest contribution to the total budget of the LPH, the CFT is entitled to share in any potential impacts from the investment in the LPH. An attribution factor based on investment contributions is included in Table 16.

Table 16: Assumptions Used in Impact Valuation of CFT Investment in the LPH

Variable	Assumption	Source
Australian annual national expenditure on conservation of terrestrial biodiversity	$2.3 billion in 2008/09 $ terms	National Biodiversity Expenditure Study (Steverson, 2010), prepared for Bid of CRC for Securing and Building Biodiversity. https://www.scribd.com/document/98359954/HVRF-Biodiversity-Expenditure-Scoping-Study-Report
Australian annual national expenditure on conservation of terrestrial biodiversity	$2.6151 billion in 2016/17 $ terms	Multiplier of 1.137 conversion assuming annual expenditure has remained the same in real terms over time
Proportion of expenditure that may be associated with regional biodiversity management programs	20%	Agtrans Research
Proportion of regional biodiversity management expenditure that may have benefited from application of policies and strategies derived from the Landscape Hub of NERP	5%	
Efficiency dividend to LPH applied to expenditure without the LPH	20%	
Investment in Associated Climate Futures Project	$853,669	Ted Lefroy, LPH
Total Investment in LPH (including the CFT project)	$6.78 million	
Proportion of LPH impact attributed to the CFT Project	12.6%	$852,669/$6.78 million
Overall attribution factor applied to CFT investment	0.0252%	20% x 5% x 20% x 12.6%
Annual gain that can be attributed to CFT funding	$659,000 per annum	$2.62b x 20% x 5% x 20% x 12.6%
Year in which annual gain commences	2016/17	Agtrans Research
Decay function as further improvements to regional biodiversity conservation management are developed	10 percentage points per annum cumulative	
Final year of gains	2026/27	

6.6 Valuation of Impact 10: More effective forest industry investment

The impacts are assumed for both the public and private plantation forestry sectors. The improved future productivity of tree varieties planted will be due to improved planting decisions that can exploit future climate change opportunities. The improved future climate information will allow forestry managers to optimise overall returns by manipulating planting that increases future wood yields and values for plantations (or avoids decreases in value for plantations). Opportunities can be identified to switch planting species, with a trade-off between predicted growth rate, and price (Robert Musk pers. comm., 2018). It is assumed a planting choice effectiveness gain to forestry in Tasmania will occur through increased prices and/or yields from the species planted based on specific tree species reactions to a changing climate compared to what would have been grown otherwise in a specific location.

Counterfactual

Without the CFT information, it is assumed the current Tasmanian plantation planting and harvest areas will remain constant at their current level into the future. This assumption is on the basis that there has been no growth in new plantation areas established within Tasmania since 2013 (ABARES, 2016b) and predictions for plantation forestry in Australia show that there will probably be either very minor or no future expansion of forestry areas (ABARES, 2016a). A second assumption is that harvest yields and prices will remain constant into the future if the CFT information had not been made available.

Gross operating surplus

The gross operating surplus (GOS) of the Tasmanian forestry sector is used as the statistical measure of profitability of the plantation forestry sector. An increase in the GOS is used to represent the impact of the CFT. The GOS is used instead of the gross value, as the former takes into account the fixed and variable costs of the production process for plantation forestry.

The average GOS from 2013-2017 in real terms as estimated in Table 17 is used to represent the future annual GOS. The GOS reported in any year takes into account the harvest value in that year and the harvest and planting costs. This harvest value can include harvesting from a number of different planting years, for example, a harvest in 2020 will include plantings from 1990s and 2000's, and 2010's due to the harvest of thinnings and logs for pulp or timbers in any one year. Therefore, for any harvest year, only a proportion of the predicted harvest value can be attributed to a specific planting year.

Table 17: Average Tasmanian plantation forestry GOS

Year	**GOS for TAS Agriculture, Fisheries and Forestry (2016/17$)**	**Proportion of GOS assumed contributed by Forestry[(a)] (%)**	**GOS contributed by forestry (2016/17$)**	**Proportion of Forestry GOS attributed to plantations[(b)]**	**GOS contributed by plantation forestry (2016/17$)**
2013	1,661,520,900	10.80%	179,513,973	58.81%	105,570,285
2014	1,827,040,100	10.80%	197,396,991	58.81%	116,087,100
2015	1,879,939,600	10.80%	203,112,357	58.81%	119,448,247
2016	2,055,334,000	10.80%	222,062,311	58.81%	130,592,517
2017	2,335,000,000	10.80%	252,277,974	58.81%	148,362,031
2018 onwards[(c)]	1,951,766,920	10.80%	210,872,722	58.81%	124,012,036

(a) Based on forestry's proportion of the gross value of agriculture, fisheries, and forestry in Tasmania (ABARES 2016a, ABARES, 2017, ABS, 2017b)
(b) Based on 5-year average (2012-2016) (ABARES 2016a)
(c) Based on 5-year average (2013-2017)

The percentage of the GOS attributed to the period after planting is based on the eight types of harvests (four thinnings and four clear fell) and in the seven harvest years after planting[2]. The proportion of the gross value of the type of wood harvested is multiplied by the estimated harvest time of the material in question. This is detailed in Table 18.

Proportion of material harvested in different years after a planting year

The approximate times after planting when trees will be thinned or clear-felled is based on predictions for Tasmania by ABARES (2016a). The proportion of the type of material harvested is based on the average yield (cubic metres per hectare) for the type of material and its use. It is assumed that the timing of the different harvests from each plantation year is uniform over time. For any given planting year, the GOS attributed to plantation forestry is distributed over the seven relevant harvest years. The proportion of GOS to each harvest year is based on the percentage yield and value of the wood and log type appropriate to the harvest event assumed as represented in Table 18 (e.g. first thinning, clear-fell etc).

Table 18: Percentage of GOS value from the harvested material after the relevant planting year

Harvest period (years after planting)	**Percentage of GOS attributed to years after planting**	**Source:** ABARES (2016a), ABS (2017)
9	5.03%	51.51% * 9.76%[(a)]
10	15.70%	51.51% * 30.49%
12	10.98%	45.45% * 24.14%
15	20.10%	51.51% * 26.83% + 51.51% * 12.20%[(b)]
17	11.40%	24.16% * 36.36% + 23.51% * 11.11%
25	11.50%	51.51% * 20.73% + 0.82% * 100%
30	25.29%	24.16% * 18.18% + 23.51% * 88.89%
All years	100.00%	

(a) The calculations are based on the proportional gross value of material type harvested per harvest year (1st figure) multiplied by the proportion of the harvest that can be attributed to the specific planting year (2nd figure).
(b) Within the harvest periods after planting year, there may be more than one type of tree harvest and one type of material harvest, therefore there are two calculations.

Valuation of impacts

For the with CFT scenario, the same assumption as for the counterfactual is made that the area of plantation forestry within Tasmania remains constant. It is assumed planting decisions using CFT information began in 2014. Benefits from these improved planting decisions will begin when the first thinning takes place, assumed to be nine years later. This is consistent for all planting years that are influenced by the CFT information.

The percentage gain from the CFT information that can attributed to a given planting year is assumed to affect only 30% of plantation forestry GOS. Within the 30% area affected, the use of CFT information is assumed to lead to a GOS increase of 2% as shown Table 19. This is applied to the predicted harvest for each of the seven years affected by CFT information. While increased yields and different harvest material due to planting more appropriate species may have different

[2] There may be different types of harvest per year that can be attributed back to the same planting year, as multiple tree types are planted. Therefore, there are more harvest types (8) than harvest years (7) relevant to a single planting year.

costs than what otherwise would have occurred, the analysis assumes these costs are constant as it is unknown what specific species will be grown and what the change in costs may be.

The increase in GOS due to the CFT and the proportion of planting area affected for a single year is then applied to each of the harvest years individually.

To take into account that the CFT information may not be used immediately in planting strategies, a ramp-up of benefits of 20%, 40%, and 80% was applied in 2014, 2015, and 2016 respectively, with the full effects of the CFT realised from the 2017 planting.

A decay function of impacts is assumed from 2026. This is set at 10% per annum. This assumed decay is due to “learning by doing” by forestry managers and the likelihood of development of improved climate models. This will take effect for plantings in 2026 (10% decay), with the last year of planting affected by the CFT being in 2034. The full set of assumptions are provided in Table 19. The predicted benefits from the CFT information for a planting year (not including any ramp up or decay function) can be viewed in Table 20.

The impact values estimated are likely to be conservative, as there will be CFT benefits post 2047, as some plantations affected by the CFT (e.g. plantings in 2034) will continue to be harvested and have benefits realised into the future.

Table 19: Estimated GOS with CFT information

Variable	**Assumption**	**Source: Tables 17 and 18**
GOS of trees harvested 9 years after planting	$6.24 m	$124.01 m * 5.03%
GOS of trees harvested 10 after planting	$19.48 m	$124.01 m * 15.70%
GOS of trees harvested 12 after planting	$13.62 m	$124.01 m * 10.98%
GOS of trees harvested 15 after planting	$24.93 m	$124.01 m * 20.10%
GOS of trees harvested 17 after planting	$14.13 m	$124.01 m * 11.40%
GOS of trees harvested 25 after planting	$14.26 m	$124.01 m * 11.50%
GOS of trees harvested 30 after planting	$31.36 m	$124.01 m * 25.29%
Percentage of harvested value affected by CFT	30%	Agtrans Research
GOS increase due to CFT	2%	
Ramp up of benefits in planting years 2014, 2015, 2016	20%, 40%, 80%	
Full benefit 2017-2025 (planting years)	100%	
Decay of benefits in planting years 2026, 2027, 2028, 2029, 2030, 2031, 2032, 2033, 2034, 2035	90%, 80%, 70%, 60%, 50%, 40%, 30%, 20%, 10%, 0%	
Year of first planting the CFT is used	2014	
Last year of planting the CFT is used	2034	
First year of valued impacts	2023	
Last year of valued impacts	2047	

Table 20: Difference between CFT and without CFT for one planting year, assuming full benefit

Years after planting	9	10	12	15	17	25	30
GOS With and Without CFT Information							
GOS with CFT ($m)	1.91	5.96	4.17	7.63	4.33	4.36	9.60
GOS without CFT ($m)	1.87	5.84	4.09	7.48	4.24	4.28	9.41
Benefit gained from CFT per planting year ($m)[(a)]	0.04	0.12	0.08	0.15	0.09	0.86	0.19

(a) The benefits do not include any ramp up or decay factors applied to the with CFT scenario

6.7 Valuation of Impact 13: Improved preparedness, prevention and operational capacity for fire management in the TWWHA

Improved protection of unique alpine habitats and biodiversity, as well as cultural heritage capital, is difficult to value due to the wide array of ecosystem types and cultural heritage values at risk in the TWWHA. Cultural heritage sites are particularly difficult to value. A thorough valuation would require substantial data collection and the application of non-market valuation techniques such as choice modelling. Instead, an estimate of the potential impact has been made in the form of the value of biodiversity loss that might be avoided due to the CFT information has been made. This has been achieved through applying a benefit transfer approach that uses estimates of the willingness to pay for avoiding biodiversity loss. This approach also required assumptions of the probability of the CFT information being used by TWWHA fire management and the cost of the increased preparedness and management changes that might be made.

The TWWHA covers over 1.5 million hectares (20% of the area of Tasmania) and encompasses areas of unique biodiversity and cultural heritage sites. It was listed as World Heritage in 1982 based on the prevailing four natural criteria and three cultural criteria.

The counterfactual for valuing this impact is that fire risk in the future in the TWWHA (from 2016/17) will be such that there may be a 5% probability in each year of one of each of the following downward species status changes e.g. unlisted to vulnerable, vulnerable to endangered, endangered to critically endangered, and critically endangered to extinct. With the availability of the CFT outputs, this probability is assumed to fall to 2.5% in each year. It is assumed that one species in each status category is at risk in any year.

The downward shift is valued through a willingness to pay estimate for Australian households of $0.89 per household (2010/11 $ terms) to avoid extinction for one plant or animal species (van Bueren & Bennett, 2004; Lai, 2011). The $0.89 per species is divided by four to estimate the value of avoiding one downward step in the four species status changes. This was necessary given the absence of further information on the marginal differences in the willingness to pay as a species moves through the different status changes towards extinction.

A probability of 90% has been assumed that the CFT future predictions will be used by TWWHA fire management. The additional cost of the usage of the CFT outputs is assumed to be 25% of the value of the probability shift.

A summary of the assumptions used in the valuation of impact is provided in Table 21.

Table 21: Assumptions Used in Impact Valuation of Improved Fire Management in TWWHA

Variable	Assumption	Source
Australian willingness to pay for avoiding a species extinction	$0.89 per annum per Australian household (2010/11 $ terms)	van Bueren & Bennett (2004); Lai (2011)
Australian willingness to pay for avoiding a species extinction	$0.94 per annum per household in 2016/17 $ terms	$0.89 x 1.057 (GDP implicit price deflator index)
Australian population of households	For years ending 30th June 9.24 million 2017-2021, 10.10 million 2022-2026 11.83 million 2027-2031 12.68 million 2032-2047	ABS (2015)

Assumed willingness to pay for avoiding a one-step downward status change	$0.235 per annum per household per status change	0.94 / 4
Potential number of downward species status changes at risk of occurring each year	Unlisted to vulnerable 1 Vulnerable to endangered 1 Endangered to critically endangered 1 Critically endangered to extinct 1	Agtrans Research
Counterfactual: Probability of status changes occurring each year without the CFT research	5%	
Probability of status changes occurring each year with the CFT information	2.5%	
Probability of usage of CFT information by TWWHA	90%	
Cost of usage of CFT information	25% of value of gain due to probability shift	
Year in which annual gain commences	2016/17	
Final year of gains	2046/47	

7. Results

7.1 Investment Criteria

All benefits and investment costs were expressed in 2016/17 dollars using the GDP Implicit Price Deflator (ABS, 2017a). All costs and benefits were discounted to the 2016/17 year using a discount rate of 5%. The base analysis used the best estimates of each variable, notwithstanding a high level of uncertainty for some of the estimates. Investment criteria were estimated for the total investment in the CFT projects over the years 2007/08 to 2016/17.

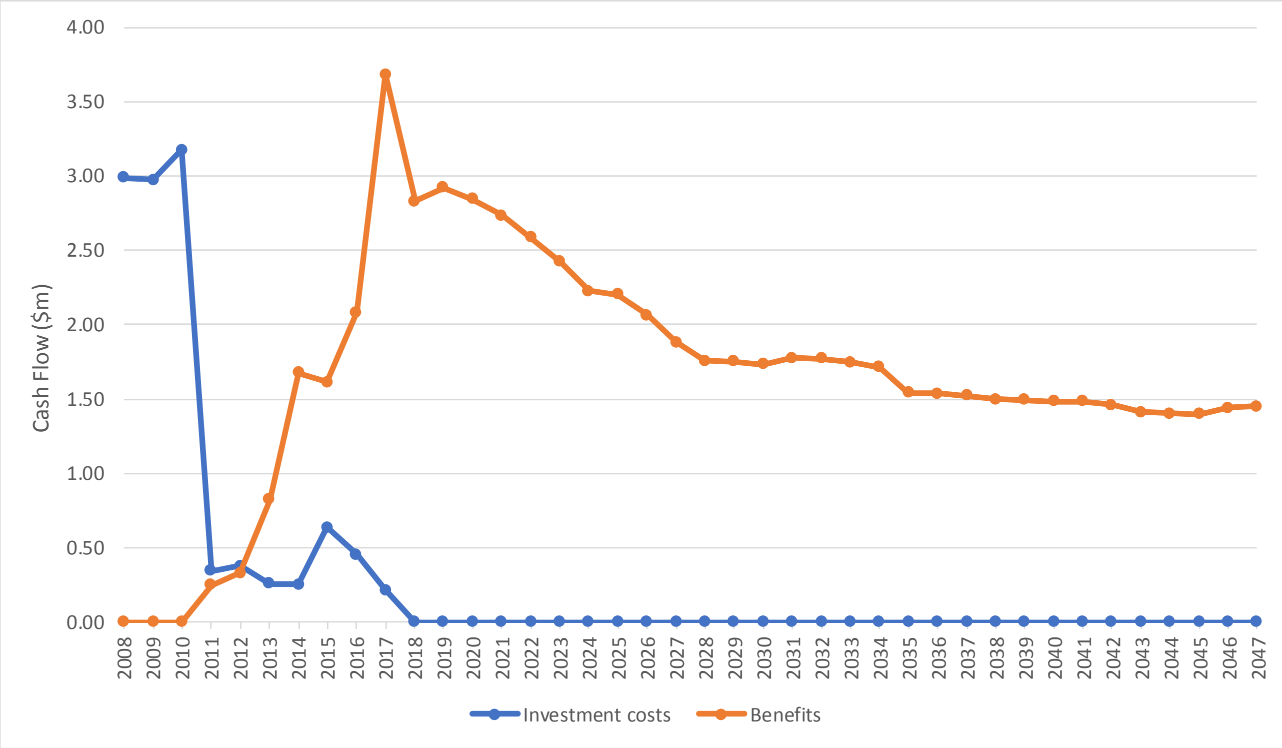
All analyses ran for the length of the investment period plus 30 years from the last year of investment (2016/17) to the final year of benefits assumed. However, due to the assumed constraints on the longevity of some benefits, the 30 years was curtailed for some impacts.

Table 22 shows the investment criteria for the different periods of benefits for the total CFT investment. Figure 2 shows the flow of undiscounted benefits derived from the analysis.

Table 22: Investment Criteria for Total Investment
(discount rate 5%)

Investment criteria	**Year after last year of investment**						
	0	**5**	**10**	**15**	**20**	**25**	**30**
Present value of benefits ($m)	11.35	23.43	30.80	35.47	38.85	41.27	43.09
Present value of costs ($m)	16.44	16.44	16.44	16.44	16.44	16.44	16.44
Net present value ($m)	-5.09	6.99	14.36	19.03	22.41	24.83	26.65
Benefit–cost ratio	0.69	1.43	1.87	2.16	2.36	2.51	2.62
Internal rate of return (%)	negative	9.9	12.5	13.3	13.7	13.8	13.9

Figure 2: Annual Undiscounted Benefits and Costs for CFT Investment



7.2 Sources of Benefits

The distribution of the total benefits estimated for each impact valued is provided in Table 23. Given the assumptions made, the benefits from the capital investment in infrastructure impact (Impact 1) contributed the highest level of benefits (42%). This impact was followed in magnitude of present values by the impacts in the areas of increased surpluses in agriculture and horticulture (17%) and from wine grape expansion (10%).

Table 23: Contribution of Individual Impacts Valued to Total Benefits
(Total investment, discount rate 5%, 30 years)

Impact Valued	**Present Value of Benefits** (PVB, $m)	**Contribution to Total PVB** (%)
Impact 1: More efficient and effective capital investment in infrastructure development	18.2	42.2
Impact 3: More efficient and effective natural disaster management	4.1	9.5
Impact 4: Increased future operating surpluses in agriculture and horticulture	7.2	16.8
Impact 5: Increased wine grape expansion and profitability	4.5	10.4
Impact 9: More efficient and effective future biodiversity conservation management	3.2	7.3
Impact 10: More effective forest industry investment	3.1	7.3

Impact 13: Improved preparedness, prevention and operational capacity for fire management in the TWWHA	2.8	6.6
Total	43.1	100.0

7.3 Sensitivity Analyses

Sensitivity analyses of investment criteria were carried out for the discount rate and for the level of attribution assumed for the CFT information across the impacts valued.

Discount rate

The sensitivity analysis for the discount rate was performed for the total investment and with benefits taken over the life of the investment plus 30 years from the last year of investment. All other parameters were held at their base values. Table 24 presents the results. The results showed a high sensitivity to the discount rate.

Table 24: Sensitivity to Discount Rate
(Total investment, 30 years)

Investment Criteria	**Discount rate**		
	0%	**5% (base)**	**10%**
Present value of benefits ($m)	66.58	43.09	33.46
Present value of costs ($m)	11.67	16.44	23.03
Net present value ($m)	54.90	26.65	10.43
Benefit-cost ratio	5.70	2.62	1.45

Attribution Levels

The sensitivity analysis for the levels of attribution assumed for the CFT information used the individual attribution levels for each of the seven impacts valued as the base. As each of these base attribution levels varied across the seven impacts, the sensitivity analysis used both a halving and a doubling of each of each of these levels to assess the sensitivity of the investment criteria to a uniform change in attribution. Results are reported in Table 25 and illustrate that this assumption has a significant influence on the investment criteria as all impacts valued are linearly related to the attribution factor. As reasonably conservative attributions to CFT information have been used in the base analysis, the sensitivity results show that the benefit-cost ratio could be significantly higher than the 2.6 to 1 estimated.

Table 25: Sensitivity to Changes in Attribution Levels across all Seven Impacts Valued
(Total investment, 30 years, 5% discount rate)

Investment Criteria	**Attribution levels assumed**		
	0.5x Base	**Base**	**2x Base**
Present value of benefits ($m)	21.50	43.09	86.54
Present value of costs ($m)	16.44	16.44	16.44
Net present value ($m)	5.06	26.65	70.01
Benefit-cost ratio	1.31	2.62	5.26

7.4 Confidence Ratings & Other Findings

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

A confidence rating based on these two factors has been given to the results of the impact assessment (Table 26). The rating categories used are High, Medium and Low, where:
High: denotes a good coverage of impacts or reasonable confidence in the assumptions made
Medium: denotes only a reasonable coverage of impacts or some uncertainties in assumptions made
Low: denotes a poor coverage of benefits or many uncertainties in assumptions made

Table 26: Confidence in Impact Assessment

Coverage of Impacts	Confidence in Assumptions
Medium	Low to Medium

Coverage of impacts was assessed as medium as there were number of impacts identified but which were not valued. There were as also likely to be unidentified impacts due to the multiple uses of future climate predictions produced by the CFT Initiative.

Confidence in assumptions was rated as low to medium. While some support for many assumptions was provided subjectively by industry and government personnel, some uncertainty remains regarding the specific levels of impacts likely to be captured in the future. To some extent this uncertainty has been offset in that the assumptions that have been made for valuing the impacts from the CFT Initiative are potentially conservative.

8. Discussion

The impact assessment reported here has been complex due to the widespread implications of improved future climate change information becoming available from the CFT investment. First, there is no doubt that communities were already aware of likely climate change impacts on their own future as well as those on future communities. However, it is difficult to identify the current actions and preparedness strategies that would have been, and will be, adopted in the absence of the CFT investment. However, some specification of the counterfactual at the individual sector/industry/community level is essential in assessing the impact of the CFT. This has been one of the more challenging aspects of the current assessment.

While there is no doubt that the CFT has produced important and relevant information, the direct and indirect attribution to the CFT via changes in preparedness planning and strategy development, and current future operational decision making is difficult to assess in relation to the specific impact subjected to valuation. The magnitude of the attribution factors varies somewhat between impacts and each has been based on the strength of evidence available. In most cases the approach taken has been to conservatively attribute only marginal or small changes to estimate each of the CFT impacts.

There will be most likely many other planning and strategy changes attributable to the CFT to those already identified in the current assessment. On the other hand, the targeted sectors and industries where the CFT has been identified as having a major impact have been defined somewhat broadly (e.g. agriculture) and therefore potentially address a significant proportion of Tasmanian economic activity. However, there are still likely to be unidentified sectors where CFT information has been used and additional impacts are likely. In this regard several additional impacts have been identified in the assessment that have not been valued in financial terms. Nevertheless, many of the impacts not valued would contribute significantly to the total value of the CFT Initiative. In particular, the improved protection afforded the cultural heritage value of the TWWHA is potentially a significant omission and further economic analysis of this impact could be warranted. Further, because of the usefulness of climate futures information to general economic and community well-being, there are likely other impacts that have not been covered by the 13 impacts identified in this assessment.

For industry impacts that have been valued, the emphasis in some cases has been on the primary beneficiary. However, two additional considerations need to be noted. In the case of additional investment in Tasmanian wine grapes, there is likely to be increased economic surplus captured by the supply chain including winemakers. For some of the other impacts such as the increase in the agricultural gross operating surplus, there will be potential sharing of the increase along the input and output supply chains.

The CFT investment assessed (2008-2017) is also providing a significant legacy in that a number of current and ongoing projects are being funded many of which are building on the projects and their output associated with the original CFT initiative. These current projects are listed in this assessment. Also, the linkages of several of these current projects to projects in the original CFT investment have been identified, but no impact valuation of the current projects have been made and therefore no attribution of benefits to the original CFT assessment included.

9. Conclusion

A changing climate will affect most sectors and industries, as well as all types of communities. The CFT investment by ACE CRC has contributed significantly to preparedness for future climate change in Australia, and particularly in Tasmania.

The current impact assessment has not been confined to Tasmanian impacts as some of the outputs from the CFT initiative also have benefited the mainland (e.g. biodiversity conservation management via the Landscapes and Policy Hub and grape wine interests domiciled in the mainland). In addition, many of the current research and development investments by the ACE CFT team are increasingly addressing wider Australian interests.

The ACE CRC CFT Initiative has created greater awareness, understanding and knowledge that otherwise would not have occurred in its absence. The survey of representatives of various sectors where impacts have been identified has provided a high level of supporting information to the difficult assumptions that necessarily had to be made for the cost-benefit analysis. However, there were still some assumptions that had to be made with limited evidential support.

The data assembled from the key user survey was not only useful in supporting best-bet assumptions for the cost-benefit analysis, but also contributed to the description of the pathway to impact via definition of outputs, outcomes and impacts from the various CFT investments. For example, users were asked to rate five key characteristics of the CFT outputs (finer scale of prediction and time lines, increased confidence for future planning, sector specific relevance of CFT outputs, meaningful communication of CFT outputs, and more specific information on future risk profiles). The sector specific relevance of the CFT outputs was the highest rated characteristic. The survey results indicated that sector specific information and the ability to improve communication of climate futures research were characteristics of significant value to key users of the CFT outputs. Apart from the inherent value of the information produced by the CFT, the process of engagement and interaction with users of CFT information was a key contributor to the overall positive impact of the Initiative.

The economic evaluation component of the impact assessment (the CBA) has reported positive investment criteria for the total CFT investment (2008-2017). Using best-bet but conservative assumptions, the present value of benefits was estimated at $43.1 million (present value terms) as a result of total investment of $16.4 million (present value terms), giving a NPV of $26.6 million, a BCR of approximately 2.6 to 1 and an internal rate of return of 13.9%. The estimated benefit-cost ratio of approximately 2.6 to 1 is within the range of benefit-cost ratios for other CRCs and other climate RD&E programs that have been estimated over the past ten years by Agtrans Research.

The conservative assumptions made in the CBA, combined with only a medium coverage of impacts, and the omission of the value of current projects that are underpinned by methods developed within the CFT, are likely to have resulted in an underestimate of the investment criteria. Nevertheless, the best estimate of the net present value of $26.6 million is an outstanding result and should be viewed positively by the ACE CRC, its research and funding partners, industry and other key stakeholders.

References

ABS. (2015, March 18). *3236.0 - Household and Family Projections, Australia, 2011 to 2036.* Retrieved from Australian Bureau of Statistics: http://www.abs.gov.au/ausstats/abs@.nsf/Latestproducts/3236.0Main%20Features42011%20to%202036

ABS. (2017a). *5204.0 - Australian System of National Accounts, 2016-17.* Retrieved from Australian Bureau of Statistics: http://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/5204.02016-17?OpenDocument

ABS. (2017b, July 7). *7503.0 - Value of Agricultural Commodities Produced, Australia 2015-16.* Retrieved from Australian Bureau of Statistics: http://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/7503.02015-16?OpenDocument

ABS. (2018, January 17). *8762.0 - Engineering Construction Activity, Australia, Sep 2017.* Retrieved from Australian Bureau of Statistics: http://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/8762.0Sep%202017?OpenDocument

ACE CRC. (2010). *Climate Futures for Tasmania climate modelling: the summary.* Hobart, Tasmania: Antarctic Climate and Ecosystems Cooperative Research Centre.

ACE CRC. (2012a). *Hobart City Council Climate Change Snapshot.* Hobart, Tasmania: Hobart City Council. Retrieved from file:///X:/ACE%20CRC%202017/Other%20reports/HCC_Climate_Snapshot_2012%20(1).pdf

ACE CRC. (2012b). *Local Government Area Climate Profiles*. Retrieved from Department of Premier and Cabinet Tasmanian Climate Change Office: http://www.dpac.tas.gov.au/divisions/climatechange/what_you_can_do/local_government/local_government_area_climate_profiles

ACE CRC. (2015a). *Our History*. Retrieved from Antarctic Climate & Ecosystems Cooperative Research Centre: http://acecrc.org.au/about/our-history/

ACE CRC. (2015b). *The ACE Partnership*. Retrieved from Antartic Climate & Ecosystems Coorperative Research Centre: http://acecrc.org.au/about/partnerships/

ACE CRC. (2015c). *About Us*. Retrieved from Antarctic Climate & Ecosystems Cooperative Research Centre: http://acecrc.org.au/about/

ACE CRC. (2015d). *Climate Futures for Tasmania*. Retrieved from Antarctic Climate & Ecosystems Cooperative Research Centre: http://acecrc.org.au/climate-futures-for-tasmania/

ACE CRC. (2015e). *2014/15 Annual Report.* Hobart, Tasmania: Antarctic Climate and Ecosystems Cooperative Research Centre.

Bennett, J., Ling, F., Graham, B., Grose, M., Corney, S., White, C., . . . Bindoff, N. (2010). *Climate Futures for Tasmania: Water and Catchments.* Hobart, Tasmania: Antarctic Climate and Ecosystems Cooperative Research Centre. Retrieved from https://web.archive.org/web/20150406013417/http://www.dpac.tas.gov.au/__data/assets/pdf_file/0005/140198/Water_and_Catchments_Technical_Report.pdf

Bindoff NL, Love PT, Grose MR, Harris RMB, Remenyi TA, White CJ (2017), Review of climate impact change work undertaken, research gaps and opportunities in the Tasmanian context: Technical report, Antarctic Climate & Ecosystems Cooperative Research Centre, Hobart, Australia.

Biosecurity Tasmania. (2017). Maintaining Tasmania's freedom from fruit fly: A strategy for the future 2017-2050. Department of Primary Industries, Parks, Water and Environment.

Retrieved from http://dpipwe.tas.gov.au/Documents/Tasmanian%20Fruit%20Fly%20Strategy%202017_2050.pdf

BTE. (2001). *Economic Costs of Natural Disasters in Australia - Report 103.* Canberra: Bureau of Transport Economics. Retrieved from https://bitre.gov.au/publications/2001/files/report_103.pdf

Burnie City Council. (2010). *Climate Change*. Retrieved from Burnie City Council: http://www.burnie.net/Environment/Climate-Change

Cechet, R., Sanabria, L., Divi, C., Thomas, C., Yang, T., Arthur, W., . . . Bindoff, N. (2012). *Climate Futures for Tasmania: Severe Wind Hazard and Risk.* Hobart, Tasmania: Antarctic Climate and Ecosystems Cooperative Research Centre. Retrieved from https://web.archive.org/web/20150406013549/http://www.dpac.tas.gov.au/__data/assets/pdf_file/0003/181884/Severe_wind_hazard_and_risk_CFT.pdf

Climate Change in Australia. (2016). *Climate Futures Exploration Tool*. Retrieved from Climate Change in Australia - Projections for Australia's NRM Regions: https://www.climatechangeinaustralia.gov.au/en/climate-projections/climate-futures-tool/projections/

Climate Futures. (2018). *Projects: Reanalysis for Tasmania*. Retrieved from climatefutures: http://climatefutures.org.au/projects/reanalysis/

Corney, S., Katzfey, J., McGregor, J., Grose, M., Bennett, J., White, C., . . . Bindoff, N. (2010). *Climate Futures for Tasmania: Climate Modelling.* Hobart, Tasmania: Antarctic Climate and Ecosystems Cooperative Research Centre. Retrieved from https://web.archive.org/web/20150406013051/http://www.dpac.tas.gov.au/__data/assets/pdf_file/0015/151125/CFT_-_Climate_Modelling_Technical_Report.pdf

CSIRO. (2009). *Sustainable Yields*. Retrieved from CSIRO - Tasmania Sustainable Yields Project: https://www.csiro.au/en/Research/LWF/Areas/Water-resources/Assessing-water-resources/Sustainable-yields/Tasmania

Deloitte - Insight Economics. (2007). *Impact Monitoring and Evaluation Framework Background and Assessment Approaches.* Canberra: The CRC Association.

Deloitte Access Economics. (2014). *Scoping Study on a Cost Benefit Analysis of Bushfire Mitigation.* Canberra: Australian Forest Products Association. Retrieved from http://ausfpa.com.au/wp-content/uploads/2016/01/AFPA-DAE-report-Amended-Final-2014-05-27.pdf

Department of Premier and Cabinet. (2016). *Mitigating Natural Hazards through Land Use Planning and Building Control.* Hobart, Tasmania: Department of Premier and Cabinet Tasmania. Retrieved from http://www.dpac.tas.gov.au/__data/assets/pdf_file/0014/312143/Coastal_Hazards_Report_version_7_-_20161201.pdf

DPEM. (2012). *2012 Tasmanian State Natural Disaster Risk Assessment.* Hobart, Tasmania: The Department of Police and Emergency Management. Retrieved from http://www.ses.tas.gov.au/assets/files/EM%20Publications/disaster_resilience/2012%20TSNDRA%20Report.pdf

DPIPWE. (2017a, May). *Farm Business Planning Tools.* Retrieved from Department of Primary Industries, Parks, Water and Environment: Agriculture: http://dpipwe.tas.gov.au/agriculture/investing-in-irrigation/farm-business-planning-tools#%E2%80%8BGrossMarginAnalysisspreadsheets

DPIPWE. (2017b, April). *Farm Business Planning Tools.* Retrieved from Department of Primary Industries, Parks, Water and Environment: Agriculture: http://dpipwe.tas.gov.au/agriculture/investing-in-irrigation/farm-business-planning-tools#%E2%80%8BGrossMarginAnalysisspreadsheets

Fox-Hughes, P., Harris, R., Lee, G., Jabour, J., Grose, M., Remenyi, T., & Bindoff, N. (2015). *Climate Futures for Tasmania: Future Fire Danger.* Hobart, Tasmania: Antarctic Climate and Ecosystems Cooperative Research Centre. Retrieved from http://acecrc.org.au/wp-content/uploads/2015/12/Report_CFT_Future-Fire-Technical-Report_2015_web.pdf

Gaynor, S. (2015, April 01). Edition #175 - 01 April 2015 - THE END. *The Hub Happenings*. National Environmental Research Program.

Gaynor, S., & Lefroy, T. (2015). *Final Report: Landscapes and Policy Hub 2011-2015.* Hobart, Tasmania: University of Tasmania. Retrieved from https://www.nerplandscapes.edu.au/system/files/LaP%20-%20Final%20Report%20-%20Mar%202015%20-%201%20April%202015_1.pdf

Gordon, H., O'Farrell, S., Collier, M., Dix, M., Rotstayn, L., Kowalczyk, E., . . . Watterson, I. (2010). *The CSIRO Mk3.5 Climate Model.* The Centre for Australian Weather and Climate Research. CSIRO. Retrieved from http://www.cawcr.gov.au/technical-reports/CTR_021.pdf

Graham, K., Green, G., & Heyward, O. (2012). *Hobart City Council Climate Change Adaptation Plan 2012-2013.* Hobart, Tasmania: Southern Tasmanian Councils Authority. Retrieved from file:///X:/ACE%20CRC%202017/Other%20reports/HCC-Corporate-Climate-Adaptation-Plan-2013_2016-v2%20(1).pdf

Graham, K., Green, G., & Heyward, O. (2013). *Regional Councils Climate Change Adaptation Strategy, Southern Tasmania.* Hobart, Tasmania: Southern Tasmanian Councils Authority. Retrieved from file:///X:/ACE%20CRC%202017/Other%20reports/STCA_Regional_Climate_Adpataion_Strategy_2013low_res%20(2).pdf

Grose, M., Barnes-Keoghan, I., Corney, S., White, C., Holz, G., Bennett, J., . . . Bindoff, N. (2010). *Climate Futures for Tasmania: General Climate Impacts.* Hobart, Tasmania: Antarctic Climate and Ecosystems Cooperative Research Centre. Retrieved from https://web.archive.org/web/20150406012929/http://www.dpac.tas.gov.au/__data/assets/pdf_file/0011/134210/CFT_-_General_Climate_Impacts_Technical_Report_-_WEB_lo-res_content_hi-res_cover_-101003.pdf

Harris, R., Remenyi, T., & Bindoff, N. (2016). *The Potential Impacts of Climate Change on Victorian Alpine Resorts.* A Report for the Alpine Resorts Co-ordinating Council. Hobart, Tasmania: Antarctic Climate and Ecosystems Cooperative Research Centre. Retrieved from http://www.arcc.vic.gov.au/uploads/publications-and-research/The%20Potential%20Impact%20of%20Climate%20Change%20on%20Victorian%20Alpine%20Resorts%20Study_FINAL.pdf

Harris, R., Remenyi, T., Fox-Hughes, P., Love, P., Phillips, H., & Bindoff, N. (2017). An assessment of the viability of prescribed burning as a management tool under a changing climate: a Tasmanian case study. In I. M. Rumsewicz (Ed.), *Research Forum 2017: proceedings from the Research Forum at the Bushfire and Natural Hazards CRC & AFAC Conference.* Melbourne: Bushfire and Natural Hazards Cooperative Research Centre.

Hobart City Council. (2014). *City of Hobart Policy - Climate Change Adaptation.* Hobart, Tasmania: Hobart City Council. Retrieved from file:///X:/ACE%20CRC%202017/Other%20reports/Climate_Change_Adaptation%20(1).pdf

Holmes, J. D., Kwok, K. C., & Ginger, J. D. (2012). *Wind Loading Handbook for Australia and New Zealand - Background to AS/NZS 1170.2 Wind Actions.* Sydney, Australia:

Australiasian Wind Engineering Society. Retrieved from https://researchonline.jcu.edu.au/30502/1/30502%20Holmes%20et%20al%202012%20Front%20Pages.pdf

Holz, G., Grose, M., Bennett, J., Corney, S., White, C., Phelan, D., . . . Bindoff, N. (2010). *Climate Futures for Tasmania: Impacts on Agriculture.* Hobart, Tasmania: Antarctic Climate and Ecosystems Cooperative Research Centre. Retrieved from https://web.archive.org/web/20150406013313/http://www.dpac.tas.gov.au/__data/assets/pdf_file/0020/140195/CFT_Ag_Tech_Rpt.pdf

Hydro Tasmania. (2011). *2011 Hydro Tasmania Annual Report.* Hobart, Tasmania: Hydro Tasmania. Retrieved from https://www.hydro.com.au/docs/default-source/about-us/our-governance/annual-reports/hydro-tasmania-annual-report-2011.pdf?sfvrsn=e96e1328_2

Hydro Tasmania. (2015). *Annual Report 2015.* Hobart, Tasmania: Hyrdro Tasmania. Retrieved from https://www.hydro.com.au/docs/default-source/about-us/our-governance/annual-reports/hydro-tasmania-annual-report-2015.pdf?sfvrsn=1f551328_2

Hydro Tasmania. (2016). *Annual Report 2016.* Hobart, Tasmania: Hydro Tasmania. Retrieved from https://www.hydro.com.au/docs/default-source/about-us/our-governance/annual-reports/hydro-tasmania-annual-report-2016.pdf?sfvrsn=1c551328_2

Hydro Tasmania. (2017). *Annual Report 2017.* Hobart, Tasmania: Hydro Tasmania. Retrieved from https://www.hydro.com.au/docs/default-source/about-us/our-governance/annual-reports/hydro_tasmania_annual_report-2017.pdf?sfvrsn=10551328_2

IPCC. (2007). *Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.* [Core Writing Team, Pachauri, R.K and Reisinger, A. (eds.)]. Geneva, Switzerland: Intergovernmental Panel on Climate Change. Retrieved from http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr_full_report.pdf

Johnson, I. R., Chapman, D. F., Snow, V. O., Eckard, R. J., Parsons, A. J., Lambert, M. G., & Cullen, B. R. (2008, April 7). DairyMod and EcoMod: biophysical pasture-simulation models for Australia and New Zealand. *Australian Journal of Experimental Agriculture, 48*(5), 621-631. Retrieved from http://www.publish.csiro.au/an/EA07133

Keating, B. A., Carberry, P. S., Hammer, G. L., Probert, M. E., Robertson, M. J., Holzworth, D., . . . Smith, C. J. (2003, January). An overview of APSIM, a model designed for farming systems simulation. *European Journal of Agronomy, 18*(3-4), 267-288. Retrieved from https://www.sciencedirect.com/science/article/pii/S1161030102001089

Lai, J. (2011). *Willingness to pay to prevent the extinction of vertebrate species in Australia and New Zealand.* Brisbane, Queensland: Agtrans Research. Retrieved from https://webcache.googleusercontent.com/search?q=cache:PKihM7OszQUJ:https://www.scribd.com/document/98360169/Willingness-to-Pay-to-Prevent-the-Extinction-of-Vertebrate-Species-in-Australia-and-NZ+&cd=1&hl=en&ct=clnk&gl=au

Love, P., Fox-Hughes, P., Harris, R., Remenyi, T., & Bindoff, N. (2016a). *Impact of climate change on weather-related fire risk factors in the TWWHA.* Hobart, Tasmania: Department of Premier and Cabinet Tasmania. Retrieved from http://www.dpac.tas.gov.au/__data/assets/pdf_file/0010/344566/Interim_Report_-_Future_fire_danger_project.pdf

Love, P., Fox-Hughes, P., Harris, R., Remenyi, T., & Bindoff, N. (2016b). *Impact of climate change on weather-related fire risk factors in the TWWHA.* Hobart, Tasmania: Department of Premier and Cabinet Tasmania. Retrieved from http://www.dpac.tas.gov.au/__data/assets/pdf_file/0009/344565/Part_II_Report_Future_fire_danger_project.pdf

McInnes, K., O'Grady, J., Hemer, M., Macadam, I., Abbs, D., White, C., . . . Bindoff, N. (2012). *Climate Futures for Tasmania: Extreme Tide and Sea-Level Events.* Hobart, Tasmania: Antarctic Climate and Ecosystems Cooperative Research Centre. Retrieved from https://web.archive.org/web/20150406013532/http://www.dpac.tas.gov.au/__data/assets/pdf_file/0009/184797/ACE_CFT_-_Extreme_Tides_and_Sea-Level_Events_final.pdf

Mitchell, M., Moore, S. A., Lefroy, E. C., Clement, S., Lockwood, M., Anderson, G., . . . Norman, B. (2015). *An evaluation of strategies used by the Landscapes and Policy Hub to achieve interdisciplinary and transdisciplinary research - Report No. 84.* Institute for Land, Water and Society (ILWS). Albury, NSW: Charles Sturt Univeristy. Retrieved from http://researchrepository.murdoch.edu.au/id/eprint/27004/1/strategies_to_achieve_interdisciplinary_and_transdisciplinary_research.pdf

National Centre for Atmospheric Research Staff. (2017, November 26). *Common Spectral Model Grid Resolutions*. Retrieved from The Climate Data Guide: https://climatedataguide.ucar.edu/climate-model-evaluation/common-spectral-model-grid-resolutions

NCCARF. (2013). *Climate Futures for Tasmania*. Retrieved from National Climate Change Adaptation Research Facility: Local Government Portal: https://www.nccarf.edu.au/localgov/case-study/climate-futures-tasmania

NERP. (2013). *Project 5 - Climate Futures*. Retrieved from National Environmental Research Program: file:///X:/ACE%20CRC%202017/ACE%20Reports%20(9)/NERP%20Landscape%20and%20Policy%20Hub%20(Project%205)/Project%205%20-%20Climate%20Futures%20_%20Landscapes%20and%20Policy%20Hub.html

NERP. (2015). *Home*. Retrieved from National Environmental Research Program - Landscape and Policy Hub: https://www.nerplandscapes.edu.au/

Rand, S. (2014). *ClimateAsyste(R) - User Guide.* pitt&sherry. Retrieved from http://climateasyst.pittsh.com.au/app/user_manual.pdf

SEACI. (2012). *The South Eastern Australian Climate Initiative*. Retrieved from South Eastern Australian Climate Initiative: http://www.seaci.org/

Smart, R., & Wells, R. (2014). *Encouraging the Development of the Wine Sector in Tasmania.* Hobart, Tasmania: University of Tasmania. Retrieved from http://www.utas.edu.au/__data/assets/pdf_file/0009/612639/Encouraging_Development_of_Viticulture_Final_Report_Jul101.pdf

Smith, L. (2017, May 16). *Thirst for cool climate wine triggers Tasmanian vineyard expansion*. Retrieved from ABC News: Rural: http://www.abc.net.au/news/rural/2017-05-16/tasmanian-grape-prices-supports-vineyard-growth/8529604

Steverson, E. (2010). *National Biodiversity Expenditure Scoping Study.* Newcastle, NSW: Hunter Valley Research Foundation. Retrieved from https://www.scribd.com/document/98359954/HVRF-Biodiversity-Expenditure-Scoping-Study-Report

Tasmania SES. (2016). *Supported Emergency Volunteer Fund Projects 2014-2015*. Retrieved from Tasmania State Emergency Services: http://www.ses.tas.gov.au/h/em/funding/evf/evf-2014

Tasmanian Climate Change Office. (2017). *Climate Change Research Report - Tasmanian Government's Response.* Hobart, Tasmania: Department of Premier and Cabinet Tasmania. Retrieved from http://www.dpac.tas.gov.au/__data/assets/pdf_file/0015/361005/Tasmanian_Government_response_Final_Report_TWWHA_Bushfire_and_Climate_Change_Research_Project.pdf

TFS. (2017). *Bushfire-Prone Areas Mapping.* Hobart, Tasmania: Tasmanian Fire Service. Retrieved from file:///X:/ACE%20CRC%202017/Other%20reports/PSA-17-4-TFS-Report-and-Maps.pdf

van Bueren, M., & Bennett, J. (2004). Towards the development of a transferable set of value estimates for environmental attributes. *The Australian Journal of Agricultural and Resource Economics, 48*(1), 1-32.

White, C., Grose, M., Corney, S., Bennett, J., Holz, G., Sanabria, L., . . . Bindoff, N. (2010). *Climate Futures for Tasmania: Extreme Events.* Hobart, Tasmania: Antarctic Climate and Ecosystems Cooperative Research Centre. Retrieved from https://web.archive.org/web/20150406013503/http://www.dpac.tas.gov.au/__data/assets/pdf_file/0013/151411/CFT_-_Extreme_Events_Tech_Rpt.pdf

White, C., Remenyi, T., McEvoy, D., Trundle, A., & Corney, S. (2016). *2016 Tasmanian State Natural Disaster Risk Assessment.* Hobart, Tasmania: University of Tasmania. Retrieved from http://www.ses.tas.gov.au/assets/files/EM%20Publications/disaster_resilience/TSNDRA-2016.pdf

Wine Australia. (2017). *2017 SA Winegrape Crush Survey.* Adelaide, SA: Wine Australia. Retrieved from https://www.wineaustralia.com/getmedia/b5e2ace8-6bf6-4965-b81e-0ab51b7edebc/SA-full-report-2017

Wine Tasmania. (2017). *Wine Tasmania Strategic Plan 2017-2019.* Hobart, Tasmania: Wine Tasmania. Retrieved from http://winetasmania.com.au/resources/downloads/Strategic_Plan_2017-19_FINAL_-_revision_June_2017.pdf