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Australian National Outlook 2015

Technical Report

Economic activity, resource use, environmental performance and living standards, 1970–2050

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Important disclaimer

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The *Australian National Outlook* is a new initiative by CSIRO, which is intended to contribute to the evidence base and understanding required for Australia to navigate the complex and often intertwined challenges involved in achieving sustainable prosperity.

This first *National Outlook* seeks to provide a better understanding of Australia's physical economy. It has a particular focus on understanding two aspects: The 'water-energy-food nexus' and the prospects for Australia's materials and energy-intensive industries, which account for one quarter of economic value and employment, but around three quarters of our use of energy, water and materials.

The analysis explores over 20 possible futures for Australia out to 2050 against the backdrop of the past 40 years to identify key future global drivers and assesses how these may impact our country. It then integrates these global perspectives into a uniquely Australian context in relation to plausible technological and policy settings we must consider as a nation to secure our future prosperity.

The *National Outlook* and science in general can contribute evidence and analysis to inform the national conversations. However, it cannot determine the choices we have to make as a community. They will – and should – be shaped by our values and collective imagination.

While this outlook identifies national opportunities, achieving these benefits will require considerable further deliberation and action. The investments and other changes required will not happen overnight. There is no overstating the challenges that exist for policymakers, industries and communities in navigating the transitions needed to secure our future prosperity.

Key messages and findings

Australia has the capacity to pursue economic growth, sustainable resource use and reduced environmental pressures simultaneously. Policies and institutions will be essential to realise Australia's full potential and manage the associated trade-offs and risks. Australia can benefit from the positive outlook for our living standards and natural assets while contributing to a secure and prosperous world.

Australia's choices will shape our prosperity. Agility, innovation and productivity will be vital to make the most of a positive – but uncertain – global economic outlook.

Global demand for our exports is projected to treble through to 2050 as global per capita income also trebles. While we can be confident in some high level trends, such as long term growth of world energy and food demand, the risks and opportunities facing specific sectors of our economy are less certain. Demand for specific materials and energy exports will vary with international developments. Flexibility in the deployment of its natural and institutional resources will be needed for Australia to prosper across a diverse range of global scenarios.

Agricultural export prices are likely to trend upwards over coming decades reversing a long historical decline. Our analysis shows that Australia's total output of food and fibre can increase – even in scenarios with significant shifts of land out of agriculture – if agricultural productivity growth is restored. However, we have not fully explored the complex distributional implications of these scenarios, and we do not yet fully understand the potential cascading impacts of future climate change and extreme events on farms, sectors, and regions. The scale and multiple complexities of these potential changes could raise unprecedented challenges for landowners and regional communities.

The future of our nation, industries and communities will depend on how we position for change, and adapt as the world around us evolves. In most cases, innovation and improving productivity are no regret moves that will help to create a better future.

Sustainability and economic growth can be partners not competitors

Our research suggests that Australia can achieve economic growth and improved living standards while also protecting or even improving our natural assets. However, this will not happen automatically. Australia's economy is projected to treble by 2050, while national income per person increases by 12%–15% above inflation per decade (assuming no major shocks) – with different choices about working hours accounting for two-thirds of the range of projected outcomes.

Energy and transport can remain affordable, with energy efficiency offsetting higher prices for electricity and fuel (including in low carbon scenarios), and better management of peak demand and improved electricity network operations and investment discipline could deliver further benefits. By 2050, electric vehicles and biofuels could reverse our mounting transport fuel imports, as well as reduce costs, improve air quality, and reduce greenhouse gas (GHG) emissions.

Business, individuals and government all need to be involved in lifting productivity and enhancing our shared social, economic and natural capital. Efficient and responsive institutional settings can turn challenges into opportunities, and have a vital role in managing trade-offs and promoting longer term sustainability and prosperity.

Decisions we make as a society matter – and will shape Australia's future more than decisions we make as businesses or individuals.

Policies and institutions are central to unlocking potential benefits and managing trade-offs and risks. Collective decisions account for 50%–90% of the differences in resource use and natural assets across the scenarios in the *National Outlook*, resulting in synergies in some cases and trade-offs in others. Institutional settings are crucial to support the deployment of existing and new technologies that match our economic and environmental aspirations in energy, water, transport, agriculture and other industries.

Managing the water-energy-food nexus will produce challenges and opportunities for rural land use and communities. We can transform and enrich our economy and regional communities by meeting national and global food, fibre, energy, carbon sequestration and conservation needs through new land sector markets, if we manage these transitions well.

While water use is projected to double by 2050, this growth can be met while enhancing urban water security and avoiding increased environmental pressures through increased water recycling, desalination and integrated catchment management. We find water demand and supply are shaped by complex interactions between food production, energy-intensive industries, energy and water efficiency, and new carbon plantings – all against a background of regional constraints on rain-fed water resources and a growing population and economy.

We can reduce our greenhouse gas emissions significantly through energy efficiency, carbon capture and storage (CCS), renewable energy, and land-sector sequestration. In the case of concerted global action on climate change, this could see Australia reduce its per capita emissions to below the global average by 2050, down from five times the average in 1990, while maintaining strong economic growth. Actual costs and benefits would be highly dependent on the details of domestic policies, and how these interact with international actions.

Australia's ecosystems are unique and globally significant. At payments for carbon farming around AUD$40–60/t$CO_2$e by 2030, carbon credits could be harnessed to reward landowners for restoring ecosystems, increasing native habitat by 17% and decreasing extinction risks by 10%, without large additional government outlays.

Statement by the expert review panel

You are about to immerse yourself in an innovative, in some ways monumental, research achievement – CSIRO's first *Australian National Outlook* report. By integrating a large number of existing models, filling some of the gaps between them, and projecting forward to the year 2050, the researchers present scenarios for Australia's future, reflecting different global contexts and different Australian trends and policy settings. These scenarios – alternative Australian futures – set the stage for a national conversation about the kind of future that would best serve all Australians and the choices and policy approaches that might get us there.

One key message of this report is that Australia has a wider range of feasible futures, and more opportunity to work proactively toward a future of its choosing, than might be apparent from the day-to-day policy discussions. A second is that this analysis is just the beginning of an ongoing back-and-forth between policy makers, analysts, and the public. The complexity and changing nature of the challenges confronting the nation and the world are made evident by the models and results that are included, and the important factors that are still to be considered.

While the findings and results of the *National Outlook* project are evidence-based, interpretation remains a human endeavour. To help ensure that modelling and interpretation are rigorous and based on the best available science, we have conducted three rounds of external review, exercising our independent judgment over two years.

A perspective on the scenarios

CSIRO researchers modelled many scenarios, highlighting four that span a range, of by no means exhaustive feasible Australian futures. Each scenario depends on a specific global context. Each assumes set-and-forget Australian policies and bottom-up trends, as opposed to scenarios that are revised as our expectations are updated by events and changing circumstances.

Where policies are involved, they are more in the nature of policy directions: broad-brush rather than detailed. Each scenario takes us on a different path and gets us to a different point by 2050; and 2050 is not an end in itself, rather it is a waypoint in Australia's continuing development. The modelling approach has an in-built conservative tendency, in that it does not and cannot anticipate the game-changing technologies and surprising "black swan" events that, while inevitable as time unfolds, are unpredictable.

The external review panel's evaluation

The *National Outlook* project is a massive effort to understand a subset of the complex interrelationships among social, economic, and environmental changes across geographies and through time. It is innovative in many ways, especially in its accomplishments in integrating diverse models, and the underlying research already is making its mark in the peer-reviewed literature. For such an impressively comprehensive and forward-looking effort, we find the model results and interpretations credible within reasonable bounds.

Of course, some of the findings are more surprising than others: we might anticipate vigorous discussion of some of the conclusions concerning increased water use, growth of biofuels, and the linking of conservation and carbon sequestration.

We see at least three directions for further research: (1) more complete elaboration of important topical areas that were not addressed in detail in this first Outlook project: for example, human capital and productivity, infrastructure and supply chains, natural capital (including the biocultural setting with Indigenous and nonindigenous perspectives), and the built environment and urban infrastructure; (2) improving the integration of models and their capacity to incorporate societal adaptations through time; and (3) given that the models integrated vary greatly in completeness and generality, further elaborating and improving some of the component models.

The external review panel's bottom line

This report sketches the broad scope that Australia enjoys to influence its own future, and in so doing invites a wide-ranging national discussion. The *Australian National Outlook* project can best achieve its potential as an on-going exercise with continuous quality improvement and full publication (updated at regular intervals) deepened by periodic focus on special issues of current relevance. With this continuing commitment, we expect the *National Outlook* would become embedded in the broad social and political discourse on desirable strategies for the present and future, and could serve as a model for the continuing and evolving global conversations on these complex challenges.

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Part I Introduction to the National Outlook

1 Navigating Australia's future: The purpose of the *National Outlook*

The purpose of the CSIRO *Australian National Outlook* 2015

The *Australian National Outlook* is a new initiative by CSIRO, which is intended to contribute to the evidence base and understanding required for Australia to navigate the complex and often intertwined challenges involved in achieving sustainable prosperity.

This first *National Outlook* seeks to provide a better understanding of Australia's physical economy. It has a particular focus on understanding two aspects: The 'water-energy-food nexus' and the prospects for Australia's materials and energy-intensive industries, which account for one quarter of economic value and employment, but around three quarters of our use of energy, water and materials.

The *National Outlook* and science in general can contribute evidence and analysis to inform the national conversations. However it cannot determine the choices we have to make as a community. They will – and should – be shaped by our values and collective imagination.

While this outlook identifies national opportunities, achieving these benefits will require considerable further deliberation and action. The investments and other changes required will not happen overnight. There is no overstating the challenges that exist for policymakers, industries and communities in navigating the transitions needed to secure our future prosperity.

1.1 Australia in a global context

We live in an age of opportunities and challenges, an age of interconnected choices and consequences.

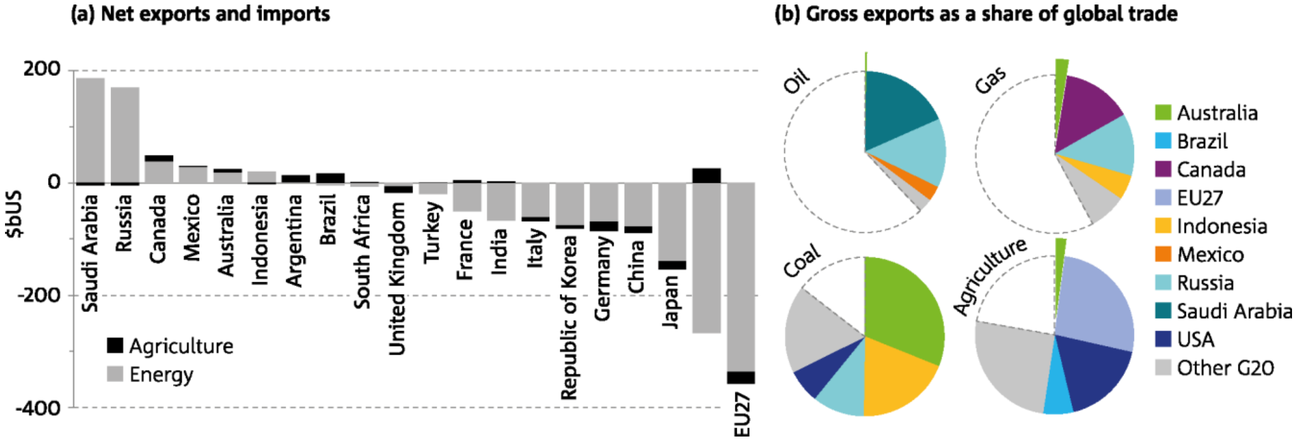
Australia is the world's largest island, an important exporter of food and energy (see Figure 1), a home for unique species and ecosystems, and a stable democracy with high living standards. Australian national income per person has been among the highest in the world for more than a century (

Figure 2) and we are ranked first in the world in the Organisation for Economic Co-operation and Development's (OECD) Better Life Index[1], which provides a broad-based view of living standards. Our species and ecosystems are globally distinctive, with 50% more unique vertebrate species

[1] http://www.oecdbetterlifeindex.org

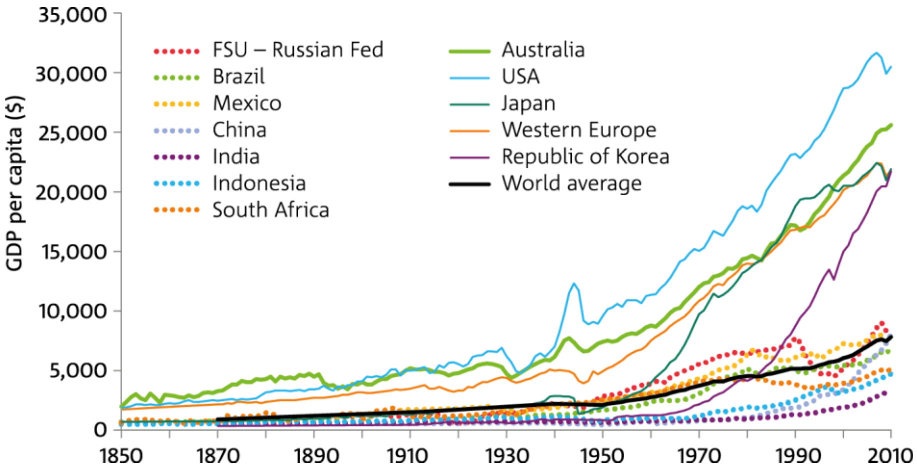
than any other country, and more major habitat types than any country other than the United States of America (USA) (Figure 3).

Figure 1. Exports and imports of energy and agricultural commodities, G20 nations, 2007



Source: Narayanan et al. (2012)

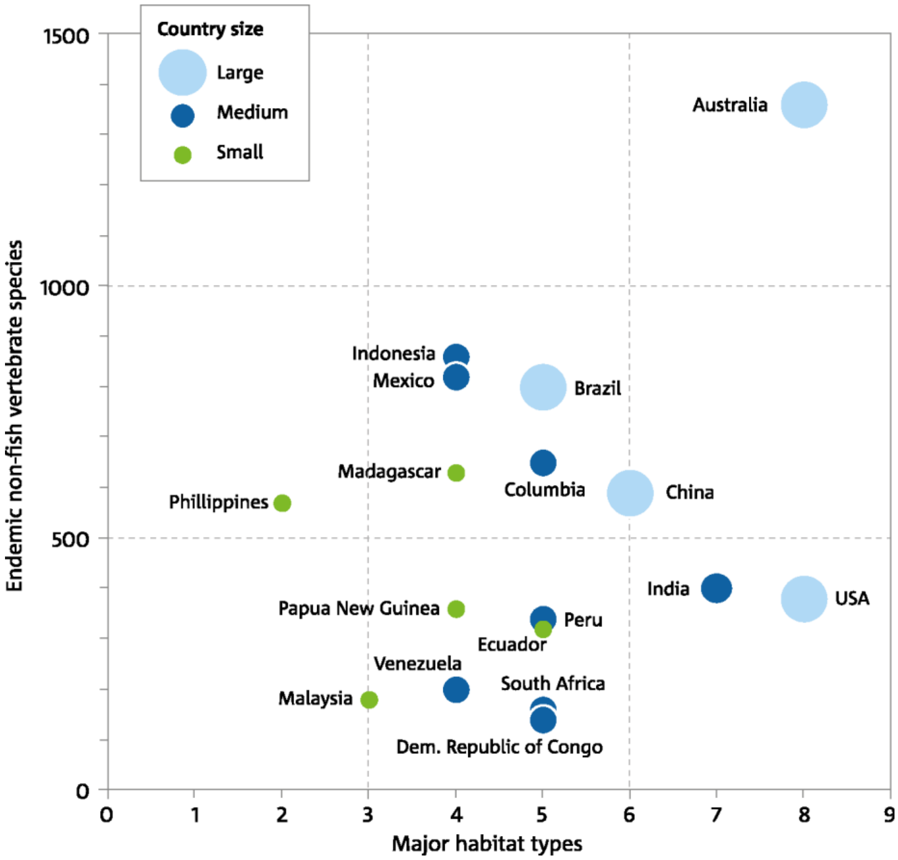
Figure 2. Australian real GDP per capita in global perspective (purchasing power parity basis), 1850–2010



Notes: Units are real 1990 Geary-Khamis dollars, equivalent to the purchasing power of US$ in 1990 across different countries, adjusted for inflation

Source: Bolt and van Zanden (2013)

Figure 3. Comparison of numbers of habitat types and unique species in 17 megadiverse countries, by land area



Notes: Figure 3 summarises key attributes of all 17 countries recognised as having 'megadiverse' biodiversity. It shows that Australia has globally distinctive levels of biodiversity (the number of different native species), with significantly more unique species than any other country and the equal greatest number of major habitat types, reflecting our diversity of ecosystems and landscapes. Unique species are also referred as endemic, defined as occurring in no other country, and are assessed here on the basis of non-fish species with a backbone. Each country is classified by land area: small countries are 0.2–0.6 million km2, medium are 0.8–3.0 million km2 and large are 7.5–9.5 million km2.

Source: Redrawn from Morton and Sheppard (2014: Figure 12).

By 2050, the value of Australian economic activity is projected to be ten times larger than it was in 1970, driven by high rates of population increase and strong long run economic growth per person. Coming decades will see growing demand for – and pressures on – natural resources such as land, water, energy and ecosystem services in Australia and around the world.

The outlook for Australian living standards, resource use and environmental performance over coming decades will be shaped by global trends, and decisions by Australian households, businesses and governments.

1.2 The purpose of this report

CSIRO's goal in producing the *Australian National Outlook* is to contribute to the evidence base and understanding required for Australia to navigate the complex and often interconnected challenges and opportunities involved in achieving sustainable prosperity.[2] CSIRO is Australia's

[2] This report uses 'sustainable prosperity' to refer to economic development that improves human wellbeing and social resilience, while significantly reducing environmental risks and avoiding reductions in scarce natural resources and flows of ecosystem services. This notion is similar

largest science agency, focused on delivering new technologies and science-based solutions that benefit industry, society and the environment.

The purpose of the CSIRO Australian National Outlook is to provide an integrated, evidence based assessment of a range of possible outlooks for Australian natural resource use and environmental performance, and their implications for national wellbeing and sustainability. Resources are defined broadly, to include land, water, energy, and ecosystem services (including biodiversity).

This report is intended to contribute to a national conversation about the future. It is not CSIRO's role to recommend that Australia pursues one course rather than another. Rather, we hope this report will provide an evidence base for a series of national conversations about our opportunities and challenges, and how we might position Australia to take advantage of these. In addition, this report seeks to help identify issues or knowledge gaps that would benefit from additional attention over the next five to ten years – including from researchers, business people and policy makers.

CSIRO intends to publish an updated *National Outlook* every three to five years, taking account of changes in circumstances, emerging challenges and trends, and improvements in national and international scientific capacity and understanding. Appendix A provides the terms of reference for the *National Outlook* project. Appendix B provides detailed supplementary information on scenario definitions and implementation. Appendix C sets out the full set of papers and reports associated with the *National Outlook* project.

1.3 Methods for exploring the future: The analytical foundations of the National Outlook

All decisions involve a view about the future, and about the consequences or merits of choosing one thing over another.

The projections that underpin the *National Outlook* have been developed through integrated analysis that provides projections of economic activity, resource use, and feedbacks at global, national and sectoral scales. The main economic models used in the *National Outlook* are the current versions of models that have been used to analyse national and global policy issues for more than 20 years[3], such as the impacts of changes in tariffs, commodity prices and global agricultural markets, or reductions in greenhouse gas emissions. The *National Outlook* analysis embeds these economic models in a wider framework that accounts for key biophysical processes and constraints – such as how future changes in land use or climate might impact on agricultural output, or how the evolving stock of electricity generation and transmission assets shape energy prices and emissions over time. Modelling inputs, linkages and results are carefully evaluated to ensure the projections are scientifically robust and credible.

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to the ideas of 'sustainable development' and more recent articulation of 'green growth economy' (see O'Connell et al. 2013, Griggs et al. 2013, UNEP 2011).

[3] For example, see http://www.vu.edu.au/centre-of-policy-studies-cops/research-consulting and https://www.gtap.agecon.purdue.edu/about/project.asp for a historical listing computerised general equilibrium models used in global economic analysis.

The analytical framework is the most comprehensive ever used to explore Australian national economic activity and resource use, and has been developed by CSIRO in collaboration with key university partners. Most of the models that make up the framework are expected to be updated and further improved over coming years.

Social and economic systems are complex and notoriously difficult to predict. For this reason the analysis for the *National Outlook* adopts a scenario based approach, exploring multiple uncertainties. This can be thought of as using quantitative analysis to explore uncertainties that have been identified through a mix of qualitative and quantitative methods, including the CSIRO megatrends analysis (Hajkowicz et al., 2012).

To provide transparency and rigour, this report is supported by a set of science papers (see Appendix C **Error! Reference source not found.**), most of which have been written for submission o peer reviewed journals. All the science papers will be made available through the project website (www.csiro.au/nationaloutlook), or through journal publication. The main report, this technical report, and drafts of the science papers have been reviewed by independent external panel of national and international experts, in addition to internal review and the review process for the papers submitted to journals. The statement by the external review panel is provided at the beginning of this report, and the main *National Outlook* report. The project website will be updated as science papers and other project outputs are published. The modelling framework, scenario assumptions and analysis are summarised in Chapter 8 and Appendix B of this report, with more detailed technical documentation and results provided through the supporting science papers.

2 Using the National Outlook: Focus, scope, and interpretation of the analysis

Scope and interpretation of the National Outlook

The National Outlook 2014 has been constructed around a diverse set of scenarios, representing a range of potential futures. Because the future is uncertain, the analysis uses a combination of global and domestic scenarios to explore the implications of interacting uncertainties about future possibilities, and does not seek to provide a detailed prediction of a single pre-determined or 'most likely' future.

We first established the range of global and national issues and uncertainties to be explored and then used three global models to develop distinct scenarios and projections for global economic growth, energy use, food production and greenhouse gas emissions. Next we combined the results of the global modelling with a range of domestic issues, and modelled over 20 national scenarios with six, linked domestic models. This delivered a deeply integrated set of scenario projections.

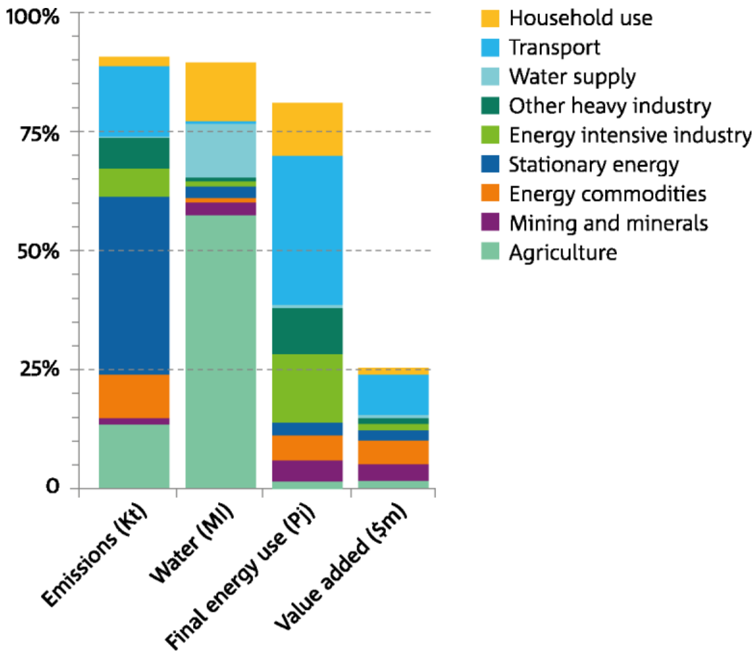
The final steps were to synthesise and interpret the results, then present them in the *National Outlook* report and supporting materials. This includes projections for economic activity (including national output and income), resource use (including energy, water, materials and land) and environmental performance indicators (including greenhouse gas emissions, water extractions, area of native habitat, and biodiversity).

2.1 Scope and focus of the National Outlook

The analysis for the *Australian National Outlook 2015* has been constructed around a diverse set of scenarios, representing a range of potential futures. Because the future is uncertain, the analysis uses a combination of global and domestic scenarios to explore the implications of interacting uncertainties about future possibilities, and does not seek to provide a detailed prediction of a single pre-determined or 'most likely' future.

The analysis and models that underpin the *National Outlook* give particular attention to Australian resource use and the physical economy, located within the global economy. While we model the whole economy, our major focus is on the material and energy intensive sectors that account for around one quarter of the value of economic activity and more than three quarters of materials and energy use. These sectors include agriculture, mining and minerals, heavy industry, energy and water supply, and transport (as shown in Figure 4). All of these economic activities are dependent on natural resources (such as agriculture), or long lived built infrastructure (such as transport), or both (such as water supply). In terms of the traditional three-level classification of economic activities, most primary industries (agriculture and mining) are material and energy intensive, but some secondary (manufacturing) and tertiary (services) sectors are also materials and energy intensive.

Figure 4. Contribution of materials intensive sectors to Australian greenhouse gas emissions, electricity demand, water use, materials flows, and value added, 2012



Notes: Figure 4 shows the national share of GHG emissions, water use, final energy use and value added accounted for by material and energy intensive industries, made up of eight broad sectors plus direct household use. These sectors account for around three quarters of emissions, energy and water use, and around one quarter of value added.

Source: MMRF base year data (see Section 8.2, Table 3 for modelling references)

The first *National Outlook* gives particular attention to the nexus and interactions between food, water and energy in the context of climate change. This reflects CSIRO's deep expertise in these domains, and the potential for cross-sector interactions across these issues. We expect future *National Outlooks* to give more attention to other aspects of resource use and the physical economy, such as the outlook for Australian mining or potential futures for our cities.

No report or project can do everything. The modelling accounts for the impacts of trend changes in temperature and rainfall on agriculture and water supply infrastructure. However, does not fully capture the effects of projected changes in climate variability and extreme events. To keep the analysis manageable, the *National Outlook* only considers a small number of potential global context trajectories. These assume the same rate of underlying global productivity growth per person so that aggregate global demand varies primarily with population. We do not explore potential near term economic events, such as different outlooks for the USA and European Union's (EU) economic recovery, or different trajectories for the Chinese, Indian and Indonesian economies. Nor do we consider geopolitical issues or natural disasters such as armed conflicts, terrorism, food shortages, floods or earthquakes. Last, we do not account for different domestic economic policies, such as fiscal and budget settings changes to taxation or policies that would influence productivity growth (such as industry or education policy).

2.2 How to use and interpret the National Outlook

The *Australian National Outlook* has been designed to provide an accessible and engaging set of projections of economic activity, exports, resource use and environmental performance across a range of possible outlooks to 2050. To show these projections in context, the report often combines the presentations to 2050 with historical data from 1970. Because the future is inherently uncertain, the analysis uses a combination of global and domestic scenarios to explore the implications of interacting uncertainties about future possibilities. It does not seek to provide a detailed prediction of a single pre-determined or 'most likely' future.

Scenarios are not predictions of the future. Instead, each scenario provides an internally coherent view of one potential future.

"Scenarios represent plausible, possible futures. The purpose of using scenarios is to break the common habit of planning for what we perceive as the 'most likely' future, or a future that looks much like the present. Exploring the implications of uncertain future trends can help decision makers recognise, prepare for and respond more effectively to change"

Wilkinson and Kupers, 2013

In most cases, for each scenario driver we identify a 'continuing trend' and contrast this with a plausible alternative as a vehicle for exploring the implications of different potential futures. We leave it to the reader to make judgments about the likelihood of the different elements that together define each scenario. The reporting of the *National Outlook* generally leaves these scenarios in the background, and instead focuses on the implications of the major uncertainties explored through this analysis.

The Australian National Outlook provides integrated observations, analysis and projections of economic activity and natural resource use from 1970–2050. Different outlooks explore potential trends and possibilities for Australian energy and water efficiency, consumption, land use and agricultural productivity under different global population and climate scenarios.

2.3 Multiple uncertainties explored through seven scenario drivers

The analysis for the first *National Outlook* explores three interconnected focal questions:

- What is the potential for decoupling Australian economic growth from environmental pressures, so that overall environmental pressures fall while living standards and population increase?
- What is the range of outlooks for Australian agriculture and energy, and what are the implications of these for our contribution to global demand for food and energy-based commodities?
- How might near term choices and trends shape long run risks and opportunities?

These questions are explored across a range of scenarios reflecting different combinations of interacting uncertainties or opportunities, each of which could have a material impact on Australian living standards, resource use and environmental performance to 2050. The analysis combines these uncertainties into a set of scenarios which together explore different potential trajectories of Australian economic activity, income and expenditure, resource use and environmental performance

Global context scenarios

The *National Outlook* explores a number of global trends because Australian economic activity is strongly influenced by global economic trends and conditions.

The first two scenario drivers shape Australia's economic context:

- *Global economic demand* is shaped by different outlooks for global population, rising from 7 billion people in 2010 to 8–11 billion people in 2050, and the world economy growing to 2.6–3.2 times larger than it is today
- *Global greenhouse gas emissions and the pace of climate change* are shaped by different levels of global greenhouse gas abatement effort, which also impacts on potential demand for emissions intensive commodities. Four global scenarios contrast different levels of global per capita emissions, with the world on track to likely temperature increases of 2°C to 6°C by 2100.

The analysis used a set of global models to develop four global context scenarios providing internally consistent projections of economic activity, energy demand, fossil energy use, agricultural prices, and net greenhouse gas emissions. The analysis was designed to provide several reference points that connect to the international literature. For this reason each scenario matches the cumulative greenhouse gas emissions of one of the benchmark emissions trajectories used in the climate science literature (Representative Concentration Pathways 2.6, 4.5 and 8.5). Each scenario is also based on one of the three United Nations' (UN) population projections. The naming convention for the scenarios refers to cumulative greenhouse gas emissions (L M H) and population (1 2 3). The characteristics of the four global context scenarios are summarised in Scenario L1, which has the lowest emissions (L) and population (1), with emissions on track to 475 ppm CO_2e in 2100 (van Vuuren et al., 2011), and around 67% chance of limiting the increase in average global temperatures 2°C or less above pre-industrial levels (Rogelj et al., 2012). World population follows the low UN projection, reaching 8.1 billion in 2050. Scenarios M2 and M3 represent 'middle ground' climate scenarios, implying likely temperature increases of up to 2.9°C by 2100, with around a 10% chance of temperature increases of 3.5°C or more. World population in 2050 is 9.3 billion in Scenario M2 and 10.6 billion in Scenario M3 and H3. Scenario H3 involves no action to reduce global emissions, implying likely a temperature increase of up to 6°C by 2100.

The L1, M2 and M3 global context scenarios involve different degrees of global action to reduce greenhouse gas emissions. Emissions trajectories that limit temperature increases to below 2°C require substantial shifts from current global trends beginning by 2015 or 2020 (Rogelj et al., 2012b). Therefore, L1 is referred to as involving *very strong* global emissions reductions or action on climate change. The differences in population in the M2 and M3 scenarios give rise to different levels of abatement in order to achieve the same target cumulative emissions by 2050. For this reason M3 is referred to as involving *strong* action to reduce global emissions and M2 is referred to as involving *moderate* action to reduce global emissions.

One final criterion in developing the global scenarios was to provide a range of outlooks for agricultural export prices. To achieve this we assume a higher rate of agricultural productivity in the M2 scenario, which results in essentially stable prices (adjusted for inflation) in Australian dollars. More details are provided in Appendix B.

Table 1. Summary of the four global context scenarios, including population and emissions per person in 2050 and projected temperatures in 2100

	2010	Global Scenarios 2050			
Climate Outlook	uncertain	L	M	M	H
Cumulative emissions (a) Gt CO_2	1089	3,134	3,769	3,769	4588
Temperature increase in 2100 (b)	Uncertain	2°C	3 –4°C	3 –4°C	6°C
Population Outlook	Uncertain	1	3	2	3
Population (c) Billion people	6.9	8.1	10.6	9.3	10.6
Abatement Effort	Varied	Very strong	Strong	Moderate	No action
Emissions per person, tpc CO2e (d)	7.0	3.1	4.4	5.0	8.7
Agricultural Outlook for 2050					
Price increase, 2050, crops (e) AUD$	N/A	51%	88%	-4%	39%

Notes: (a) Temperature increase is for 2090–2099 relative to pre-industrial, upper bound of the 66% range, from Rogejl et al.(2012); (b) matches cumulative emissions from 1861–2050 for RCP 2.6, 4.5 and 8.5 (Moss et al., 2010), calculated as Gt CO_2e and then converted to Gt C; (c) based on UN (2012); (d) tpc = tonnes per capita; (e) the M2 scenario assumes higher global agricultural productivity to provide a wider range of export price outlooks for the national analysis. Price increase shown is from 2010–2050 in Australian dollars.

Source: Moss et al. (2010); Rogejl et al. (2012); UN (2012); van Vurren et al. (2011); and, projections from GIAM.GTEM (see Section 8.2, Table 3 for modelling references).

Domestic scenario drivers

The domestic scenarios explore the interactions between these different global contexts and five domestic scenario drivers, representing different potential trends or opportunities within Australia:

- *Australian consumption trends* – exploring the implications of continuing trend increases in the consumption of ‘experiences’ (such as holidays and eating out) rather than physical goods, as a share of total consumption, contrasted with maintaining the current consumption mix.
- *Australian leisure trends* – exploring the implications of a continuing trend decline in average working hours (due to increases in the proportion of people working part time), contrasted with maintaining the current average annual working hours.

- *Australian resource efficiency trends* – exploring the implications of recent trends in energy, water and resource use, and contrasting these with achieving a step change in the uptake of cost effective energy and water efficiency options.
- *Emerging Australian land sector markets* – contrasting scenarios with ‘new land markets’ allowing landholders to supply carbon credits or private conservation (generating ‘biodiversity benefits’), where this is profitable, with scenarios that maintain current agricultural land use and do not allow these new markets for non-agricultural products and services.
- *Australian agricultural productivity* – exploring recent trends in agricultural productivity and contrasting this with achieving a threefold increase in the rate of agricultural productivity improvement.

The key criteria for selecting the uncertainties were that they: (i) could have a material impact on Australian living standards and resource use, (ii) could be explored through available models and tools, and (iii) were considered likely to be interesting and relevant to household, business and government stakeholders. In addition, the set of uncertainties was chosen to provide insights into a diverse range of issues, build on CSIRO’s existing work and expertise, and illustrate the diversity of subjects that would be explored through the *National Outlook* analytical framework.

The uncertainties were identified through a series of expert workshops and interviews involving around 25 experts and researchers, held from July to October 2012. This process generated a large set of potential uncertainties which was narrowed down by the project team. Four of the uncertainties are closely linked to the CSIRO global megatrends (Hajkowicz et al., 2012).[4]

2.4 More than 20 scenarios, with four ‘touchstone’ scenarios

Each of these scenarios drivers is made tangible by identifying two or more trends or potential trajectories to 2050 (as summarised in Table 2). The different settings for each scenario driver are then combined to make potential scenarios (see Figure 5 and Appendix B). Despite limiting each scenario driver to a small number of possibilities, the interactions between the uncertainties give rise to hundreds of potential combinations of global and national trajectories, each of which represents a potential scenario that could be modelled.

The *National Outlook* focuses on 20 domestic scenarios, which are chosen to allow the impact of each uncertainty to be assessed through controlled comparisons of pairs of scenarios, as well as assessing the interactions between uncertainties.

To make it easier to discuss and communicate the results, the report often refers to four ‘touchstone’ scenarios. These are summarised below and shown in relation to the others scenarios in Figure 5.

[4] These four megatrends are ‘more from less’ (efficiency), ‘going, going .... gone’ (threats to biodiversity), ‘the silk highway’ (the global rise of Asia), and ‘great expectations’ (the shift towards experiences) (see Hajkowicz et al., 2012).

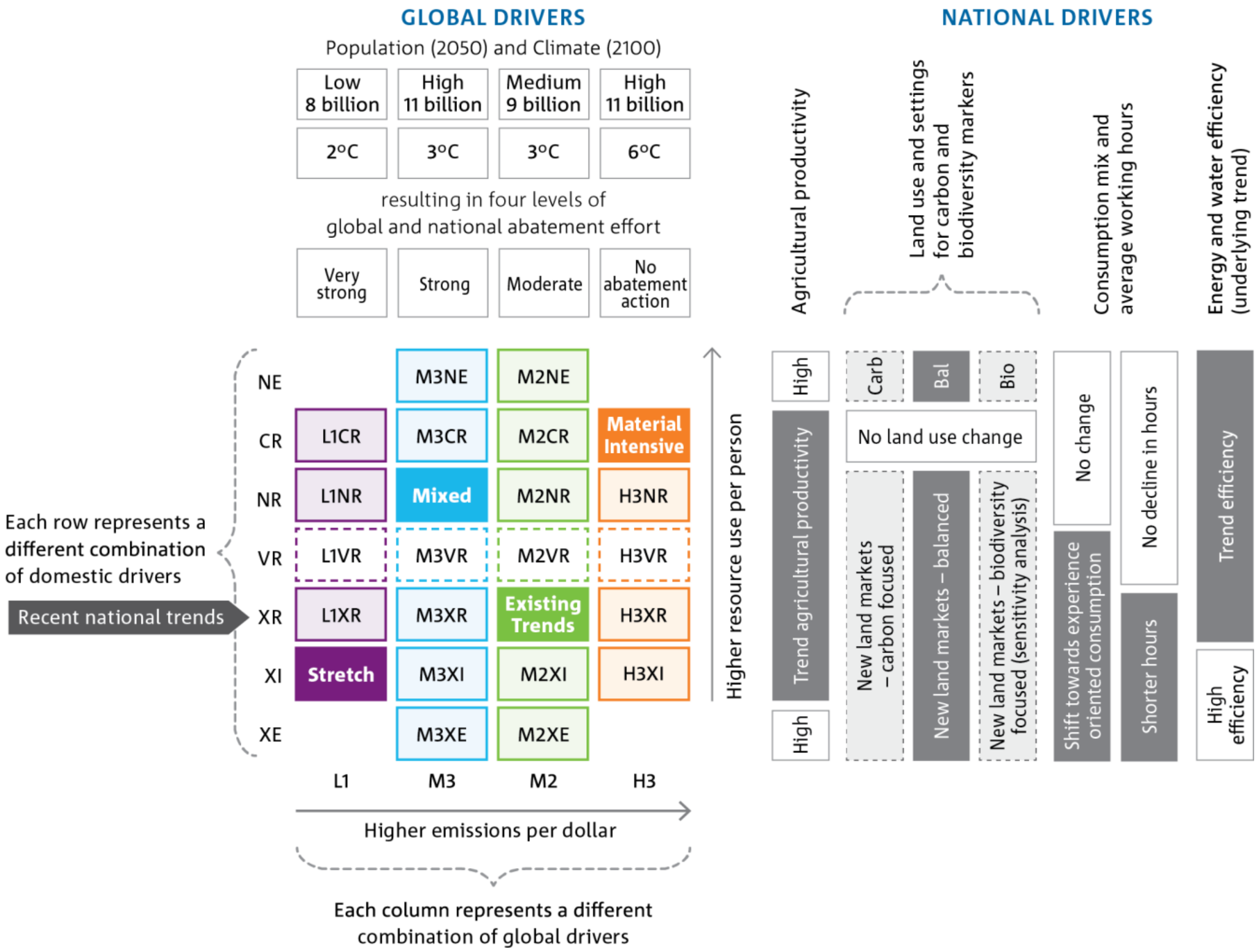
Existing trends provides an anchor point, projecting future national trends that evolve in line with the recent past. Rising incomes drive a gradual decline in working hours and shifts in consumption patterns. New land sector markets are available for carbon offsets and biodiversity. As noted in section 3.1, current trends in relation to global climate action are highly uncertain. The scenario is located in the M2 global scenario, which assumes moderate efforts to reduce global and national emissions, with increasing abatement effort over time.

Stretch illustrates concerted uptake of energy efficiency along with 'very strong' national and global action to reduce greenhouse gas emissions. This results in the lowest resource and carbon intensity of the four touchstone scenarios (that is, the lowest resource use and greenhouse gas emissions per dollar of economic activity).

Mixed combines no shift towards experience oriented consumption with strong abatement effort, so that resource intensity is higher but carbon intensity is lower than *Existing Trends*. (Resource intensity refers to the level of energy materials per dollar or economic activity. Carbon intensity refers to the level of net greenhouse gas emissions per dollar, before accounting for the use of international emissions permits.) This scenario assumes no decline in working hours.

No abatement action freezes national consumption patterns, working hours, and abatement policy where they were a few years ago. (Underlying trends in working hours and consumption are the same as the *Mixed* scenario.) Land use is limited to current agricultural markets. Global and national settings assume 'no action' to reduce emissions beyond policies in place around 2007. As a result, both resource intensity and carbon intensity are higher for Australia than under *Existing Trends*.

Figure 5. Main scenario combinations and 'touchstone scenarios' in the *National Outlook*



Notes: Figure 5 shows the relationships across the set of National Outlook scenarios, with the four touchstone scenarios shown in solid colours. Each row represents a different combination of domestic drivers, as detailed on the right. Each column represents a different combination of global drivers, which together give rise to four different levels of abatement effort (including no abatement), as set out in Table 1. The rows and columns are ordered so that emissions intensity (emissions per dollar of economic activity) increases from left to right, and resource use per person increases from row XI (bottom) to NE (top). The abatement effort in the scenarios has been calculated to result in cumulative global GHG emissions that match RCP 2.6, 4.5 and 8.5 to at least 2060. Temperature for 2100 is the increase from pre-industrial (Rogejl et al., 2012). For the national drivers, continuing recent national trends are shown in dark grey in the key on the right, with the XR scenarios assuming continuing trend for all drivers (third row from the bottom). The VR scenarios, shown with dotted outlines, are modelled but not referred to in this report; as for simplicity we treat shorter hours, increased leisure and the shift towards experience oriented consumption as inter-related trends. Sensitivity analysis of settings for new markets (carbon focused, balanced and biodiversity focused) are all based on the NR scenarios. We also model additional scenarios (not shown), including with no land use change and high agricultural productivity.

Overall, the set of scenario combinations explored in the first *National Outlook* covers a wide range of socio-economically and biophysically plausible outcomes. We consider the set of outlooks provides interesting insights into interactions across uncertainties, allowing assessment of the relative impacts associated with different uncertainties. The set of scenarios is not comprehensive and does not claim to cover all possible or likely future outcomes. Within the set of scenarios, each of the uncertainties could be explored in more depth than has been possible in this first report. Future *National Outlook* reports are expected to explore different uncertainties and issues, as well as return to some of the issues explored in the first *National Outlook*.

Table 2 summarises the modelling assumptions for each scenario driver. Appendix B provides more details, including on the scenario logic and naming conventions, implementation of the project logic and modelling, and aspects of the modelling results.

Table 2. Summary of the six major uncertainties explored in the *National Outlook*

Global context	Four global context scenarios			
Global population (and demand) growth and ...	**On track to 2°C Moderate demand growth (L1).** Population rises to 8.1 billion in 2050.	**On track to 3–4°C Strong economic demand (M3).** Population rises to 10.6 billion in 2050.	**On track to 3–4°C Moderate demand growth (M2)** Population rises to 9.3 billion in 2050.	**On track to 6°C Strong economic demand (H3).** Population rises to 10.6 billion in 2050.
cumulative greenhouse gas emissions to 2050	Very strong abatement required to limit emissions to 3,100 Gt CO_2e.	Strong abatement is required to limit cumulative emissions to 3,800 Gt CO_2e.	Moderate abatement is required to limit emissions to 3,800 Gt CO_2e.	No abatement action sees cumulative emissions of 4,600 Gt CO_2e.
Domestic uncertainties	**Continuation of trend**		**Counterfactual**	
Consumption patterns	**Experience oriented (X):** Consumer preferences continue current trends, so that the share of experience oriented expenditure increases from 18% in 2010 to around 24% in 2050.		**Neutral (N):** (Current Markets (C) scenarios also assume neutral consumption.) Consumer preferences are fixed, with no trend. Projected consumption patterns may change in response to changes in relative prices.	
and working hours	Average working hours decline 11% by 2050, as incomes rise around 50%.		Average working hours do not change from 2010 levels as income increases.	
Resource efficiency	**Recent Trends (R):** Underlying energy and water demand continues recent trends. Energy demand increase at an average of 2.4% per year to 2050 in scenarios with no action and 1.1% per year in scenarios with moderate abatement action. Non-agricultural water demand grows at 2.5% and 1.8% per year in the corresponding scenarios. Agricultural water use is capped in water limited areas, consistent with current policies.		**Efficiency step change (I):** (Agricultural productivity step change (NE) scenarios all also assume efficiency step change.) Underlying energy demand grows at around half the rate of recent trends, with an average increase of 0.6% per year to 2050. The improvement the water use intensity is around double the trend change in the recent trend scenarios. Water available for agricultural use in water limited states (NSW, Vic and SA) is reduced by 15% over 30 years from 2020. Settings for new plantings ensure that water interceptions from new plantings in water limited catchments do not result in total water use exceeding current levels as share of available water.	
Emerging land-sector markets	**New Markets (N)** or (X)**:** Agricultural land shifts into carbon plantations or private biodiversity conservation where this is more profitable than agricultural production. Land use change lags the switch in relative profitability by up to 16 years, with 50% change after 8 years.		**Current Markets (C):** Agricultural land does not shift to other uses.	
Agricultural productivity	**Reference (R):** (Efficiency step change scenarios (XI and XE) assume reference productivity.) Trend compound productivity growth of 1.0% per annum in crops, livestock and other sectors, and 0.35% in forestry.		**Productivity step change (E):** Trend compound growth of 2.8% per annum is achieved, implying substantial innovations in agricultural techniques.	

Notes: Three trajectories for global population growth and three levels of cumulative emissions are combined in four global context scenarios as shown. Domestic scenarios that assume a continuing trend towards experience oriented consumption also assume a continuing decline in working hours, while scenarios with no change in consumption shares assume no decline in hours. More details are provided in Appendix B.

2.5 The lenses used to report across scenarios

One of the challenges of undertaking integrated analysis is that it can be difficult to communicate the results in an accessible way. We have chosen to organise the information and insights from our analysis using several 'lenses' or perspectives:

- **Chapter Three** reports the results for the development of the global context scenarios (which are used as an input to the more detailed national analysis) and the projections for the evolution of Australian economic structure;
- **Chapter Four** reports on *Outlooks for living standards*, including: income, working hours, energy affordability and security, and material footprint of Australian consumption
- **Chapter Five** reports on *Outlooks for resource use*, including: land use, food and energy production, and extractions of water and materials
- **Chapter Six** reports on *Outlooks for environmental performance*, including: projections for native vegetation, biodiversity, ecosystem services, and greenhouse gas emissions and sequestration.
- **Chapter Seven** reports on *Outlooks for prosperity, sustainability and security*, including: findings around synergies and trade-offs across the scenarios.
- **Chapters Eight and Nine** describes the modelling framework and provide some reflections on insights from – and challenges of – seeking to develop a more integrated perspective.

Each section reports different aspects of the findings arising from our integrated analysis, including interactions and linkages within and across different domains (such as land use, energy and greenhouse gas emissions).

These reporting lenses also relate to major recurring challenges that emerged from CSIRO's discussions with a wide range of stakeholders about our national contribution (conducted as a key input to the development of the *CSIRO Strategy 2011–2015*). These discussions identified a clear role and mandate for CSIRO science to help find pathways that satisfy three interrelated objectives: enhancing economic prosperity and security in a connected world; providing sustainable food, water and energy solutions for a growing population; ensuring healthy ecosystems and communities in a climate challenged future. Addressing these inter-related challenges is central to CSIRO's role as a multidisciplinary, mission-directed science and technology organisation. The *National Outlook* initiative was launched within CSIRO as part of the same strategic planning process.

Part II Outlooks through different lenses

3 Outlooks for Australia's global context and national economic structure

3.1 Looking out: The global context for the national analysis

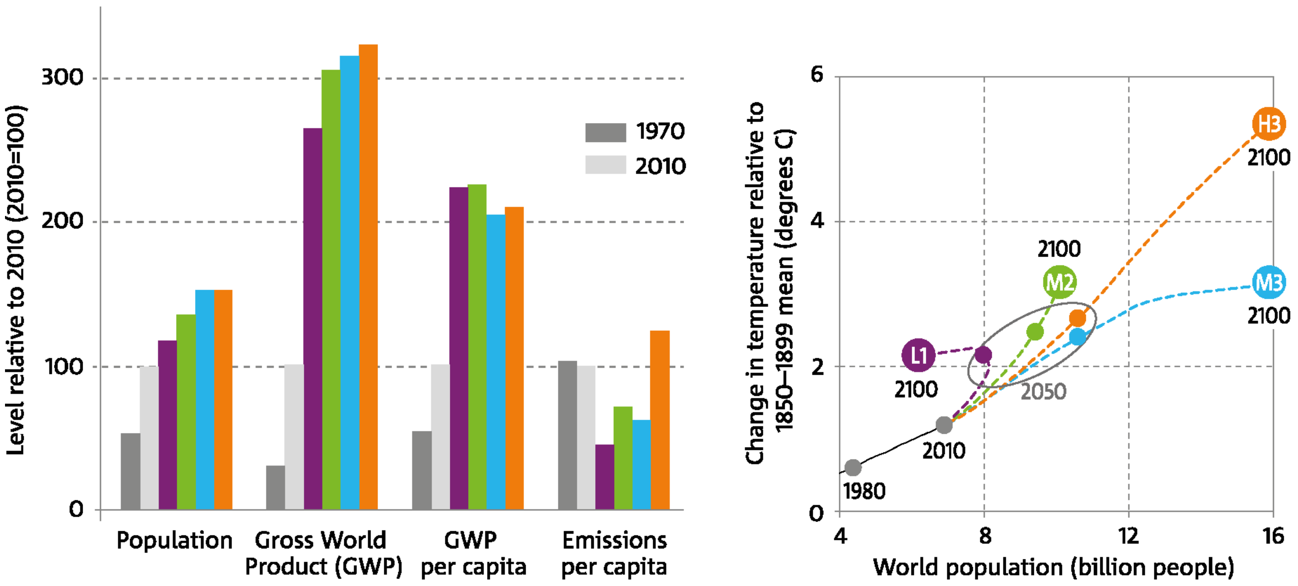
Global demand for Australian food and energy exports grow, but the prospects for specific commodities vary across different global scenarios

The global context for the national analysis is provided through four global context scenarios (see Table 1). Consistent with other studies, we find that world economy is projected to grow to be around three times larger than it is today, driven primarily by different outlooks for global population, which rises from 6.9 billion people in 2010 to between 8.1 and 10.6 billion people in 2050. Average global income per person more than doubles from 2010–2050 across all scenarios, as an increasing proportion of the world's nations transition from being what we currently describe as 'developing countries'. Across all four global context scenarios, the number of people living in countries with average incomes above US$10,000 rises from around one billion today to around three billion people in 2050. All scenarios see growing demand for Australian agriculture output, and export of energy commodities and energy-intensive goods and services. The set of global context scenarios provides a range of outlooks for agricultural prices and demand for different energy commodities

Different global scenarios see the world economy growing to be 2.6 to 3.2 times larger than it is today, driven primarily by different outlooks for global population, which rises from 6.9 billion people in 2010 to between 8.1 and 10.6 billion people in 2050 (based on the 2012 UN low, medium and high population projections) (UN, 2013). The global growth of economic activity and trade occurs predominantly in emerging economies, particularly in Asia, but also including South Africa and Central and South America. The analysis does not account for potential damages associated with extreme events and other impacts of climate change. Results of the global context analysis is summarised in Figure 6 below.

Average global income per person more than doubles from 2010–2050 across all scenarios, as an increasing proportion of the world's nations transition from being what we currently describe as 'developing countries'. Across all four global context scenarios, we shift from a world in 2010 with around one billion people living in countries with average incomes above US$12,000, to a world with around three billion people above this crucial threshold in 2050, with GDP per capita in the remaining two thirds of the world only a little below the threshold (see Figure 7). GDP per capita grows most strongly in China, increasing around 700% from 2010–2050, and is projected to pass US$12,000 around 2025. This has a significant impact on the global distribution of income and economic activity.

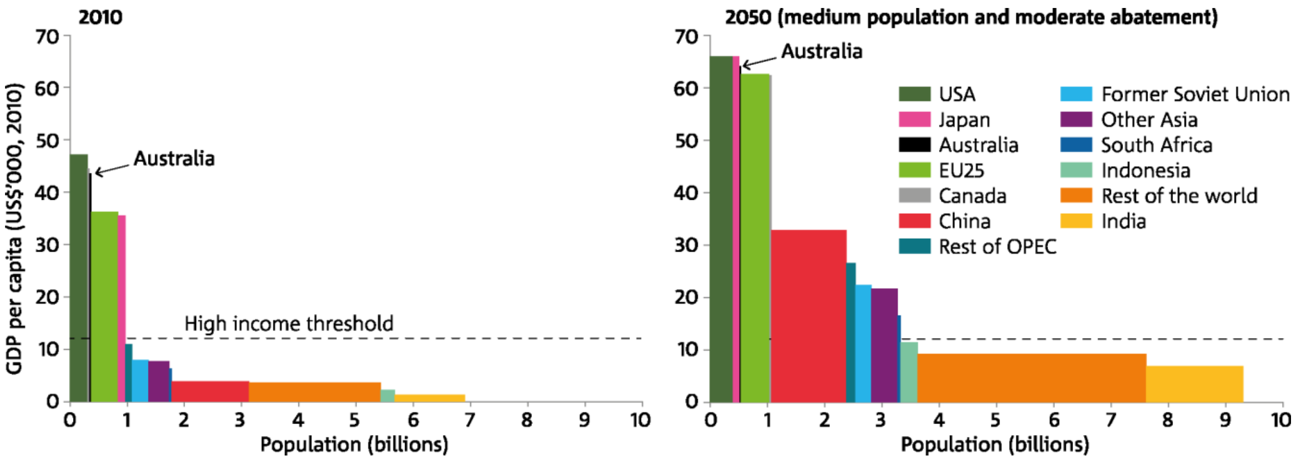
Figure 6. Key Indicators for the four global context scenarios, 1970, 2010, 2050 or 1980–2100



Notes: The left hand panel shows population, real gross world economic output (GWP), average income (GWP per person) and net GHG emissions per capita (CO_2e from all sources) for 1970, 2010 and 2050, for the four global context scenarios (as described in Figure 5). The right hand panel shows population and indicative change in average global temperature for 1980–2100, relative to the 1890–1899 mean.

Source: Historical data from World Bank (2012); UN (2013); and Moss et al (2010) for RCP 4.5 emissions. Population projections from UN (2013); GIAM.GTEM; and, GIAM.Climate (see Section 8.2, Table 3 for modelling references).

Figure 7. GDP per capita and population by selected major nations and groupings, 2010 and 2050 (M2 scenario)

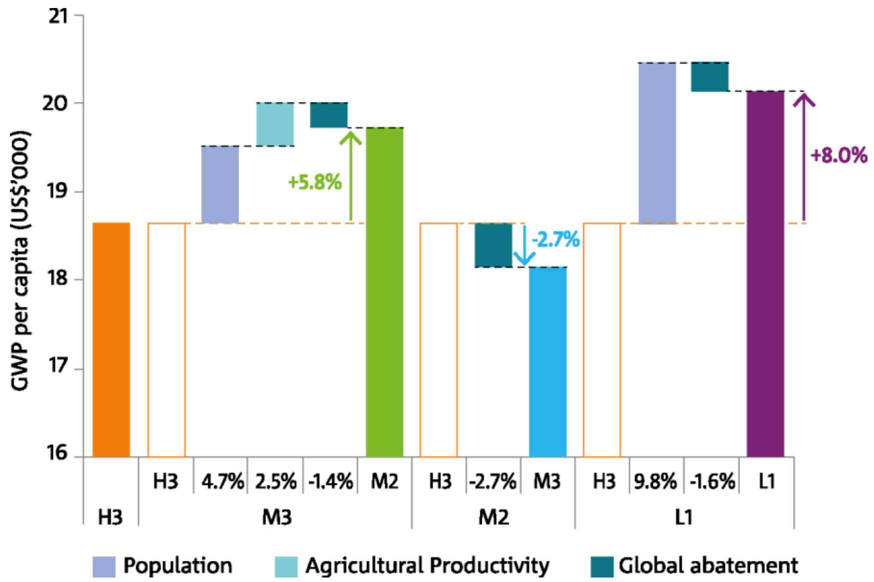


Notes: This figure shows population (horizontal axis) and the value of economic output (Gross Domestic Product (GDP)) per person by 13 countries or global groupings. The area of each rectangle is proportional to the value of economic output of each country or grouping. Population is an input assumption based on UN projections (UN, 2013). The projected value of economic output is in real dollars, adjusted for inflation. The analysis assumes the same underlying regional productivity trends per person across all global scenarios, but the value of GDP per person in each scenario is influenced by differences in population growth, levels of abatement effort and agricultural productivity as shown in Figure 6. The high income threshold of US$12,000 GDP per person is consistent with World Bank (2014a) classifications, in 2010 real international dollars.

Source: Population from UN (2013); GDP per capita from GIAM.GTEM (base year data and projections) (see Section 8.2, Table 3 for modelling references).

Average global income (GWP per person) in 2050 varies by 11% across the different global context scenarios. Differences in population growth account for most of this difference in average income, with lower population growth resulting in higher average global incomes. (The lowest trajectory sees population stabilising at around 8 billion people with 10% higher average global income relative to high population trajectory (all else equal), which increases to around 11 billion in 2050, and then continues to rise. Stronger levels of global abatement effort slow the rate of economic growth, resulting in average income in 2050 being 2%–3% lower than it would be otherwise. This abatement impact is more than offset by population growth. However, when comparing scenarios with high population and no abatement action (H3) with low population and very strong abatement (L1), or with moderate population growth and moderate abatement (M2), we also find that achieving an equivalent abatement outcome involves higher costs in scenarios with higher global populations, as shown in Figure 8. This is largely due to the effects of increased competition for arable land from reforestation and avoided land clearing, and associated impacts on food prices (as discussed in Section B.3).

Figure 8. Impact of population, agricultural productivity and abatement incentives on global GDP per capita, four global context scenarios, 2050



Notes: This figure shows the impact of key assumptions on average global income (GWP) for the four global context scenarios, stepping out the effects of population, abatement effort and global agricultural productivity.

Source: GIAM (see Section 8.2, Table 3 for modelling references).

Greenhouse gas emissions vary significantly across the four global context scenarios, involving abatement of 50%–70% relative to no action (see Figure 61 in Appendix B), illustrating the capacity to decouple economic growth from emissions. There are long lags between greenhouse gas emissions and changes in temperatures, therefore likely temperatures are projected to increase by 1.5°C–2.8°C across the four global scenarios by 2050 (relative to 1850–99 mean temperature). Temperature impacts of different emission trajectories range between around 2°C to around 6°C by 2100 (see Figure 6 above).

All scenarios see growth in the demand for Australian agriculture output, energy commodities, and other energy-intensive goods and services. Global per capita consumption of energy and agricultural products increases, however these sectors decline as a share of global activity. The outlooks for food and energy are discussed in more detail in Section 5 below.

3.2 Australia's economic structure to 2050

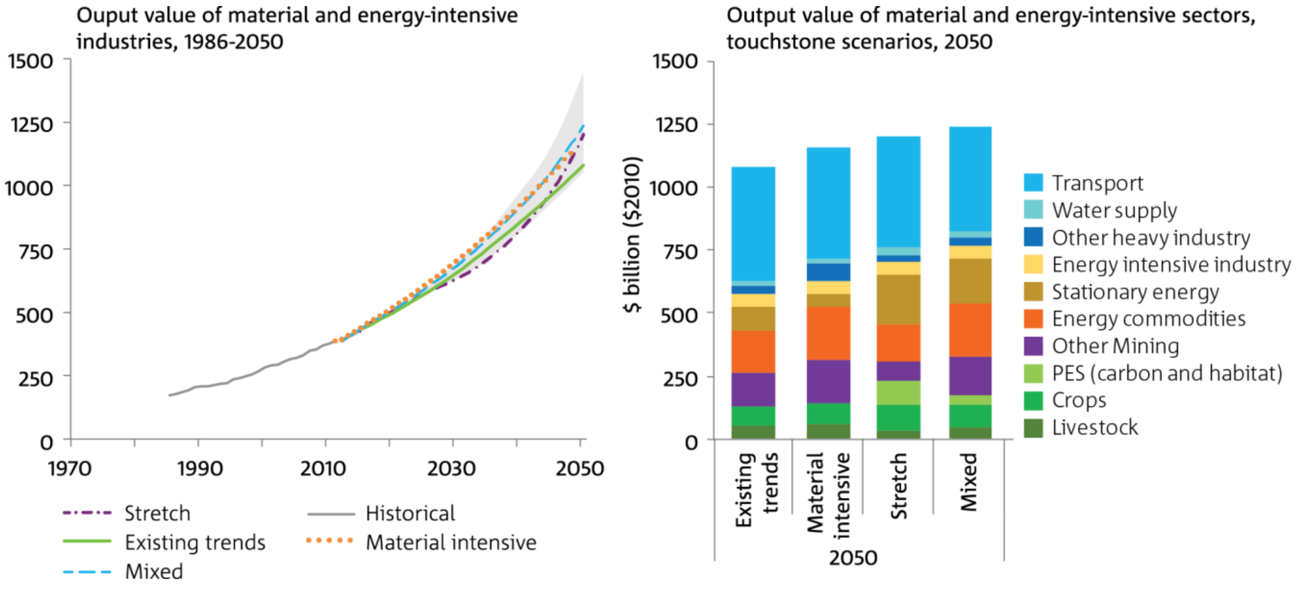
Energy and material-intensive industries remain central to Australia's economy and prosperity across all scenarios explored

We find that the value of Australian economic activity is projected to be 10 times larger in 2050 than it was in 1970, driven by high rates of population increase and strong long run economic growth per person. Population is projected to increase to 2.9 times its level in 1970, while economic activity per person increases 3.2 to 3.6 times its level in 1970. Energy and material intensive industries remain central to the Australian economy across all the scenarios we explore, remaining stable or increasing as a share of the value of national economic activity.

The analysis for the *National Outlook* suggests that resource based industries remain central to the Australian economy, and thus to Australian wellbeing and sustainability, across all the scenarios explored.

Materials and energy intensive sectors currently account for around one quarter of the value of economic activity, and three quarters of energy and water use, emissions and material extractions. These sectors are projected to more than triple in value over the period to 2050 (as shown in Figure 9), and to increase their share of national economic activity from 24% to an average of 30% (see Figure 4 above), with some variations in share across scenarios.

Figure 9. Value of material- and energy-intensive sectors, 1986–2050



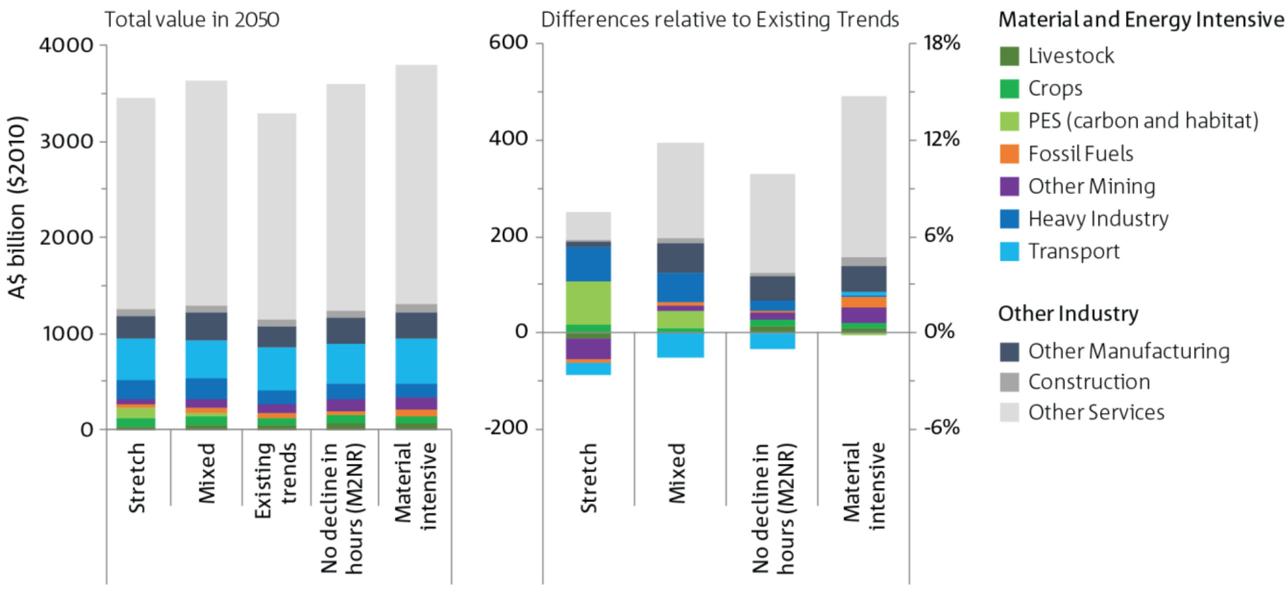
Notes: All values in real AUD$ 2010 (adjusted for inflation). Due to differences in sector definitions, historical values are scaled to match 2010 and should be treated as an index.

Source: Calculated from ABS (2013d); and, MMRF projections (see Section 8.2, Table 3 for modelling references)

The value and composition of material and energy intensive output varies significantly across the different scenarios, and is strongly influenced by different global population trajectories and levels of abatement effort. Material and energy intensive exports grow by around 50% from 2010–2050 in the scenario with the lowest population growth and strongest abatement efforts (L1) – but grow by around 250% over the same period with high global population and no global abatement efforts. These differences in growth see the share of exports from materials and energy range from falling to around half of total exports in the L1 scenario, to remaining stable at around three quarters of total exports in the H3 scenario. The value of agricultural exports are influenced by both global demand (reflecting global population and income growth) and the extent of changes in land use towards carbon plantations in Australia (see Section 5.1).

These shifts in global economic context see land sector markets for ecosystem services (particularly carbon sequestration) emerge as a significant new source of national income in scenarios with strong or very strong abatement, offsetting the loss of income from fossil fuel production (as shown in Figure 10). These shifts are discussed in more detail in Section 7.2.

Figure 10. Contributions to Australian national income (GNI) by sector, 2050.



Notes: All values in real AUD$ 2010 (adjusted for inflation).

Source: MMRF base year data and projections (see Section 8.2, Table 3 for modelling references)

It is likely that global (and regional) population and income growth will also create significant opportunities for Australian service-oriented exports, particularly education and tourism, but the prospects for these sectors have not been analysed in depth as part of the *Australian National Outlook*.

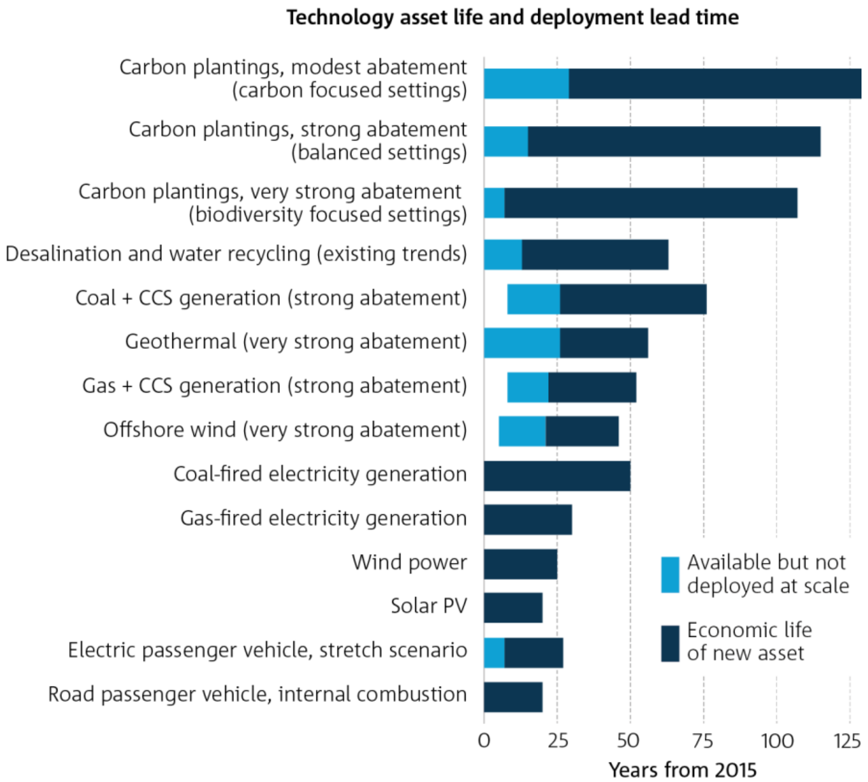
3.3 Understanding the dynamics of long run change

Many of the processes and trends explored in the *Australian National Outlook* involve threshold effects, or tipping points. Threshold effects can occur through the relative competiveness or profitability of different sectors or types of economic activities, impacting on land use (see Section 5.1) and other economic decision making.

Patterns of resource and energy use are shaped by underlying demand, characteristics of the stock of energy and resource-using assets and institutional settings (including regulations, taxes and subsidies, and direct government provision). For example, household energy use is shaped by desired comfort and service levels (for room temperature, fridge capacity, television hours); the size, location and age structure of the stock of dwellings and appliances; the energy efficiency of these dwellings and appliances (shaped by building regulations, energy standards for appliances); and, contextual factors such as planning regulations, the prices of electricity, gas and solar technologies, and social norms and attitudes.

While new technologies are generally substantially more efficient than old ones, the pace and causes of technology deployment varies. Personal choices on vehicles, refrigerators, air-conditioners and appliances can replace the current asset stock over 10 to 15 years, and could do so again before 2050. Whereas it would generally take a decade or more to decide on and build significant new water and energy infrastructure assets, and require a long operational life to repay such large capital investments (see Figure 11).

Figure 11. Transition time frames are shaped by investment decision context and the life cycle of different assets



Notes: The figure shows the projected time to deployment of different technologies across different scenarios and the year in which the analysis assumes new technologies become available. The time shown for electricity generation technologies are based on first deployment. For electric vehicles and non-traditional water supply, the time shown is based on the first year that these technologies account for 10% of the stock of passenger vehicles, or of national water supply excluding interceptions. For carbon plantings the time shown is based on the year payments to landholders for single species carbon plantings reaches AUD$50/t$CO_2$e. Economic life represents typical expected life; actual asset life may be shorter or longer as influenced by operating costs and other factors.

Source: Modelling assumptions and results from GIAM.GTEM, LUTO and ESM (see Section 8.2, Table 3 for modelling references); water supply asset life based on author judgements.

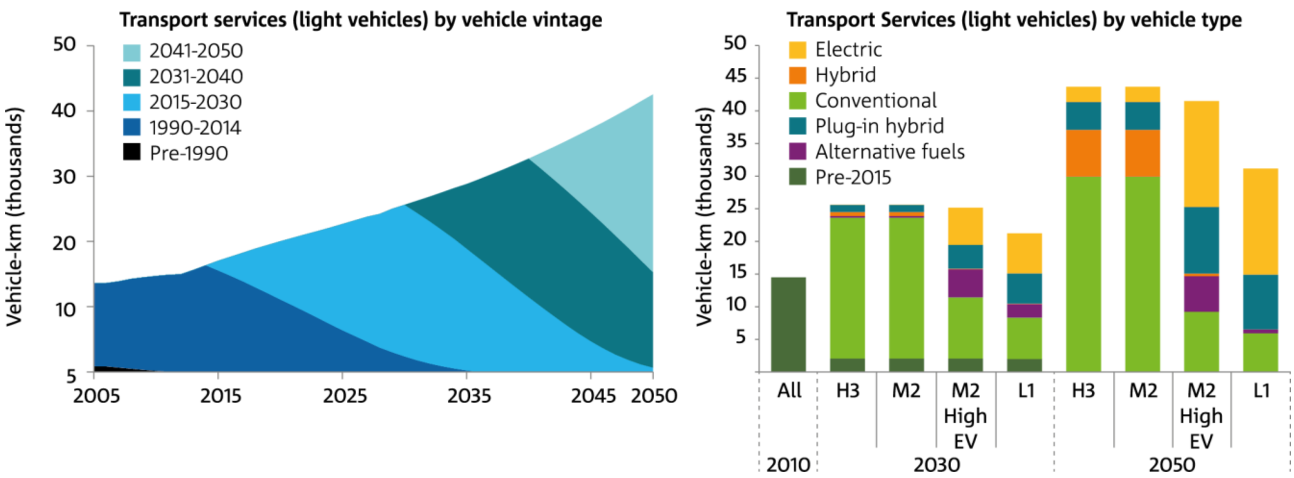
Stocks of assets and infrastructure evolve over time through investment in new assets and the retirement of old assets. In some cases, the efficiency of existing assets may also change – declining over time as they wear out, or being improved through retrofitting. Some assets, such as passenger vehicles, household refrigerators and air condition units turn over relatively quickly, allowing technology improvements to penetrate most of the stock over 10–15 years. Other assets, such as water storage infrastructure and electricity generation assets, last for many decades and are renewed or replaced very infrequently.

Asset turnover can result in significant changes in the characteristics of these stocks over time. This occurs more quickly for stocks with a shorter average life (such as motor vehicles) or strong underlying growth (mobile phones), and more slowly in stocks with long lived assets that are able to be repaired or refurbished (such as power stations and buildings). For example, we find that the national stock of light vehicles is likely to effectively turn over more than twice before 2050, while around half of the dwellings in 2050 will have been built after 2015. Most of Australia's existing electricity generation assets are not due for replacement until around 2030.

Choices about new assets are shaped by context and expectations about the future. For example, sharp increases in fuel prices often have a rapid and significant impact on new vehicle purchases (increasing the share of smaller and more efficient cars). Whereas a more gradual impact on fuel use takes place as both transport patterns and the average efficiency of the vehicle stock respond more gradually to the change in prices. Similar dynamics influence other characteristics of asset stocks, such as the share of apartments and townhouses versus detached homes (influencing urban density), or the mix of electricity generation technologies (influencing average emissions intensity of electricity). Confidence in long-term policy settings is therefore essential to minimise investment risks and release cost-effective solutions.

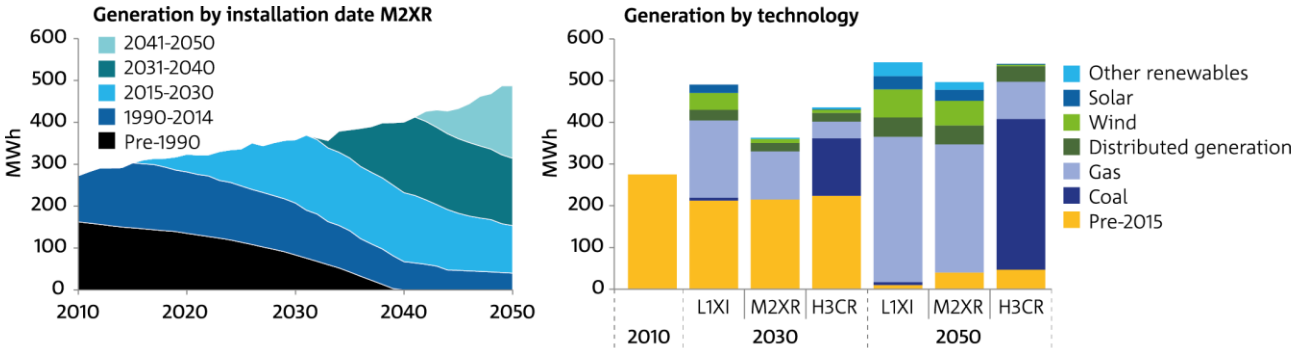
Figure 12, Figure 13 and Figure 14 show the composition of the stock of motor vehicles, electricity generation assets, and dwellings by age and technology type across different scenarios, illustrating different rates of turnover, and how stock composition is shaped by different decision contexts.

Figure 12. Australian passenger vehicle stock, selected scenarios to 2050.



Source: ESM (see Section 8.2, Table 3 for modelling references)

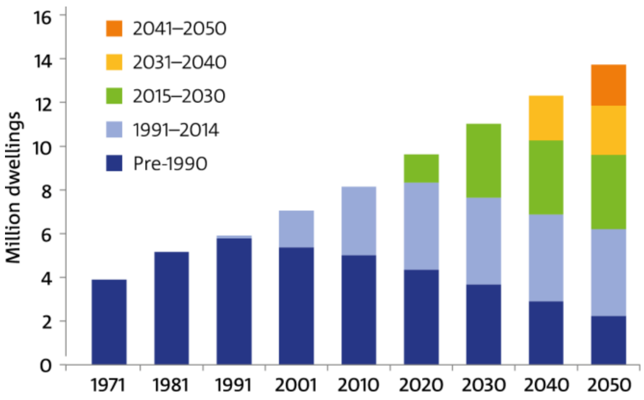
Figure 13. Australian electricity generation, by technology and age cohort, selected scenarios, 1970–2050



Notes: Pre-2015 refers to existing generation assets, showing stock turnover by 2030 and by 2050.

Source: ESM (see Section 8.2, Table 3 for modelling references)

Figure 14. Australian housing stock by age cohort, *Existing Trends*, 1971–2050



Source: MEFISTO (see Section 8.2, Table 3 for modelling references)

4 Outlooks for living standards

This section reports the projections for living standards (including income and average working hours), energy affordability and security, and the implications of potential global action on climate change for Australian economic performance over the long term.

4.1 Income, consumption and working hours

Australian average income is projected to rise in all scenarios.

Australian GDP is projected to treble from 2010–2050 and real per capita income also continues to rise within its long-term trends: between 12% and 15% per decade above inflation. To put this in context, the *National Outlook* projects that the total value of Australian economic activity will increase by a factor of 10 over the 80 years to 2050, with population rising by a factor of three and average income rising more than three-fold.

Two-thirds of the range in projected incomes in 2050 is accounted for by different potential choices about working hours over coming decades. If we reduce our average working hours by 11% (in line with the trend since 1990), our incomes are still projected to rise by around 60% over the next four decades. Maintaining our current hours of work would result in higher incomes, but less leisure time. Alongside changes in working hours, recent decades have seen consumer spending shifting towards experiences and away from durable goods, a trend that is expected to continue. This would see consumer spending on experiences growing around one-third faster than total private consumption (such as in the *Existing Trends* and *Stretch* scenarios), as the share of experience-oriented consumption increases.

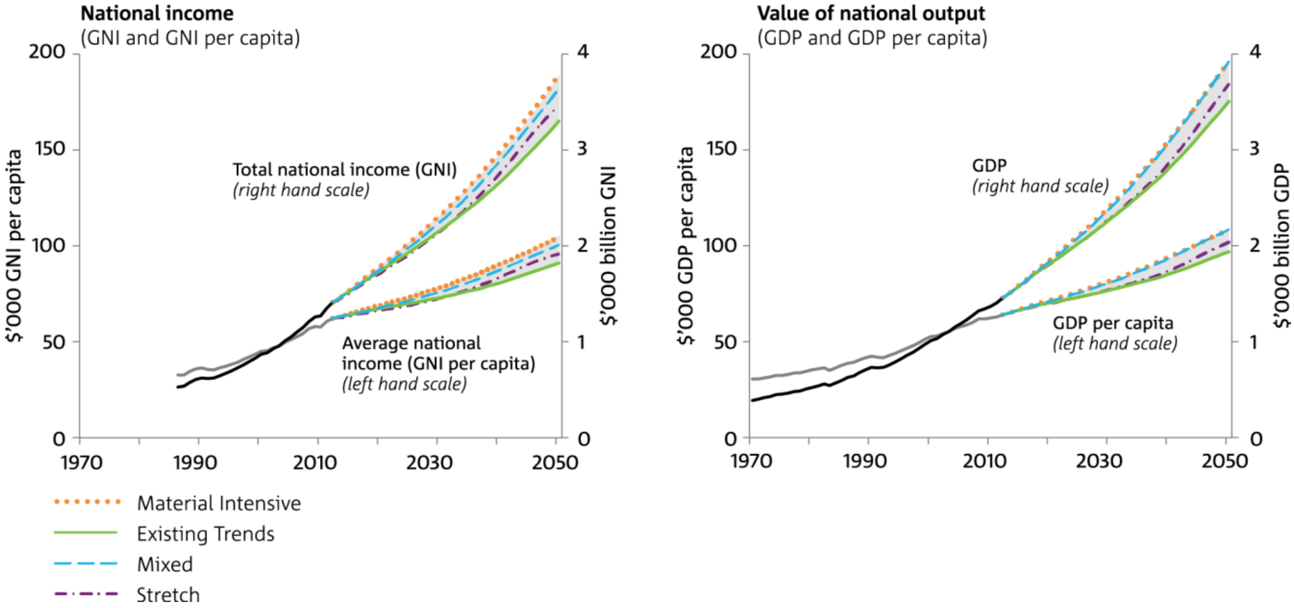
Looking across the other drivers analysed in the *National Outlook*, higher energy and water efficiency, higher agricultural productivity, and new rural land use and markets all boost national income. Stronger global action to reduce greenhouse gas emissions may have a positive or a negative impact on our income, boosting or slowing the rate of economic growth, depending on detailed policy settings and interactions.

National income per person

National income (GNI) per person is projected to rise by 58%–65% above inflation from 2010–2050 in scenarios that assume a continuation of the trend decline in working hours (see Figure 15 below). Average national income increases by 75%–82% by 2050 in scenarios which assume that working hours do not decline. The total variation in income is 15% ($13,500 per person) in 2050 between the scenarios with the highest and lowest incomes. Different assumptions about future trends in average working hours account for two thirds of this variation in income, as discussed below.

This growth in income and the value of economic activity is consistent with the Australian economy increasing by a factor of 10 over the 80 years from 1970, with population increasing to 2.9 times its 1970 level by 2050, and the value of economic activity (GDP) per person increasing to 3.2–3.6 times its 1970 level (reflecting variations across scenarios), as shown in Figure 15. The scenarios for the *National Outlook* all assume the same population projection as shown in Figure 64 in Section B.4.

Figure 15. National income (GNI and GNI per capita) and the value of national output (GDP and GDP per capita), all scenarios, 1970–2050.



Notes: The figure shows the range of projections for total and per capital national income and the value of national output across the 20 *National Outlook* scenarios, highlighting the four touchstone scenarios within this range. All values real AUD$ 2010.

Source: Historical data calculated from ABS (2013d: Tables 11 and 33); price indexes data from ABS (2012); projections from MMRF (see Section 8.2, Table 3 for modelling references).

What issues are not accounted for in the *National Outlook*?

The *National Outlook* assesses a range of possible outlooks for Australian natural resource use and environmental performance, and their implications for national economic wellbeing. It provides the most integrated and evidence-based national scenario assessment of these issues yet attempted, including providing projections of a very broad range of indicators.

It is important to remember that scenarios are not predictions of the future. Instead, each scenario provides an internally coherent view of a plausible possible future – are intended to be used to explore how the future might be different from the past and how to best position for a range of potential futures.

The analysis for the *National Outlook* accounts for the impacts of trend changes in temperature and rainfall on agriculture and water supply infrastructure, but does not fully capture the effects of projected changes in climate variability and extreme events (see Figure 50).

Yet no report or project can do everything. To keep the analysis manageable, the *National Outlook* only considers a small number of potential global context trajectories. These assume the same rate of underlying global productivity growth per person, so that aggregate global demand varies primarily with population.

We do not explore potential near term economic events, such as different outlooks for the USA and the EU economic recovery, or different trajectories for the Chinese, Indian and Indonesian economies. Nor do we consider potential geopolitical issues or natural disasters such as armed conflicts, terrorism, food shortages, floods, or earthquakes. Last, we do not account for different domestic economic policies, such as fiscal and budget settings, or changes to taxation, or policies that would influence productivity growth (such as industry or education policy).

Consumption, working hours, and leisure

Recent decades have seen consumer spending on ‘experiences’ growing much faster than expenditure on durable goods. This shift towards experiences has been identified as a significant future trend (Hajkowicz, 2012). We define ‘experience oriented consumption’ to include expenditures on holidays, recreation, food and drink away from home, and recreation equipment (including for sport, photography and the like). These items account for one fifth to one quarter of total household expenditure and account for a larger share of expenditure in households with higher incomes. Analysis of detailed Australian Bureau of Statistics (ABS) data for 16,500 households found that experience oriented consumption had increased substantially as share of total expenditure over the decade to 2010. Expenditure on experiences growing 3.5 times faster than total expenditure, while other ‘material oriented expenditure’ grew around half the rate of total expenditure (see Section B.4).

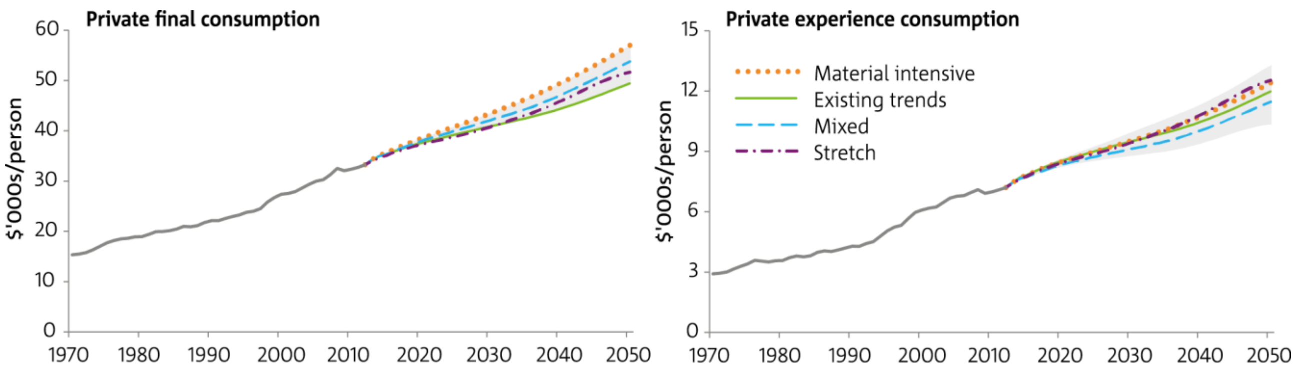
Recent decades have also seen a clear decline in average working hours, which fell by 7% over the two decades to 2010 (National Sustainability Council, 2013; see Figure 17). This reduction is not widely recognised. The result reflects an increase in the share of people working part time and a modest decline in average hours worked by full time employees. These trends are not easy to observe, however, as working hours are not evenly distributed, with over 15% of Australian employees working more than 50 hour per week (see Section B.4 for more details).

The analysis for the *National Outlook* explores the potential impacts of these shifts in consumption patterns and working hours. This is achieved by assuming a continuation of these trends in some scenarios and contrasting this with scenarios that assume no change in consumption mix along with no decline in average hours.

The experience oriented scenarios assume a modest continuing shift in consumption patterns and that working hours continue to decline by around 0.5% per year, consistent with the trend over the last two decades. This is equivalent to a decline of one hour per week each decade, from 35 hours per week in 1990 to 33 hours in 2010, and a projected fall to an average of 31 hours per week in 2030 and 29 hours in 2050 (in these scenarios). The modelling is specified in terms of average hours per year, and does not assume any particular pattern of working hours within the year (such as shorter average working week versus longer holidays), or across different workers (such a change in the proportion of full time versus part time workers). Another perspective on the assumed trend is that it would result in the equivalent of 15 additional days of annual leave per year by 2050, which implies around 20% increase in 'leisure days' (including weekends, existing leave and public holidays) phased in over 15 years. This would see future Australian average working hours moving closer to current European levels. The alternative scenario setting assumes no decline in hours.

Key results are shown in Figure 16. Experience oriented consumption grows a third more than total private consumption in the experience oriented scenarios (increasing by 71% from 2010–2050 in *Existing Trends*, for example, while total consumption increases by 53% over the same period). This results in a modest increase in experience oriented consumption as a share of total expenditure, rising from around 22% to around 25%. Average working hours fall by 11% by 2050 in these scenarios – 'buying' increased leisure though lower income growth, reflected in 9% higher income per person in scenarios with no decline in working hours.

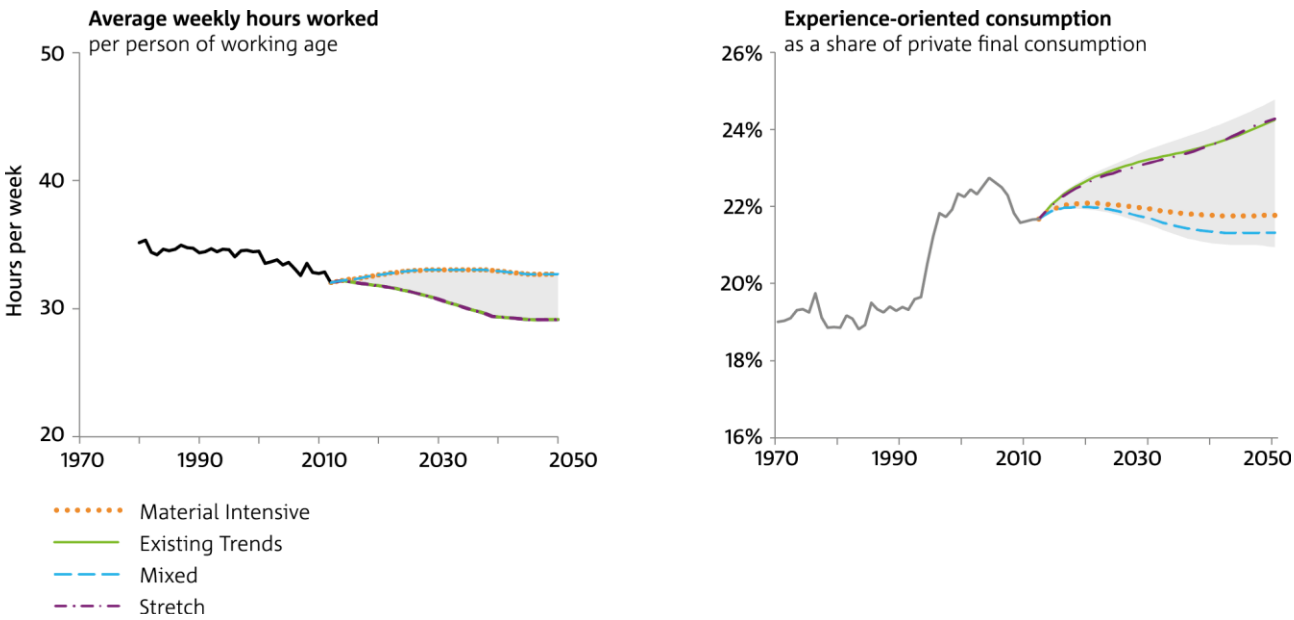
Figure 16. Experience oriented consumption, private final consumption, all scenarios, 1970–2050



Notes: The two panels of the figure show private final consumption (PFC) and experience oriented consumption (EOC), as defined in the text. The historical value of experience oriented consumption from 1970–2010 is calculated from ABS national accounts data which is more aggregated than the Household Expenditure Survey data used to calibrate the scenario modelling, and should be treated as an index. All projections are for the range of the 20 *National Outlook* scenarios, highlighting the four touchstone scenarios. All values are real AUD$2010.

Source: Historical data calculated from ABS (2013d: Table 8); price indexes from ABS (2012) and National Sustainability Council (2013: Figure 13D.7); and, projections from MMRF (see Section 8.2, Table 3 for modelling references).

Figure 17. Working hours, and the share of experience oriented consumption, all scenarios, 1970–2050



Notes: The two panels in show average working hours (per person in employment) and experience oriented consumption as a share of private final consumption. All projections are for the range of the 20 *National Outlook* scenarios, highlighting the four touchstone scenarios. All values are real AUD$2010.

Source: Historical data calculated from ABS, 2013d, Table 8; price indexes data from ABS,2012a,; NSC, 2013, Figure 13D.7); and, projections from MMRF (see Section 8.2, Table 3 for modelling references).

Different people will make different assessments of the implied trade-off between national income and leisure. The trend reduction in working hours is consistent with the average worker choosing to divide each potential $100 increase in income as $89 of additional consumption and $11 of additional leisure. But the underlying scenario logic assumes that the trend in each scenario is driven by bottom-up choices by employees and employers, reflecting their preferences and circumstances. Therefore, the implications of these alternative outcomes are difficult to assess in terms of overall economic welfare.

We find that different consumption trends have implications for energy and water demand, and greenhouse gas emissions. However, the magnitude of these impacts are modest relative to other scenario drivers (see the discussion of bottom up versus top down choices in Section 7.3).

Major drivers of differences in national income

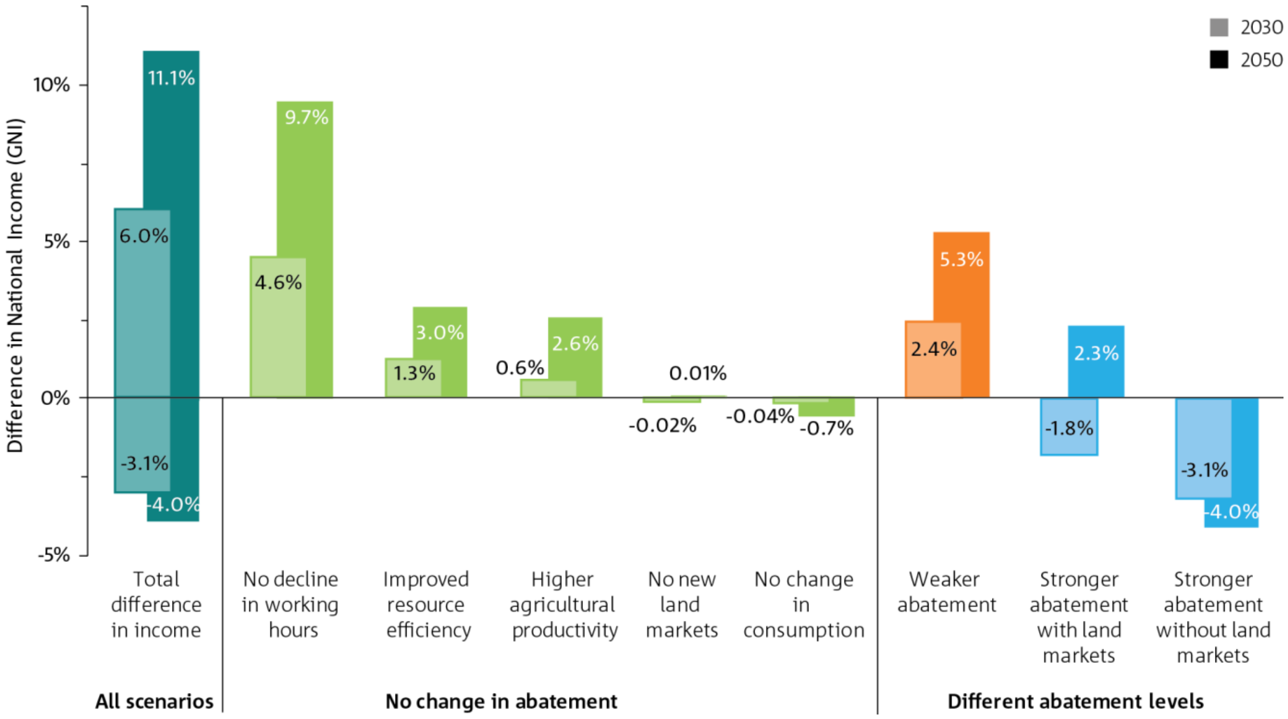
The analytical framework used for the *National Outlook* provides insights into a range of aspects of living standards, including average income, working hours (and leisure), household energy use, household transport demand, and different potential trends in household consumption.

National income in 2050 varies by 15% across the scenarios explored. Around two thirds of this difference arises from different assumed trends in average working hours, reflecting different balances between income and leisure – both of which contribute to living standards. This implies that living standards vary by around 6% across the scenarios (although the precise measure will depend on the relative weights assigned to income and leisure).

Across the combinations of uncertainties explored in the *National Outlook*:

- Trends in future working hours are the most significant factor in explaining difference in projected national income. A continuation of current trends in working hours would see average national income growing by 58%–65% by 2050 while average working hours fall 11%. Other scenarios see 9% higher income in 2050 with no decline in working hours, so that average income grows by 75%–82% by 2050. Judgements on which of these scenarios enjoys higher living standards will depend on the weight given to additional leisure versus additional income.
- Enabling changes in rural land use is the second most significant factor influencing differences in national income, increasing national incomes by up to 4.5% in 2050 in scenarios where abatement incentives encourage carbon plantings. And, by up to 5.3% in 2050 in scenarios with no global or national abatement action (reflecting increased competitiveness of biofuels as oil prices rise into the future), relative to scenarios with no flexibility in rural land use.
- Uptake of energy and water efficiency also has a significant impact on economic growth. National income is around 3% higher in scenarios that achieve high levels of resource efficiency, relative to the same scenarios that assume recent trends for energy and water efficiency. These gains are equivalent to $900 per person in 2030 and $2,400 per person 2050.
- Achieving higher agricultural productivity would increase the value of agricultural output from approximately 15%–40% for grain and from 15%–50% for livestock. It would also contribute an additional 2%–3% to national income by 2050.

Figure 18. The implications of different scenario drivers on national income in 2030 and 2050



Notes: The figure shows the difference in national income in 2030 and 2050 associated with each scenario driver and key combinations of drivers. Differences are calculated relative to *Existing Trends* (M2XR) or relevant XR scenarios (see Figure 5).

Source: MMRF (see Section 8.2, Table 3 for modelling references).

4.2 Household energy affordability and national energy security

Energy and transport affordability can be maintained or improved, and electric vehicles and biofuels could reverse decline in transport energy self-sufficiency.

After transport fuels, electricity is the largest component of household energy consumption (on average), followed by natural gas. However, the positions of electricity and natural gas switch in regions of Australia where gas is used as the main heat source. Australia has abundant coal, gas and renewable energy resources to supply our electricity and gas consumption needs for many decades to come. However, Australian oil production is declining and we are a net importer of oil.

We find that affordability of household electricity improves or is maintained across all scenarios, with electricity costs projected to fall slightly as a share of household income in most scenarios. We find improved energy efficiency has the greatest impact on affordability outweighing projected increases in generation costs, thus the lowest price scenario does not necessarily deliver the best affordability outcome.

Average vehicle ownership and running costs are projected to decline by 5%–15% across all scenarios, with the largest improvements projected in scenarios with high penetration of electric vehicles (which have dramatically lower fuel costs than conventional vehicles). Scenarios with stronger abatement incentives also see a more significant shift towards liquid biofuels and higher uptake of electric vehicles in the transport sector, reducing oil imports and improving national transport fuel self-sufficiency to over 80% by 2050 compared to 15% if no further steps were taken to deploy alternative fuels

In understanding the future outlook for household energy affordability we have focussed on transport fuels and electricity as the first and second largest sources respectively of household energy consumption, on average. However, it should be noted that in some regions of Australia natural gas, which is the third largest source, switches places with electricity to be the second largest source of household energy being used primarily in heating, hot water and cooking where readily available. The outlook for household energy affordability and security is complex, shaped by changes in prices, total household energy consumption, income and the possible future intertwining of transport fuel costs and electricity bills through vehicle electrification. For simplicity and ease of comparison with the present, the analysis for the *National Outlook* reports non-transport electricity and transport (including electricity) affordability separately.

Future retail electricity prices for residential customers are projected to increase by 2050 by between 45% and 75% in real terms. However, residential electricity bills are not expected to increase their share of household expenditure, due to a combination of increased energy efficiency and price increases being offset by increases in per capital income.

The retail price increases are mainly derived from changes in generation, transmission and distribution. In the generation sector prices increase in response to an expected gradual removal of excess supply in capacity and, in scenarios with abatement incentives, to accommodate the inclusion of higher cost low emissions intensive generation technologies. In the transmission and distribution sectors, unit costs of these services are expected to rise due to lower capital utilisation rates. Lower utilisation is being driven primarily by adoption of on-site generation leading to low volume throughput in the grid, which is not offset by better energy management to reduce peak demand (with the exception of one sensitivity scenario where we explore successful deployment of energy management practices). Retail prices for industrial customers are projected to increase further, by 66%–118% by 2050, because generation costs are a greater proportion of their tariff structure and generation experiences greater proportional increases than other parts of the electricity supply chain.

Despite these retail price increases, when we take into account the potential for improved energy efficiency and when we include management of peak demand we find that these measures could moderate, or more than offset, projected increases in electricity retail prices over the medium to long term, particularly in scenarios with abatement incentives. This implies that scenarios with the lowest prices may not necessarily provide the best outcome for electricity affordability (see Figure 19). Affordability outcomes will depend also on how electricity tariffs are structured to offer incentives for energy management, the availability and costs of metering and control systems and of energy management capable appliances, and the responses chosen by households.

Whilst acknowledging the potential scope and many benefits of change, the transport sector analysis assumes no significant modal shift in road transport or changes to Australia's historically stable and low rates of public transport usage, even for high resource efficiency scenarios. This implies continuation of similar behaviour patterns as present, with relatively high rates of car ownership. For transport, the cost of road passenger travel is projected by calculating the whole cost of travel which includes the vehicle, fuel, maintenance, registration and insurance. Vehicle electrification significantly impacts the cost of travel[5]. Vehicle electrification is projected to become economically viable as vehicle costs decrease, oil prices increase, and abatement incentives are implemented. Across the range of assumptions applied in the *National Outlook* electric vehicles are projected to contribute to satisfying transport demand by as much as 48% under high abatement incentive scenarios, or as little as 6% under no climate action by 2050.

The average costs of travel associated with vehicle electrification are initially increased. In the long run however, this change leads to lower average costs of travel due to substantially reduced exposure to rising liquid fuel costs. Across the scenarios, the greater the electrification, the greater the improvement in the affordability of road transport by 2050. Whilst the timing of uptake of electric vehicles is primarily impacted by economic factors, their total share of vehicle kilometres travelled in the long term will depend on consumer choices and preferences. Vehicle electrification has the potential to be a moderating factor in the expected lower utilisation of the electricity grid if it can contribute additional volume demand without adding to peak demand. This was the assumed approach here and in practice it will require deployment of appropriate charging control systems and tariff incentives to be achieved.

Overall the analysis finds that the affordability of in-home household electricity changes little as a share of income from current levels, or could improve modestly, as shown in Figure 19. We find that the uptake of energy efficiency and management of peak demand are the most important

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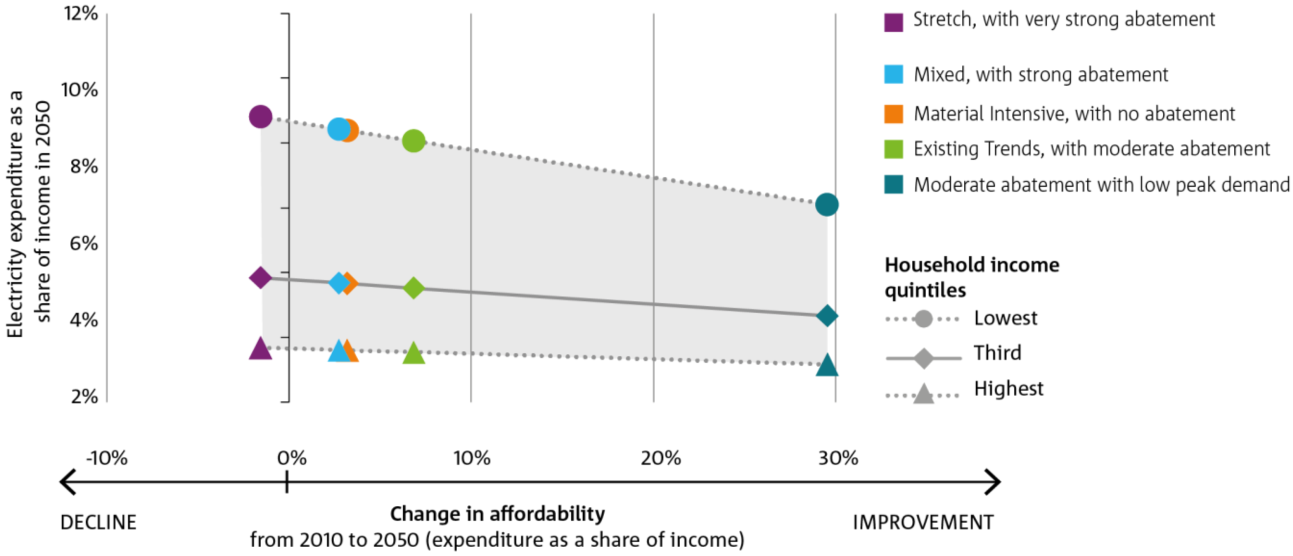
[5] Note that modelling has selected the battery driven electric drive train on a least cost basis over hydrogen fuel cells. However, small differences in relative costs and consumer preferences for vehicle driving range could result in the opposite outcome. In either case, the relevant shift is from liquid fuel internal combustion to electric motor driven transport. Whether the dominant energy store is batteries or fuel cells remains highly uncertain.

drivers of changes in affordability; with potential to result in significant improvements. The affordability of household transport, by contrast, improves significantly with expenditure as a share of income falling by around a third. Larger improvements would be possible in scenarios that assumed reductions in overall reliance on private vehicles (which provide significant flexibility and autonomy, but at a higher cost per kilometre than other options).

Figure 19. Average household expenditure on electricity as a share of income, change from 2010–2050, selected scenarios



Notes: Figure 19 shows projected affordability of electricity in 2050 (defined as average household expenditure on electricity as a share of household income), and the change in affordability relative to 2010. Projections are shown for the lowest income quintile (the lowest 20% of households by income), third income quintile and highest income quintile across the four touchstone scenarios and a supplementary scenario based on *Existing Trends* (with moderate abatement) that assumes lower peak demand. The results indicate that affordability improves around 7% by 2050 under *Existing Trends*, but could improve by around 30% with lower peak demand. Affordability improves by only 3% in the scenarios with strong abatement and no abatement action, and declines by 2% with very strong abatement. The projected changes in electricity prices account for changes in generation mix, technology costs and network costs (including transmission and distribution). Reductions in peak demand relative to average demand reduces network costs, and thus reduce prices per unit of electricity. Changes in demand account for price and non-price drivers of energy efficiency. The results shown do not include electricity used to charge grid-powered electric vehicles, as transport energy is not included in the 2010 base year, and projected shifts to electric transport yield net cost savings to households relative to conventional passenger vehicles.

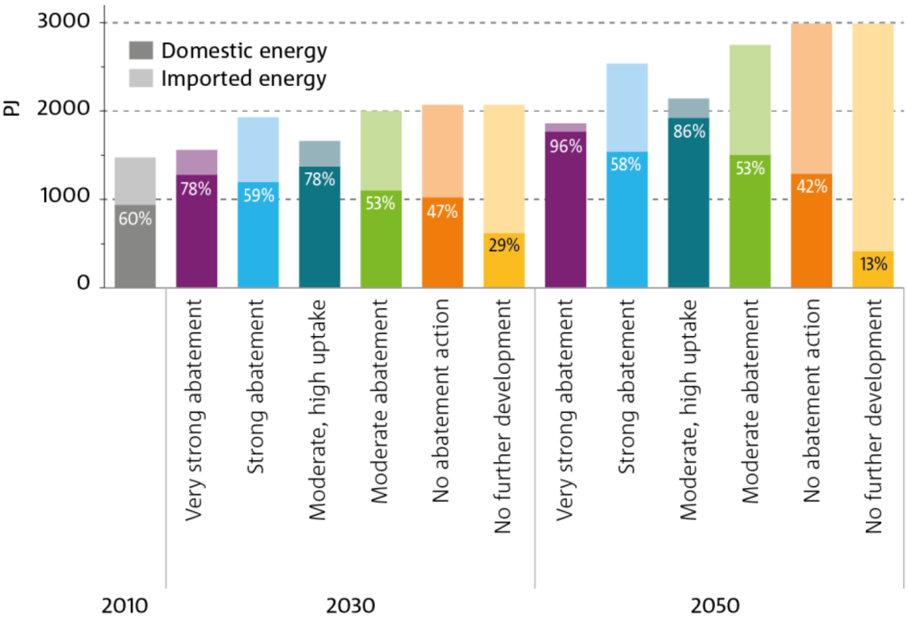
Source: ESM (see Section 8.2, Table 3 for modelling references)

Although there is no widely accepted definition of fuel security, the ratio of domestic transport fuel production to consumption is an indicator of transport fuel self-sufficiency and, in some circumstances, could represent transport fuel security. Although Australia's energy resources are vast, taken as a whole, we lack in particular domestic oil resources. Consequently, domestic oil production and exports are expected to continue to decline in the future. To maintain or even improve transport fuel self-sufficiency, increased uptake of domestically produced alternative fuels such as electricity, biofuels, compressed or liquefied natural gas and liquids converted from coal and natural gas could make a contribution. Across the scenarios fuel self-sufficiency by 2050 is expected to range between 40% and 90%, compared to 55% today (Figure **20**). We expect some uptake of alternative fuels under all scenarios, however, if there was no further development of alternative domestic fuels, transport fuel self-sufficiency would be projected to decline to around 15% by 2050.

All of these alternative fuels and their associated supply chains are technically feasible but generally involve creation of a new value chain including some large capital intensive projects which we generally assume are not likely to occur until after 2020. However, in reality the delay could be much longer. For low alternative emission fuels, abatement incentives would reduce the delay proportional to the strength of incentives provided.

Integration of land use with transport modelling enabled us to verify the availability of feedstock quantities under various scenarios. It showed that, providing there is growth in agricultural productivity, up to 10% biofuels share in transport by 2050 is also compatible with biodiversity and carbon plantings. The approach accounts for the impact of electric vehicle usage on electricity demand. It also finds that the competition for biomass between the electricity and transport sectors of the economy is projected to be resolved decisively in favour of transport. The substantial reductions in the cost of wind and solar photovoltaic power in the last decade have reduced the prospects for biomass-fuelled electricity generation.

Figure 20. Projected transport energy self-sufficiency for selected scenarios in 2030 and 2050.



Notes: Figure 20 shows projected transport energy self-sufficiency for selected scenarios in 2030 and 2050, reporting both domestic and imported energy, and proportion of domestic energy (shown as a percentage). The projections account for production and use of petroleum products, biofuels, grid-sourced electricity and alternative fuels such as natural gas. The figure shows results for the four touchstone scenarios, plus a supplementary scenario based on *Existing Trends* (with moderate abatement) and higher uptake of non-petroleum powered road transport. The figure also shows projected transport self-sufficiency in 2030 and 2050 with no further uptake of non-petroleum powered road transport. The results indicate that self-sufficiency would continue to fall without alternative fuels, but is projected to stabilise in scenarios with new land markets (including with no, moderate, or strong abatement action). Self-sufficiency increases to around 90% by 2040 in scenarios with very strong abatement (*Stretch*) and with high uptake of alternative transport and moderate abatement.

Source: ESM (see Section 8.2, Table 3 for modelling references).

5 Outlooks for resource use: land, food, energy, water and materials

This section reports the projections for resource use across the range of scenarios explored, particularly the outlooks for land use, agricultural production, water, energy and materials.

5.1 Land use

Profitable rural land use could shift dramatically, raising challenges and opportunities

We find that land use is central to the intersecting global challenges of improving food security, reducing pressures on biodiversity and ecosystem services, limiting climate risks and reducing net greenhouse gas emissions. The analysis for the *National Outlook* draws on new detailed modelling of different potential land uses, and how land use interacts with food, energy, water, ecosystems and the economy as a whole. This analysis focuses on the 85 Mha (850,000 km^2) of agricultural land in the intensive-use zone, including all non-arid agricultural land down the east coast around to South Australia, Tasmania and South West Western Australia. We find significant potential for land use change and diversification across different scenarios, supplying carbon credits, native habitat and energy feed-stocks – in addition to existing agricultural products. These new land-sector markets are transformative in some scenarios, enabling novel win-win outcomes and – in some circumstances – turning major national challenges (such as responding to stronger global action on climate change) into opportunities, so that a potential economic cost becomes a net economic benefit.

The last two decades have seen growing international interest in the development of new voluntary mechanisms to reward and encourage landholders for supplying different mixes of food, fibre and ecosystem services. In Australia, governments at all levels (and some businesses and non-profit groups) have invested in the design, testing and implementation of a wide variety of incentives and market-based schemes to provide ecosystem services and encourage environmental improvements. This has included nature conservation, pollution reduction, carbon sequestration and improved water quality. These initiatives are intended to enhance and complement existing agricultural practices and commercial land use.

In the analysis for the *National Outlook*, different scenarios explore the continuation of this trend to use land-sector markets to supply ecosystem services (particularly carbon credits and native habitat) and various forms of biofuels and bioenergy. These scenarios are contrasted with scenarios that focus on servicing current agricultural commodity markets and do not allow or enable these new land-sector market options.

We find that new land-sector markets play an important enabling role, allowing landholders to provide new services and products where this is profitable. The impact of these new markets varies across the different combinations of scenario drivers. Land use is influenced most strongly by the level of abatement incentive (which determines the level of payment for land-sector carbon credits), yet is also shaped by biodiversity policy settings, agricultural productivity trends, and global agricultural price trends. We find some land use change into biofuel production in scenarios with no national or global action to reduce emissions, due to rising oil prices, especially in scenarios with high agricultural productivity. Other underlying determinants of relative profitability include variations in production and productivity across the landscape, rainfall, tree growth and carbon sequestration rates, the spatial distribution of biodiversity priorities and payments, water use and prices, and a range of input costs.

We find that payments for carbon sequestration has the potential to drive significant land use change by 2050. We find a marked threshold effect in relation to carbon sequestration, where carbon credits are not attractive at national scale until payments reach \$40–60/tCO_2e, above which carbon plantings become attractive across significant areas of land (Bryan et al., 2014; Bryan et al., 2015). This profitability threshold rises slightly over time, due to rising export prices for agricultural products. With moderate abatement incentives (M2) this profitability threshold is not reached until around 2040. With stronger incentives, the threshold is reached earlier – around 2030 in M3 and around 2020 in the L1 global scenario (Figure 21). This reflects that abatement incentives increase over time in all scenarios, as lower cost opportunities become fully exploited and larger incentives are required to encourage additional abatement. The same logic implies that scenarios requiring larger cumulative global abatement (to achieve lower, more ambitious concentration targets) require stronger incentives from the outset, thus abatement incentives (and carbon payments) start at a higher level.

These potential changes in land use are driven by the substantial new opportunities provided by new markets for carbon sequestration. These changes are not marginal. We find that where carbon plantings are attractive, they are at least five times more profitable than the most attractive agricultural use across more than 60% of this land, and at least twice as profitable on at least 84% of this land, across all three levels of abatement. (It is the size of this profitability margin that allows carbon incentives to be harnessed to deliver biodiversity outcomes, as discussed below.) This in turn reflects pronounced differences in agricultural productivity across the intensive use zone. As discussed below, one third of land in the intensive use zone currently provides two thirds of the value of output.[6] Relatively little of this most productive land shifts out of agriculture, with 70%–80% of projected land use change occurring on less productive land in the strong and very strong abatement scenarios.

To capture the time lag in adoption of new land uses, the modelling assumes that land takes up to 16 years to switch from existing use to its new, more profitable use, with an average lag of eight years (see Bryan et al., 2015). This lag is not applied to land that is selected for mixed species plantings supported by the biodiversity fund, as this practice represents an annual auction or

[6] The most productive agricultural land is identified on the basis of the value of output per hectare for each agricultural commodity in 2012. This identifies the most productive land for beef production, for example, rather than for all agricultural commodities in aggregate (which would be dominated by irrigated production).

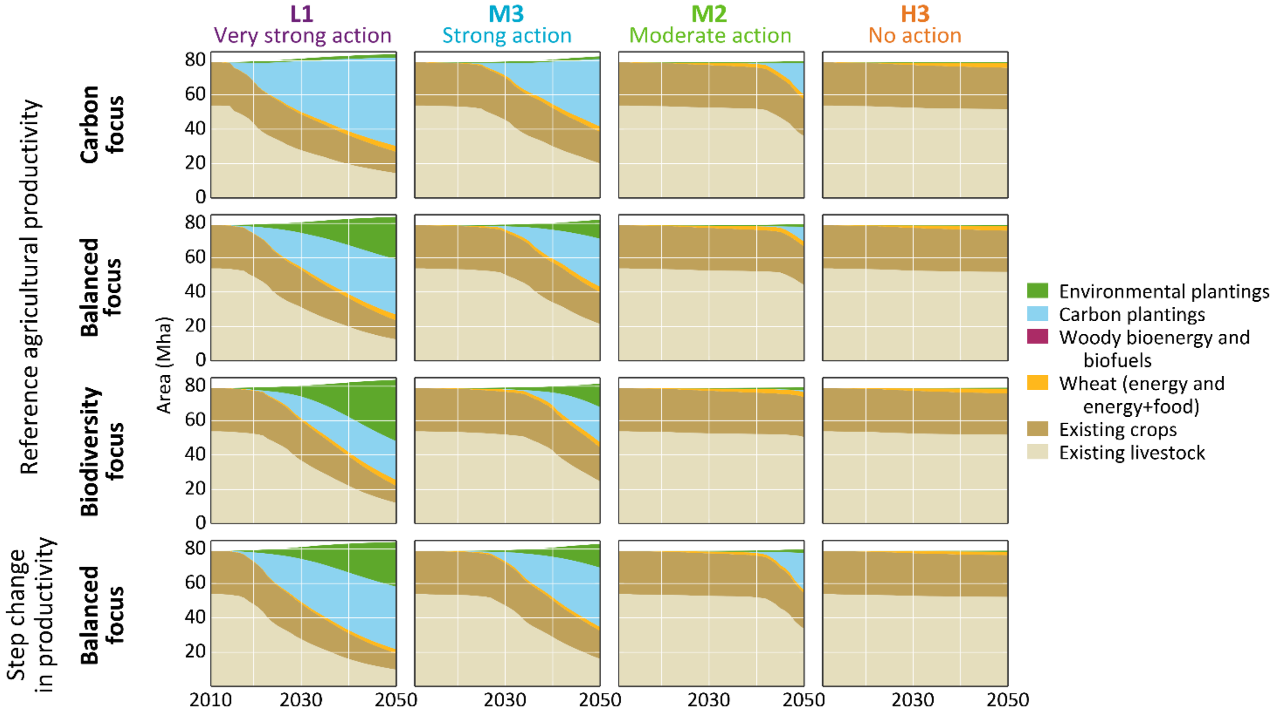
tender process, with a portfolio of land selected each year to provide the most cost effective biodiversity improvements. The time lag is also not applied to changes that occur within enterprises, and are easily reversible, such as from wheat for food to wheat for biofuel or wheat for a mix of food and biofuel.

We find that under voluntary payments based on carbon sequestration alone, single species plantations (referred to as carbon plantings) are projected to provide the vast majority of plantings. For example, a plantation using a native species selected on the basis of its carbon potential grows faster and sequesters more carbon than environmental plantings of mixed local species. To explore the potential for achieving different mixes of carbon and biodiversity benefits, we model three stylised policy settings. A 'carbon focused' strategy involves a straightforward payment based solely on carbon sequestration, complemented by a biodiversity fund of $125 million per year that provides a top up payment to cover the gap between mixed species plantings and the next most profitable use in a specific location. These funds are allocated to deliver the maximum biodiversity benefits per dollar, based on spatially explicit information on relative biodiversity priorities and the payment gap that would be required in each location. A 'balanced' strategy tilts the playing field towards biodiversity in two ways: first, by applying a 15% levy to carbon plantings revenue, and second by using these funds to increase biodiversity payments which are then cost-effectively allocated to environmental plantings. A 'biodiversity focused' strategy tilts the playing field further by applying a 30% levy on carbon plantings. Projected conservation and biodiversity outcomes under these settings are described in Section 6.1 below, along with the impacts on total carbon sequestration (see Figure 38).

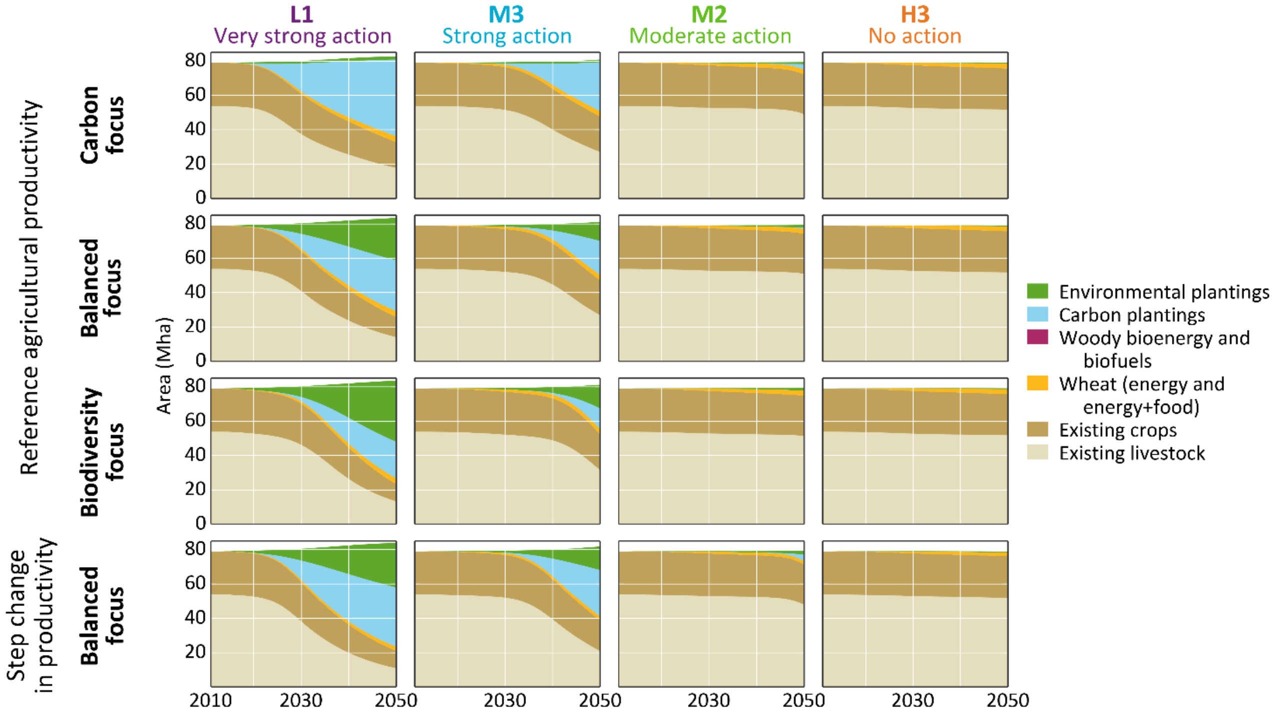
The extent of changes in most profitable land use under these combinations of scenarios is shown in Figure 21.

Figure 21. Change in most profitable land use over time under different global scenarios and biodiversity policy settings, intensive use zone, 2010–2050

(a) Most profitable land use



(b) Land use accounting for uptake lag



Notes: Projections for reference agricultural productivity and step change in agricultural productivity, allowing land use change due to new markets including energy crops (scenarios NR and NE). Panel (a) shows most profitable land use over time, and Panel (b) shows projected land use accounting for the uptake lag, as discussed in the text.

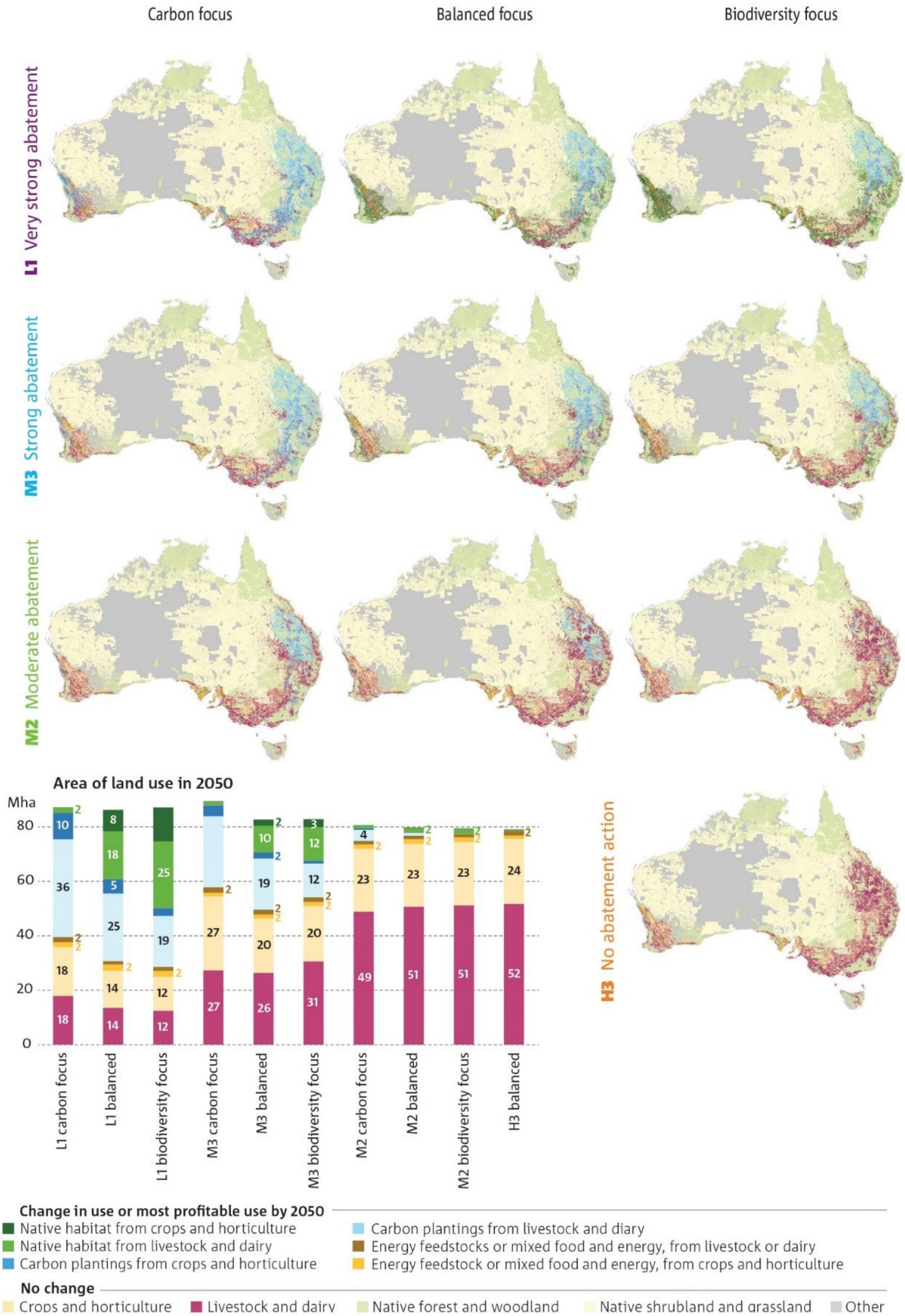
Source: LUTO (see Section 8.2, Table 3 for modelling references)

The extent and patterns of changes in most profitable land uses vary across the landscape. Changes in profitability are more pronounced in areas of lower value extensive livestock grazing in Queensland and New South Wales – environments which are also conducive to tree growth and carbon sequestration. These patterns of change are shown in Figure 22.

The figures indicate that markets for carbon credits have the potential to motivate large areas of land use change into carbon plantings, but only modest areas into environmental plantings which produce both carbon and biodiversity co-benefits unless policy settings deliberately support these outcomes (see Bryan et al., 2014; Bryan et al., 2015; Bryan et al., under review). Similarly, market-based biodiversity payments result in only modest areas of land use change into environmental plantings in the absence of markets for carbon credits. Together though, carbon and biodiversity markets have the potential to motivate significant areas of environmental plantings and the supply of biodiversity benefits is highly dependent upon the presence of both a strong carbon market and a biodiversity payment scheme (i.e. L1 strong biodiversity in Figure 21). When strong incentives for carbon and biodiversity combine, large areas of land may be converted to environmental plantings rather than carbon plantings, particularly in the high biodiversity priority areas in the south-west and south-east of Australia (see Figure 22).

We find this level of land use change has a relatively modest impact on agricultural output, as discussed in Section 0 below.

Figure 22. Location of new most profitable land use under different global scenarios and biodiversity payment schemes at 2050 (modelled for the intensive use zone).



Notes: Figure 22 shows maps of most profitable land use in 2050, and column charts of the area of potential land use in 2050 (accounting for uptake lags), classified by current and potential land use, for seven scenarios assuming new land markets and recent trend agricultural productivity. Column labels show the area for categories that are 2Mha or more in 2050. Each scenario assumes a different level of carbon payment for single-species plantings, expressed as a share of the maximum payment in the very strong abatement scenario. Differences in payment rate arise from the level of global abatement incentives, interacting with biodiversity settings. Shifts in land use lag changes in most profitable use, with the analysis assuming shifts from agriculture to single species carbon plantings occur over 16 years after the change in most profitable use. As most native habitat plantings receive top-up funding through a competitive tender, native habitat is assumed to be established with no uptake lag. The analysis assumes that no land shifts from native vegetation (including forest, woodland, shrubland and grassland) to agricultural use. The H3 map is for balanced land market settings. High resolution versions of these maps are provided at **www.csiro.au/nationaloutlook.**

Source: LUTO projections and calculations as described, drawing on GIAM.GTEM projections of agricultural prices and abatement incentives and GDM analysis of spatial biodiversity priorities (see Section 8.2, Table 3 for modelling references).

5.2 Agricultural production

We find that the outlook for agriculture is positive, but we cannot afford complacency about improving productivity, or about responding to climate variability and change

We project agricultural prices to trend upwards over coming decades, reversing a long historical decline.

Output of food and fibre can increase, even with substantial land use change, if declining investment in productivity is restored. However, we do not yet fully understand the potential cascading impacts of future climate change and extreme events on farms, sectors and regions.

The analysis for the *National Outlook* explores the implications of different agricultural price and productivity trends, and how these might shape the outlook for Australian agriculture.

Improving agricultural productivity has maintained farm viability against declining agricultural margins for much of Australia's agricultural history. (This decline in margins also often referred to as the 'cost-price squeeze' or a decline in agricultural 'terms of trade'.) The last 50 years has seen sustained improvements globally in agricultural productivity. Global agricultural output has tripled, while population has doubled, with only a 12% increase in the area of land under cultivation. These same trends have seen a long term decline in agricultural commodity prices. The last decade, however, saw a series of food price spikes (in 2002, 2008, 2010 and 2012) breaking the long run downward trend in prices. This appears to reflect a slowing in agricultural productivity growth – particularly in more developed countries – combined with weather-related shocks and policies promoting biofuels (Tadesse et al., 2014).

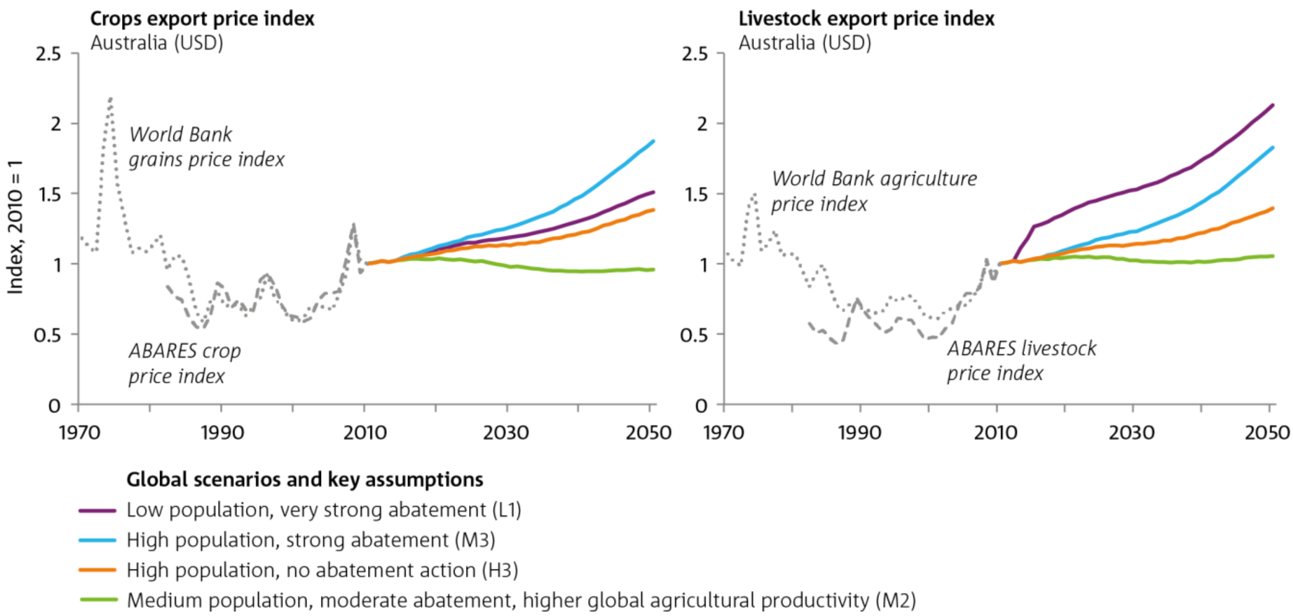
Australian agricultural output doubled from 1960 to 2000 (Sheng et al., 2013), but recent Australian productivity trends are not clear. Total agricultural output was essentially static from 2000 to 2010, with no growth, coinciding with the period of the Australia-wide Millennium drought. While untangling the impacts of the drought are complex, there are signs that total factor productivity growth in agriculture has slowed to under 1% per annum over the last 10%–15 years, down from growth of more than 2% over the previous three decades.

We explore a range of export price outlooks for grain and livestock. As shown in Figure 23, export prices trend up in most of the global scenarios, representing a reversal in the long term trend; resulting from rising global population and increased competition for land outweighing productivity growth. Grain prices to Australian producers are projected to increase by 38% by

2050 in the H3 scenarios with high population growth but relatively low competition for land, and by 51%–88% in the L1 and M3 scenarios with strong or very strong incentives for carbon plantations globally (increasing global competition for land), across different population levels. To test the significance of price trends, the M2 global scenario assumes stronger improvements in global agricultural productivity, resulting in stable export prices to 2050 (falling 4% over four decades). The outlook for farm gate livestock prices is similar. The pattern of export price trends for livestock is similar to grain price trends, as shown in Figure 23. Actual future export prices will be highly sensitive to agricultural productivity outcomes in different commodities and regions, and Australian exchange rate movements. We are likely to see continuing – or increasing – volatility in prices, volumes and market access over coming decades (but this has not been modelled in the projections, which focus on trend changes).

Looking forward, improving agricultural productivity will be central to maintaining landholder incomes, improving food security, and enhancing the resilience of agricultural enterprises and regions in the face of climate variability and other shocks. We explore the implications of different productivity trends through domestic scenarios that contrast a continuation of long term productivity trends (around 1% per annum) with scenarios that assume potential step change in Australian agricultural productivity trends (2.8% per annum), in the context of the M2 and M3 global scenarios. To maintain consistency across scenarios, the analysis assumes that higher Australian productivity does not affect global prices. Prices received by Australian producers are modelled to allow deviation from the global prices – as land use change displaces agricultural production through time, the decrease in the supply of agricultural commodities increases the price, and hence, profitability of remaining agricultural production.

Figure 23. Projected change in crops and livestock prices to 2050 across the global context scenarios.



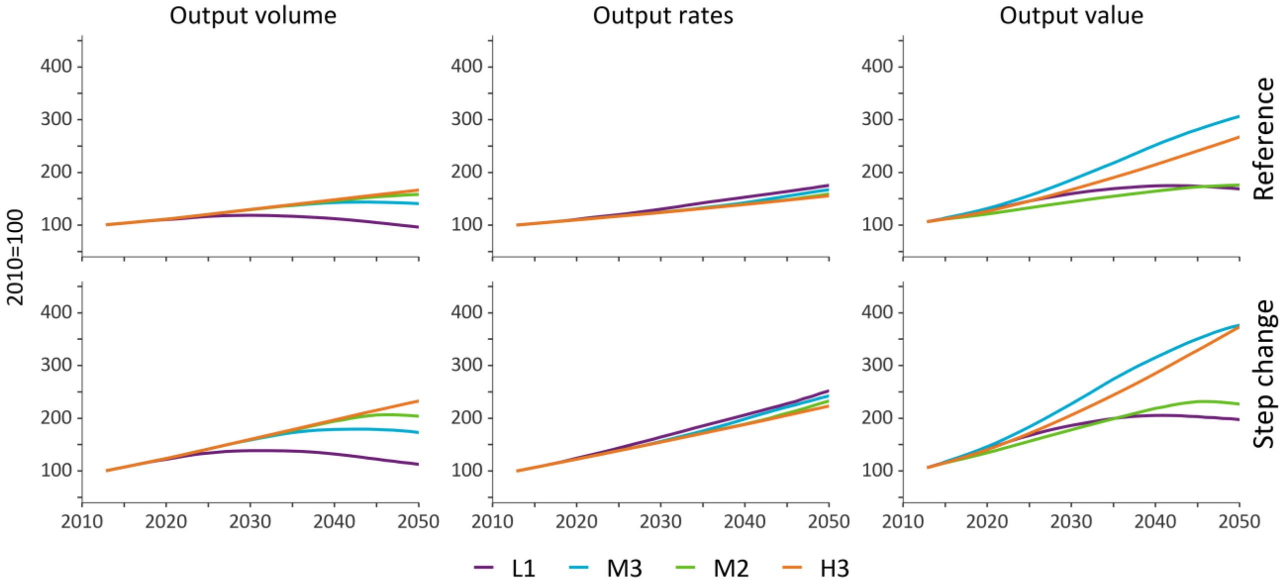
Notes: Figure 23 shows projected change in grain and livestock prices from 2010–2050 across the global context scenarios. The projections account for differences in population (with higher population driving higher prices) and the impact of global land sector abatement incentives. This reduces the supply of arable land for agriculture in the abatement scenarios (M2, M3 and L1) relative to the no abatement action scenario, due to reforestation and reduced land clearing. Stronger levels of abatement contribute to higher prices. The modelling assumes that livestock emissions are subject to global abatement incentives and obligations in the very strong abatement scenario (L1) but not in the moderate and strong scenarios. In order to provide a wider range of prices across the domestic scenarios, the global scenario with medium population and moderate abatement (M2) also assumes higher global agricultural productivity. This reduces agricultural prices and increases output relative to the levels with no adjustment to productivity. The modelling does not fully account for potential impacts of climate change on agricultural output and prices.

Source: ABARES (2012, 2013), World Bank (2014b), GIAM (see Section 8.2, Table 3 for modelling references).

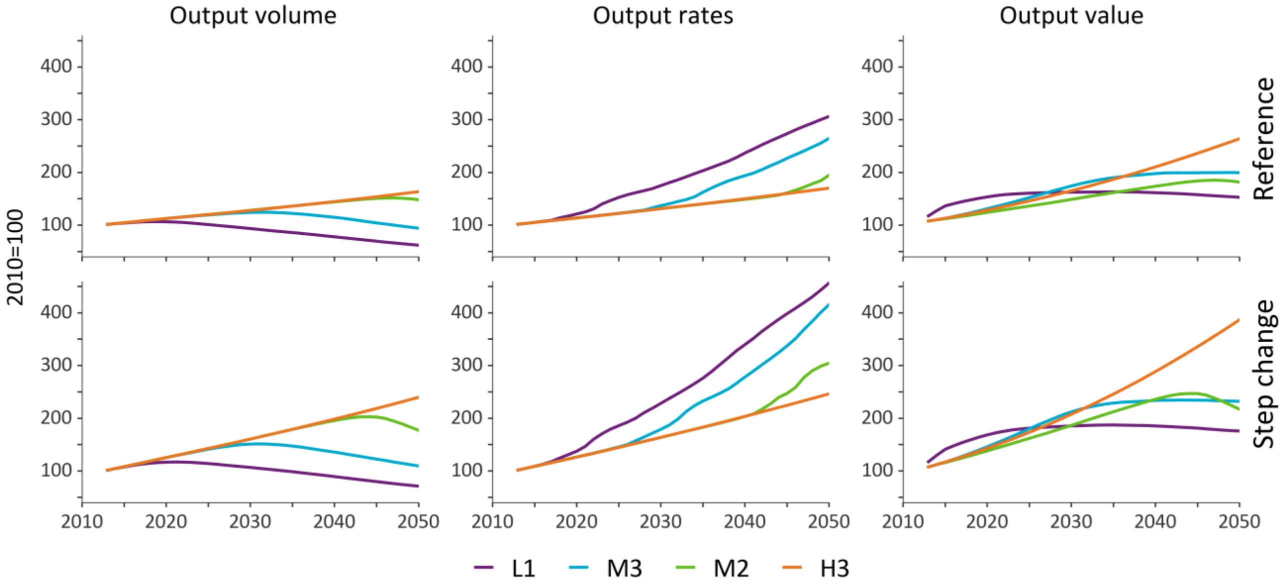
We find that the outlook for agricultural production, land use and profitability are strongly influenced by interactions between prices, productivity trends and the range of market opportunities available. In broad terms, grain output per hectare increases by around 50% by 2050 under existing productivity trends, and by at least 120% with a step change in productivity (as shown in Figure 24). Total revenues increase by at least the same amount, and by much more in some scenarios. Potential land use change influences outcomes for livestock production more strongly than for crops, diary and horticulture. We find incentives for carbon plantings could see a significant change in land use away from livestock within the intensive use zone (which accounts for around half of Australian livestock production and around a quarter of national exports. Land use change towards carbon plantings largely occurs on the least productive land, from an agricultural perspective, focusing production on more productive land and boosting average output per hectare. The impact of land use change is larger than productivity improvements in some scenarios, however, resulting in net declines in projected livestock output volumes. The value of livestock output is projected to rise by at least 50% under existing productivity trends across all scenarios, however, and by at least 75% with a step change in productivity, as price increases offset reductions in production area in the strong and very strong abatement scenarios.

Figure 24. Agricultural output volume, output rates and values, livestock and grain, sensitivity analysis for selected scenarios, 2012–2050

Grain indicators, intensive use zone



Beef and sheep indicators, intensive use zone



Notes: The graphs in Figure 24 show changes in total physical output volume, output rates (volume per hectare) and output value (reflecting changes in both physical volume and price). Projections for NR and NE scenarios (allowing land use change due to new markets, including energy crops and high productivity (NE only)). These projections assume no uptake lag for land use change, and thus indicates an 'upper bound' or maximum change projection, given the assumptions for each scenario.

Source: LUTO volume and GIAM price projections (see Section 8.2, Table 3 for modelling references).

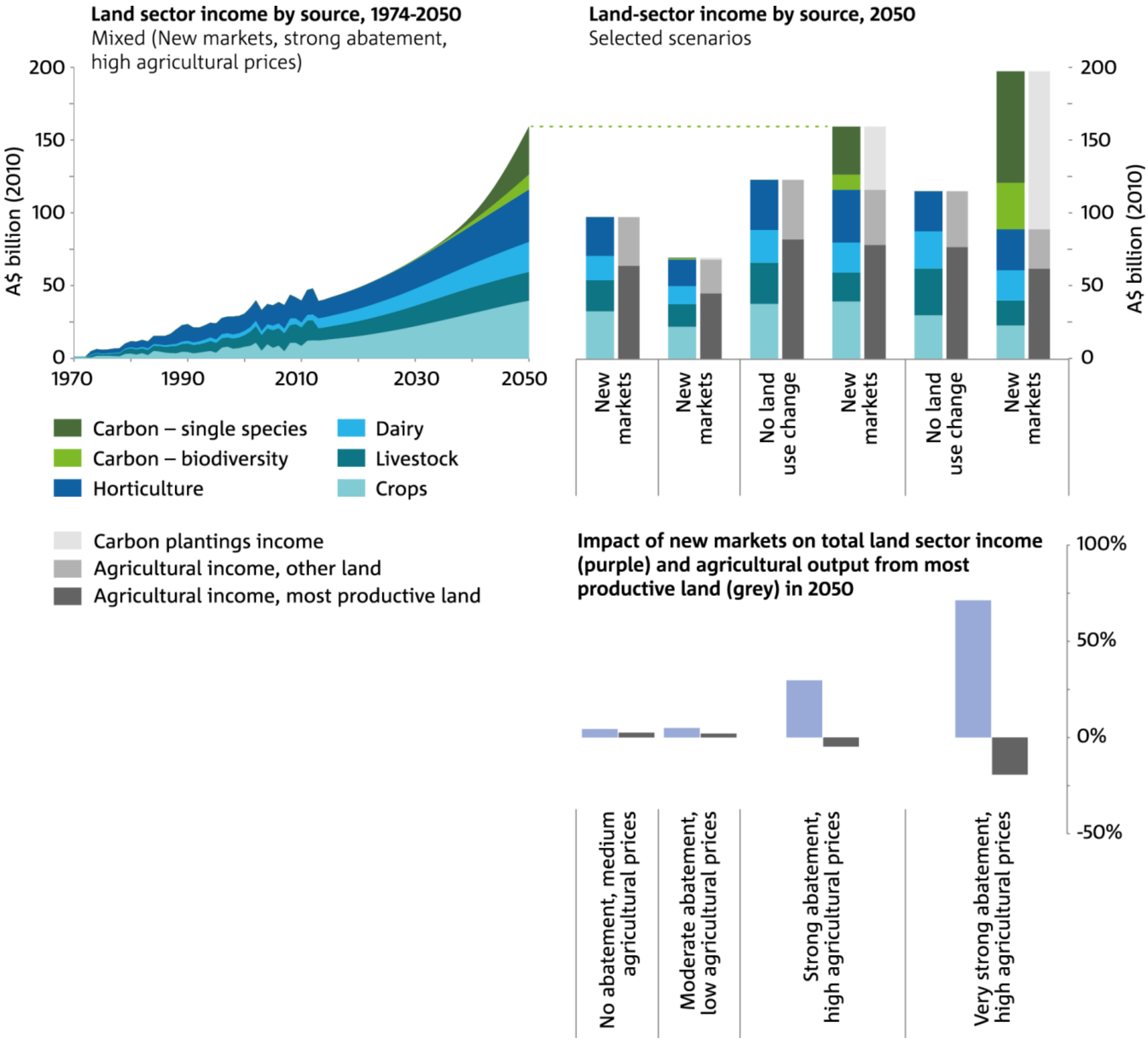
The analysis confirms that maintaining and improving the productivity of Australian agriculture will be central to the economic future of the sector, and to enhancing Australia's contribution to meeting global needs for food and fibre. While underlying causes are difficult to determine, the low rates of agricultural productivity growth over the last 10–15 years signals that we cannot take future improvements for granted. Government investors, industry bodies, farm businesses and supporting services all have important roles, as productivity growth reflects the performance of the entire production system. The analysis for the *National Outlook* suggests that policy settings can be highly influential in shaping Australia's land use and agricultural productivity. Policy options include: research, development and demonstration; improving essential infrastructure through new investment or improved governance arrangements (such as for irrigation assets); providing effective extension and advisory systems; enabling private sector support services (such as biofuel plants, or nurseries for plantations); and through ensuring an efficient and flexible economic environment (including competitive and efficient markets, access to finance and risk management services, and appropriate tax settings).

Our last major finding on the outlook for agriculture is that new markets could offer significant advantages to landholders and to Australia as a whole. We find these new market opportunities have the potential to drive significant land use change, with most diversion from food production projected to be from grazing lands. New income streams from supplying energy feedstocks and ecosystem services (carbon sequestration and native habitat), could enhance land-sector profitability and provide a range of benefits beyond the farm gate. The demand for renewable energy crops and feedstock grows across all the scenarios explored, including scenarios with little or no action on climate change (driven by rising oil prices). New markets act to maximise land sector incomes and revenues under different combinations of circumstances, so that the value of land based outputs – food, carbon mitigation, energy feedstock, and biodiversity services – is higher in scenarios with new land sector markets than in the corresponding scenarios without these market opportunities. The underlying mechanics of market interactions also buffer many of the potential adverse impacts of land use change: the proportion of land that changes use is larger than the relative change in agricultural output as production is concentrated within more productive land, and the reduction in agricultural income is more than offset by the increase in non-agricultural income.

This capacity to increase food production on a smaller proportion of the land base is consistent with the level of increase needed to maintain Australian contribution to global food supply, assuming trend improvements in productivity, and the level of global production needed to match current need and changes in dietary demand. The potential for combining multiple land use functions on a given area of land is not fully modelled in the analysis, suggesting that net benefits may be larger and more widely distributed in practice, particularly for livestock producers. Scenarios with a relatively high degree of land use change also see significant win-win outcomes from new markets, delivering new native habitat (reversing the historical decline), substantial cost-effective carbon sequestration, and significant additional income for landholders as a whole – as illustrated in Figure 25. Achieving this kind of multiple-benefit outcome in practice will require policy approaches that integrate across sectors and policy objectives.

The timing and extent of projected land use change is sensitive to national and global abatement policy settings. The modelling assumes that abatement efforts increase over time, along with associated carbon payment levels. We find that relatively minor change occurs at payment levels below AUD$40/t$CO_2$e. However, once payment levels rise above this point the range of profitable choices available to landholders widens and more varied patterns of land use emerge. In scenarios with moderate to strong abatement effort most land use change occurs after 2030, while significant change begins prior to 2030 in scenarios that assume very strong national and global efforts (consistent with limiting temperature increases to around 2°C).

Figure 25. Impact of emerging markets on land sector income and agricultural output, 1974–2050



Notes: Figure 25 shows the projected value of agricultural crops, livestock, dairy and horticulture output, and the value payments for carbon and biodiversity plantings, accounting for projected changes in land use in the intensive-use zone. The left hand panel shows the projections to 2050 with strong abatement incentives, along with historical data from 1974 to 2012. Historical data shown also includes the extensive land-use zone which is a significant share of national livestock output. The right hand panel shows percentage change in land sector incomes in 2050 attributable to new land sector markets (purple), and the percentage impact of new markets on the value of agricultural output from 'most productive land' (grey). Most productive land is defined for this purpose as the area that accounts for two thirds of the value of output in 2010 for each of 20 agricultural commodities modelled in LUTO, totalling one third (36%) of the area of agricultural land in the intensive use zone. Results assume trend agricultural productivity and a balanced approach to carbon and biodiversity, across different levels of abatement effort, with and without new markets.

Source: Historical data from ABARES (2013); prices from GIAM; and, volumes and spatial details from LUTO (see Section 8.2, Table 3 for modelling references).

There are a number of limitations to the modelling of land use and agricultural output.

A first caveat is that realising the potential benefits of new markets will involve dealing with their wider potential community and sector impacts. The modelling represents land use change as a bottom-up process – maximising farm profitability over time – which may not coincide with different views of a 'desirable' pattern of land use from a regional or national perspective. The modelling does not explore or assess a number of spatial processes that may impact on agricultural productivity and rural amenity, including: potential ecosystem services and agricultural production benefits from native vegetation (expected to be generally positive); changes in fire risk and intensity from increased areas of plantations (expected to neutral or adverse); direct and indirect employment effects of land use change (expected to vary across locations and contexts); and, the impacts of higher and more diverse landholder income streams, some of which may accrue outside rural areas. We consider these issues a priority for further research and public discussion.

A second major caveat is that the modelling only accounts for potential climate change impacts in a limited way, focusing on smooth trend changes in rainfall to 2050. Nor does the modelling assess the impacts of extreme events or variability, such as droughts, floods, storms, or changes in seasonal minimum or maximum temperatures. This means that the implications of expected increased frequency and intensity of climate shocks (which appear to be already occurring) are not fully explored or assessed. Our analytical capacity does not yet capture the impact of climate thresholds in agricultural systems, such as the relationship between minimum night temperatures and flowering of fruit crops. These climate shocks and key thresholds are likely to be significant for agricultural production and regional livelihoods over coming decades. Depending on the severity and duration of climate shocks, the impact on productivity and production may well differ from the trends modelled in this study.

Other caveats involve the scope of the analysis, which is focused on the intensive use zone and did not model the extensive grazing lands of northern and arid Australia. Within the intensive use zone, the analysis focuses primarily on rain-fed agriculture (although irrigated agriculture is included) and does not include detailed modelling of the capacity for multiple land uses within the land-use areas.

5.3 Energy and energy intensive sectors

Australia can benefit from strong global demand for energy and energy intensive products, across both high-carbon and low-carbon futures

Australian energy demand is projected to increase by between 1.0% and 2.9% per annum to 2050 across all scenarios, exploring different combinations of energy efficiency, levels of greenhouse gas abatement effort, and economic growth rates. Demand reflects both growing population and growth in energy-intensive parts of the economy.

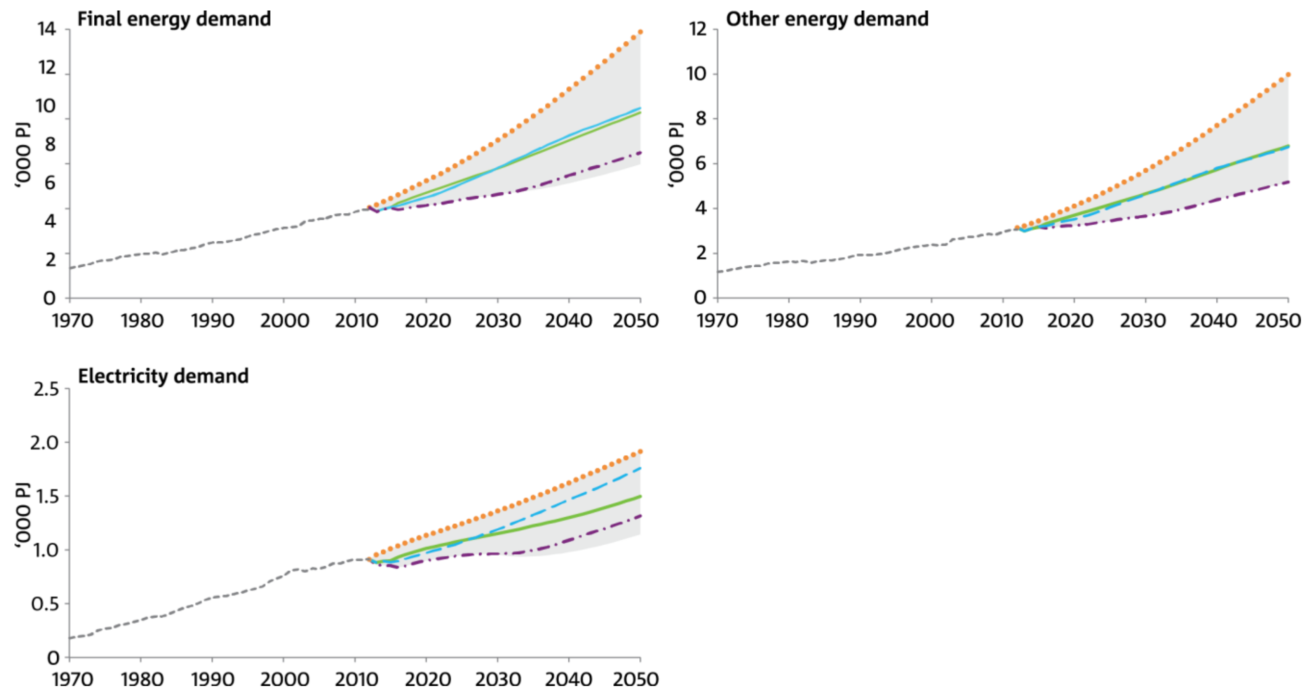
Australia’s per capita energy footprint, measuring the energy embodied in all goods and services consumed in Australia (regardless of whether they were produced locally or imported) is projected to be flat or declining by 2050, while that of China is expected to triple over the same period.

We find successful implementation of CCS is central to achieving deep cuts in global emissions, and would significantly reduce the global costs of action. Success or failure to develop and deploy CCS technology will have a critical impact on the global costs of achieving emission reductions, and on Australian fossil fuel exports.

Energy supply and demand

Total energy demand is projected to grow by 1.0%–2.9% per annum from 2010–2050 across the range of scenarios explored. For the *Existing Trends* scenario, total energy demand is projected to grow 1.9% from 2010–2050, consistent with the historical trend and implying a recovery from recent slower annual demand growth. Total energy demand is higher in scenarios with higher GDP growth (with no decline in average working hours), resulting in cumulative energy demand over the 40 year projection period being 6% higher in 2050 than in the *Existing Trends* scenario. Trend growth in energy demand is lower in scenarios with stronger abatement action, and in scenarios assuming a step change in resource efficiency. These factors interact, with non-price energy efficiency making the largest difference in scenarios with no abatement action to reduce greenhouse gas emissions, and the smallest difference in scenarios with the strongest abatement incentives. Outcomes across the full set of scenarios are shown in Figure 26, highlight results for the four touchstone scenarios.

Figure 26. Australian energy demand (final energy demand and electricity), all scenarios, 1970–2050

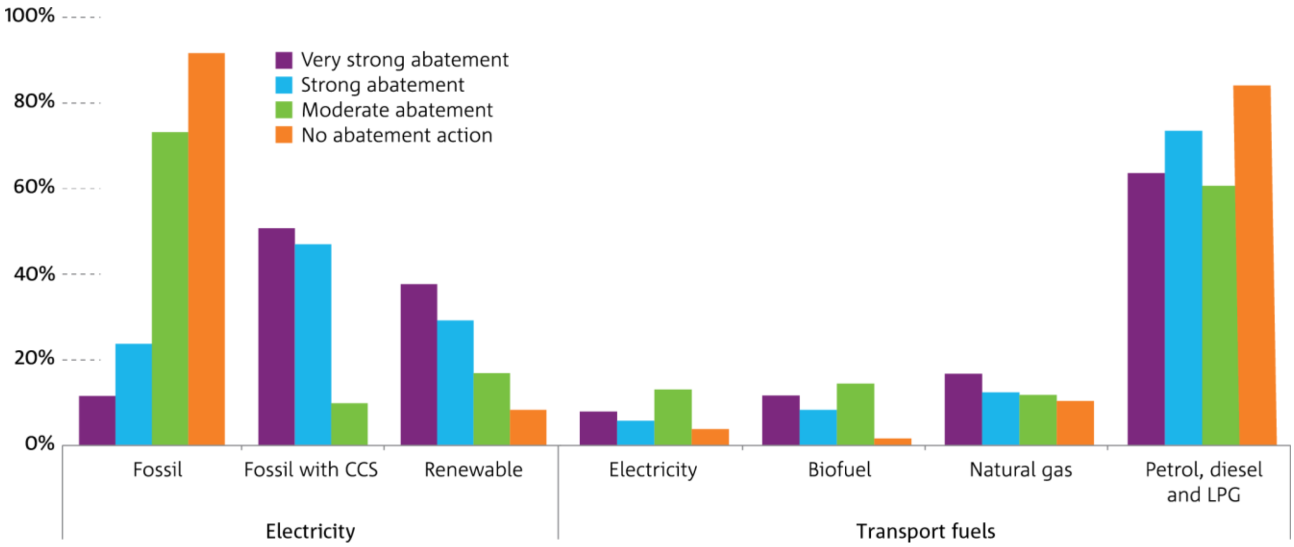


Source: MMRF and ESM (see Section 8.2, Table 3 for modelling references); historical data from Stark et al. (2012)

The mix of fuels and technologies in the electricity generation and transport sectors is projected to vary significantly over different scenarios to 2050 (Figure 27). The share of renewables in electricity generation is projected to be between 8%–37% by 2050 influenced by changes in coal and gas prices and abatement incentives. Under a higher renewable share, generation also tends to more decentralised, mostly through the deployment of solar roof-top panels. Carbon capture and storage is only projected be deployed as a significant share if GHG abatement incentives are strong.

As oil prices rise, a range of alternative fuel and vehicle engine technologies become more economically viable in the transport sector, only moderately more so if GHG abatement incentives also exist and the fuels are less emission intensive than conventional oil based fuels. Electricity, biofuel and natural gas meet these criteria and are projected to reduce the share of conventional fuels (petrol, diesel and liquefied petroleum gas) in 2050 by 20%–40% across the scenarios. Modelling of biofuel indicated that it is biophysically possible to supply volumes of biomass for bioenergy as well as producing agriculture outputs and expanding carbon forestry. This is because a significant amount of potential bioenergy feedstock is a by-product of agricultural production. However, we also found that if expected improvements in agricultural sector productivity are not realised then potential biofuels supplies are very limited (see Brinsmead et al., under review, for more details).

Figure 27.Projected shares of conventional fossil fuels, CCS and renewables in electricity generation (left chart) and electricity in 2050, biofuels, natural gas and conventional transport fuels (petrol, diesel and LPG) in transport in 2050 (right chart)



Source: ESM (see Section 8.2, Table 3 for modelling references)

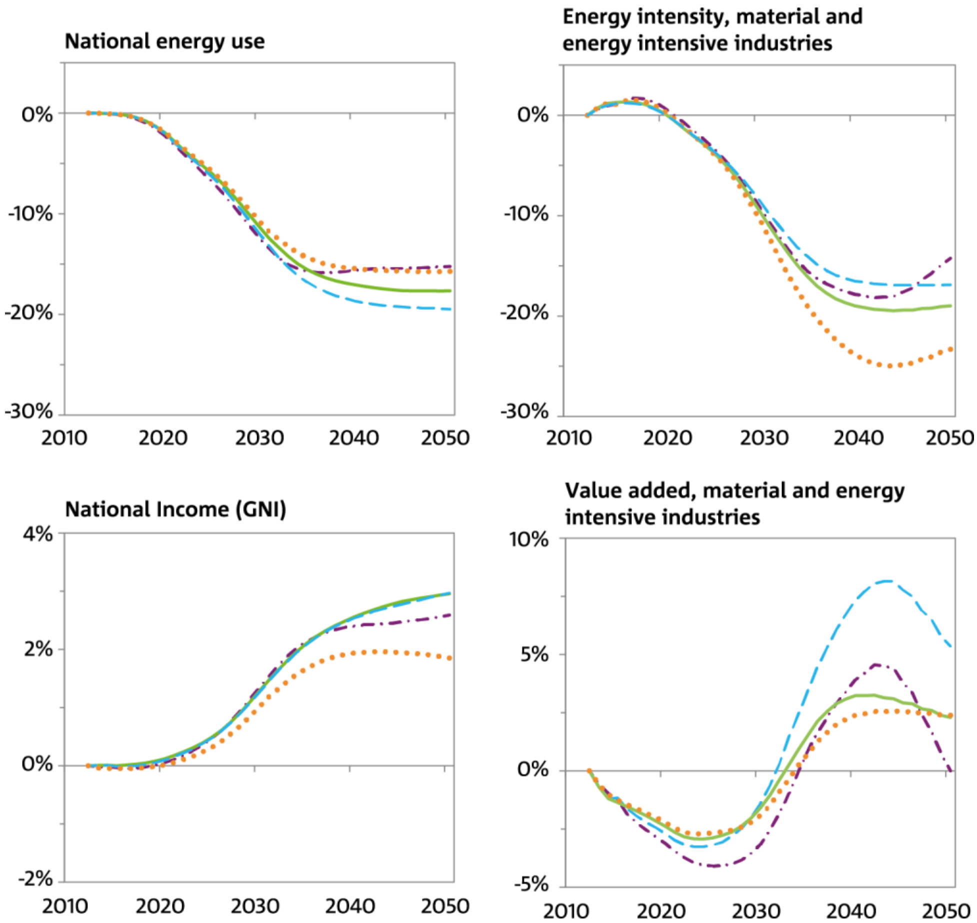
These technology projections are necessarily based on current knowledge and consequently mostly conservative in the amount of change foreshadowed. On the other hand some of the technologies assumed adopted, such as CCS and some emerging renewables, have not yet been demonstrated at commercial scale. Nuclear power was not explored in the analysis, but could potentially contribute to the fuel mix under strong or very strong global abatement action (see Jotzo et al., 2014). In transport, we have not explored deep substitutions in transport modes (such as between road transport and rail) given the relative stability of mode shares over the last few decades. Major changes in transport mode share would require significant changes to our urban landscape. The future size, location and structure of Australian cities are important areas for future research.

Impacts of domestic energy and water efficiency

The analysis finds that uptake of cost effective energy and water efficiency measures would reduce energy use and boost national income across all abatement outlooks, from no abatement to very strong abatement globally and nationally. Comparing the efficiency step change scenarios to their equivalent recent trends scenarios, energy use falls by around 15% by 2035, and then stabilises between 15% and 20% below recent trends, as shown in the top left panel of Figure 28.

The impacts on energy intensity (energy use per dollar of value added) of material and energy intensive industries are similar. These outcomes reflect the time profile of the scenario assumptions, which are based on information about currently available energy efficiency opportunities, and are more conservative in relation to additional opportunities after 2030. The step change in efficiency increases national income (GNI) by 1.6%–2.2% in 2035, rising to 1.9%–3.0% higher across the scenarios by 2050. The results for value added by material and energy intensive sectors are more complex, as shown in the bottom left panel of Figure 28. Implementing an efficiency step change involves some additional up-front investment, reducing value added (and increasing energy intensity) in the first 5–10 years before the portfolio of efficiency options yield net financial benefits. The value of output and value added from intensive sectors is also negatively impacted by reduced national demand for energy (particularly fossil fuel extraction, electricity generation and petroleum refining). These effects dominate to around 2025, after which value added begins to improve relative to the recent trends scenarios, achieving net positive results shortly after 2030. The time profile of the scenario assumptions see these gains satiate in around 2040–45, however, reflecting the stabilisation of physical non-price efficiency gains after 2030 (as shown in the top left panel), which are based on data on currently unimplemented efficiency opportunities (see Baynes, 2015), and the time profile of changes in working hours (see Figure 17). The combined effect of these assumptions results in the difference in value added plateauing in the moderate and no abatement scenarios, and converging back to the level in recent trends in the strong and very strong abatement scenarios (which have high levels of price-induced energy efficiency).

Figure 28. Impacts of non-price energy and water efficiency on energy use, energy intensity, and national income, 2010–2050



Notes: Figure 28 reports the impact of a step change in energy and water efficiency, calculated as the difference between XR and XI scenarios for four global and national abatement levels.

Source: MMRF (see Section 8.2, Table 3 for modelling references)

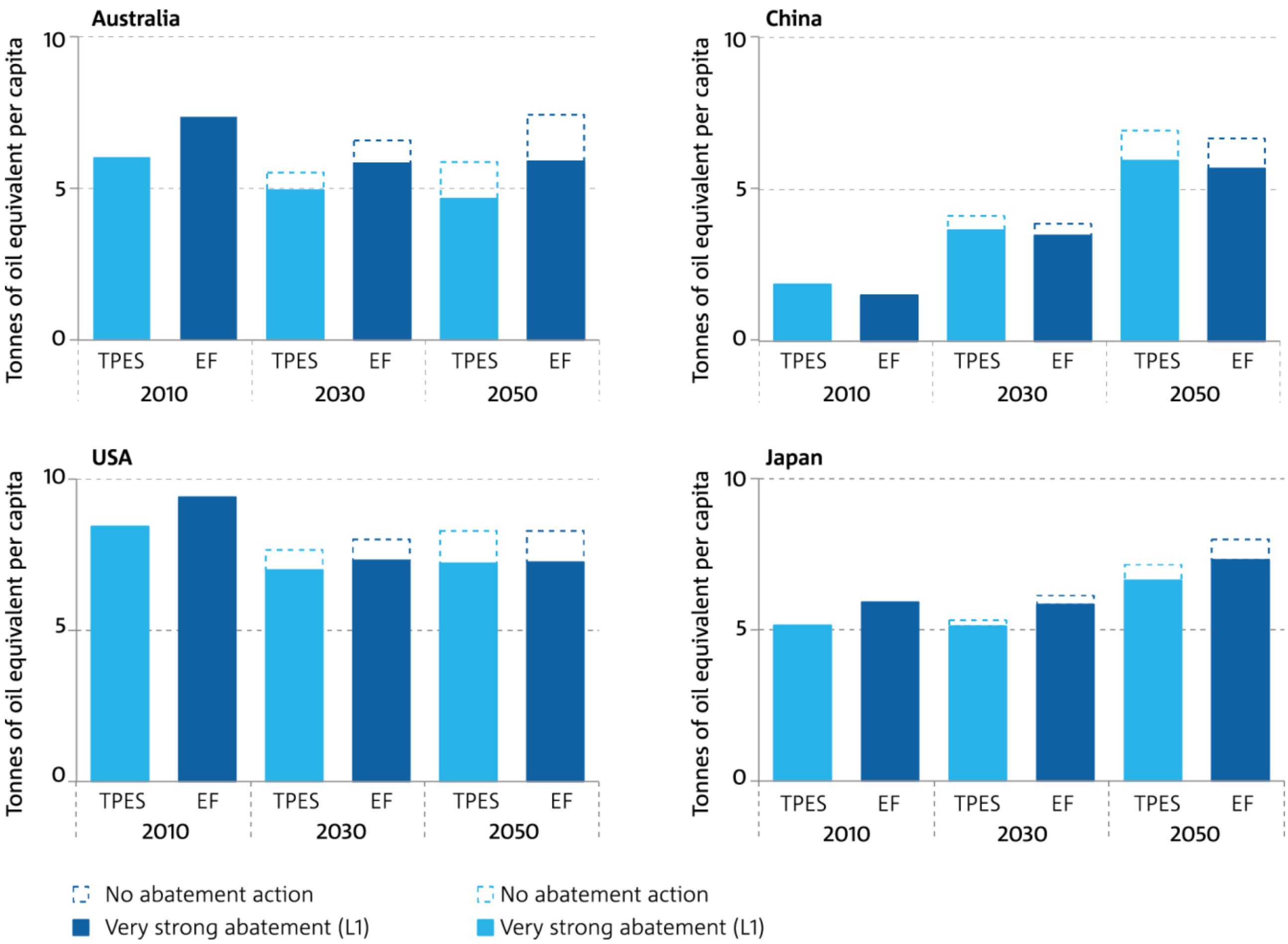
Australia's energy footprint

The most common approaches to measuring national per capita energy consumption include all energy consumption whether it is consumed directly or indirectly in Australia or exported overseas. Additional insights into energy use can be achieved through attention to measures of direct domestic energy supply (called total primary energy supply) and total energy embodied in all domestic or imported goods and services consumed (called a national energy footprint). Using these latter approaches, we find that Australian per capita energy use is not high relative to other high income countries, and that global differences in embodied energy use are projected to contract over the period to 2050.

Figure 29 shows two indicators for per capita energy use in Australia and three other countries: China (an emerging manufacturing giant, with rising per capita material and energy use), the USA (with relatively high direct energy use) and Japan (with relatively low direct energy use). Total primary energy supply indicates direct energy use within each country, while the per capita 'energy footprint' indicates energy use attributed to goods and services consumed within the country, regardless of where this energy use occurs in the global supply chain. The figure indicates that global abatement efforts have only modest impacts on total energy use.

The per capita energy footprint of consumption in the US, Australia and Japan is higher than direct energy use, indicating that from a consumption perspective, all three high-income countries are net importers of embodied energy. For Australia, this implies that more energy is embodied in the supply chain of our (largely manufactured) imports than is embodied in the production of our exports (noting that, for example, this refers to the energy used to extract and ship coal and gas, not the unexpended energy embodied in the coal and gas itself). The analysis finds the opposite for China, consistent with its significant export oriented (and largely energy intensive) manufacturing industry. The USA has the highest per capita energy footprint among globally important economies with 9.4 tonnes oil equivalent per capita currently whereas Japan only has 5.9 tonnes per capita. China's per capita energy use and energy footprint increase dramatically over the period to 2050, to 5.7–6.7 tonnes per capita (across different scenarios for global abatement action), representing levels of energy use similar to Japan despite significant differences in per capita GDP (see Figure 7 above).

Figure 29. Total Primary Energy Supply (TPES) and Energy Footprint (EF) for four countries, 2010–2050



Notes: The coloured columns in Figure 29 show energy use (TPES and EF) in the L1 global scenario, with very strong action to reduce emissions, while the dotted boxes on top of the columns show the additional energy use in the H3 global scenario, with no additional action to reduce emissions.

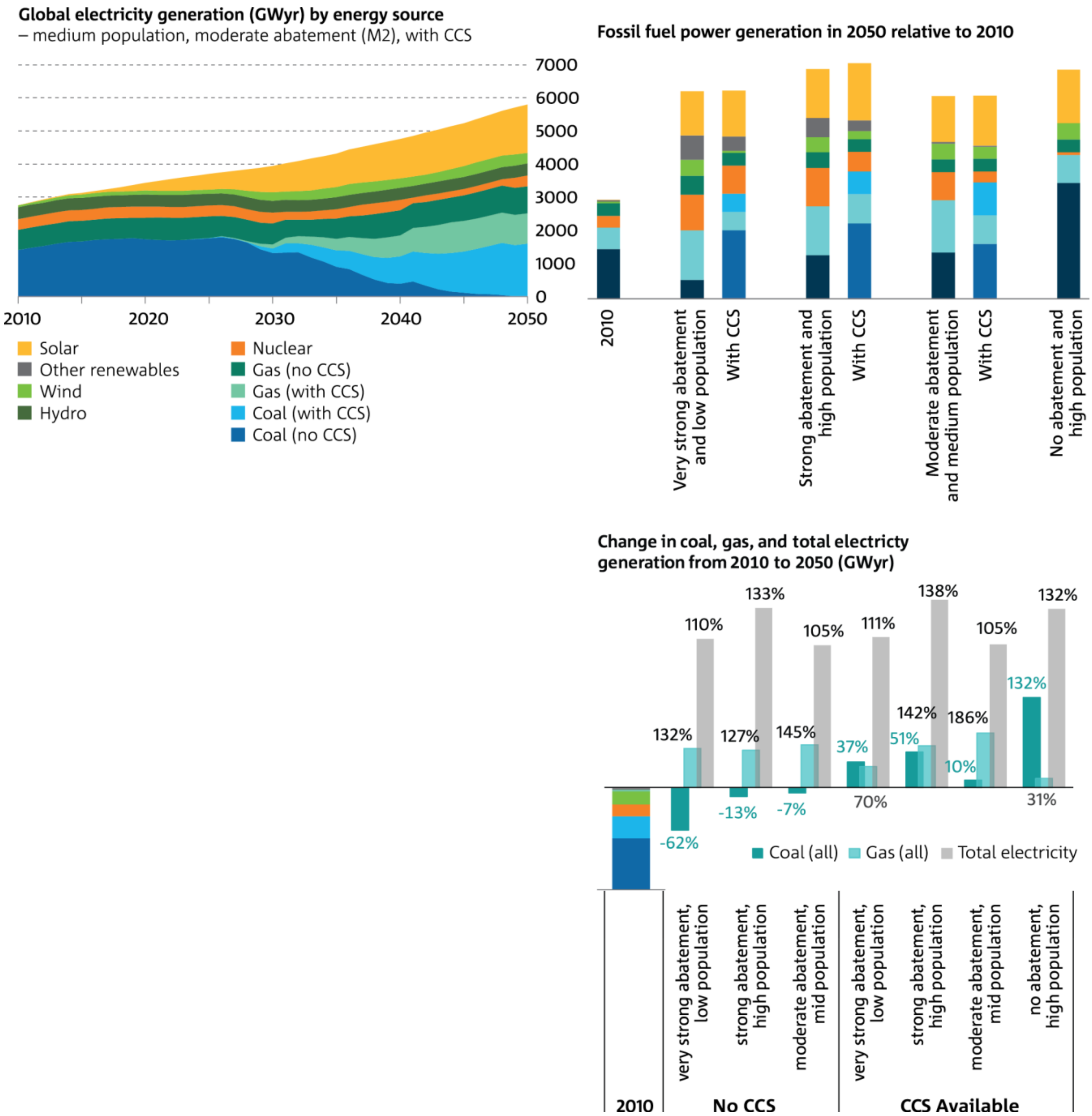
Source: GIAM.GTEM and MEFISTO projections (see Section 8.2, Table 3 for modelling references).

Global demand for energy, and the importance of CCS technology

Global demand for both electricity and total energy are projected to more than double by 2050, reflecting trends in population growth, per capita income and energy efficiency. However, demand for Australia's coal and gas will depend on the policy settings of our key trading partners, influenced in turn by the evolution of international action on reducing greenhouse gas emissions.

The outlook for specific energy commodities is therefore less certain than for energy as a whole, particularly for coal (IEA, 2012), which is sensitive both to the pace of action to reduce carbon emissions and to the relative competitiveness of coal verses gas and other renewables across different contexts. Over the range of global scenarios explored, we find global demand for fossil fuel powered electricity ranges from a small decline (4%) to doubling (increasing 102%) from 2010–2050, with even larger differences in outlook for coal, as shown in Figure 30 below.

Figure 30. Global electricity generations by energy source, selected scenarios with and without CCS technology, 2010–2050



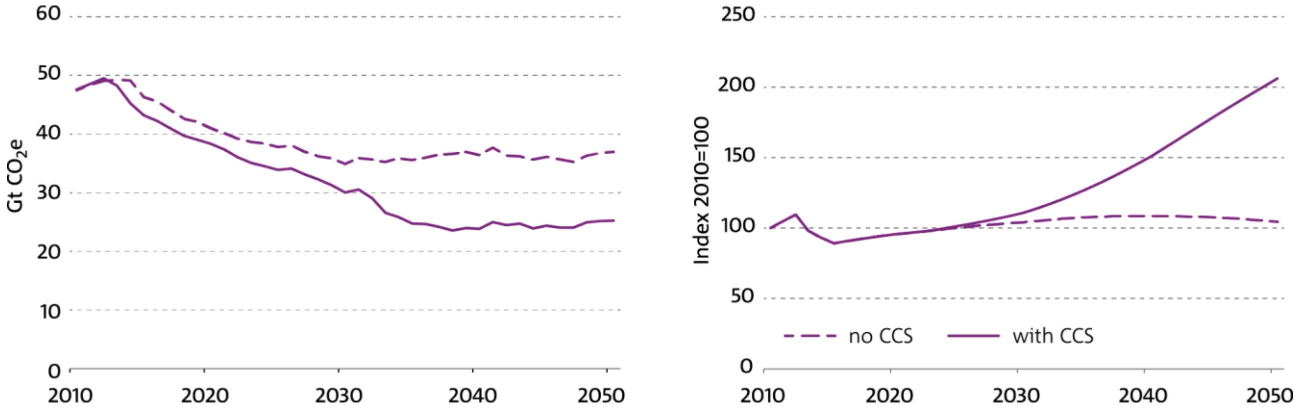
Notes: Figure 30 shows changes in projected global electricity supply, by fuel or technology. The panel on the top left shows supply for the period 2010–2050 for the M2 global context scenario. The top right panel shows the generation mix in 2050 for the four global scenarios, which all assume CCS technology is available, and three supplementary scenarios where CCS technology is not available. The bottom right panel shows the change in global coal, fossil fuel, and total electricity generation in 2050 relative to 2010 levels. The height of the columns reflects change in generation output (GWyr) from 2010 on the same scale as the other panels, with percentage change provided using labels.

Source: GALLM.

Our analysis confirms that successful implementation of CCS is central to meeting global aspirations to limit global warming, and would ease the transition of Australia's coal sector in scenarios with strong or very strong abatement efforts. A supplementary global scenario explores the impact of failing to deploy CCS technology, assuming the same population, underlying economic trends and level of abatement incentives as the L1 scenario. We find failing to deploy CCS would results in 21% higher global emissions over the four decades to 2050, and the value of

Australia's coal exports are 49% lower by 2050, as shown in Figure 31. While not explored in the *National Outlook*, other studies also suggest that bioenergy with CCS could help provide a practical 'negative emissions' technology option over the longer term, which could play a crucial role in limiting temperature increases to 2°C or lower (see Fuss et al., 2014).

Figure 31. Implications of non-deployment of carbon capture and storage technology on global emissions and the value of Australian coal exports (right), L1 global context scenario, 2010–2050



Notes: The right panel in Figure 31 shows total global emissions from all sources in the L1 scenario, and the supplementary L1 scenario without CCS technology. (This supplementary scenario assumes the same level and coverage of abatement incentives, but does not match the cumulative emissions for RCP 2.6.) The left panel shows the value of Australian coal exports for the same global context scenarios with and without CCS technology.

Source: GIAM.GTEM (see Section 8.2, Table 3 for modelling references).

Achieving successful deployment of CCS technology will be contingent on choices by government and business, and is crucial to achieving reductions in global greenhouse gas emissions and to moderating the impact of global emissions reductions on the demand for Australian coal. Australia has the natural and institutional resources to participate in any global energy future, and to prosper in any scenario for global energy demand and action on greenhouse gas emissions. This suggests Australia should position itself to take advantage of a range of opportunities and global trends (see Sections 5.2 and 7.2).

5.4 Water use

Rising water demand can be met, while enhancing water security.

National water use is projected to double (increasing 80%–120% in most scenarios), driven by increased population, economic growth and new carbon plantings. This growth in demand can be met while enhancing non-agricultural water security, without increasing pressure on water-limited catchments, through water recycling, desalination and integrated catchment management.

We find total water use is projected to increase, but that the extent of this increase varies significantly across scenarios. Non-agricultural water use is projected to increase around 65%–150% from 2000 levels by 2050, shaped by strong connections between water use and average income (reflecting working hours), the growth of energy and emissions intensive sectors (reflecting global abatement efforts), and the uptake of water efficiency. Total water use (including interceptions associated with land use change) is projected to increase by a similar proportion, around 30%–170% from 2000 levels by 2050, but with a different pattern of water use across scenarios, with higher interceptions from carbon plantings outweighing lower water use in energy intensive sectors in scenarios that assume stronger national and global abatement efforts.

The analysis assumes existing water policy arrangements prevent overall increases in water extractions in the Murray Darling Basin, and so the growth in national extractive water use is supplied by a combination of increased extractions in other areas of Australia (particularly in Queensland) and new supply from water recycling and desalinisation. This allows substantial growth in water use without increases in extractive pressures on water limited catchments.

We find that new carbon plantings and mixed species plantings could have a significant impact on surface flows. Interceptions by plantings in high rainfall areas are projected to account for 25%–50% of total national water use in 2050 in scenarios with significant levels of land use change. Plantings in water limited catchments intercept up to approximately 5 TL by 2050 in these scenarios, which would risk increases in water stress unless offset by reductions in other uses. We find that the uptake of carbon plantings is not sensitive to water prices. Not allowing carbon plantings in water limited catchments would reduce cumulative national land sector sequestration by up to 2.2Gt over the period to 2050.

Australia is the world's driest populated continent, with an average annual rainfall of 417 mm, and has the smallest proportion of rainfall that becomes runoff into rivers. The total renewable water resource in Australia is about 414,000 GL/year, derived from runoff (9% of rainfall) and groundwater recharge (2% of rainfall). The rest (89% of rainfall) evaporates back into the atmosphere, mainly through vegetation. Despite being generally an arid continent, Australia has moderately plentiful water resource per person because of its very low population density. Australia uses around 6% of the total renewable water resource, on average, which is low relative to other regions of the world. About 68% of the water consumed is used in irrigated agriculture, 23% by industries and 9% by households[7].

Australia's rainfall and runoff is highly variable, over both space and time. Australia has a relatively high rainfall zone in the north, east and south-west coasts but the rest of the continent has low rainfall. The year-to-year variability of Australian river flows is the highest in the world, and combined with high evaporation, presents significant challenges to water management in Australia. The available water resource in some regions is fully or over-allocated, while other regions remain largely undeveloped (Prosser, 2011).

Existing water management challenges will be accentuated by climate change, growing population and increasing demand for water from multiple users, particularly in south-eastern Australia where water use is very high and projections indicate a drier future (Chiew and Prosser, 2011; Teng et al., 2012; Chiew et al., 2009). While there is a perception that Northern Australia has plentiful water resources, there are significant challenges in developing economically and environmentally sustainable water systems in these regions. As water interacts with practically all sectors and is a key part of the nexus between future climate, population, and food and energy production, policies and development approaches must properly consider variability over space and time, as well as interactions across sectors.

The water analysis for the *National Outlook* incorporates several innovations. Projections are developed for water demand as a function of population, economic activity, and potential water efficiency trends. This water demand is met through projections of rain-fed water and alternative sources of supply, accounting for modelled impacts of climate change on rainfall and runoff across Australia, and estimated costs of different additional supply options. The modelling caps extractions of rain-fed water sources in New South Wales, Victoria and South Australia at 50% of projected annual average flows, consistent with recent water reforms (MDBA, 2012). Runoff is projected to decline slightly nationally from 2010–2050 across the different global climate outlooks (linked to the global context scenarios), with NSW projected to have the largest decreases (2.8%–4.4% from 2010 levels). New supply from desalinisation or water recycling is considered for use in urban areas and non-agricultural industries. The scenarios exploring improved water use efficiency assume high rates of uptake of cost-effective efficiency measures across all non-agricultural water use. Improved water-use efficiency in agriculture is represented as a reduction in total water use, reflecting a system level perspective in which water efficiency both enhances industry profits and reduces water extractions and related pressure on riverine ecosystems. (Modelling improved efficiency at the enterprise level would be expected to result in increased agricultural production from the same amount of water in capped catchments, and higher water use in unconstrained catchments.)

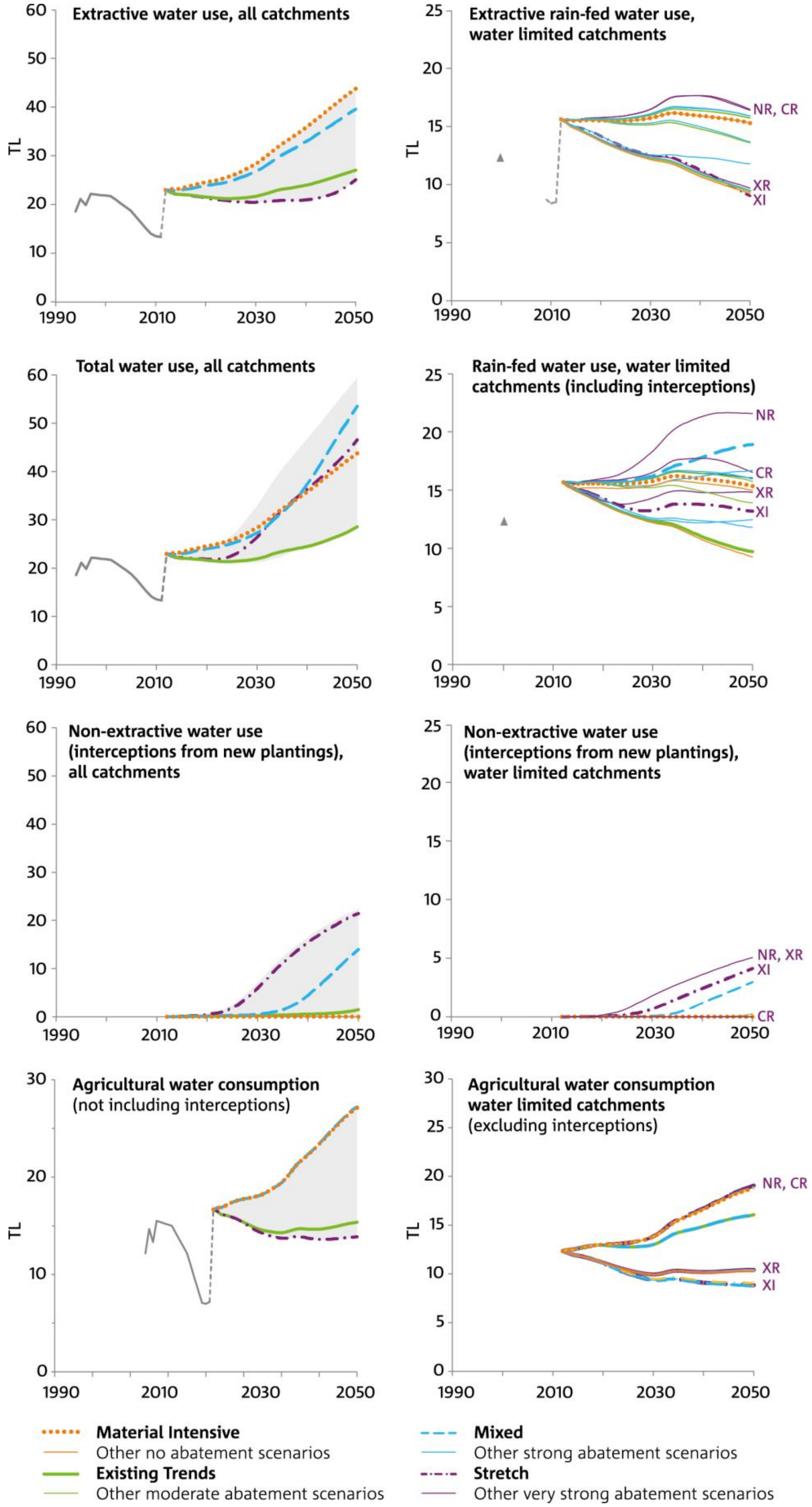
[7] (Australian Bureau of Statistics, http://www.abs.gov.au/ausstats/abs@.nsf/mf/4610.0

Integrated analysis is essential to understanding future patterns of water use

Water sits at the heart of the water-energy-food nexus. We find that future demand for water and the mix of supply options are shaped by complex interactions between local constraints on rain-fed water resources, the costs of different water supply options, the growth of energy-intensive industries (reflecting abatement incentives and other factors), the uptake of more energy and water efficient technologies, and water interceptions by new carbon plantings – all occurring against a background of population growth and rising per capita incomes. We find that integrated analysis is essential for exploring and understanding potential water futures.

We find that projected demand for water varies widely across the *National Outlook* scenarios, as shown in Figure 32, with non-agricultural extractive water use increasing by 65%–150% by 2050, while population grows 64% and the value of national economic output grows 156%–186%. Agricultural water use is projected to increase by up to 80% by 2050, driven primarily by increases in catchments outside the Murray Darling Basin where water resources are not yet fully allocated.

Figure 32. Extractive and non-extractive water use, nationally and in water-limited catchments, 18 scenarios, 1990–2050.



Notes: Figure 32 shows the range of projected national water use across 18 scenarios. Projected water extractions are scaled relative to 2000-2001 water use, considered a typical water use year. Water interceptions are projected for catchments with an annual rainfall of greater than 600 mm. The *Stretch* scenario (purple dot dash line) assumes very strong abatement and the *Mixed* scenario (blue dash line) assumes strong abatement, giving rise to significant water interceptions from carbon plantings before 2040, and so total water use is higher than extractive water use. The top row shows national water use, highlighting four touchstone scenarios. Extractive water use includes supply from desalination and water recycling. The bottom row shows rain-fed water use only, for all scenarios. The *Stretch* scenario [XI] assumes high resource efficiency, which is defined as preventing increases in water stress, and is implemented through the higher water licence price as described in the text. The [XR] scenario assumes a trend decline in working hours, and has lower extractive water use than the [NR] scenario, which assumes no decline in hours (as explained in the text). These scenarios involve the same land use for a given abatement level, and thus the same water interceptions. The policy settings assumed in the [XR] and [NR] scenarios do not prevent increases in water stress in the very strong abatement scenarios.

Source: Historical data from ABS (2000; 2010; 2011; 2013b), MMRF.H_2O and LUTO projections using NIAM.FLOW and GIAM.CLIMATE inputs (see Section 8.2, Table 3 for modelling references).

The level of water demand varies with the value and qualities of economic activity

We find that the differences in the level of extractive water use are strongly associated with differences in the total value of economic activity – which varies with assumptions about trends in the average number of hours worked. (As discussed in Section 4.1, around two thirds of the differences in GDP and national income (GNI) across the *National Outlook* scenarios are explained by different assumptions about average working hours.) The value of economic activity (GDP) is 8%–10% lower and non-agricultural water use is 9%–13% lower in 2050 in scenarios with a trend decline in hours (shown in blue and orange in Figure 33) relative to equivalent scenarios with no decline in hours (shown in green and purple).

We find, however, that a complete explanation of differences in national water demand requires attention to underlying qualities of economic growth, as well as differences in the value of economic activity. We explore these through analysing water intensity (defined as extractive water use per dollar of sector output), with a focus on non-agricultural material- and energy-intensive industries, as agricultural water use varies relatively modestly across scenarios.

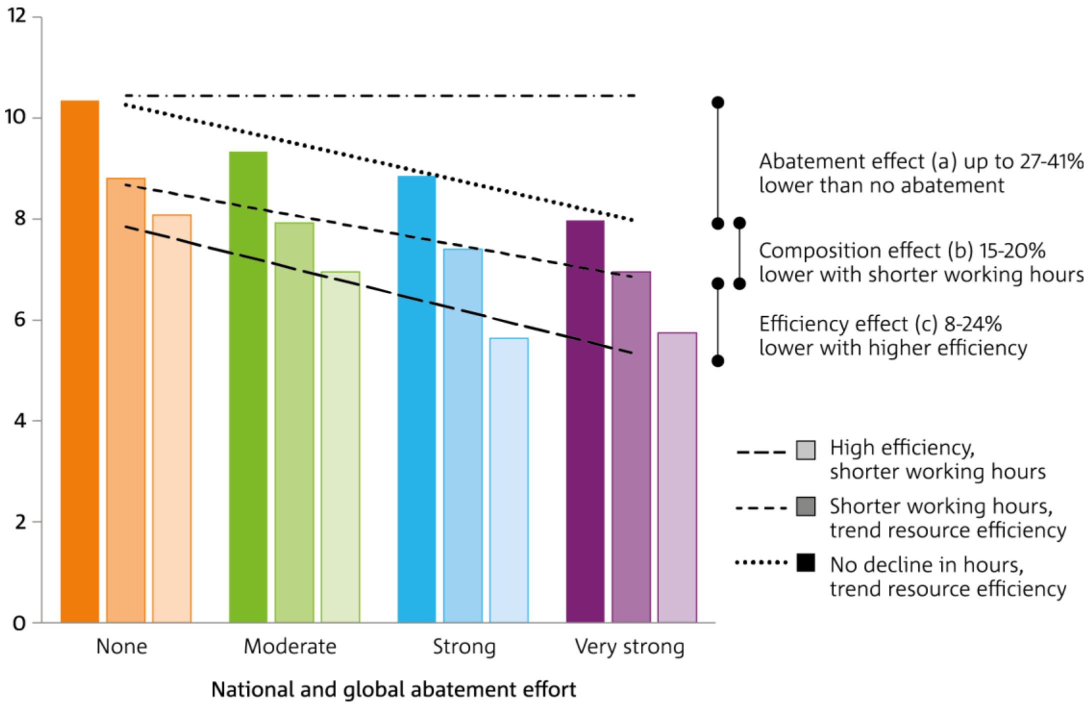
The analysis identifies three significant underlying drivers of variations in water intensity: differences in GHG abatement incentives and emissions intensity; the composition of economic activity (reflecting different consumption patterns and working hours); and different levels of water and energy efficiency (reflecting differences in the assumed uptake of efficiency options with a payback period of 3–5 years):

(a) *The level of abatement incentives* indirectly influence water demand, through effects on the demand for material and energy-intensive products, which account for three quarters of non-agricultural water use (and one third of Australia's total extractive water use). The water intensity of energy and material intensive industries is 27%–41% higher in scenarios that assume no national or global abatement effort, relative to 'very strong' abatement efforts, while energy intensity is 53%–63% higher over the decade to 2050. This effect is shown by the slope of the lines across different levels of abatement effort in Figure 33.

(b) *The composition of economic activity* is shaped by shifts towards experience oriented consumption (rather than tangible goods) and associated shorter working hours, resulting in 26%–28% lower total water use and 15%–20% lower water intensity over the decade to 2050 – as shown by the distance between the 'shorter hours' and 'no change in hours' lines in Figure 33.

(c) *The uptake of water and energy efficiency* has complex impacts on water demand. In scenarios that assume moderate or no abatement incentives, high uptake of energy and water efficiency decreases energy use by 16%–18% but increases total water use by 10%–19% over the decade to 2050 (relative to scenarios assuming recent trend efficiency improvements). This is because higher efficiency improves the competiveness of material and energy intensive industries, and increases their total output in these scenarios, which more than offsets projected water savings per unit of output (resulting in increased total water use). However, in scenarios that assume strong or very strong abatement scenarios, higher energy and water efficiency reduces total physical energy use a similar amount (15%–19%) but does not induce a significant increase in the value of industry output in these scenarios. As a result, total water use is 3%–8% lower in the high efficiency scenarios. Controlling for differences in the value of output, we find water intensity is 8%–24% lower in the high efficiency scenarios in the decade to 2050, all else equal, as shown in Figure 33.

Figure 33. Water intensity of non-agricultural material- and energy-intensive industries, average for 2040–2050, selected scenarios



Notes: Figure 33 shows extractive water use per dollar of output for non-agricultural energy and emissions intensive industries for twelve scenarios (rows NR, XR and XI for the four abatement levels, as shown in Figure 5 above).

Source: Hatfield-Dodds, McKellar et al. (under review), based on MMRF projections (see Section 8.2, Table 3 for modelling references).

Constraints on rain-fed water resources sees new demand met through desalination and water recycling

National extractive water use is projected to double by 2050 from 2000 levels[8] (increasing by 80%–120% in most scenarios), shaped by population, income, the growth of energy-intensive industries (which are also significant water users), water supply costs, and the uptake of energy

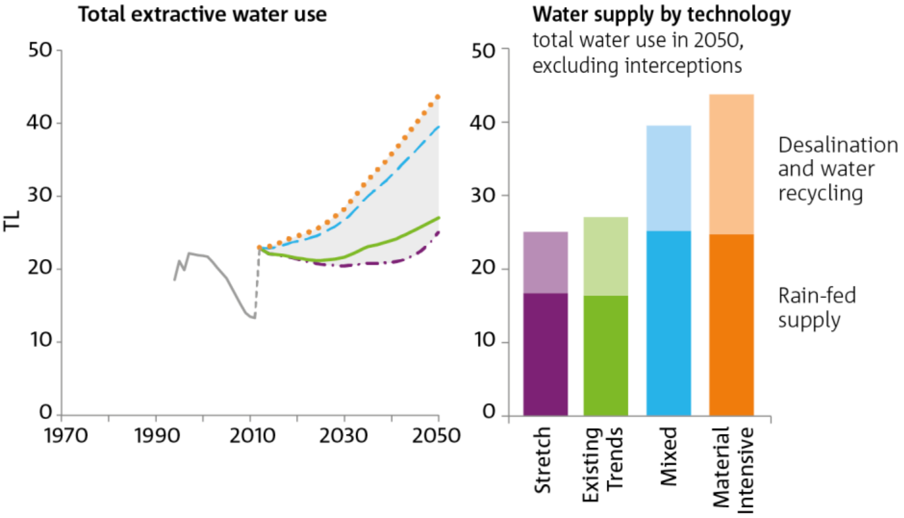
[8] We use water use recorded in the year 2000-2001 rather than 2010 as an indicator of typical current use, as agricultural water use in 2010 was severely impacted by the Millennium Drought in south-eastern Australia.

and water efficiency. We find that this growth in demand can be met without increasing pressure on water-limited catchments through water recycling, desalination and integrated catchment management – while also enhancing non-agricultural water security. There is large uncertainty in future rainfall and runoff projections, with little agreement between climate models in the direction of rainfall change in the north, while the majority of climate projections show rainfall declines in southern Australia (CSIRO and BOM, 2015). Limited modelling with projections from three climate models here show largest projected runoff reduction in NSW and Victoria (4% and 3% by 2050 relative to current levels), the two most populous states in Australia (as detailed in Hatfield-Dodds, McKellar et al., under review; see Chiew, 2006).

The analysis assumes existing water policy arrangements prevent overall increases in water extractions in the Murray Darling Basin and other water limited catchments, and so the growth in national water use is supplied by a combination of increased extractions in other areas of Australia (particularly in Queensland) and new supply from water recycling and desalinisation, determined by the most cost effective option in different locations. This allows substantial growth in water use without increases in extractive pressures on water limited catchments.

Meeting the growth in water demand thus involves a substantial increase in the use of desalination and water recycling, which are projected to account for 3%–15% of national water use in 2030, rising to 32%–56% by 2050 as population and economic growth outstrip the capacity of rain-fed water resources, as shown in Figure 34. This reflects that the majority of Australia's population lives in places that are already at or near the limits of available rain-fed supply, and that alternative water supply options are cost competitive relative to building major new surface water storages (Burn, 2011; Prosser, 2011). We find (Figure 34) that the energy implications of alternative water supply are noticeable but manageable, with desalination and water recycling projected to account for up to 8% of national electricity use in 2050 across different scenarios.

Figure 34. Historical and projected total extractive water use, 1990–2050, and projected water supply by technology in 2050.



Notes: Figure 34 shows historical and projected total water consumption for 1990–2050,not including interceptions from new plantings (left), and projected water supply by technology in 2050 (right). The grey area shows the range of water consumption across all *National Outlook* scenarios. The decline in water consumption in the years before 2010 reflects the impact of the Millennium Drought, which significantly reduced water availability nationally. There is large uncertainty in future rainfall and runoff projections, with little agreement between climate models in the direction of rainfall change in the north, while the majority shows rainfall decline in southern Australia (CSIRO and BoM, 2015). Limited modelling with projections from three climate models here show largest projected runoff reduction in NSW and Victoria (4% and 3% by 2050 relative to current levels). The modelling does not account for potential impacts of climate change on water demand (such as due to higher temperatures).

Source: Historical data (ABS, 2000; 2010; 2011; 2013), MMRF (see Section 8.2, Table 3 for modelling references).

Water interceptions from land use change and new carbon plantings could be significant, and will require careful governance

We find that uptake of carbon and mixed species plantings could have significant impacts on projected surface flows, and thus on total water consumption (including interceptions). These interceptions account for 25%–50% of total national water use in 2050 in the scenarios with strong or very strong abatement incentives (including the *Stretch* and *Mixed* scenarios shown in the figures here). (The method for investigating impacts on surface yields from carbon and environmental plantings is outlined in Bryan et al. (2015).) We report interceptions in catchments with >600 mm average annual rainfall, on the basis that interceptions by trees in these catchments would impact on the amount of surface water runoff reaching streams, but this would less likely to be the case in low rainfall areas. The 600 mm threshold was selected on this basis of the relationship between long-term average evapotranspiration and rainfall reported in Zhang et al. (2001) and the Australian Government's Carbon Farming Initiative general exclusion of tree planting projects in areas that receive greater than 600 mm average annual rainfall (with specific exemptions for environmental plantings and the mitigation of dryland salinity). This is because permanent tree plantings have the potential to impact on water availability by intercepting surface or groundwater, especially in moderate to high rainfall areas (Australian Government, 2015). Catchments with average annual rainfall >600 mm account for 37% of the study area of our analysis, or 31.3 Mha. The modelling assumes new plantations need to buy a water licence based on projections of licence costs under existing conditions, but does not fully account for price feedbacks that would be expected to occur as a result of water interceptions from new plantations. This is in part due to difficulties in estimating the impact of interceptions on inflows to streams and storages. We find, however, that the area of carbon plantings and supply of carbon credits is not sensitive to differences in the price of water licences, with a doubling of water licence prices resulting in a 4% reduction in planting area in water limited catchments (see Hatfield-Dodds, McKellar et al., under review).

As noted above, the *National Outlook* analysis focuses on water extractions from water limited catchments as our primary indicator of environmental pressure. (Other issues and indicators might include seasonal water demand, in-stream salinity in the Murray Darling Basin), sediment loads in the Great Barrier Reef (GBR) region, and other water quality issues.) We find that interceptions from new plantings could have a significant impact on surface flows in water-limited catchments, defined here as Class C and Class D catchments (National Water Commission 2012). These plantings are projected to intercept up to approximately 3 TL by 2050 in the M3 (strong abatement) scenarios, and 5 TL in the L1 (very strong abatement) scenarios, which would risk increases in water stress unless offset by reductions in other uses, including for irrigated agriculture. While we are not able to model all the relevant interactions at this stage, the available results suggest that plantations would be likely to out-compete some lower margin irrigated agriculture in scenarios where land sector carbon credits are able to be sold for AUD$40–60/t$CO_2$e, or more. As an indication of the potential trade-offs involved, carbon plantings in Class C and D water limited catchments account for up to 21% of total interceptions, up to 10% of national water use, and up to 2.2 Gt CO_2e of cumulative national land sector sequestration over the period to 2050.

These findings illustrate both the importance of potential changes in surface flows from land use change, and the potential scale of the impacts and unintended consequences that could arise from governance arrangements that do not account for and manage cross-sector interactions.

5.5 Material extractions

Australian material extractions are strongly influenced by global population growth and the level of global abatement effort

We find the outlook for extractions of raw materials are broadly similar to the outlooks for gross domestic emissions, with some scenarios seeing annual extractions doubling by 2050, and others seeing them fall by around a third to 2030 and then stabilising.

We also find that Australia’s material footprint (adjusted for exports and imports of materials) is currently around one third lower than our domestic extractions, reflecting significant exports of minerals, energy commodities and agricultural products. Material extractions per person are projected to decline to 2050 across all scenarios, and the gap between extractions and our material footprint is projected to narrow, particularly in scenarios with very strong national and global abatement efforts.

Material flow accounts measure the amount of material throughput of economic activities of national economies, i.e. the amount of biomass, fossil fuels, ores and minerals that provide crucial inputs to processes of production and consumption. Methodology to establish such material flows accounts has been internationally agreed (see Eurostat, 2012) and have become integrated with the System of Environment Economic Accounts (SEEA) (UN, 2014). We focus on two indicators from material flow accounts, domestic material extraction (DE) and material footprint (MF). DE refers to the amount of materials extracted or harvested in a nation, while MF refers to the attribution of global material use to final consumption (including private and government) in a country, sourced both domestically and through global resource supply chains. Per capita DE is thus a proxy for the size of primary industry in a country while per capita MF is a proxy for the material standard of living.

We display similar indicators for territorial energy use and energy footprint and territorial emissions and carbon footprint based on energy and emission accounts that are compatible with the SEEA logic.

Australia’s current per capita material extraction of 75 tonnes per capita is one of the highest in the world, but once corrected for consumption outside of Australia decreases to below 50 tonnes per capita. With strong abatement, Australia’s MF is projected to be below 25 tonnes per capita and domestic extraction slightly above 25 tonnes per capita in 2050. With no global or national abatement, DE in Australia is projected to be around 50 tonnes per capita and MF around 40 tonnes per capita. Investment into abatement reduces Australia’s MF in 2050 by around 40% and brings Australia’s MF of consumption more in line with other major economies such as the US, Japan and China.

The current MF of the USA economy is much lower than Australia at 31 tonnes per capita, with two thirds coming from domestic extraction at 20 tonnes per capita. With no global or national abatement, DE would remain stable and MF would decline to about 25 tonnes per capita in 2050, double the level that could be achieved with strong abatement action. The Japanese economy shows comparable levels of MF per capita to the US, but with much lower levels of DE, pointing to a highly import dependent economic pattern.

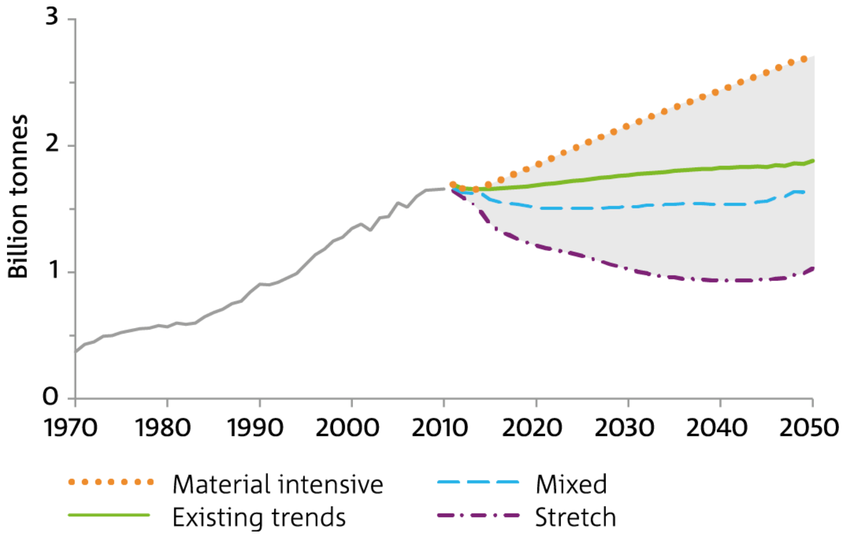
China’s MF of consumption is currently lower than other economies shown at 14 tonnes per capita and would rise to 26 tonnes per capita in 2050 (around the projected level for Australia) in the very strong abatement scenario. It would rise to around 50 tonnes per capita – perhaps unrealistically high – with no abatement action. Material footprint and DE are very similar in China because of a very large economy with most interaction in regard to bulk material flows occurring internally. China continues on a growth path, even with strong abatement because of the continuous need for building its infrastructure which will continue over the next decade’s contribution to a comparably large material throughput while other economies, most notable Japan and the US, will be able to continue with their existing infrastructure assets.

Despite energy use remaining high or growing there is a potential for reducing greenhouse gas emissions enabled by strong abatement action and a decarbonisation of the energy system through moving to renewable energy. Very strong abatement action would allow the USA and Australia to reduce CO_2 emissions by two thirds by 2050. Carbon footprint in the USA would be reduced from 21 tonnes per capita in 2010 to 7 tonnes per capita in 2050. Australia would reduce its carbon footprint from 20 to 6 tonnes per capita. These reductions would be achievable without any significant impact on GDP growth. Japan’s current carbon footprint at 11 tonnes per capita is half that of the USA and Australia and would be reduced to 7 tonnes per capita in 2050 through investment in strong abatement. As a result, all three economies would have a similar level of carbon footprint by 2050.

The carbon footprint of China would rise from 4.6 tonnes per capita in 2010 to 7 tonnes per capita in 2030 and then slightly decline to 6.6 tonnes per capita in 2050, and would converge to the level of the other three nations. Territorial carbon emissions would be somewhat higher than the carbon footprint in China whereas the other three countries are showing more balanced measures for both indicators.

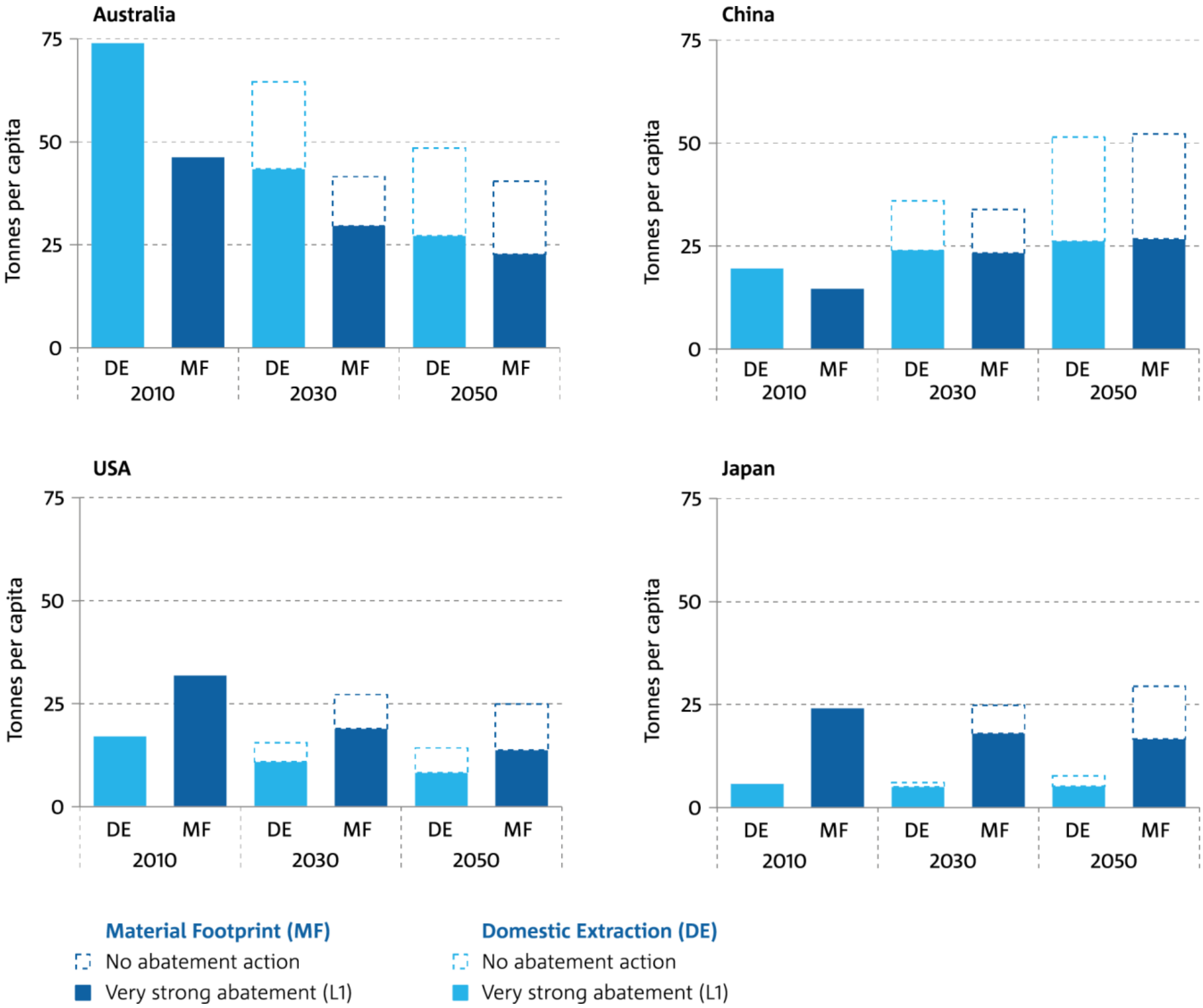
In summary, it appears that economic growth in all four countries will remain strongly linked with energy use but that large achievements in dematerialisation and decarbonisation could be achieved by investing in resource efficiency and climate change mitigation. This would have little or no adverse impact on economic growth (as measured by GDP) and may even enable stronger trend economic growth by reducing resource price volatility and long term climate impacts.

Figure 35. Domestic material extractions 1970–2010 (historical) and 2010–2050 (projected for all scenarios, including touchstone scenarios).



Source: MMRF, MEFISTO, EORA (see Section 8.2, Table 3 for modelling references).

Figure 36. Materials – Domestic Extraction (DE) and Material Footprint (MF) for four countries, 2010–2050



Source: GIAM (see Section 8.2, Table 3 for modelling references), MIFISTO and EORA (see Schandl et al., 2015).

6 Outlook for environmental performance: Ecosystems and emissions

This section reports the projections for two important aspects of Australia's environmental performance: land-based ecosystems (including native vegetation, biodiversity and ecosystem services), and GHG emissions.

6.1 Native vegetation, biodiversity and ecosystem services

Abatement incentives can be harnessed to restore Australia's globally significant ecosystems.

Harnessing markets for carbon would be the first opportunity in Australia's history as a nation to reward landowners for restoring and conserving Australia's ecosystems at national scale, without large government outlays. The *National Outlook* models three policy approaches within the new land markets scenarios. Under a 'carbon focused' approach, payments are based solely on carbon sequestration, resulting in mixed species plantings accounting for less than 5% of the area of new plantings – and providing only marginal biodiversity benefits. A 'biodiversity focused' approach achieves 10 times the area of native habitat relative to the pure carbon focused approach, with little impact on the total area, but provides up to two thirds (-61%) less carbon sequestration (forgoing 2.8–3.3 Gt CO_2e) over the period to 2050. We find a middle-ground 'balanced approach' could increase native habitat around eight-fold, for up to a one third reduction in carbon sequestration (1.3–1.4 Gt CO_2e) relative to the pure carbon focused approach. This results in a 17% increase in native habitat (12 Mha) relative to today in Australia's intensive-use zone in the strong abatement scenarios, reducing projected extinction risks by 10% (see Figure 21), while providing 3.1 Gt CO_2e of carbon abatement. We also find that climate change appears likely to have substantial adverse impacts on native ecosystems and biodiversity over coming decades, interacting with existing pressures.

Two centuries of land use intensification in Australia has resulted in a reduction in the area of native vegetation remaining in a relatively natural state, and an increase in pressures acting on native ecosystems in the form of pollution, competition for water resources, invasive species and pathogens. In the near future, changing climate and land use will interact with these existing pressures. Reduction of the total area amount r average condition of native vegetation would be likely to lead to a loss of overall biological diversity from the continent, and a loss of services delivered by these ecosystems.

The analysis for the *National Outlook* explores these issues in a number of ways. The analysis of land use explores the potential uptake of carbon plantings in response to payments to landholders based on the quantity of carbon sequestered in trees and plants. Where these payments are based solely on carbon sequestration (described here as 'carbon focused' strategy), we find that future plantings are likely to consist largely of monocultures of native forestry plantations (as illustrated in Figure 38). To explore this further, we modelled two alternative strategies that tilt incentives towards combinations of biodiversity benefits and carbon sequestration. We find these strategies (described as 'balanced' and 'biodiversity focused' approaches) deliver larger areas of native habitat, but with some trade-offs for carbon sequestration and revenues that could otherwise be achieved.

The second stage of the analysis assesses future patterns of native habitat under different projected outlooks for climate change, based on the interactions between landscape features (soils, topology, altitude) and climate variables (seasonal rainfall, and maximum and minimum temperatures) using the Generalised Dissimilarity Modelling techniques (GDM) (see Harwood et al., under review; Ferrier et al., 2004; Ferrier et al., 2007).

What are ecosystem services, and how do they relate to biodiversity?

Ecosystems services refers to the multiple ways that native plant, animals, and ecosystems are of value to humans. Ecosystem services are often grouped into different functional categories:

– *provisioning services*, including fuel, food, water

– *regulating services*, including water quality, erosion control, carbon sequestration

– *cultural services*, including recreation, visual amenity, and cultural and spiritual connections

– *supporting services*, including pollination, nutrient cycling, soil formation.

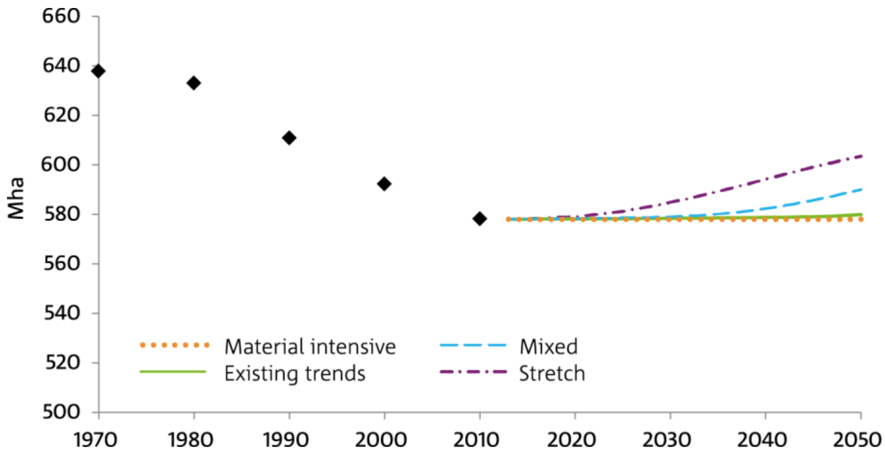
Biodiversity is defined by the Convention on Biological Diversity (UN, 1992) as "the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems".

Australia is home to rich and unique biodiversity, with more unique vertebrate species and types of habitat than any other country (see Figure 3). The quality and extent of our biodiversity is in decline (as it is around the world) due to increasing pressure from habitat change, overexploitation, pollution, invasive alien species and climate change.

Degradation of ecosystems and decline of biodiversity due to climate change and other pressures is likely to have a negative effect on the quality of ecosystem services provided.

As discussed in Section 5.1, we find significant potential for land use change after 2030 in scenarios with strong or very strong abatement incentives, as landholders take advantage of new income opportunities from supplying carbon offsets and biodiversity conservation (see Figure 21). We also find that active targeting of biodiversity priorities could be highly effective in achieving environmental plantings of local, mixed-species native vegetation instead of potential monocultures and in harnessing the carbon value of these plantings. At the same time, covering the difference in financial returns to the landholder, and thereby maximising biodiversity benefits achieved per dollar.

Figure 37. Historical area of native vegetation and projected revegetation through environmental plantings, Australian intensive use zone



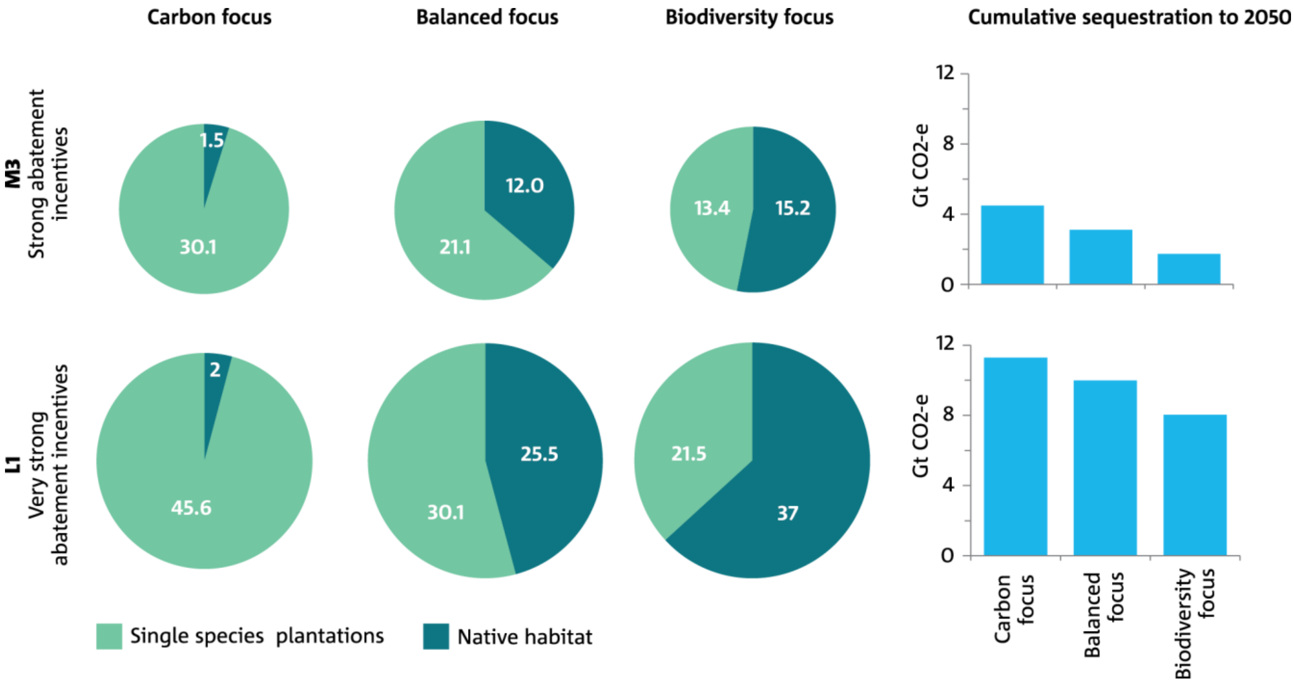
Notes: In Figure 37 historical area of native vegetation is shown by data points for each decade to 2010. Environmental plantings are modelled on the 'balanced' strategy.

Source: Harwood et al. (under review) and LUTO (see Section 8.2, Table 3 for modelling references).

We find a balanced strategy that seeks a mix of carbon sequestration and biodiversity benefits could deliver 7–12 times more native vegetation than a strong carbon strategy, but this would entail forgoing around 10%–30% of potential land-sector carbon credits (L1 and M3 scenarios). This is a gain of around 10–23 Mha of native vegetation for a national trade-off of around 1.3 Gt CO_2e over the period to 2050. Tilting the balance further towards biodiversity would deliver an additional 312 Mha of native vegetation gains for a trade-off of a further 1.4–2 Gt CO_2e. This is equivalent to an 8%–17% increase in native vegetation in the intensive use zone under the balanced strategy, and up to a 25% increase under the strong biodiversity strategy. In the *Existing Trends* (M2) scenario, the balanced strategy is projected to deliver an additional 1.9 Mha of native vegetation by 2050, an increase of 1% from current levels.

The core *National Outlook* scenarios are all based on the balanced strategy.

Figure 38. New native habitat and single species plantings (Mha) and cumulative carbon sequestration (Gt CO_2e) under different policy approaches, M3 and L1 global context scenarios, cumulative outcomes to 2050



Notes: In Figure 38 the area of each pie chart is proportional to the total area of plantings. The analysis is for the new markets scenarios (NR) and variants, and incorporates an uptake lag of 16 years.

Source: LUTO (see Section 8.2, Table 3 for modelling references)

Emerging markets for carbon and biodiversity offer new opportunities for landholders, and could increase total landholder incomes, more than offsetting forgone income from agricultural production.

While the full biodiversity potential of restored land could take many years to be realised, any action to increase the area of native vegetation is likely to contribute positively to the persistence of native species. Access to greater areas of habitat will help to maintain the viability of native populations. Decreased fragmentation of vegetation will facilitate the adaptive migration of species across landscapes in response to climate change. Environmental plantings are also likely to provide a wide range of valuable ecosystem services including, for example, soil stabilisation and water quality regulation (although it is worth noting that such plantings may also reduce total water availability through increased evapotranspiration).

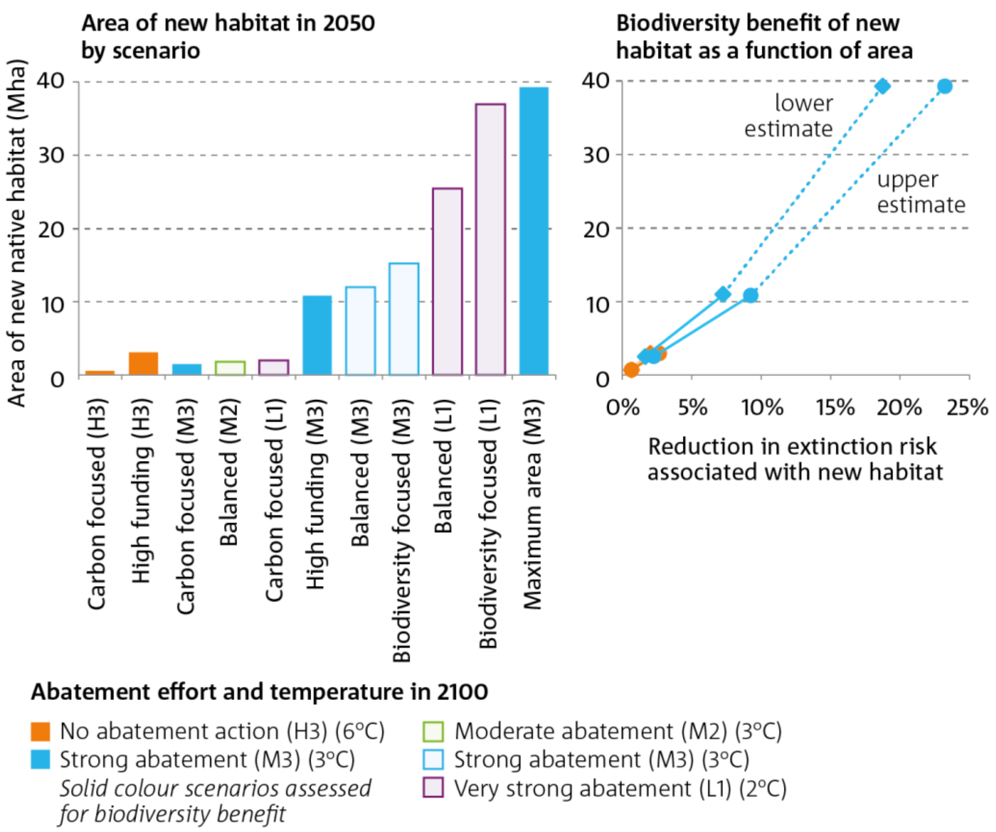
While any policy significantly increasing the area of native vegetation is expected to benefit the persistence of native species, and therefore overall biodiversity, relative to the level of persistence expected without this action, proper interpretation of these benefits needs to also consider potential impacts of ongoing climate change on biodiversity persistence. To incorporate these impacts we use a widely-accepted species-area relationship to scale the effect that changes in the area of native vegetation under different types of climate might have on the proportion of native plant species expected to persist over the longer term. Under the current landscape configuration 92.5% of species would be expected to persist in the absence of climate change. This allows a maximum 7.5% gain in the absence of climate change relative to an in principle benchmark of restoring all currently cleared land with environmental plantings. By 2050, projected changes in climatic conditions reduce the proportion of species expected to persist to between 53% and 71%

(with current land use), and to between 58% and 77% under full restoration benchmark (see Harwood et al., under review). In practice, the impact of climate on biodiversity may be moderated by factors such as existing genetic flexibility and capacity for genetic adaptation, while other factors such as dispersal limitations may instead act to exacerbate the projected outcome.

Overall, we find that re-establishing native vegetation can reduce the negative impacts of climate change, but is unlikely to be sufficient to entirely offset climate impacts in scenarios involving 3°C or 6°C average global warming by 2100 (Harwood et al., under review). With strong abatement incentives, we project up to 15 Mha of mixed species plantings could be established by 2050. Under the 3°C climate trajectory (RCP 4.5), this would reduce climate impacts by 7%–9% (relative to the impacts in an equivalent scenario but no revegetation) (Figure 39), with improvements of up to 28% in specific bioregions. Under the 6°C climate trajectory (RCP 8.5), however, the same policy settings would only reduce climate impacts by 2%–3%. To explore the effect of the area of new native vegetation, we also analysed the projected revegetation in the L1 strong biodiversity scenario variant, but assessed for the 3°C climate outlook. Here we found that that 38 Mha of new mixed species revegetation would reduce climate impacts on biodiversity by 19%–23% nationally. Achieving revegetation on this scale would raise a number of social, economic and technical challenges.

Across the scenarios examined, the area of habitat plantings is the most important factor in determining the level of biodiversity benefits achieved. Increases in area provide diminishing additional benefits for each additional hectare of plantings, particularly when comparing the area under very strong abatement incentives (up to 38 Mha of plantings) with the area under strong abatement incentives (10–15 Mha in 2050). However, for smaller total areas this effect is only modest. These two effects are more significant than the difference in climate outlooks.

Figure 39. Benefit from restoring native habitat in 2050, selected scenarios



Notes: Figure 39 shows the projected area of new native habitat (left) and biodiversity benefits of this new habitat (right) for selected scenarios. Biodiversity benefits are assessed in terms of the reduction in extinction risk due to new habitat and single species native plantings, which provide some benefits. Scenarios used in the biodiversity benefit assessment are shown in solid colours in the left hand panel and include supplementary scenarios. Other *National Outlook* scenarios are included in light colours for comparison. All scenarios assume a competitive top-up funding approach to awarding voluntary conservation payments, where funds are allocated to maximise the biodiversity benefit achieved per dollar through an annual tender, repeated each year. (New habitat plantings are modelled as being retained for at least 100 years, with the top up payment covering the net present value of the difference between the economic returns to mixed species plantings and the next most profitable land use.) The ‘carbon focused’ scenarios assume government funding of AUD$125m per year. The ‘biodiversity focused’ and ‘high funding’ scenarios assume payments of AUD$125m and AUD$430m per year respectively, and supplement this through a levy on the carbon value of single species carbon plantings that is used to increase the amount of top-up funding available for conservation payments (harnessing carbon incentives to support greater biodiversity outcomes). The assumed levy rates are zero, 15% and 30% in the carbon focused, balanced, and biodiversity focused approaches respectively. The ‘maximum area’ scenario is calibrated to provide an area of new habitat similar to the L1 biodiversity focused scenario, but is assessed under the M3 climate outlook.

Source: Area of habitat from LUTO and biodiversity benefits from GDM, drawing on other model inputs (see Section 8.2, Table 3 for modelling references).

The above modelling focused exclusively on terrestrial environments. Australia is mainly an arid continent, but its inland waters support a rich diversity of life, often characterised by extremes in water availability. We find that water extractions and interceptions will increase in some scenarios, which would have implications for freshwater ecosystems. Increased extractions would interact with changes in rainfall, evaporation and other direct effects of climate change in the form of temperature change (driving increased metabolism, eutrophication, cyanobacterial blooms) and acidification. This is a particular issue in water stressed catchments where significant water extractions and changes in flow patterns are or will drive changes in biodiversity. Careful consideration of these interactions is required to maintain ecosystem function in the long term. However, information on inland water systems in Australia remains limited, despite significant investment, and further research is required to improve monitoring, decision making and the drivers of ecosystem change.

6.2 Greenhouse gas emissions

We can reduce our greenhouse gas emissions significantly through actions across all major sources.

We find that the outlook for greenhouse gas emissions across different scenarios involves a wider range than any other indicator. The analysis explores different scenarios for global action on climate change, consistent with average global temperature increases of around 2°C, 3°C or 6°C by 2100, and assumes Australian action to reduce greenhouse emissions is closely coordinated with the level of global action in each scenario.

Australian can reduce its per capita emissions to below the global average by 2050, down from five times the average in 1990, by pursuing a mix of policies including energy efficiency, carbon capture ad storage, renewable energy, and large-scale land-based sequestration.

We find the land sector is central to cost effective long term action on climate change, partially replacing imported oil with biofuels and sequestering carbon through new plantations. Our analysis suggests that land sector credits could supply between a third and half of Australia's total abatement between 2030 and 2050 (with plantings occurring up to a decade before that), while both increasing and diversifying land sector incomes. At the upper end of this range, land sector credits could allow Australia to meet a wide range of national emissions targets without using international emissions permits – substantially reducing the macroeconomic impacts of Australia participating in global action to limit climate change.

Overall, we find that with very strong abatement incentives – consistent with global action to limit temperature increases to 2°C – deep reductions in direct emissions combined with significant land sector abatement could result in Australia acting as a net emissions sink, withdrawing more GHG emissions than it emits, for several decades after 2040.

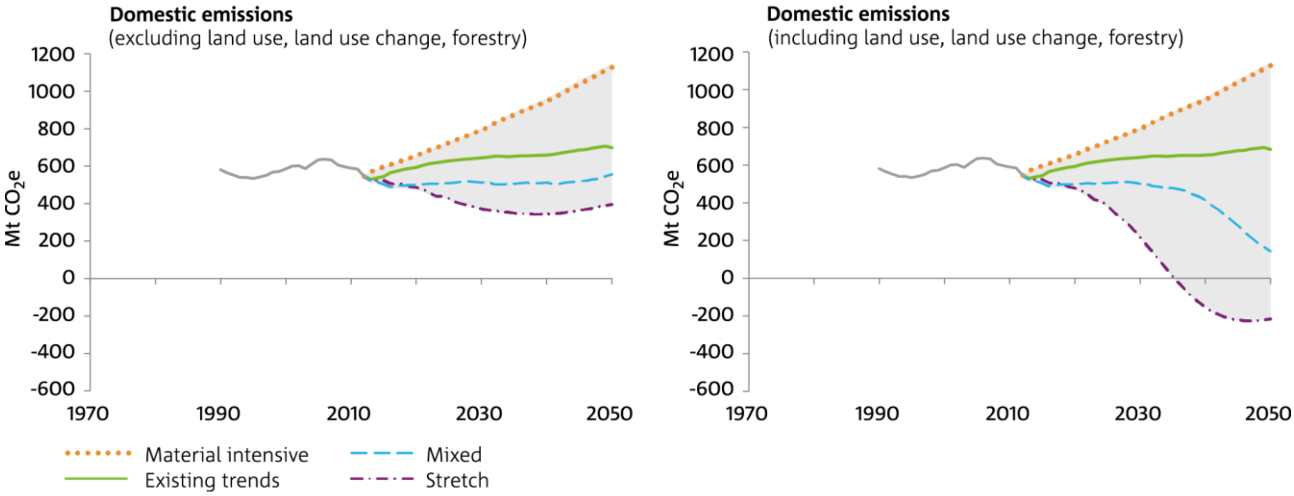
We find that the outlook for greenhouse gas emissions across different scenarios involves a wider range than any other indicator. Projected emissions are influenced by many factors and scenario drivers, but differences in global and national abatement incentives are the most important. The analysis explores the effects of four levels of abatement incentives and effort (referred to as *no abatement action,* and *moderate, strong,* and *very strong abatement* incentives). Each scenario assumes the level of Australian abatement incentives matches the level of effort globally. The level of global abatement incentives has been set to reconcile four combinations of global population growth with global emissions trajectories and temperature increases of around 2°C, 3°C or 6°C by 2100. These trajectories match the cumulative emissions of RCP 2.6, RCP 4.5 and RCP 8.5, as described in Sections 2.4 and 3.1 above. The different levels of national and global abatement effort interact with other scenario drivers, including consumption and working hours, energy efficiency trends, and emerging land sector markets, together resulting in a very wide range of protected emissions trajectories across the scenarios explored.

Domestic emissions are projected to double in scenarios that assume no national or global abatement effort ('no abatement action', on track to around 6°C), rising from around 550Mt CO_2e today to around 1150Mt CO_2e in 2050. Domestic emissions rise gradually to around 700Mt CO_2e in the *Existing Trends'* scenario (on track to 3°C), which assumes modest abatement efforts. With very strong action to reduce emissions (as part of global action to limit temperatures to 2°C or lower), direct domestic emissions are projected to fall by one third from current levels, to around 400 Mt CO_2e in 2050 – largely from industrial process and transport. These reductions in direct emissions are then complemented by significant abatement provided by land sector carbon sinks, as shown in Figure 40.

A recent collaboration led by ClimateWorks Australia and the Australian National University (ANU) (Jotzo et al., 2014; ClimateWorks Australia, ANU, CSIRO and CoPS, 2014) suggests the *National Outlook* abatement estimate may be very conservative in the context of very strong global abatement efforts, with the collaboration finding that per capita emissions could be reduced to around half the *National Outlook* estimate (with around the same economic costs) through a combination of reductions in building energy use and electrification of transport, industrial gas (direct combustion) and industrial processes.

Overall, we find that with very strong abatement incentives (L1) – consistent with global action to limit temperature increases to 2°C – the combined effect of deep reductions in direct emissions and significant land sector abatement could result in Australia acting as a net emissions sink, withdrawing more greenhouse gases than it emits, for several decades from 2035. While not modelled, it is likely that a similar outcome could be achieved with a more gradual increase in abatement incentives for several decades beginning after 2050. This effect is transitional, however, as the annual volume (or flow) of sequestration from new plantings in any specific location rises to a peak, then declines due to the physical profile of carbon sequestration as plantings mature. This suggests that reforestation and new plantings can be thought of as a temporary bridge to lower national and global emissions, buying time for longer term changes in technologies and processes in energy, transport and broader economy.

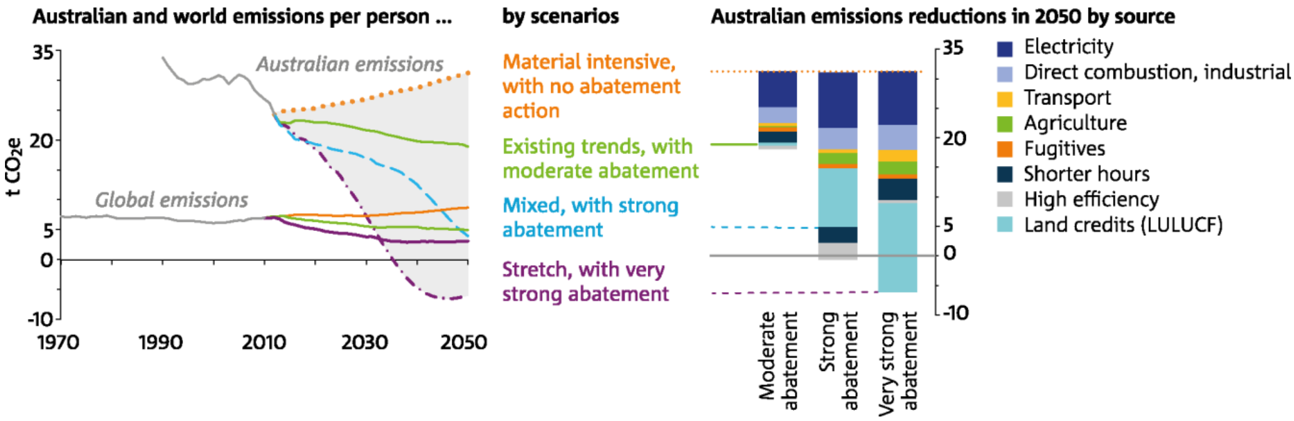
Figure 40. Domestic greenhouse gas emissions, with and without sequestration from new carbon plantings, all scenarios, 1990–2050



Source: Historical data (Climate Change Authority, 2014); MMRF and LUTO (see Section 8.2, Table 3 for modelling references).

Viewed on a per person basis, direct emissions in 2050 (before accounting for land sector credits) are projected to range from 31tCO_2e per person (a 16% increase from current levels), to 15tCO_2e per person (a reduction of up to 45%) in the very strong abatement scenarios. When land sector credits are included, emissions per person fall to -6tCO_2e per person in the very strong abatement scenario, and 4tCO_2e per person in the strong abatement scenario – implying a potential transformation from being one of the world's highest rates of emissions per person to matching the global average in the strong abatement (M3) global context scenario, or well below the average with very strong national and global abatement.

Figure 41. Australian and global per capita emissions, 1970–2050, and Australian abatement in 2050 by source



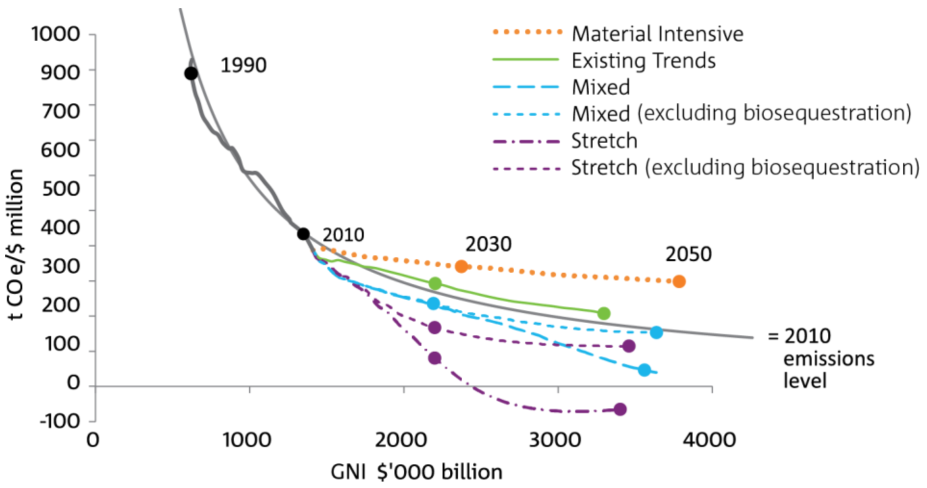
Notes: Figure 41 shows projected Australian and global per capita emissions, and the sources of domestic abatement in 2050. The grey area indicates the range of projected emissions across all scenarios, with the touchstone scenarios highlighted. Global per capita emissions are shown for the global scenarios assuming high population and no abatement action (H3) (orange), medium population and moderate abatement (M2) (green) and low population and very strong abatement (L1) (purple). Projected national and global emissions are calculated by aggregating electricity sector emissions from ESM and GALLM, land sector sequestration from LUTO and supplementary global analysis, and other emissions (including from livestock, industry and transport) from MMRF and GIAM. Abatement by source and scenario driver are calculated as the difference in emissions relative to the Material Intensive scenario for each source or driver. *Existing Trends* includes land sector credits (from new markets), shorter working hours and trend efficiency. *Stretch* includes land sector credits, shorter working hours and high efficiency. The *Mixed* scenario includes land credits (from new markets). In the strong abatement scenarios shorter working hours and high efficiency are projected to further reduce per capita emissions by 2.7tCO_2e and 2.2tCO_2e respectively, together resulting in projected emissions just below zero in 2050 for scenario M3XI.

Source: Moss et al (2010); Climate Change Authority 2014; GIAM, GALLM, MMRF, ESM, LUTO, and estimates of global land sector abatement (see Section 8.2, Table 3 for modelling references).

We find all sectors have the potential to contribute to reductions in GHG emissions. We find the uptake of energy efficiency, shifts in consumption towards experiences, and reductions in working hours all contribute to reducing emissions. The contributions of these 'bottom up' trends account for a larger share of total abatement in scenarios assuming modest abatement incentives or no action on climate change, and a smaller share in scenarios assuming stronger abatement incentives. The abatement contributions of different sectors (or emissions sources) and bottom-up drivers are shown in Figure 41.

Analysis of the projected emission intensity of the Australian economy suggests that projected volumes of abatement achieved are relatively modest, or conservative, in relation to what is implied by the global context. (Emissions intensity is defined as emissions per dollar of economic activity, measured by GDP or GNP, in real dollars.) Over the last two decades, emissions have remained stable while the economy has grown, resulting in a reduction in emissions intensity (Climate Change Authority, 2014). As shown in Figure 42, we find the *Existing Trends* scenario (which assumes moderate abatement incentives) returns to this long run trend, while the scenarios with strong and very strong abatement continue the recent more rapid decline in emissions intensity. Direct domestic abatement in these scenarios returns towards trend after 2030.

Figure 42. Emissions intensity by GNI, touchstone scenarios, 1990–2050. Domestic emissions are shown with and without LULUCF. Historical emissions to 2011 includes LULUCF.

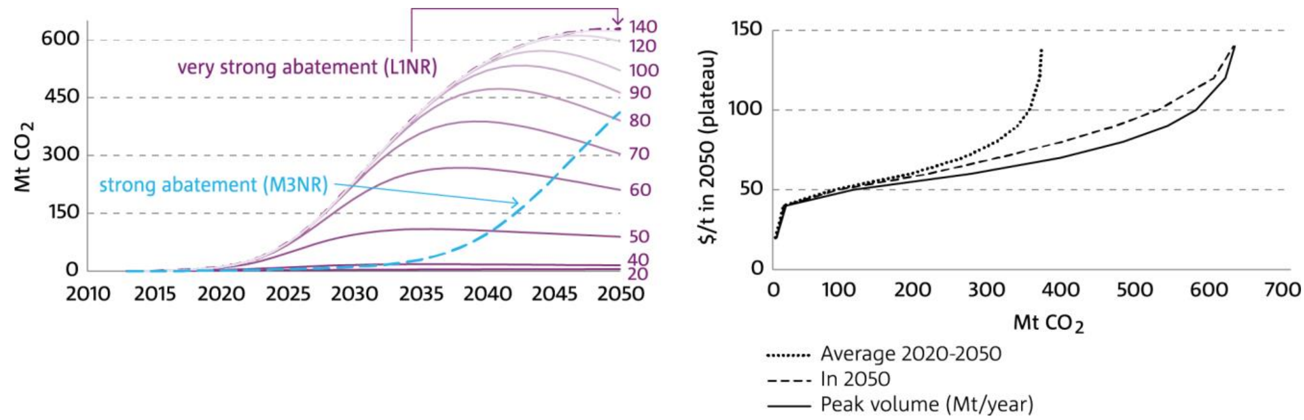


Source: ABS 2012a; Climate Change Australia 2014; MMRF, ESM and LUTO (see Section 8.2, Table 3 for modelling references).

The response to abatement incentives is complex. Different sectors and sources of emissions have different abatement potential and respond differently to abatement incentives. At the national scale, we find that both reductions in direct emissions (particularly from energy and industrial process) and land sector sequestration respond in a non-linear way to the level of abatement incentives; requiring incentives to reach a certain level before delivering substantial national abatement, after which the additional abatement achieved declines as incentives increase further. For direct emissions, the strong abatement scenarios hit this high response threshold almost immediately, achieving the highest proportional abatement response. Levels of abatement incentives roughly double at each step: the strong abatement incentive is double the level of moderate abatement; and, the very strong abatement incentive is two thirds higher than strong abatement. Yet the strong abatement scenarios deliver more than double the abatement achieved in the moderate scenarios, while the very strong abatement scenarios deliver only a third (20%–45%) more over most of the period. These differences narrow after 2035, as the absolute level of abatement incentives increase.

A similar more pronounced sweet spot is observed for land sector sequestration, where we find that carbon plantings are not attractive to landholders at national scale until carbon payments reach \$40–60/tCO_2e – but very substantial volumes of carbon sequestration could be profitably supplied at payment levels at or above this range. This threshold level occurs before 2020 in the very strong abatement scenarios (through linkages to the global carbon price in these scenarios), and before 2030 in the strong abatement scenarios. The supply of land sector sequestration occurs with a lag, however, reflecting both the social processes of land use change and the physical sequestration of carbon as plants grow in the decades after planting (and cease to sequester additional carbon as plantings mature). Figure 43 illustrates the supply of carbon sequestration nationally under different potential levels of carbon payment.

Figure 43. Supply of land-sector sequestration under different potential levels of carbon payments to landholders, 2010–2050



Notes: The analysis assumes carbon payments start at \$20/tCO₂e in 2015 and increase at an average rate of 5% until reaching the level shown on the right for each line, and then remain constant at that level in real terms (before inflation). Each purple line shows the supply of carbon over time accounting for a social uptake lag. All other assumptions match the L1NR scenario. The solid purple line shows carbon supply under no cap for the L1NR scenario. The dashed blue line shows carbon supply with an initial payment level of \$30/tCO₂e and no cap, under the M3NR scenario settings.

Source: LUTO (see Section 8.2, Table 3 for modelling references)

We find the land sector is central to cost effective long term action on climate change, replacing imported oil with biofuels and sequestering carbon through new plantations. The supply and use of plant-based biofuels is projected to increase in all scenarios, including scenarios with no abatement incentives, through shifts to use crop residues (supplemented in some cases by grain). Biofuels account for around 5%–15% of domestic abatement in the strong and very strong abatement scenarios and make a larger contribution where rates of vehicle electrification are lower.

Our analysis suggests that land sector credits could supply between a third and half of Australia’s total abatement between 2030 and 2050 (with plantings occurring up to a decade before that), while both increasing and diversifying land sector incomes. This suggests that land sector credits could allow Australia to meet a wide range of national emissions targets without using international emissions permits, reducing the macroeconomic impacts of Australia participating in global action to limit climate change.

7 Outlook for prosperity, sustainability and security in a connected and complex world

7.1 The prospects for sustainable resource use

Strong economic growth and stewardship of Australia's natural assets do not need to be in conflict

The analysis for the *National Outlook* finds that it is possible to break the links between economic growth and environmental performance, so that average incomes and population rise while pressures fall. But this does not happen across all scenarios.

The value of Australian economic activity (GDP) increases 156%–189% above inflation from 2010–2050 across the set of scenarios explored, with a 15% difference between the maximum and minimum scenarios in 2050. Population increases by 64% in all scenarios over the period. National income per person (GNP per capita) increases by 58%–82% from 2010–2050, with trend growth of 12%–15% per decade above inflation. Different assumed trends in working hours and leisure explain about two thirds of these differences in income.

The projected differences in economic growth across scenarios are modest when compared to the range of outcomes for key environmental pressures. Greenhouse gas emissions, for example, are projected to double in some scenarios and fall below zero in others (through land sector sequestration). Water extractions from stressed catchments is projected to increase in some scenarios, increasing pressure on freshwater ecosystems, but projected to fall in other scenarios (as water efficiency more than offsets the effects of population and economic growth). The area of native habitat is stable in some scenarios, but increases in others through voluntary conservation agreements (reducing the risk of extinctions).

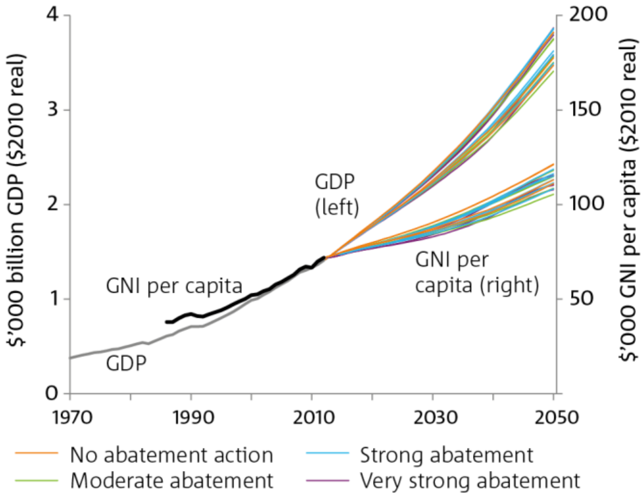
The contrast between the narrow range of outlooks for economic growth and the wide range of outlooks for different types of environmental pressure implies that economic growth is not the primary driver of increasing environmental pressures. Rather, we find that changes in environmental pressure arise through choices of production technologies, resource use trends and patterns of consumer demand for different types of goods and service. Across the set of scenarios and performance indicators explored, we find that individual (private) choices typically account for up to a third of the differences in resources use and environmental performance, while collective (policy) choices account for two thirds or more of the differences in outcomes.

The analysis for the *National Outlook* explores a wide range of scenario drivers and potential futures.

We find that it is possible to break the links between economic growth and environmental performance, so that average incomes and population rise while pressures fall. The value of economic activity and average national income rises across all scenarios, as shown in Figure 44.

As discussed in Section 4.1, the value of economic output (GDP) is projected to increase around ten-fold over the 80 years to 2050, driven by a 2.9 times increase in population and a 3.2–3.6 increase in real GDP per capita. Economic output (GDP) and GNI are projected to increase by 156%–187% and 144–181% respectively over the 40 years to 2050. Assumptions about working hours have the largest single impact on market income, with GNI per capita rising 75%–82% from 2010–2050 in scenarios with no decline in working hours. Scenarios that assume a continuation of recent trend reductions in hours see GNP rising by 58%–66% per person, while average hours decline 11% over the four decades to 2050.

Figure 44. Economic activity (GDP), national income (GNI per capita), 20 scenarios, 1970–2050



Notes: Gross Domestic Product (GDP, solid line and top array) measures the market value of goods and services produced. Gross National Income (GNI), dotted line and bottom array, previously GNP) measures payments to national residents from domestic and foreign production. Neither is adjusted for changes in asset values, such as depreciation or the depletion of stocks of natural resources.

Source: Historical data for real GDP and real GNI per capita calculated from ABS (2012a; 2013c; 2013d; ABS (2013e; 2014)., Projections from MMRF.H2O (see Section 8.2, Table 3 for modelling references).

Technology and institutional settings enable ‘physical decoupling’: allowing us to increase the services derived from natural resources (water, energy, food), while associated environmental pressures decline. This underpins ‘economic decoupling’: where strong economic growth is combined with improved stewardship of our irreplaceable natural assets and life support systems. But this decoupling does not happen automatically, with pressures projected to increase in some scenarios and decrease in others, as shown in Figure 45 below. This implies that protecting environmental assets can be fully consistent with strong economic growth, but that Australia’s future sustainability is a matter of choice.

Net greenhouse gas emissions show the greatest decoupling potential. Energy use grows across all scenarios, increasing by 1.0%–2.9% per year to 2050 (Figure 45, see Section 7.1). Scenarios with very strong abatement incentives see emissions fall around a third from 2010 levels by 2030, including an 80% reduction in the emissions intensity of electricity by 2030, complemented by reductions in transport and industrial emissions. New carbon plantings provide significant abatement through biosequestration from 2030 or 2040, resulting in Australia becoming a net carbon sink by 2040 in scenarios with the strongest abatement incentives (see Section 6.2**Error! eference source not found.**).

Native vegetation illustrates the potential for partial decoupling. Incentives for carbon and biodiversity plantings make it profitable for large areas of grazing land to shift into 'carbon farming'. This increases landholder incomes, but reduces livestock numbers relative to scenarios with no land use change. The value of agricultural output from the intensive use zone is projected to increase, but output volumes peak and then decline in some sectors due to land use change. (While not modelled explicitly, it is likely that the number of beef cattle would be expected to grow nationally in these scenarios, with increases in the northern rangelands offsetting declines within the intensive use zone.) The area of native vegetation increases substantially in scenarios with strong or very strong abatement incentives. Market based carbon and biodiversity payments are projected to increase the area of native vegetation in the intensive use zone by 8%–17% (12–25 Mha) through mixed species plantings in the central 'balanced' scenarios (and up to 25% in the variant strong biodiversity scenario). We find that this projected increase in native vegetation could reduce the negative impacts of climate change on biodiversity by up to 9% in the 3°C strong abatement scenario (based on 11 Mha of new plantings), relative to the outlook with no new plantings (see Section 6.1, including Figure 38 and Figure 39).

The analysis of water use illustrates the potential to decouple water use from pressure on freshwater ecosystems (in and around creeks, rivers and lakes). It also illustrates the need to integrated planning and management of environmental pressures (discussed in Section 7.3). Total water use is projected to grow by 30%–172%; total extractions of water from water scarce catchments, however, are not significantly higher than current levels in 2050 in most scenarios. This is because recent water reforms[9] are projected to result in increased extractive water use being supplied through increased in water re-use (improving water system efficiency) and the creation of fresh water through desalinisation. These results are consistent with limited additional water resources in southern mainland areas; findings that water efficiency and recovery is generally more cost competitive against new rain-fed water supply options involving new major dams; and, that the average unit cost of desalination is often cost competitive with new supply (see Section 5.4, including Figure 32 and Figure 34). Carbon and biodiversity plantings intercept significant volumes of water, reducing surface water flows, and account for up to half of total national water use in 2050 in scenarios with significant land use change. Plantings in water limited catchments result in substantial interceptions in these scenarios, which would risk increases in water stress unless offset by reductions in other uses. Not allowing carbon plantings in water limited catchments would reduce cumulative national land sector sequestration by 2.2Gt CO_2 or 22% over the period to 2050.

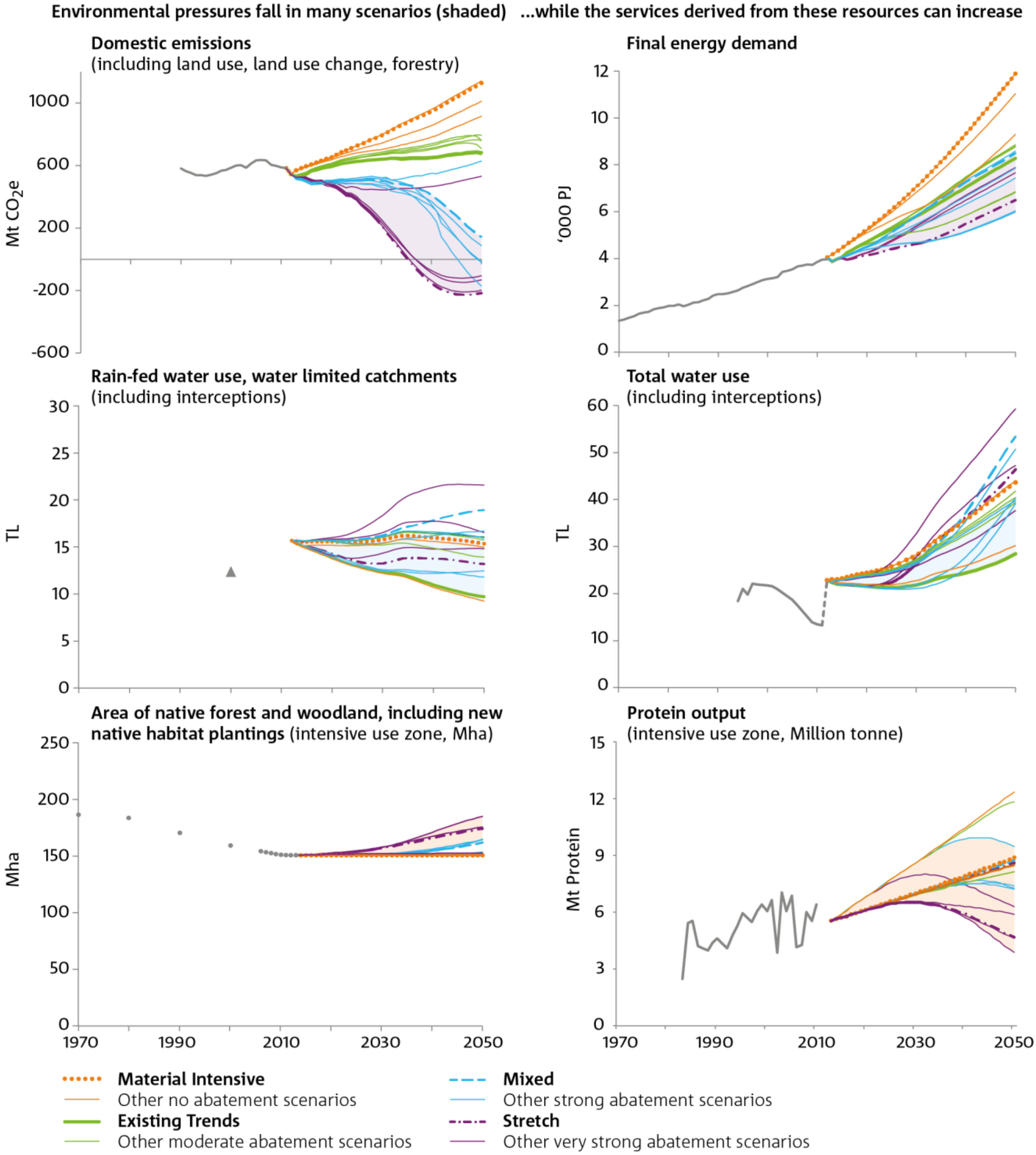
Australian material flows are strongly linked to energy use. The total mass of biomass, fossil fuels, metals and non-metallic minerals (Fisher-Kowalski et al., 2011) used is projected to decrease by 36% from current levels by 2050 in scenarios with very strong abatement and improved resource efficiency. It is also projected to increase by 69% in scenarios with no abatement incentives and trend resource efficiency (Schandl et al., 2015; see Section 5.5). The potential to decouple economic growth from environmental pressure does not reflect a projected dematerialisation of Australia's economic structure. The value of energy and material intensive sectors is projected to

[9] See http://www.mdba.gov.au/what-we-do/managing-rivers/the-cap

grow more strongly than the economy as a whole across all scenarios, including scenarios with the strongest global abatement efforts (see Section 3.2).

The contrast between the very narrow range of projected outcomes for economic growth, and the very wide range of projected outcomes for environmental pressure and performance, implies that economic growth is not the primary driver of increasing environmental pressures. Indeed, we find that the rate of economic growth has little to do with environmental outcomes. Instead, the level and shape of environmental pressures are determined by choices about production technologies, management and use of resources, and consumer demand for different types of goods and service.

Figure 45. Physical indicators of decoupling growth from pressure: energy, net greenhouse gas emissions, livestock production, native habitat, selected scenarios, 1970–2050



Notes: Each panel in Figure 45 shows the projected trajectories for a key indicator of resource use or environmental pressure for multiple scenarios. The shaded area indicates scenarios in which environmental pressure decreases from current levels (in the left hand panel), involving a decrease in GHG emissions or water extractions and an increase in area of native habitat, with the same scenarios highlighted in the right hand panel of each pair of charts. The top two rows show projections for 18 scenarios (all except rows VR and XE in Figure 5 in Section 2.4). The bottom row shows 20 land use scenarios: new markets trend agricultural productivity (NR) carbon focused, balanced and biodiversity focused, new markets high productivity (NE) balanced, and no new markets trend productivity (CR) for each of the four abatement levels. Livestock output value and volume both increase in all but two scenarios, with output value increasing but volume falling below 2010 levels in the balanced and biodiversity focused approaches with current trends in agricultural productivity. This fall in value is offset by income from carbon plantings, as shown in Figure 7. Historical data for livestock is estimated using the proportions of sheep and beef in the intensive use zone as a share of the national numbers of sheep and beef in 2012, applied to national data from 1970–2012.

Source: Hatfield-Dodds, Schandl et al (2015); MMRF, ESM, LUTO (see Section 8.2, Table 3 for modelling references).

7.2 Exploring synergies and trade-offs across scenarios

Middle ground approaches may not deliver the best outcomes, and stronger global action on climate change would deliver higher economic growth and other benefits, relative to moderate global action

We find that stronger action to improve resource efficiency, boost agricultural productivity and reduce environmental pressures could deliver net economic benefits to Australia. Even before accounting for the value of cleaner air, healthier rivers and landscapes and reduced climate impacts. More efficient and productive resource use could boost national income by 3%–5% or more. We find stronger incentives for land sector abatement deliver multiple benefits, including: higher land sector incomes; reduced extinction risks (through restoration of native habitat); and higher national income (due to largely to new areas of comparative advantage). In other scenarios, with moderate abatement incentives, carbon payments remain below the threshold required to motivate carbon plantings until around 2040 – and thus these scenarios forgo most of these benefits. This illustrates that middle ground approaches may forgo opportunities as well as avoiding risks.

We find some tensions between reducing threats to river-dependent ecosystems versus terrestrial ecosystems, with new plantings benefiting terrestrial ecosystems while also reducing surface flows, potentially exacerbating pressures on rivers and floodplains. However, it is also likely that synergies can be achieved through integrated planning and management, delivering multiple benefits, particularly in scenarios that support improved water system efficiency. We consider these issues warrant further exploration.

We find that Australia would benefit economically from an increase in the level and pace of global action to reduce emissions, with higher economic growth in scenarios with strong or very strong abatement, relative to moderate abatement. In contrast to previous studies (such as Garnaut 2008), these economic benefits accrue well before 2050 (perhaps as early as 2035), particularly due to higher estimates of profitable land sector sequestration, in addition to the benefits of avoided climate impacts over the longer term. We also find stronger global action to reduce emissions is likely to benefit Australian agricultural exporters by increasing global agricultural prices (due to increased competition for land), and would be expected to limit the impacts of increased climate variability on agriculture over the longer term. These findings reflect the specific modelling assumptions and scenario definitions in the *National Outlook*, including details of assumed national abatement policies (including international pledges or targets), as well asinteractions between national policy implementation (such as access to land sector credits) and global abatement efforts.

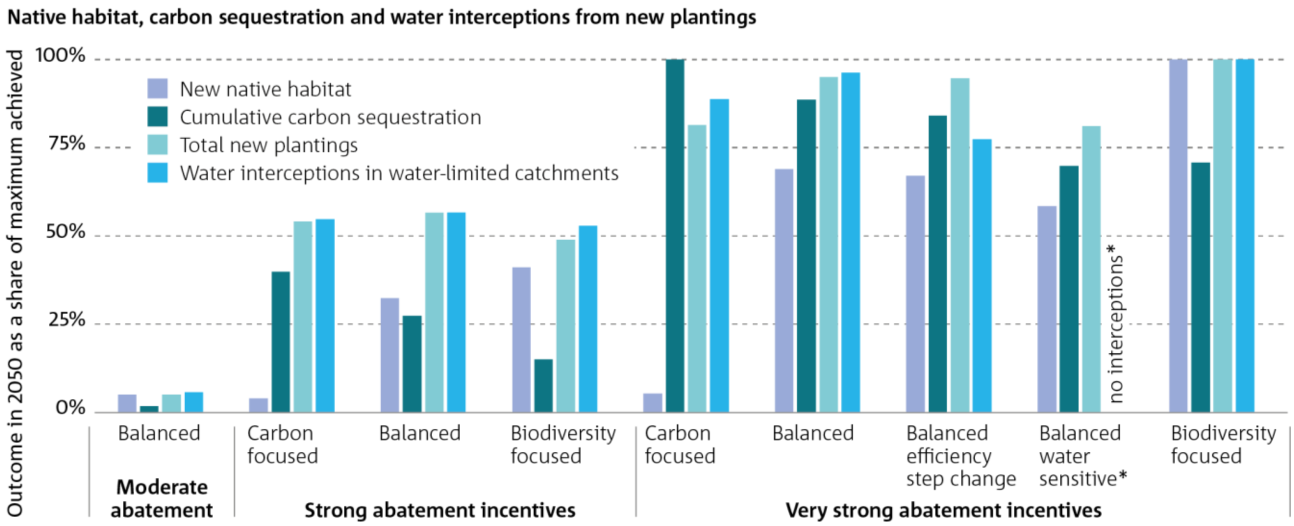
Last, we also find potential for major trade-offs. Scenarios that assume no global efforts to limit emissions are projected to deliver stronger trend economic growth to 2050 than the *Existing Trends* scenario (which assumes moderate national and global abatement). The extent of this stronger relative performance is likely to be overstated. This is because the modelling does not account for a range of potentially significant climate impacts. These scenarios represent an unsustainable development pathway, achieving higher near term living standards at the cost of undermining Australia’s natural assets, in conjunction with increased risks to global prosperity and the Earth’s life-support systems (see Griggs et al., 2013; World Bank 2012).

Managing synergies, trade-offs and risks

National resource use and economic performance are shaped by complex interactions across different scales, sectors, and time-frames, giving rise to significant thresholds, tipping points and cross-sector interactions. Prosperity, security and sustainability are also multi-dimensional – implying a need to weigh or balance different factors and considerations in assessing national performance and potential future pathways. This implies a need to monitor, adjust and integrate our already sophisticated policy and institutional settings.

For example, we find that the profitability of carbon plantings is not very sensitive to water prices; a doubling of water licence prices would result in only a 4% reduction in planting area in water-limited catchments. Policy design and implementation therefore needs to continue to evolve in response to changing circumstances, drawing on the full toolkit – markets, information, regulation, planning and community participation – to achieve long-term policy goals. Figure 49 illustrates how different institutional settings give rise to different water, carbon and ecosystem outcomes through to 2050, even with the same level of abatement incentive. Integrated approaches are needed to identify and manage synergies and trade-offs – such as responding to competing uses of ground and surface water, while accounting for employment, food, carbon, recreation and conservation values.

Figure 46. Detailed policy settings drive different outcomes for carbon, native habitat and water – even with the same level of abatement incentive



Notes: Figure 46 contrasts the implications of different policy settings for the environmental implications of new land sector markets, reporting four indicators of environmental performance as a percentage of the maximum projected outcome across nine scenarios. The indicators are the area of new native habitat and total carbon plantings (including single and mixed species plantings) in 2050, cumulative carbon sequestration from 2015–2050, and volume of water interceptions in 2050. Seven scenarios assume new land markets, trend energy and water efficiency, and moderate, strong or very strong abatement effort (row NR in Figure 5). Two scenarios assume new markets, very strong abatement and a step change in water efficiency (row XI in Figure 5). The figure also reports the implications of carbon focused, balanced and biodiversity focused policy settings (see Section 6.1). The scenario specification for a step change in water efficiency includes that new plantings are managed to avoid net increases in rain fed water extractions from water limited catchments (including non-agricultural water use). This is modelled as a higher water licence price scenarios with very strong abatement, reducing the area of plantings, and thus reducing both water interceptions and carbon sequestration. Results for a 'balanced' water sensitive variant are based on the balanced water efficiency step change scenario, which shows the implications of not allowing any plantings in water limited catchments, while holding all other results constant.

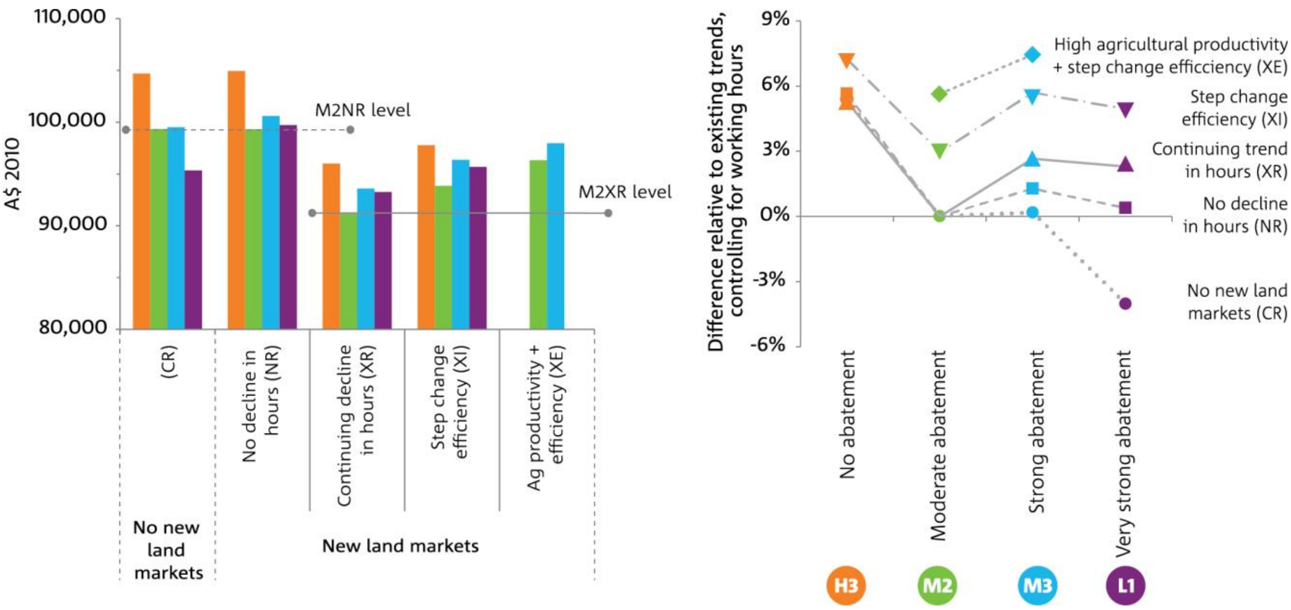
Source: LUTO

Implications of different levels of global action on climate change for Australian economic performance

Scientific assessments find that current levels of abatement action and commitments are not consistent with limiting global temperatures to 2°C or less, relative to pre-industrial levels, but do not preclude this goal with substantial further emissions reductions beyond 2020 (IPCC, 2014).

We find there are synergies – or potential win-win outcomes – from stronger global action to improve energy and resource efficiency, and to reduce environmental pressures. This implies Australia could benefit economically from an increase in the level of global action to reduce emissions, with higher Australian economic growth projected for scenarios with strong or very strong abatement before 2050, relative to moderate abatement scenarios. Figure 47 shows average income (GNP per capita) in 2050 across 16 scenarios, along with the difference in average income relative to the *Existing Trends* scenarios (controlling for working hours).

Figure 47. National income (GNP per capita) in 2050, and difference relative to *Existing Trends* (with moderate global action), all scenarios



Notes: The difference relative to *Existing Trends* is calculated as CR and NR relative to M2NR (no decline in hours) and XR, XI and XE scenarios relative to M2XR (continuing trend decline in hours), for each level of abatement. Projections of GNP do not fully account for the impact of climate change on economic activity, and are thus likely to overstate the relative performance of the 'no action' scenarios and understate the performance of the 'very strong action' scenarios.

Source: MMRF (see Section 8.2, Table 3 for modelling references).

Our specific findings include that national income (GNP and GNP per capita) is projected to be 0.4%–2.7% higher in 2050 with strong or very strong abatement in scenarios that allow land sector credits, all else being equal (see Figure 49 and Figure 18). Without land sector carbon markets, however, GNP in 2050 is projected to be up to 4% lower with stronger global action. The underlying intuition of this finding is that stronger global action to reduce GHG emissions reduces the value of emissions intensive activities (particularly extracting and combusting fossil fuels). However, it also increases the value of low or negative emissions activities (particularly sequestering carbon through new plantings) – and thus shifts the basis of Australia's comparative advantage from non-renewable resources towards living natural assets and renewable energy sources. This implies, given the specific assumption of the scenarios, that the loss of national income and profit margin from emissions intensive activities is smaller than the gain in national income and profit margin from carbon sequestration.

We also find stronger global action to reduce emissions is likely to benefit Australian agricultural exporters by increasing global agricultural prices (due to abatement policy increasing the competition for land globally), all else being equal. While beyond the scope of the current analysis, strong action to limit climate change would also be expected to limit increases in climate variability and associated impacts on agriculture over the longer term (through reducing the pace and extent of climate change).

Both these findings fall within the second impact channel, shown in Figure 48: the direct economic impacts of policies and actions by other countries (see Government Office for Science, 2011). The actions of other countries may be influenced by Australia, but are largely beyond our control. Australia's primary choices relate to how we use the opportunities created (such as by global markets for land sector credits, or higher agricultural prices), and manage potential risks and threats (such as changes in global demand for coal).

Because these economic gains arise from the direct effects of abatement policies, the findings will be sensitive to the details of assumed national abatement policies in Australia and other countries, and to the assumed form and level of national pledges or targets, as well as how these assumptions are characterised in the models. More generally, these findings reflect the specific modelling assumptions and scenario definitions in the *National Outlook*, including the interactions between national policy implementation (such as access to land sector credits) and global abatement action.

Figure 48. Impact channels of national and global action on climate change

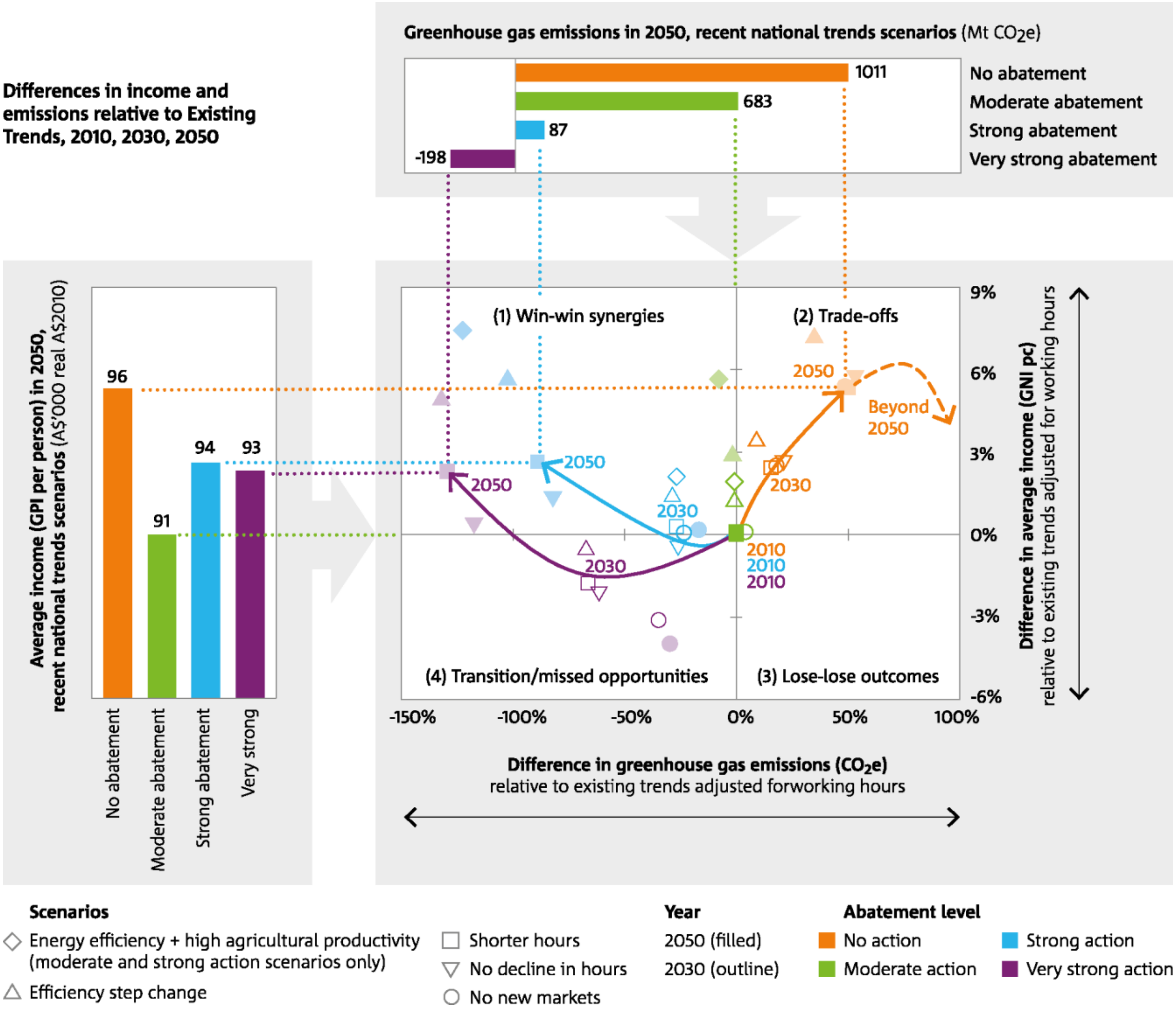
CAUSES		EFFECTS
Australian policies and actions (largely within Australian control)	**Other country policies and actions** (largely beyond Australian control)	
DIRECT IMPACTS OF AUSTRALIAN ACTIONS	**DIRECT IMPACTS OF OTHER COUNTRY ACTIONS**	
Policy impacts on government budgets, and on prices of energy other emissions intensive goods and services, and related assets. Policy may also impact on business costs and competitiveness.	Potential policy impacts on demand or export prices for Australian exports (such as coal, gas, uranium, aluminium, minerals, beef, carbon sequestration, energy technologies), or through other economic effects, such as exchange rates	**Direct economic impacts of climate policies and actions**
INDIRECT IMPACTS OF AUSTRALIAN ACTIONS	**INDIRECT IMPACTS OF OTHER COUNTRY ACTIONS**	
Public and private adaptation actions can influence vulnerability to physical impacts and economic flow on effects. *(The level of Australian emissions will only have a small impact on physical future climate and climate impacts in Australia.)*	Cumulative global emissions will influence the level and pattern of physical climate impacts on Australian infrastructure, natural resource based industries (particularly agriculture), health, and climate sensitive activities. Physical climate impacts overseas will impact on Australia through international markets, trade, and other connections.	**Indirect economic impacts through avoided climate change**
International perceptions of Australian policy may impact Australia through reputational effects or channels such as trade agreements.	Climate, energy and food security policies of other nations may impact on global business confidence and/or geopolitical stability, with implications for Australia.	**Other indirect impacts**

Figure 49 builds on this information to identify synergies and trade-offs between near term living standards and protecting natural assets that are essential to long term prosperity and security. The figures showing differences in average income on the vertical axis, as an indicator of living standards, and differences in GHG emissions on the horizontal axis, as an indicator of environmental performance. (Both comparisons are to the *Existing Trends* scenario in 2030 and 2050, controlling for differences in working hours, as lower working hours contribute to higher living standards).

All scenarios with lower GHG emissions land sector markets for carbon and biodiversity also perform better economically in 2050 than *Existing Trends*, with up to 6% higher GNP in 2050 (in scenarios with the same agricultural productivity as *Existing Trends*). These scenarios fall in the top right hand quadrant in 2050, involving *synergies* between economic and environmental performance. We identify one scenario as representing *missed opportunities* in 2050 (shown in the lower right quadrant), where a lack of land-sector markets both reduces living standards and constrains emissions reductions.

We also find potential for long term *trade-offs*. All scenarios involving no action to reduce emissions also have stronger economic performance than the *Existing Trends* scenario (which assumes moderate national and global abatement), with GNP projected to be 5%–7% higher than existing trends in 2050, along with 35%–51% higher emissions. These scenarios fall in the top left quadrant and represent the classic 'unsustainable development' trade-off of achieving higher near term living standards at the cost of undermining Australia natural assets, and increased risks to the Earth's natural capital and life-support systems in the longer term (see Griggs et al., 2013). As noted in Figure 49 below, it is likely that the relative economic performance of these scenarios in 2050 is overstated (relative to *Existing Trends*) because the modelling does not account for a range of potentially significant climate impacts. Indeed, over a longer time frame these scenarios would be expected to fall in the lower left quadrant, with worse economic performance and worse environmental performance than scenarios with stronger global action to limit climate change.

Figure 49. Synergies and trade-offs in economic and environmental performance relative to *Existing Trends* in 2030 and 2050, accounting for differences in working hours, all scenarios

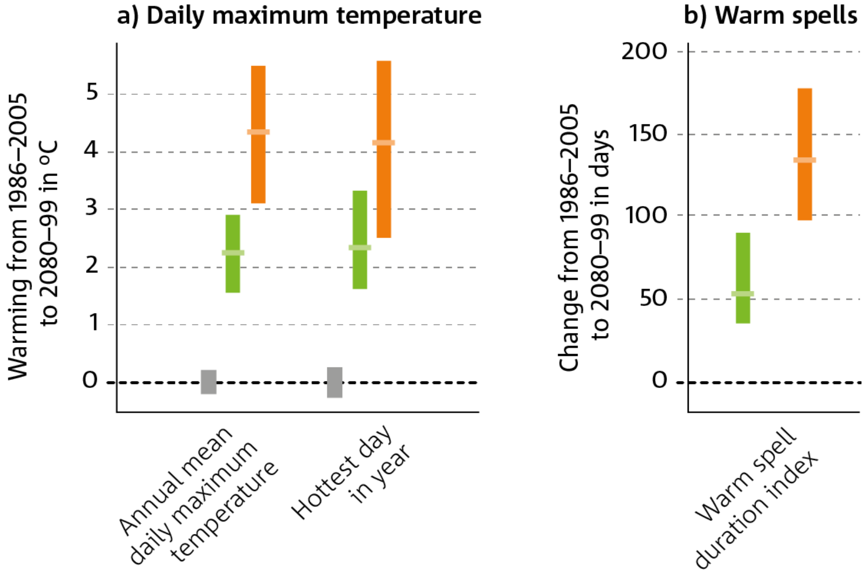


Notes: Calculation is CR, NR, and NE scenarios relative to M2NR (no decline in hours) and XR, XI, XE scenarios relative to M2XE (continuing trend decline in hours), for each level of abatement. XE scenarios are only modelled for moderate and strong abatement levels, and assume both higher agricultural productivity than the other scenarios and a step change in energy and water efficiency. Projections of GNI do not fully account for the impact of climate change on economic activity, and thus are likely to overstate the relative performance of the no abatement scenarios and understate the performance of the very strong abatement scenarios.

Source: GNP from MMRF; Emissions from MMRF, LUTO and ESM (see Section 8.2, Table 3 for modelling references).

The modelling is likely to overstate the relative economic performance of the scenarios with no climate action (shown in orange), and understate the relative economic performance of the very strong abatement scenarios (shown in purple). This is because the analysis accounts for only a limited set of climate impacts, associated with trend changes in temperature and rainfall on agricultural production. It does not account for the impacts of increased extreme events (such as droughts, floods, storms and coastal inundation), including disruption to economic activity due to damage to buildings and infrastructure. Yet we know that the impacts of changed frequency and severity of extreme weather and climate events may be very significant, as shown in Figure 50, and the implications of these changes may outweigh the benefits of productivity improvements in some sectors and regions. These impacts are expected to be more negative (imposing net costs) for higher rates of climate change. The extent of overstatement and understatement by 2050 is difficult to judge, for several reasons, including that near term trends in extreme events are less well understood than longer term trends in average temperatures.

Figure 50. Extreme climate events are projected to become much more common



Notes: Figure 50 shows the projected median and 10th to 90th percentile range of projected change in mean and extreme daily maximum temperature averaged over Australia for 2080–2099 relative to the 1986–2005 period (grey bar), for RCP4.5 (green) matching the M2 and M3 global scenarios, and RCP8.5 (orange) matching the H3 global scenario. Projected changes in daily maximum temperatures are shown for annual mean (left in panel a) and hottest day of the year (right in panel a). Projected changes in number of days per year of warm spells are shown in panel b, defined as periods of six or more consecutive days above the 90th percentile of daily temperatures for the 1961–1990 period.

Source: Figure 7.1.7 from CSIRO and Bureau of Meteorology (2015)

Overall, these findings remind us that there are many opportunities for creating value from more efficient resource use, including the adoption of technologies that reduce pollution and other forms of waste, and that it is incorrect to frame sustainability policies as always requiring a trade-off between ‘development’ and ‘the environment’. They also illustrate that costs and benefits are not always proportional. Therefore, middle ground approaches may underperform more decisive options in situations involving thresholds and complex interactions, such as where moderate action may incur significant adjustment costs but fail to deliver the full potential benefits associated with stronger uptake of efficiency measures or new technologies.

Comparison to previous studies

These findings imply that more ambitious global action could yield net economic benefits for Australia significantly earlier than suggested by previous studies, particularly Garnaut (2008). This reflects a range of factors, including more rapid reductions in the cost of low emissions energy technologies than previously anticipated, and higher estimates of domestic land sector credits. Garnaut (2008, 2011) found that the benefits of participating in global emissions reductions would yield long term benefits from avoided climate risks and impacts (particularly by reducing the risk of crossing major climate 'tipping points', see Lenton et al., 2008; Hughes et al., 2013) that outweighed the short term direct policy costs. Garnaut and others conclude that it is in Australia's national interest to support global action to limit the increase in global temperatures to 2°C or less (see Climate Change Authority, 2014).

In common with previous studies, the analysis for the *National Outlook* also finds that national income would be higher before 2050 in a world taking no action on climate change, relative to a world with moderate global action (see Figure 47 and Figure 49). We note above, however, that this does not account for a range of potentially important direct and indirect climate impacts on Australian economic activity before 2050, particularly the impacts of extreme events (such as droughts, floods, storms and coastal inundation). Nor does it account for long term costs and benefits (occurring after 2050) resulting from near-term greenhouse gas emissions or abatement.

Economic studies that account for a reasonably narrow range of climate impacts find that limiting temperatures to 2°C would provide net benefits globally over the long term (Stern, 2008, Nordhaus 2010, see Heal 2009), and that earlier more ambitious action involves lower long term costs and risks than later action to achieve the same cumulative emissions (Rogelj et al., 2013; IPCC 2014). Studies that explore a wider range of factors – such as the distribution of impacts across rich and poor countries, and the potential for cascading impacts across food, water, health, regional security and financial stability – are more emphatic about the risks and net costs of temperature increases of 4°C or more (New et al., 2011; Thornton et al., 2011; Beddington et al., 2011; Fung et al., 2011; Scheffran and Battaglini, 2011; Standards and Poor's, 2014). The World Bank (2012), for example, concludes that there is "no certainty that adaptation to a 4°C world is possible" while an independent USA security study found that a 5.6°C increase in temperature by 2100 "would pose almost inconceivable challenges as human society struggled to adapt" to the intersecting challenges of climate change, international terrorism and the geopolitics of energy (Campbell et al., 2007). Even if Australia was able to manage the direct climate impacts of a 6°C increase in mean global temperatures, it is difficult to imagine that there would not be significant adverse impacts on Australia through international trade and other connections to the wider world (see Government Office for Science, 2011). We thus concur with previous studies that stronger global action would be in Australia's national interest, and that a decline in global action from current levels would not be in our long term national interest.

While the findings of the *National Outlook* reflect the specific modelling assumptions and scenario definitions of our analysis, and the limits to the scope of the impacts we are able to explore, they illustrate the complex interactions involved in understanding the implications for Australia of different potential patterns of global action, accounting for the multiple types and channels of potential impacts.

7.3 Assessing the roles of private and public choices

Policies and institutions are central to unlocking benefits, and managing trade-offs and risks

Policy choices – in Australia and globally – and institutional settings account for 50%–90% of the range of projected resource use and environmental outcomes. The detailed design and implementation of policies will have significant implications for resource use and environmental outcomes – resulting in synergies in some cases and trade-offs in others. Institutional settings are crucial to support the deployment of existing and new technologies that match our economic and environmental aspirations in energy, water, transport, agriculture and other industries.

The contribution of 'bottom-up' and 'top-down' choices

Collective choices about policy settings shape individual decisions by households and firms. We find these decisions we make as a society matter – and do more to shape Australia's future than the decisions we make as businesses or individuals, particularly in terms of shaping resource use and environmental outcomes.

For example, policy settings will be central in determining our future electricity and water supply, which have environmental impacts that are not automatically reflected in supply prices. Future energy affordability will be strongly influenced by peak demand ratios, drawing attention to peak demand management and network governance. While extractive water use is projected to double by 2050, this growth can be met while enhancing non-agricultural water security and avoiding increased environmental pressures through increased water recycling, desalination and integrated catchment management.

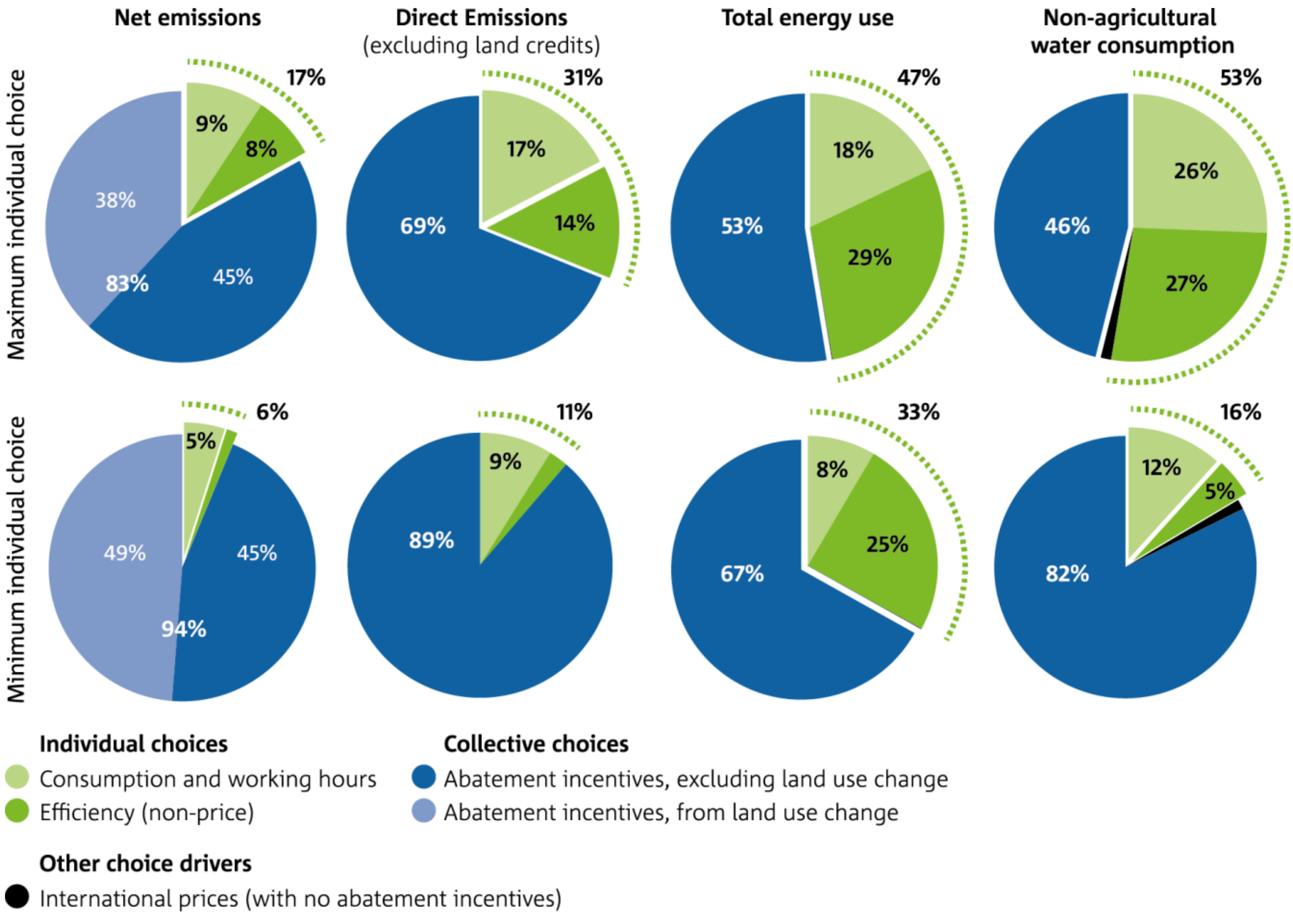
Managing the water-energy-food nexus will produce challenges and opportunities for rural land use and communities. We can transform and enrich our economy and regional communities by meeting national and global food, fibre, energy, carbon sequestration and conservation needs through new land sector markets, if we manage these transitions well.

Australia can reduce GHG emissions significantly through energy efficiency, CCS, renewable energy and land-sector sequestration. In the case of concerted global action on climate change, this could see Australia reduce its per capita emissions to below the global average by 2050, down from five times the average in 1990, while maintaining strong economic growth. The actual costs and benefits of Australian climate policies will depend crucially on interactions between international commitments (particularly by our trading partners), national greenhouse gas emissions targets or pledges, and the details of policy design and implementation (such as rules for creating and accessing land sector credits).

The *National Outlook* scenarios can be used to provide insights into the nature of these choices, by identifying 'bottom-up' individual choices by household and firms and 'top-down' choices that can only be made and implemented collectively (and then constrain or empower individual choices). For example, individual choices about transport options – such as whether to drive or catch a train to work – are strongly shaped by prior collective choices about transport infrastructure. Three scenario drivers primarily reflect individual choices: working hours; consumption patterns; and, the uptake of resource efficiency (including energy and water use). Two scenario drivers are clearly collective: the level of abatement incentives; and, enabling new land sector markets for carbon and biodiversity. Together, these five scenario drivers explain 98%–100% of the range of outcomes for 2050 across the main set of scenarios explored. (The unexplained residual is the result of international price effects in different no climate action scenarios.)

We find both individual and collective choices impact on environmental pressures and performance, but that individual choices account for only a small share of the difference in ‘public good’ environmental performance across the scenarios explored (on the right of Figure 45 above). They also make a larger contribution to reduction in resource use and historical underlying drivers (shown on the right of the figure), where resource efficiency provides financial savings over time. Individual choices account for up to one sixth (6%–17%) of difference between the maximum and minimum projections of net GHG emissions, and up to a third (11%–31%) of the difference in direct emissions, as shown in Figure 51. (This in part reflects that the analysis does not include any mechanism for simulating voluntary payments for land credits.) Results for water and energy use indicate choices by households and businesses account for at least one sixth (16%–33%) and up to half (47%–53%) of the difference in projected energy use and non-agricultural water consumption. This pattern of results is consistent with expectations that individual choices will be more important where there are synergies between individual benefits and wider public good benefits. Policy will be more important where individuals do not directly benefit from options involving lower environmental pressure, such as where upstream technology choices shape environmental outcomes (illustrated here by the carbon intensity of electricity, or differences in environmental pressure associated with different water sources).

Figure 51. Relative contribution of individual and collective choices in explaining the range of outcomes in 2050 for greenhouse gas emissions, energy use, and non-agricultural water use



Notes: In Figure 51 we report the maximum and minimum estimates of the contribution of each scenario driver, as interactions imply there is no unique attribution to each driver. The analysis attributes the range between the maximum and minimum across 18 scenarios (all except M2NE and M3NE), by identifying the chain of scenarios pairs that implies the greatest and smallest contributions from individual choices. We use non-agricultural water use because the approach to modelling agricultural water efficiency is not able to be interpreted as individual choice in this context.

Source: Hatfield-Dodds, Schandl et al (2015), greenhouse gas emissions from MMRF, ESM and LUTO; Energy use from ESM and MMRF; non-agricultural extractive water use from MMRF (see Section 8.2, Table 3 for modelling references).

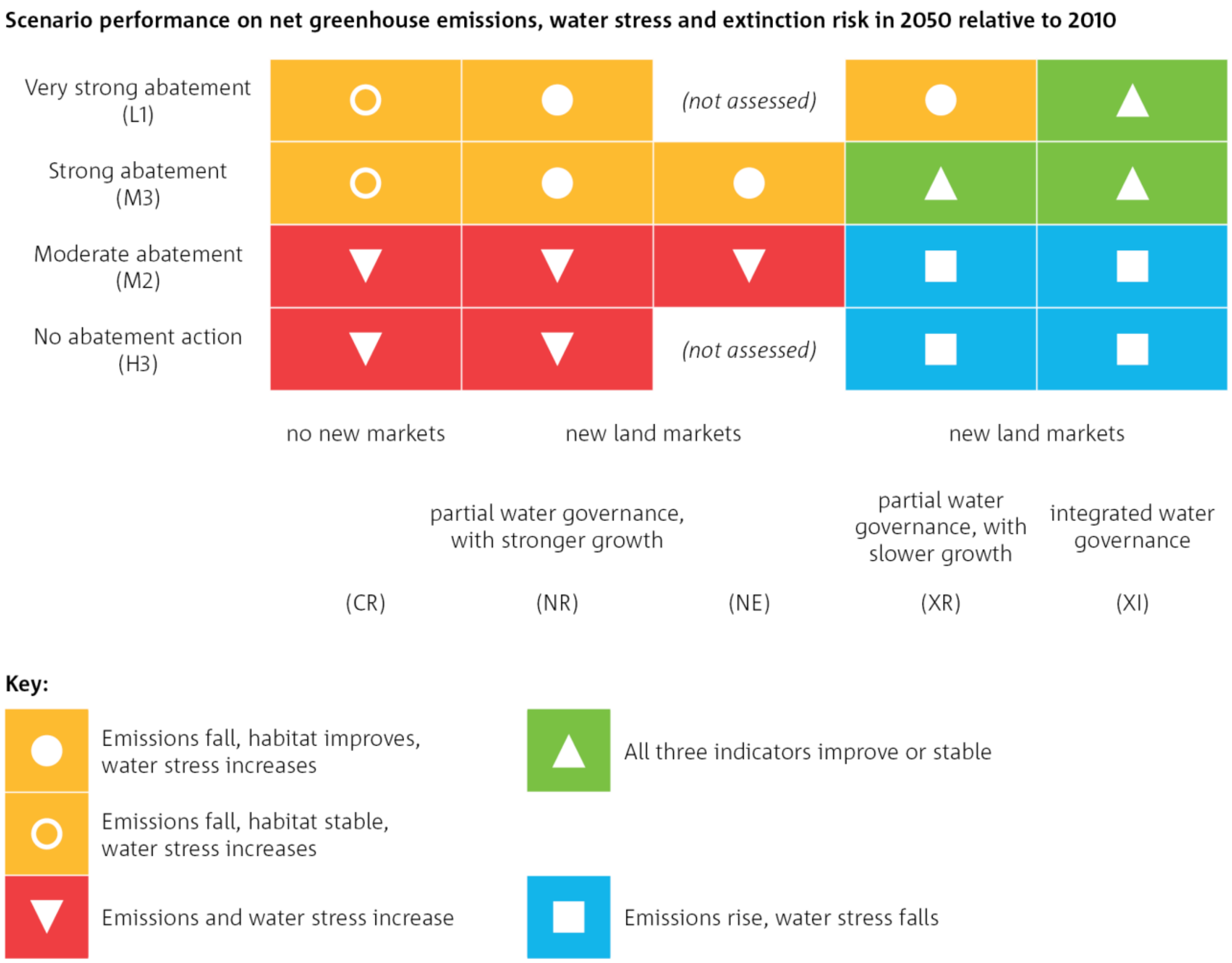
The role of integrated governance

The discussion in Section 7.1(above) highlights the potential to decouple economic growth from environmental pressures, so that living standards improve while environmental pressures decline – maintaining of improving our irreplaceable natural assets and life support systems.

The *National Outlook* analysis finds that synergies and win-win outcomes are possible, but are likely to require integrated governance. The discussion of decoupling and Figure 45 treats each headline pressure indicator separately: GHG emissions; water extractions from limited catchments; and, area native habitat. Considering each indicator in isolation, one to two thirds of the scenarios show improvements or avoid increases in pressure. However, when considered together only four of the 18 scenarios show improvements in all three indicators.

As shown in Figure 52, net GHG emissions are only projected to fall in scenarios with strong or very strong abatement incentives, combined with new land markets (enabling land sector sequestration)[10] – totalling seven scenarios. The incentives for new carbon plantings, however, result in substantial interceptions of surface water flows. In scenarios with partial water governance (CR, NR, XR) this non-extractive water use does not feed back into water licence prices, and so the total volume of extractive and non-extractive water use can increase above current levels, increasing pressure on water limited catchments. This occurs by 2050 in both scenarios with very strong abatement scenarios (L1NR and L1XR), and in the strong abatement scenario with stronger economic growth, resulting in higher extractive water use (M3NR). (The other strong abatement scenario (M3XR) would be expected to result in increased water stress after 2050.) In scenarios that assume integrated water governance, future interceptions from carbon plantings feed back into water licence prices and requirements, avoiding increases in total water use in water limited catchments (L1X1, M3X1, M3NE).

Figure 52. Scenario performance for net greenhouse gas emissions, water stress and native habitat, 2050 versus 2010, 18 scenarios



Notes. Figure 52 assesses changes in environmental pressure for 18 scenarios, matching the scenarios for Figure 45 above, as described in the text.

Source: Hatfield-Dodds, Schandl et al (2015) Data from MMRF, LUTO, ESM (see Section 8.2, Table 3 for modelling references)

[10] All scenarios, including no new land markets (CR), assume settings prevent net loss of habitat.

Implications for sustainability

Declines in environmental pressure accompanied by improvements in living standards represent a move towards sustainability, but do not necessarily imply that sustainable development has been achieved.

While there is no single agreed definition, the essence of sustainable development is that current patterns of human activity and development do not undermine the social, economic and natural assets which are essential for future human wellbeing (WCED, 1987; Griggs et al., 2013). Sustainability assessment thus requires the ability to understand and account for how flows of materials (including pollutants) and modification of ecosystems impact on the qualities of these assets – or at least to identify and manage major threats (see O'Connell et al., 2013). While most of the analysis for the *National Outlook* focuses on material flows and land use change, we can interpret implications for a number of types of assets, drawing on the examples above.

All scenarios involve a net increase in cumulative greenhouse gas emissions. In best performing scenarios, net negative emissions are projected from around 2035. By 2050 this net sequestration would offset (or repair) previous emissions back to around 2025. This could be interpreted as Australia having no net adverse impact on climate from 2025 or 2035.

A number of scenarios also see significant recovery of the area of native vegetation, reversing the historical trend decline. In practice, these new areas would take time to mature and provide the full range of terrestrial biodiversity functions and ecosystem services. Assessed in isolation, this restoration would repair past damage to natural assets – promoting sustainability – but we find that the area of new native habitat only partly offsets the likely impacts of climate change, assessed for 3°C or 6°C scenarios. (The analysis also does not take account of other potentially threatening processes, such as invasive species.) We suggest this restoration of national habitat represents a substantial step towards sustainability, but would only be expected to achieve 'no net adverse impact' on natural assets if the world was on track to limiting climate change to 2°C or less.

As discussed earlier in this section, a number of scenarios see reductions in water extractions from stressed catchments, however, increased interceptions of surface flows from carbon and biodiversity plantings. There is a net reduction in extractions and pressure in scenarios with high water use efficiency, including scenarios with very strong abatement incentives (and thus larger areas of plantings and higher interceptions). There are clear tensions and synergies between the health and functions of ecosystems and biodiversity across rivers, floodplains, and dryland areas which have not been explored in any detail in this assessment. We suggest this implies the potential to prevent further declines in freshwater ecosystems, through integrated planning and management in the context of wider action to restore native vegetation and habitat, in the context of global action to limit climate change to 2°C or less.

Part III Developing and integrated perspective

8 The analytical framework for the *National Outlook* 2015

The purpose of the *National Outlook* modelling framework is to enable integrated, evidence-based assessments of potential outlooks for Australian economic activity, natural resource use and environmental performance. Natural resources are defined broadly to include land, water, energy, biodiversity and other ecosystem services. Environmental pressure and performance indicators include greenhouse gas emissions, carbon sequestration, water extractions from water-limited catchments, area of terrestrial native habitat, and extinction risk. The framework provides a large number of economic indicators, including: national income (GNI), output value (GDP), consumption, employment, production volumes, trade flows and the value of economic activity.

8.1 Modelling strategy

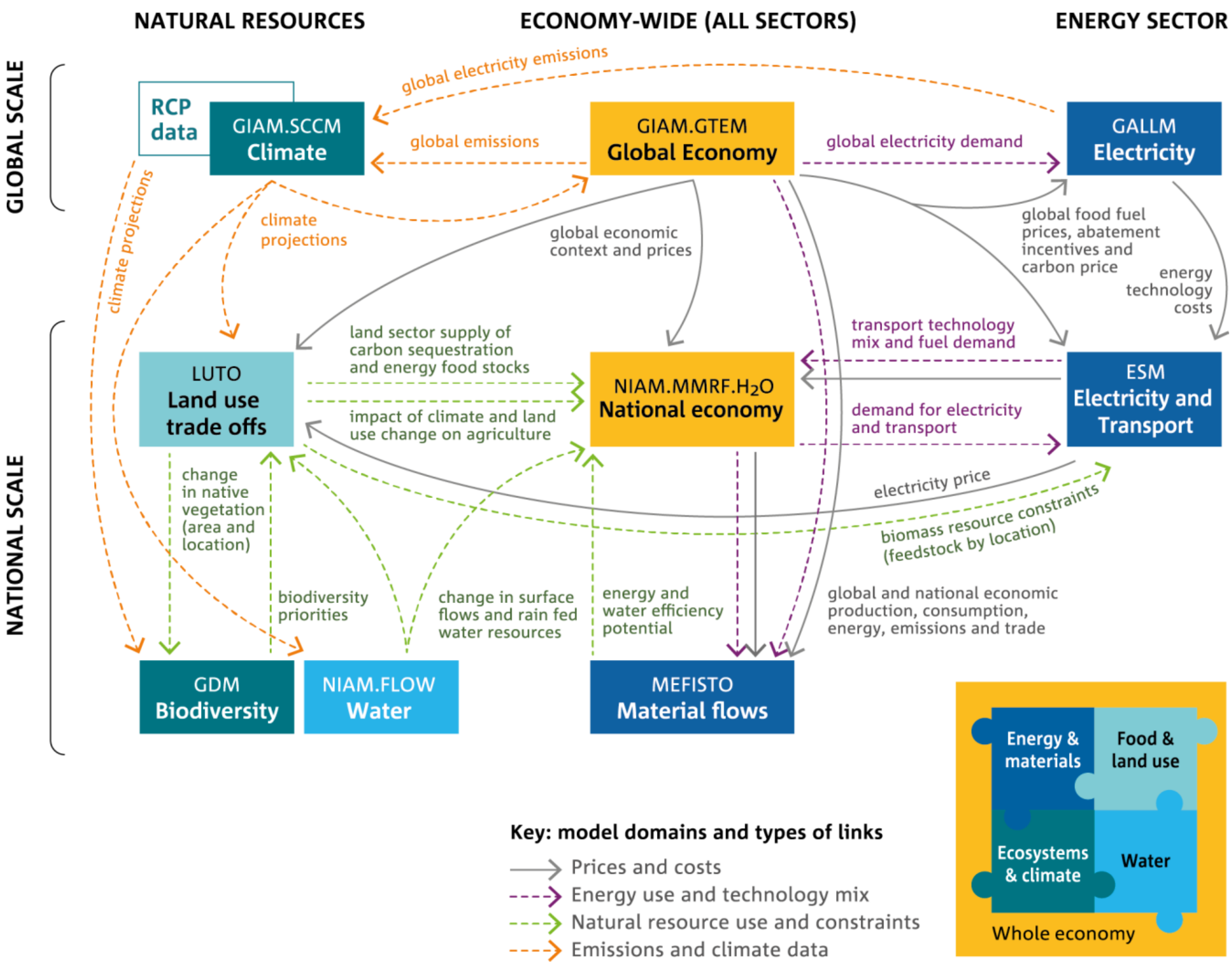
The modelling framework for the *National Outlook* links nine computer models representing different aspects or processes within the physical economy, at global or national scale.

We adopted a comprehensive model-linking approach, rather than a single-model approach (see Kelly et al., 2013). As shown in Figure 53, different models focus on simulating different sectors or processes, shown here in terms of five domains: global or national economy, water, food and land use, ecosystems and climate, energy and materials.

A key advantage of this approach is that it allows us to build on the depth and track record of these established models – many of which are the current versions of models that have been used to analyse national and global policy issues for more than 20 years. The models vary in their scope, purpose, structures, variables, spatial resolution and dynamics. One common feature is that all provide projections to 2050 or beyond, usually in an annual time step.

The strategy links an economy-wide computable general equilibrium (CGE) model to several detailed sector models, so that the economy-wide model provides context (such as demand trajectories for globally traded commodities like energy and food) while the sector models provide detailed analysis of stocks and flows, which are also used to calibrate representation of key sectors in the economy wide model. National (continental) scale models are nested within multi-regional global models. At national scale the framework involves two way interactions with sector models for energy (electricity generation and distribution, and transport), stock-flow dynamics (including supply chains and environmental footprints), rural land use (agricultural production, forestry, and carbon and environmental plantings), and terrestrial biodiversity under climate change. An additional model provides downscaled input projections of water availability under climate change. The central national economic model has seven states (sub-national regions) and is implemented here with 63 sectors, which are reported in different ways, including eight material- and energy-intensive activities (see Figure 54). Project implementation also involved off-model analysis where required, including to calibrate key scenario assumptions.

Figure 53. Overview of dynamic model linkages



Notes: Figure 53 summarises the major data linkages between the models implemented for the *National Outlook* project.

The major scientific advance that underpins the *National Outlook* is the linkages between these models, integrating across domains that are usually modelled in isolation, to provide projections to 2050 or beyond at global, national and regional scale. This allows us to explore multiple complex interactions between biophysical processes and economic activities, to obtain a more holistic picture.

The analysis focused on potential impacts and implications of near term trends and choices, reporting scenario results out to 2050. The analysis includes the impacts of broad scale climate trends on agriculture, forestry, and carbon plantings, but not the potential effects of changes at sub annual or local scales, or in the frequency or severity of extreme events. Future development of this capacity is expected for modelling climate-economy interactions in more depth and detail.

8.2 Project logic and implementation

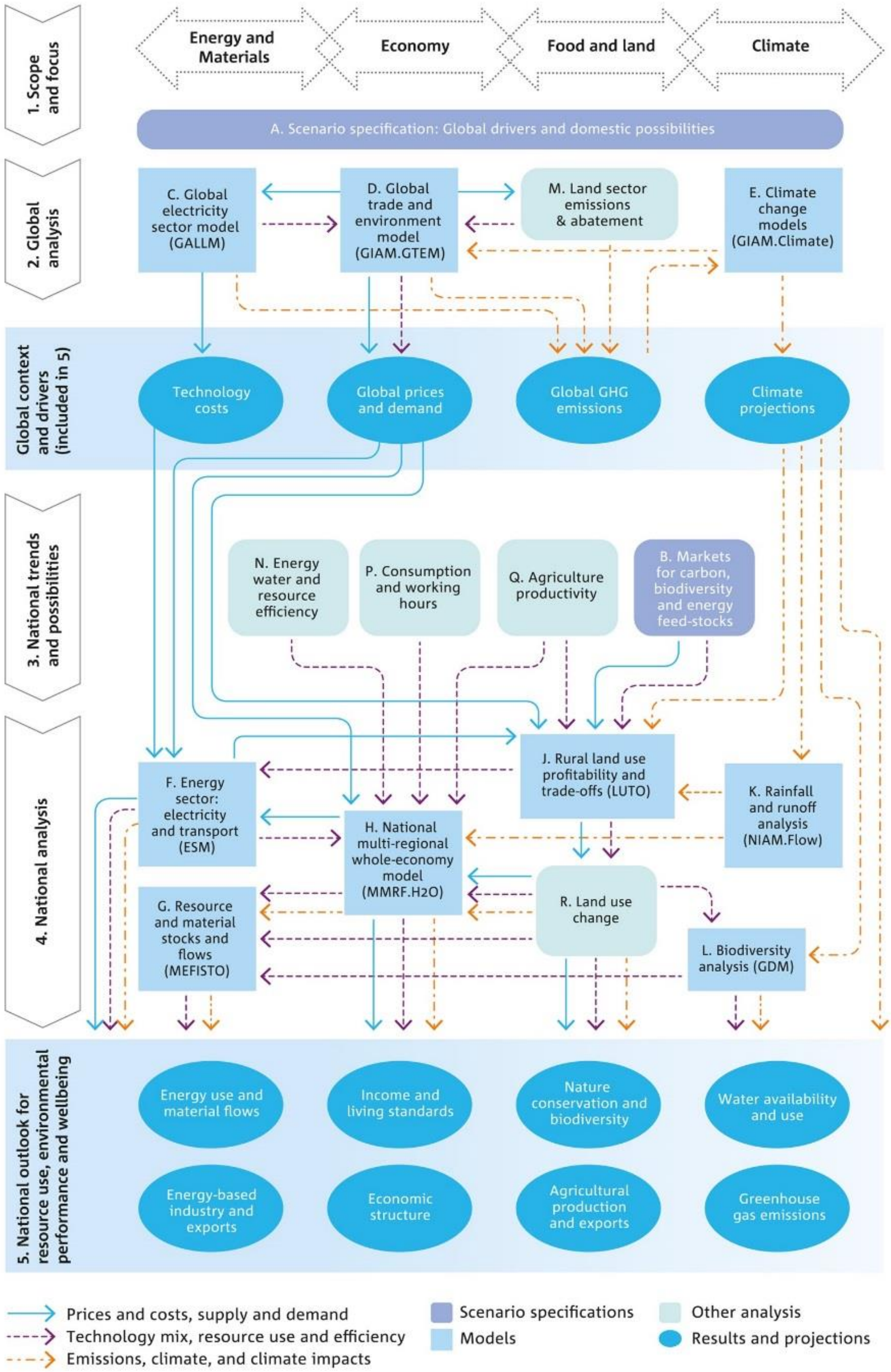
The project logic and model implementation involved five main steps:

1. Defining the scope and focus of the analysis, including the key issues and uncertainties to be explored, and developing detailed scenario specifications to implement the analysis.

2. Modelling a set of global scenarios that meet the project specifications and provide the required context for the domestic analysis.
3. Scoping the input assumptions and modelling the uncertainties that define the domestic scenarios including: recent trends in consumption; the magnitude of cost effective improvements in resource efficiency; the emergence of new land sector markets; and, recent trends and stretch potential for agricultural productivity.
4. Modelling the domestic biophysical economy, drawing on both the results of the global analysis and the domestic scenario inputs.
5. Synthesising and interpreting the results to provide insights into the outlook for economic activity, resource use, environmental pressures and living standards – with key findings distilled into the *National Outlook* report.

These steps are shown in Figure 54. The figure distinguishes four distinct elements in this project implementation: scenario specifications (parallelograms A and B), the nine models (rectangles C–K, described below), other analyses (hexagons M–R, see below), and the modelling outputs and results. Data flows are grouped into price signals, resource allocation and technology, and climate – indicated by blue, purple and orange lines respectively. Table 3 below summarises the component models and key linkages between them.

Figure 54. Project logic and modelling flow



Notes: Figure 54 sets out the overall project logic and implementation of modelling linkages.

Table 3. Summary of component models and key linkages

	MODELS FOR GLOBAL ANALYSES *Letters in square brackets [A]–[R] refer to models and processes in Figure 54 above*	MODEL TYPE
C	**GALLM** (Global and Local Learning Model) is a multi-region global electricity model (Hayward and Graham, 2013). GALLM simultaneously projects change in power generation technology costs and the supply mix using endogenous learning curve relationships, producing unique technological development paths for alternative scenarios of global political, technological and economic drivers. Key inputs are the global scenario specifications [A], electricity demand [D], and global prices for coal, gas and carbon [D]. This model has been developed by CSIRO.	Partial equilibrium energy sector model of the evolution, use, and capital and operating costs of electricity generation assets, incorporating technological learning (mixed integer programming).
D	**GIAM.GTEM** (Global Trade and Environment Model) is a multi-region global dynamic economic model with up to 57 sectors, including detailed energy sector representation, and capacity to include climate impacts (Pant, 2007; Raupach et al., 2011). It has been calibrated to reproduce economic and energy patterns using the latest GTAP database (Narayanan et al., 2007). Key inputs are the global scenario specifications [A] and climate trajectories [E]. This model was originally developed by ABARE and has been adapted and rebuilt by CSIRO using the latest GTAP database.	Computable general equilibrium (CGE) with detailed energy technology bundle.
E	**GIAM.Climate** uses the SCCM (Simple Carbon Climate Model) (Harman et al., 2011) to derive trajectories of mean global, annually-averaged near-surface air temperature that are consistent with GTEM emission trajectories and available GCM results. Key inputs are the composite emissions data from GALLM [C], GIAM GTEM [D] and global land sector analysis scenarios [M] drawing on (Treasury, 2011; Alexandratos and Bruinsma, 2012; Sathay et al., 2011). This model has been developed by CSIRO.	Box model calibrated to 27 CGMs in the international Coupled Model Intercomparison Project (CMIP5) database (Taylor et al., 2011).
	MODELS FOR NATIONAL ANALYSES ***Letters in square brackets [A]–[R] refer to models and processes in Figure 54 above***	**MODEL TYPE**
F	**ESM** (Energy Sector Model) is a set of interconnected models of the Australian energy sector, including models for electricity generation, transmission and distribution, and road transport energy use (Graham, et al., 2013; Reedman and Graham, 2013). The ESM models detail projections of electricity prices, system costs, and the mix of electricity and transport technologies and fuel use. Key inputs are global technology, fuel and carbon prices [A, C, D], together with Australian electricity and transport demand [H] and bioenergy supply [J]. This model has been developed by CSIRO.	Partial equilibrium energy sector model of the evolution and use of stocks of generating assets and transport vehicles (linear programming).
G	**MEFISTO** (Material and Energy Flows Integrated with Stocks) (Baynes et al., 2014) is a multi-scale flexible modelling framework used for analysis of energy and environmental pressures and supply chain or 'footprint' analysis of economic production and consumption. It generates environmental satellite accounts for material and energy flows and emissions based on technology coefficients and stock dynamics. It is linked to a global multi-regional input-output database (EORA, see Lenzen et al., 2012; Lenzen et al., 2013) to account for the full supply chain of resource use and environmental pressure attributable to national consumption, including through imports. Key inputs are national production, consumption and trade by sector [H], supply chain characteristics of imports and exports [D], energy, water and resource efficiency [N], consumption trends [P], agricultural productivity [Q], markets for land use and biodiversity [B], land use and sequestration [R] and biodiversity outcomes [L]. This model has been developed by CSIRO.	Linked technology-based physical stocks-and-flows model of the economy, based on input-output data.

H	**MMRF.H_2O** is a dynamic economic model of Australia, able to assess greenhouse gas emissions and policy options for seven state regions and up to 110 sectors (Adams and Parmenter, 2013; Wittwer, 2013). The model has recently been extended to include accounts for water trading and three water supply options (rainwater, desalination, and recycled waste water). Climate impacts on agriculture are incorporated in this project through data from LUTO [J] [R]. Key inputs beyond the global and domestic scenario specifications are global demand and prices for carbon, energy, agricultural commodities [D], impacts of land use change and climate change on agricultural output [R], stream flow inputs to water supply [K]. This model was developed by the Centre for Policy Studies, formerly at Monash University and now based at Victoria University, and is being used in partnership with CSIRO.	Computable general equilibrium (CGE) with enhanced energy and water sector detail.
I	**NIAM.Flow** is a module that provides climate-linked projections of water availability in rivers and storages for use as an input into LUTO and MMRF.H2O [H], [J]. It draws on climate projections from GIAM.Climate [E]. This module has been developed by CSIRO.	Surface water balance equations to calculate runoff and statistical regressions relating global temperature change to local change in temperature, precipitation and runoff.
J	**LUTO** (Land Use Trade Offs) (Connor et al., 2015; Bryan et al., 2014) is a spatially detailed model that calculates the relative profitability of a wide range of potential Australian rural land uses. Uptake lags and implications for land use change, agricultural output, carbon sequestration and habitat restoration are calculated at [R]. Key inputs beyond the global and domestic scenario specifications are global demand and prices for carbon, energy, agricultural commodities [D], catchment-area climate projections [E], stream flow inputs to water supply [K], and biodiversity priorities [L]. This model has been developed by CSIRO.	Integrated spatially detailed partial equilibrium model of land use profitability and dynamics.
L	**GDM**-based biodiversity projection (Generalised Dissimilarity Modelling) provides an analysis of biodiversity and its relationship with the physical environment over space and time (Ferrier et al., 2007), applied here at continental scale. This approach allows for biological scaling of the pace of climate change, informing adaptive prioritisation. The key input beyond the global and domestic scenario specifications is the extent and location of land available for conservation [J] [R]. A potential link to catchment-area climate projections [E] is not implemented, and the analysis here draws on RCP projections. This model has been developed by CSIRO and applied in a variety of collaborations.	Assessment based on raster model of compositional turnover and persistence of vascular-plant diversity as a function of multidimensional environment in space and time, and landscape-scale habitat configuration.

We distinguish between the use of formal quantitative models and 'other analyses' undertaken for the *Australian National Outlook* project. The other analyses (the hexagons M, N, P, Q and R) typically involve quantitative data analysis to estimate relationships between two or more variables over time, without explicit simulation of state variables over that period. A summary of the five 'other analysis' tasks is given in Table 4.

Table 4. Summary of inputs used for modelling

M – Global land sector emissions and abatement
This analysis complemented GIAM.GTEM by providing a set of land sector emissions trajectories [output E], including a reference scenario (with no carbon price) for each of the three global population trajectories. Land sector abatement estimates were developed from published GCOMAP results, and are consistent with Treasury (2008). The analysis also informed the calibration of feedbacks to agricultural output from reduced access to land due to land sector abatement (output D), combining GCOMAP data with FAO data from Alexandratos and Bruinsma (2012). See Supporting Information Appendix B in this paper and Newth et al. (2013).
N – Energy, water and resource efficiency
This analysis used a combination of simulation modelling and statistical analysis to develop projections for energy and water intensity. Intensity is defined as physical volume or resource use per dollar of sector value added. The analysis was used to calibrate energy and water demand trends [outputs H and F, and to inform material flows analysis [G]. See Hatfield-Dodds, McKellar et al. (under review).
P – Consumption and leisure trends
This analysis quantified recent historical trends for twelve consumption categories as a function of time, and of increases in total real household expenditure. The categories contrasted 'experience-oriented consumption' (EOC) such as meals out or holiday travel with 'material-oriented consumption' (MOC). The analysis used detailed unit record data from the ABS household expenditures surveys of 1998/99 and 2009/10. The analysis also identified trends in average working hours (part time, full time, and all workers) since 1980 from National Sustainability Council (2013). The results were calibrated [output H] and applied as a trend change in tastes within NIAM.MMRF model [H]. The experience-oriented scenario assumes the shift towards experiences occurs at around half the observed rate for 1998/98 to 2009/10. Before accounting for changes in relative prices, this would see EOC's share of total expenditure rise from 18.4%–24.8% from 2010–2050. With average consumption increasing 50% this would imply 100% increase in EOC. All other expenditure (MOC) rises by around a third over the same period, reflecting a decline in share from 82%–75%. The experience-oriented scenario assumes average working hours decline by 11% from 2015–2040, compared to an observed 8% decline over the 25 years to 2012. This implies that for each $100 of additional potential income, $89 is spent on additional consumption and $11 is 'spent' on reducing working hours. See further information in Appendix D .
Q – Agricultural productivity
This analysis assessed agricultural productivity for different sub-sectors over the last four decades. The analysis indicates that trend productivity estimates vary significantly across sectors, and also that small variations in the choice of start and end years have significant impact on the implied average productivity. Because the primary focus is on the outlook for agriculture as a whole, rather than specific sectors, the project team decided to apply uniform 'round number' productivity assumptions across all agricultural sectors. These assumptions were then applied in the LUTO model [J] of rural land use profitability and trade-offs, and the economy-wide Monash NIAM.MMRF model [H]. See further information in Grundy et al. (under review) and Hatfield-Dodds, McKellar et al. (under review).
R – Land use change
This analysis adds a time profile to the projections of land use change made by the LUTO model [J], as specific land areas are switched to more profitable uses. Land use change is assumed to occur along a symmetric non-linear sigmoid curve, with 50% of the change achieved after eight years and 100% achieved after 16 years. This uptake curve is applied to the LUTO model [J] and the NIAM.MMRF model [H] to each annual cohort of land, in aggregate for each State, and for each agricultural sector. The same rates of change apply to shifts in agricultural output and to the supply of carbon credits from carbon plantings. The uptake curve is not applied to land that switches to biodiversity conservation as a result of a top-up payment from a biodiversity fund (as this is modelled as an annual auction process that spends all the available funds), or to the supply of carbon credits from this land. See further information in Bryan et al. (2015) and Grundy et al. (under review)

Tracing cross scale and cross-sector linkages – an example

This process can be illustrated in relation to developing our projections of Australian land use and agricultural production. We use three global models to develop a coherent set of scenario projections for agricultural prices (for Australian exporters), potential payments for land-sector sequestration, and climate (including spatially-explicit changes in temperature and rainfall across Australia). The global modelling accounts for how different levels of abatement effort impact on competition for agricultural land, and thus impact on agricultural output, demand-supply balance and prices. Projections of prices and climate variables from the global analysis are used as scenario inputs to LUTO, which provides spatially detailed projections of land use and agricultural output in the Australian intensive zone for different scenarios.

Differences in agricultural output across LUTO scenarios are used to estimate the effect of climate and land use change on agricultural production, which are used as an input to NIAM.MMRF to ensure these effects are accounted for in projections of agricultural output, national production (GDP) and national income (GNI). LUTO projections of the area and spatial distribution of new habitat and single-species plantings are used as in input to the GDM model in its analysis of the biodiversity benefits of projected land use change (which also draws on spatial climate projections for RCP 4.5 and RCP 8.5). NIAM.FLOW uses global climate projections as inputs to modelling changes in stream flow and water availability, which are used as an input to NIAM.MMRF projections of extractive water demand and supply. These projections are combined with LUTO projections of water interceptions to allow assessments of total water use.

Similar chains of linkages and data exchanges occur across other models to explore other issues and interactions.

8.3 Advances in modelling capacity

The analysis for the National Outlook uses a suite of nine models to provide integrated projections of a very wide range of system process and variables. The modelling framework embodies a number of advances in analytical capacity, both within individual models and through the new linkages between different models. As noted above, the major advance comes from establishing an integrated multi-model framework, allowing us to assess interactions and trade-offs across sectors and systems that are normally analysed in isolation. But the framework also embodies advances in many of the component models. These include:

Energy system:	Analysis of dynamic land use constraints for bioenergy supply, and whole of electricity system analysis of efficiency and costs, including transmission and distribution network utilization under different policy settings and demand scenarios, and the implications of different rates or patterns of electrification and biofuels use in road transport.
Energy and water efficiency potential:	Cohort analysis of future buildings and capital stock, management practices, and associated flows of energy and water use.
Land sector interactions:	Integrated spatially detailed analysis of land use and land use change (carbon forestry, bioenergy, biodiversity) on production of more than 20 agricultural commodities, accounting for competition for land and providing consistent estimates of carbon sequestration, changes in terrestrial habitat, and other land sector outputs.
Water:	Inclusion of water constraints on urban supply options, land use and land sector production, interactions between extractive and non-extractive water use, detailed projections of water demand from materials and energy-intensive industries across different contexts, and interactions between water demand and supply given local constraints on rain fed water supplies.
Climate feedbacks:	Inclusion of impacts of trend climate change on agriculture, carbon plantings, and terrestrial biodiversity, and projected changes in rainfall, surface flows and rain-fed water resources (aggregated to state jurisdictions).
Biodiversity:	Analysis of outcomes from alternative biodiversity investment strategies and scales of investment (for implementing voluntary conservation payments) under climate uncertainty.

Supply chains and environmental footprints:	Analysis of multiple environmental pressures, and their relationships with Australian population, economic growth, technology and consumption patterns across different scenario outlooks.
Environmental pressures:	Analysis of multiple environmental pressures, and their relationships with Australian population, economic growth, technology and consumption patterns across different scenario outlooks.

9 New insights from cross sector integration

The integrated modelling framework used for the *National Outlook* provides new analytical traction and distinctive insights into national challenges and opportunities.

9.1 New analytical traction

The *National Outlook* analysis draws attention to several areas where the insights and findings could only have been achieved by cross-sector integration associated with the comprehensive model-linking approach. The supporting science paper on the integrated modelling framework (Hatfield-Dodds, McKellar et al., under review) highlights three sets of results which are not reported in depth in other *National Outlook* science papers. We conclude that analysis of this kind – and the insights provided – would not be possible without the integration of robust evidence based projections from the different component models of the *National Outlook* framework.

Understanding the complexities of water use

The analysis finds that water sits at the heart of the water-energy-food nexus. The demand for water to 2050, and the mix of supply options, is shaped by complex interactions across energy-intensive industries, food production, and new carbon plantings, in addition to population and economic growth. These issues are explored nationally through three models (MMRF.H_2O, LUTO, and NIAM.FLOW) in the context of other national linkages and the global scenarios (from GIAM.GTEM and GIAM.SCCM).

The level of water demand varies substantially with the value and qualities of economic activity. Agricultural water use varies only modestly across scenarios, and is projected to increase by up to 80% by 2050, driven primarily by increases in catchments outside the Murray Darling Basin. But non-agricultural water use varies widely, with projected increases of by 65%–150% by 2050 (while population grows 64%). The analysis finds that explaining this range requires attention to underlying 'qualities' of economic growth, as well as differences in the value of economic activity. We identify three key drivers of variations in water intensity: differences in GHG abatement incentives and emissions intensity; the composition of economic activity (reflecting different consumption patterns and working hours), and, different levels of water and energy efficiency.

On the supply side, the analysis finds that constraints on rain-fed water resources sees new demand met through desalination and water recycling. Rain-fed water resources in many of Australia's populated areas are already at or near the limits of sustainable extractive use. Meeting the growth in water demand thus involves a substantial increase in the use of desalination and water recycling, which are projected to account for 3%–15% of national water use in 2030, rising to 32%–56% by 2050 as population and economic growth outstrip the capacity of rain-fed water resources (as shown in

Figure 34). The analysis finds that alternative water supply options are cost competitive relative to building major new surface water storages (Burn, 2011). And, that the energy implications of alternative water supply are manageable, with desalination and water recycling projected to account for 1%–6% of national energy use in 2050 across different scenarios.

Last, the analysis finds that water interceptions from land use change could be significant, and will require careful governance. We find that these interceptions from carbon and biodiversity plantings account for up to a quarter of total (extractive and non-extractive) water use nationally in 2050 in scenarios with very strong abatement incentives, and will require detailed analysis to inform appropriate management and governance.

In essence, the analysis finds that water demand and supply mix are emergent properties of global and national economic trends and policy settings (in addition to regional water constraints), with demand influenced by complex qualities of economic growth as well as total value of economic activity. The finding that water demand is very strongly influenced by the growth of energy intensive industries is not surprising, given that these industries are significant water users. It seems likely, however, that a less integrated framework would fail to identify that increased energy and water efficiency could decrease energy use but increase water use by these industries in some circumstances while decreasing them in others (here as a result of different competitiveness effects across scenarios). The spatially detailed modelling of land use is also essential for accounting for potential water stress, including extractive and non-extractive water use.

Assessing markets for ecosystem services

The analysis also explores interactions around land use, and the potential contributions of emerging markets for ecosystem services – particularly land sector carbon sequestration, the biodiversity benefits of native habitat, and bioenergy – and the implications of these for food production and extractive and non-extractive water use, including downstream national economic impacts. These issues are explored nationally through two spatially detailed models (LUTO and GDM) in the context of other national linkages (such as ESM in relation to biofuels, and MMRF.H_2O) and the global scenarios (from GIAM.GTEM, GIAM.SCCM and GALLM). The development and application of these models is documented in several papers (see Ferrier et al., 2007; Bryan et al., 2014; Connor et al., 2015; Bryan et al., 2015; Harwood et al., under review).

The analysis finds these new land sector markets could be transformative for Australia in global scenarios where the world takes stronger action to reduce emissions (underpinning long term payments for reafforestation-based carbon sequestration). In these scenarios, markets for ecosystem services account for 30%–40% of national GHG abatement, and carbon incentives can be harnessed to reverse the long term decline in the area of native habitat, and reducing extinction risk by 10% or more (Figure 39). These voluntary markets could also diversify and increase landholder incomes, particularly from land that is less productive or profitable (Figure 25), and could increase national income by up to 3% relative to scenarios without these new markets (discussed in more detail below). There is no free lunch, however. Large scale shifts in land use to carbon and biodiversity plantings would slow the growth in agricultural output, while projections for some scenarios see the volume of livestock output peak and then fall below current levels. New carbon plantings could also reduce surface water flows, as discussed above, and reducing groundwater recharge (see Bryan et al., under review). Large scale changes in land use and the mix of farm enterprises within regions could also have potentially significant impacts on rural communities, which are not explored in our analysis.

While this analysis could be undertaken on a 'stand-alone' basis, without the wider framework, embedding this analysis in an integrated framework: (a) ensures input assumptions are internally consistent for each scenario (such as the carbon price and agricultural export prices), and that the economy wide modelling properly accounts for competition for land; (b) assesses the biodiversity implications of projected area and location of new habitat, including reductions in extinction risk, and (c) explores how projected changes in land use fit into wider patterns of economic development and opportunity, such as the macroeconomic implications of displacing international emissions credits with domestic sequestration, and replacing oil imports with domestic biofuels.

Exploring potential shifts in competitive advantage

A unique attribute of the integrated modelling framework for the *National Outlook* is the ability it provides to explore and assess the 'whole of economy' implications of interactions between resource use and potential wider economic trends (that are not always addressed well in sector-based models), and the implications of these for national economic performance. These issues are explored at national scale through the economy wide model (MMRF.H2O) in the context of linkages and inputs to all the other models in the framework.

As discussed in earlier sections, we find that decoupling (or 'green growth') is possible. Australia is projected to achieve strong economic growth, with GDP increasing by 156%–190% from 2010–2050 (Figure 44), including in multiple scenarios where environmental pressures fall or are stable (Figure 45 and Figure 52). Around two thirds of the differences in economic growth and average income across the scenarios is explained by different assumptions about working hours.

The projected decoupling of economic growth from environmental pressure is not achieved, as might be expected, through shifting energy and emissions-intensive industry offshore and importing these goods from other countries. Rather, material- and energy-intensive industries projected to grow faster than the average for the economy (see Figure 10 and Figure 15). Instead, decoupling occurs through a mix of (top down) collective choices to deploy technologies that reduce pollution or promote restoration of natural assets – particularly low carbon energy sources and carbon plantings – supported by (bottom-up) individual choices by households and firms that shift towards production and consumption patterns that involve lower resource and energy use per dollar.

But there is more to this story. Our analysis finds that there are potential economic benefits to Australia from stronger national and global action to reduce GHG emissions – providing win-win economic and environmental outcomes before 2050, as shown in Quadrant 1 of Figure 49 above. Importantly, these benefits are not the result of differences in physical climate impacts, or a reduction in the size of material and energy intensive sectors relative to the rest of the economy in scenarios with stronger abatement efforts. Instead they arise from projected shifts in competitive advantage and trade balances which are not projected to occur with moderate abatement settings, and which outweigh the incremental costs of stronger domestic abatement. The main sources of these benefits are higher agricultural value added, net gains in farm (and national) income from land sector sequestration, and lower oil imports associated with higher transport fuel self-sufficiency. The underlying drivers of these benefits include: new opportunities to supply carbon sequestration through reafforestation, where this is profitable given global prices for agriculture and carbon (while also accounting for competition for land and the reduction of agricultural output associated with new plantings); incorporating trend climate impacts on agricultural yields; and, accounting for the uptake of biofuels and switches to electric vehicles in transport, and the implications of these for agricultural production, oil demand and imports.

This analysis of the indirect economic impacts of different scenarios relies entirely on the new cross-model linkages established by the integrated framework. Previous studies have found that global action to limit global average temperature increases to 2°C or lower would be in Australia's national interest, and would provide net benefits to Australia after 2050 through reduced climate impacts and risks (Garnaut, 2008; 2011). Our findings on potential shifts in national comparative advantage complements this previous analysis, which could only be identified by tracing cross-domain economic interactions through the linkages shown in Figure 53 and Figure 54 above.

9.2 The contribution of integrated analysis to our key findings

A complementary second perspective on the contribution of integrated analysis can be provided by examining the extent to which these cross-model linkages underpin the *National Outlook*'s key findings on challenges and opportunities for Australia.

DTable 5istinctive key findings from the Executive Summary of the *National Outlook* are summarised in Table 5. The new integrative capacity provided by the modelling framework is central to six of the 10 key findings – in the sense that these findings and insights could not be made in a robust and defensible way without careful cross-sector integration, such as the linkages implemented in the *National Outlook* framework. Two of the 10 key findings could have been arrived at with existing simpler multi-model frameworks that cover a less comprehensive set of sectors (such as used in Treasury, 2008; or Graham et al., 2013). Cross-sector integration is judged as important for the other two key findings, improving the confidence in this finding and quality of the underlying analysis. The table also identifies the domain issues that were included in the analysis that underpins each of these findings.

Table 5. Role of integrated analysis in underpinning *National Outlook* key findings

KEY FINDINGS[A]	CROSS SECTOR INTEGRATION	DOMAINS INVOLVED[B]
While global demand for our exports is projected to treble, demand for specific materials and energy exports will vary with international developments.	Previous scope sufficient	economy – energy – emissions – land use[c]
Australian total output of food and fibre can increase, even with significant shifts of land out of agriculture. Managing the water-energy-food nexus will produce challenges and opportunities for rural land use and communities.[d]	Central and necessary	economy – land use incentives for carbon sequestration and biodiversity conservation – water – climate
Sustainability economic growth can be partners not competitors.	Central and necessary	all
Living standards are set to increase, with only minor variations across scenarios.	Important	all
Electricity and transport can remain affordable.	Previous scope sufficient	energy – economy
Electric vehicles and biofuels could reverse mounting transport fuel imports.	Important	energy – land use – economy
Collective decisions account for 50%–90% of the differences in resource use and natural assets across the scenarios, with synergies in some cases and trade-offs in others.	Central and necessary	all
While water use is projected to double by 2050, this growth can be met while enhancing urban water security and avoiding increased environmental pressures.	Central and necessary	all
We can reduce our GHG emissions significantly, including per capita emissions below the global average by 2050 in some scenarios.	Central and necessary	all
Incentives for voluntary land sector sequestration could be harnessed to increase native habitat by 17% and decrease extinction risks by 10%, without large additional government outlays.	Central and necessary	economy – land use incentives for carbon sequestration and biodiversity conservation – water – climate

Notes: Dark shading indicates integration is necessary, or involves more than three sector domains, mid shading indicates it is important or involves three to four sector domains. (a) Key findings are shown in the order of the statements in the executive summary, except as noted. Some statements are treated as 'messages' involving interpretation of findings and their implications. (b) The five domains are global or national economy, water, food and land use, ecosystems and climate, energy and materials – as shown in Figure 53. (c) Analysis of global land use informs the level of global abatement effort, agricultural prices and energy mix. The global analysis of land use in the *National Outlook* is fit for purpose, but is not as robust as the national analysis. (d) This finding appears before the water finding in the executive summary but has substantial overlap with the finding on agricultural output.

Source: *National Outlook* project team.

9.3 Advantages and disadvantages of the multi-model approach to integration

A central feature of the *National Outlook* framework is the way that physically-grounded sector models inform and extend economy-wide computable general equilibrium (CGE) models. The framework informs the central CGE model by providing scenario-consistent inputs, such as rainfall and stream flow data, or the reduction in agricultural output associated with the projected supply of carbon sequestration. The framework also extends scope of the CGE model which, operated in isolation, would not provide projections of the uptake of electric vehicles, liquid biofuels or land sector carbon sequestration. In addition, the national CGE model used (MMRF.H_20) explicitly includes three water supply options, which is unusual (as most CGE models do not include water because it is not explicitly included in the UN's System of National Accounts (UN, 2013). Cross-model linkages are also used to calibrate transition dynamics. This is relevant because CGE models are focused primarily on flows and can find it difficult to represent changes in flows that are buffered by long-lived stocks of assets. For example, it is widely considered that CGE models overstate the reductions in greenhouse gas emissions in the first few years after the introduction of an abatement incentive such as a carbon price. For this reason, the *National Outlook* uses technology-based electricity models for projections of global and national electricity emissions, and the land use model for national sequestration. We also explicitly account for uptake lags in projected changes in rural land use.

Advantages of this approach includes that it addresses a crucial weakness of CGE models – by providing explicit representation of stock turnover and stock-flow dynamics in key sectors, and capitalises on the strengths and established track record of the component models. The approach provides better representation and more detailed results for land use, water stress and biodiversity than previous integrated Australian modelling (with broader coverage than previous multi-model approaches focused on climate policy (Garnaut, 2008; Treasury, 2008, 2011; Treasury and DIICCSRTE 2013). It provides better representation of economic processes than previous national and global single model systems dynamics approaches (Foran, 2002; Foran et al., 2005; Randers, 2012), including providing projections of changes in economic structure that have material impacts on resource use (as illustrated by the water results above), and allows accurate reporting of economic metrics such GDP. This is consistent with the view that a model-linking (or 'coupled component model') strategy allows for more depth and very detailed representation of system processes (Kelly et al., 2013).

A weakness in the current implementation is that model-linking occurs through manual data exchange, which can be time consuming and requires very careful data custody and quality controls. A manual approach also effectively prohibits large ensemble analysis, where the suite of models might explore thousands of combinations of scenario parameters (each representing a specific 'scenario'). In addition, the current project did not actively include non-research stakeholders in scoping and defining the issues to be explored (see Hamilton et al., 2015). We propose to address each of these issues in future capacity development and projects, along with improved representation of climate-economy interactions in the context of the water-energy-food nexus.

9.4 Limitations of the modelling and analysis

Our analysis shows that Australia's total output of food and fibre can increase – even in scenarios with significant shifts of land out of agriculture – if agricultural productivity growth is restored. However, we have not fully explored the complex distributional implications of these scenarios, and we do not yet fully understand the potential cascading impacts of future climate change and extreme events on farms, sectors and regions. The scale and multiple complexities of these potential changes could raise unprecedented challenges for landowners, regional communities and our nation.

The current modelling framework is able to account for some aspects of trend changes in climate, including impacts of trend changes in average annual rainfall and average annual temperature, and the effect of trend changes on aggregate stream flow and water supply. But our current models do not fully account for significant likely changes in climate variability and extreme events (see Figure 50 above). Changes in climate variability – the intensity and frequency of droughts, floods, storms – will have impacts on agriculture and other sectors, potentially outweighing productivity improvements in some regions, including through damage to infrastructure and built assets, disruption of business activity, and effects on human health. Better representation of these impacts would have implications for the projections presented in this report. However, would be unlikely to have significant implications for relative performance across different scenarios before 2050 due to time lags between emissions and the manifestation of physical differences in climate.

We consider improving the representation of climate-economy impacts is an urgent major challenge (New et al., 2011; Stern, 2013; Fisher and Le, 2014) – including interactions across the water-energy-food nexus at regional, national and global scales, accounting for potential changes in variability and earth-system tipping points (Steffen et al., 2015), and giving specific attention to potential impacts on production of food and fibre, water supply, built assets, labour productivity, and social and organisational capital (or coping capacity) (see Stern, 2013).

Part IV Supporting Information

Appendix A Terms of reference for the National Outlook 2015

Scope and purpose

The CSIRO *National Outlook* will provide benchmark integrated assessments of observations and projections of a range of possible outlooks for Australian natural resource use (including land, water, energy and ecosystem services) and associated environmental pressures, and their implications for national wellbeing and sustainability.

The analysis is intended to contribute to the public and technical understanding required for effective responses to Australia's national sustainability and development challenges and opportunities. The analysis and projections will be policy relevant, but not policy prescriptive, and will give particular attention to the long-term risks or consequences of near and medium term decisions or trends. It will draw upon the latest peer reviewed research, best available historical data and a suite of advanced models to produce regular reports for Australia.

A key component of the analysis will be to account for interdependencies across domain areas in order to provide an integrated understanding of potential synergies and trade-offs. The analysis for the *National Outlook* will account for trends and factors such as continuing economic and population growth, climate variability and change, and complex interactions across social, economic and biophysical systems.

Project outputs

The first *National Outlook* Report will deliver three types of science products:

- A concise *National Outlook* report – combining historical observations with integrated projections to provide a set of future outlooks for Australia's physical economy and natural resources to 2050;
- A set of at least five scientific papers exploring specific issues in more depth that will be submitted for publication in high quality journals (with supporting materials as required); and
- A set of accessible supporting papers and factsheets.

These products will be underpinned by a robust, thorough and fully documented integrated scientific process, consistent with international best practice.

Terms of reference

The formal terms of reference for the series of *National Outlook* reports are to:

1. Provide evidence based integrated assessments, observations and projections of a range of possible trajectories and outlooks for Australian natural resource use (including land, water,

energy and ecosystem services) and associated environmental pressures, and their implications for national wellbeing and sustainability.

2. Identify and assess nationally significant opportunities, risks, synergies and trade-offs across different resource use domains, and associated economic sectors, with particular attention to near and medium term opportunities and risks with significant potential long term consequences.
3. Present this information and assessments in a concise and highly accessible report, with supporting materials as required, to be repeated every three to five years. The report should be relevant, interesting and accessible to national decision makers, opinion leaders and the general public.
4. Through this process, identify and assess gaps in available data, methods, knowledge and understanding, and indicate priorities to address these gaps over the next 5-10 years. This information may be captured in a separate report or science prioritisation process.

CSIRO proposes to repeat the *National Outlook* process every three to five years. The focal issues explored are expected to evolve and change across the series of reports. It is envisaged that these terms of reference will be periodically reviewed and refined.

Extract from the project outline,
as provided to the External Expert Review Panel,
November 2013.

Appendix B Supplementary information on scenario definition and implementation

This Appendix provides additional details and technical information on the development and modelling of the scenarios, particularly in relation to:

- locating the discussion of specific scenario assumptions and drivers in this report
- the scenario definitions and naming conventions
- the development and implementation of the global context scenarios, including reconciling population with global climate outlooks (through different levels of abatement), estimating global land sector abatement, and achieving an appropriate spread of agricultural export price outlooks, and
- analysis underpinning the domestic scenario assumptions, including estimating potential for energy and water efficiency, assessing recent trends in consumption patterns and working hours, identifying appropriate values for trend agricultural productivity, and developing the Australian population trajectory used in the domestic analysis.

B.1 Locating the discussion of scenario drivers in this report

The analysis and projections for the first *National Outlook* explore multiple interacting uncertainties, referred to as 'scenario drivers'. These were chosen on the basis that they have the potential to have a material impact on Australian living standards, resource use and environmental performance to 2050; are relevant to the central questions explored in the first *National Outlook* (see Section 2.3); and, are able to be explored through the *National Outlook* modelling framework (summarised in Chapters 8 and 9).

Taken together, the set of scenario drivers give rise to a wide range of projected trajectories for Australian economic activity, income and expenditure, resource use and environmental performance. This range of outcomes across scenarios provides the basis of the analysis for the *National Outlook*.

One implication of this approach is that the technical aspects of the analysis are dealt with in a variety of places across the report, as set out in Table 6 below.

Table 6. Location of technical discussions of scenario driver assumptions and their implications in this report

SCENARIO DRIVER	GENERAL NOTES	PRIMARY DISCUSSION
All drivers		Assumptions and framing of scenarios: Sections 2.3 and 2.4 (Table 2 and Figure 5), Appendix B.3 (Figure 56). Combined impacts Sections 4.1, 7.1, and 7.3.
Global economic demand associated with different levels of global population growth *Global greenhouse emissions and the pace of climate change*	Global demand and emissions trajectory are bundled into four global context scenarios. Demand for output from specific sectors will vary with other scenario drivers. Domestic abatement incentives are assumed to align with global abatement efforts within all scenarios.	Detailed implementation of the global context scenarios: Appendix B.3. Key results for the global scenarios: Section 3.1. Global food prices: Section 5.2 (Figure 26) and Appendix B.3. Global G emissions: Section 3.1 and 6.2, and Appendix B.3. National impacts of global (and national) action to reduce emissions: Section 7.2 Limitations of the analysis in relation to climate impacts. (see Newth, et al., under review)
Australian consumption trends *Australian average working hours and leisure trends*	Consumption trends and working hours are treated as a combined scenario driver.	Historical trends and scenario projections: Section 4.1.
Australian resource efficiency trends, particularly non-price factors	The step change scenarios assume the uptake of all commercially attractive options with 3–5 year pay back. Energy and water demand are also influenced by different prices across scenarios – this is referred to as price elasticity.	Energy demand and impacts of energy efficiency: Section 5.3. Water demand, impacts of water efficiency, and the impact of energy efficiency of water demand: Section 5.4. (see Baynes, 2015)
Emerging Australian land sector markets	The analysis of land use and emerging land markets for carbon, conservation, and energy feed stocks is central to the new integrated modelling framework, and the first *National Outlook* report.	Implications for land use: Section 5.1 Implications for agricultural output and farm sector income: Section 5.2. Implications for non-extractive water use (water inceptions): Section5.4. Implications for native habitat and biodiversity: Section 6.1. Implications for net GHG emissions (accounting for land sector sequestration) Section 6.2. Implications for national economic performance: Sections 4.1 and 7.2. (see Grundy et al., under review; Bryan et al., 2014; Connor et al., 2015; Bryan et al., 2015)
Australian agricultural productivity	The analysis assumes uniform proactivity improvements across different sub-sectors of agriculture.	Implications: Section 5.2. Historical trends: Appendix B.4. (see Grundy et al., under review)

B.2 Scenario logic and naming conventions

Sections 2.4 and 2.5 of this report provide an overview of the scenario logic that underpins the *National Outlook* analysis. This logic and the relationships between the scenarios are summarised visually in Figure 5, with specific scenario assumptions are set out in Table 2.

This section sets out the logic of the naming conventions used for the global and national scenarios and provides additional information on the population assumptions.

Global context scenarios

The global context scenarios used in the *National Outlook* were designed to provide cover a range of projected variables that impact on Australian economic activity. The specific variables required for the analysis were:

- physical climate, including temperature and rainfall, consistent with cumulative global greenhouse gas emissions benchmarked to the international literature using Representative Concentration Pathways (RCP) RCP 2.6, RCP 4.5 and RCP 8.5. (The *National Outlook* projections were supplemented by use projections for the RCPs from other sources in the biodiversity analysis)
- levels of global action to limit GHG emissions, consistent with the RCPs
- levels of export demand for food, energy and energy intensive goods and other exports
- a wide range of export prices for agricultural commodities.

The naming convention for the global context scenario refers to climate outlook (L=RCP2.6, M=RCP4.5; H=RCP8.5) and population levels (1, 2, 3), as set out in Table 1**Error! Reference source not found.** and Figure 5. The process used to develop the global scenarios is summarised in Section B.3 below.

Domestic scenario combinations and naming conventions

The different assumptions for the seven scenario drivers explored in the *National Outlook* could be combined in 288 ways, each representing a potential national scenario. (See Table 2 for a summary of these assumptions.)

To make the analysis tractable, the *National Outlook* structures the set of scenarios through a sequence of steps:

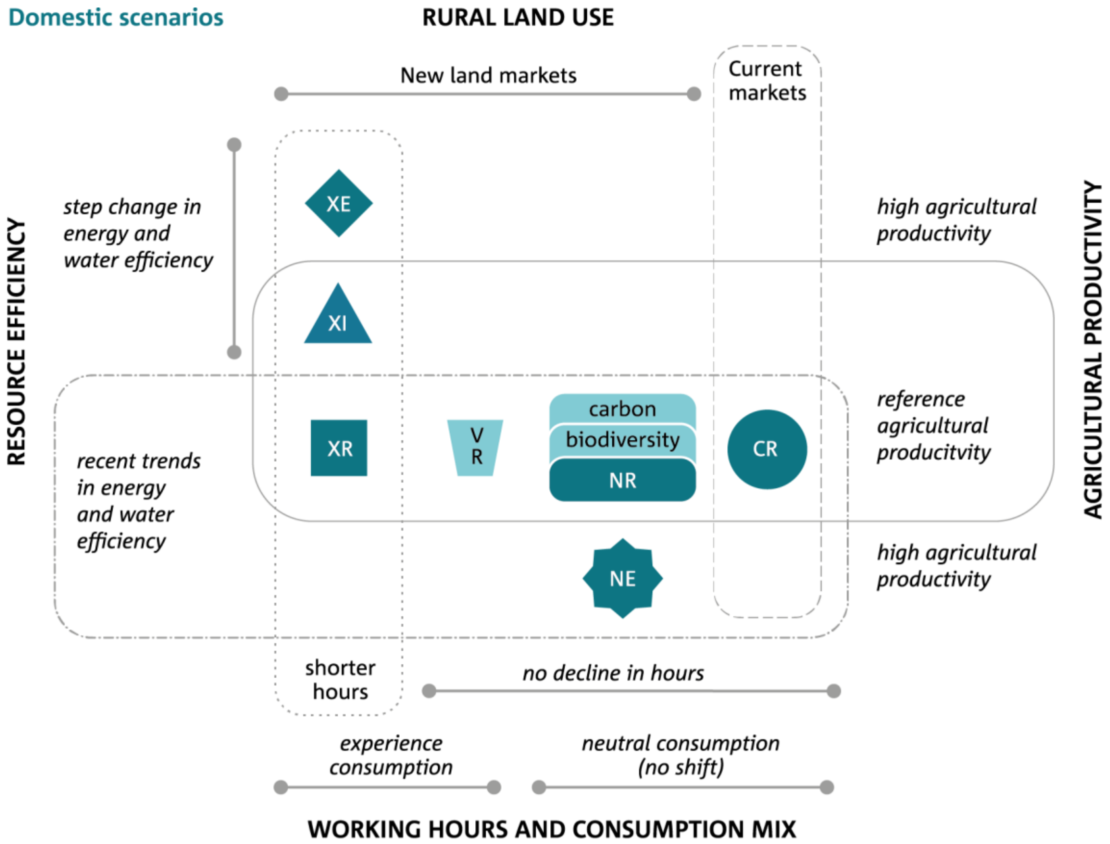
- from current land markets to new land markets (CR to NR)
- from neutral consumption to experience oriented consumption (NR to XR)
- from recent efficiency trends to a step change in efficiency (XR to XI)
- from reference agricultural productivity to high productivity (XI to XE and from NR to NE)

This approach results in six domestic scenario combinations. These are shown visually in the Venn diagram in Figure 55, moving from the right to left across the bottom row, and then up the right hand side. Table 7 below provides additional information on the domestic scenario codes and naming convention.

These domestic scenarios are combined with the global context scenarios to give 20 core scenarios for the *National Outlook*. The CR, NR, XR and XI combinations are each modelled in the context of the four global scenarios to give 16 combinations. The XE and NE combination is modelled for the M2 and M3 global context scenarios, but not the L1 and H3 scenarios.

The full set of domestic and global combinations is shown visually in Figure 5 in Section 2.4 above.

Figure 55. Visual representation of the combinations of assumptions in the domestic scenarios



Notes: Figure 55 shows the domestic scenario components of the 20 core *National Outlook* scenarios. The LUTO modelling explores three sets of policy settings for new land sector markets in the NR scenarios: 'carbon focused' and 'biodiversity focused' approaches, along with the 'balanced' approach in the core scenario. All other models, including MMRF.H2O only explore the balanced approach, The VR combination, with experience oriented consumption but no decline in working hours, is treated as a sensitivity analysis and not reported in detail.

Source: Developed by the *National Outlook* project team.

Table 7. Naming conventions and scenario codes for the domestic scenario drivers

ASSUMPTION CODES					TEXT DESCRIPTIONS			
Scenario code	Land markets	Consumption and working hours	Resource efficiency	Agricultural productivity	Land markets	Consumption and working hours	Resource efficiency	Agricultural productivity
CR	C	**C**	**R**	R	Current markets	Neutral, no decline in hours	Recent efficiency trends	Reference productivity
NR	N	**N**	**R**	R	New land markets	Neutral, no decline in hours	Recent efficiency trends	Reference productivity
VR	(N)	**V**	**R**	R	New land markets	Experiences, no decline in hours	Recent efficiency trends	Reference productivity
XR	(X)	**X**	**R**	R	New land markets	Experiences, shorter hours	Recent efficiency trends	Reference productivity
XI	X	**X**	**I**	I	New land markets	Experiences, shorter hours	Step change efficiency	Reference productivity
XE	(X)	**X**	**E**	E	New land markets	Experiences, shorter hours	Step change efficiency	High productivity
NE	N	**N**	(R)	**E**	New land markets	Neutral, no decline in hours	Recent efficiency trends	High productivity

B.3 Development and implementation of the global context scenarios

The global context scenarios used in the *National Outlook* were designed to provide a coherent set of projections in which to locate the national analysis, allowing it to explore the implications of different trends for Australia. The projections cover a range of key factors influencing Australian economic activity, particularly demand and global prices for Australian agriculture, energy and other exports, in the light of global population and income growth, emissions and climate, and associated global abatement incentives. The scenarios are developed using the *National Outlook*s global analytical framework (shown in the 'global analysis' row of Figure 54 above) to ensure that the projections for each scenario are internally consistent, and that the relationships across the different scenarios are coherent. This allows the analysis to quantify the significance of the different assumptions that underpin the set of scenarios. The characteristics of the four global scenarios are described in Section 2.3 and Table 2. Key results are reported in Section 3.1 above and later in this section.

Reconciling population with global climate outlooks through different levels of abatement

The global scenarios explore the implications of different global population outlooks, based on the low, mid and high UN population projections (UN, 2013), which see population increasing between

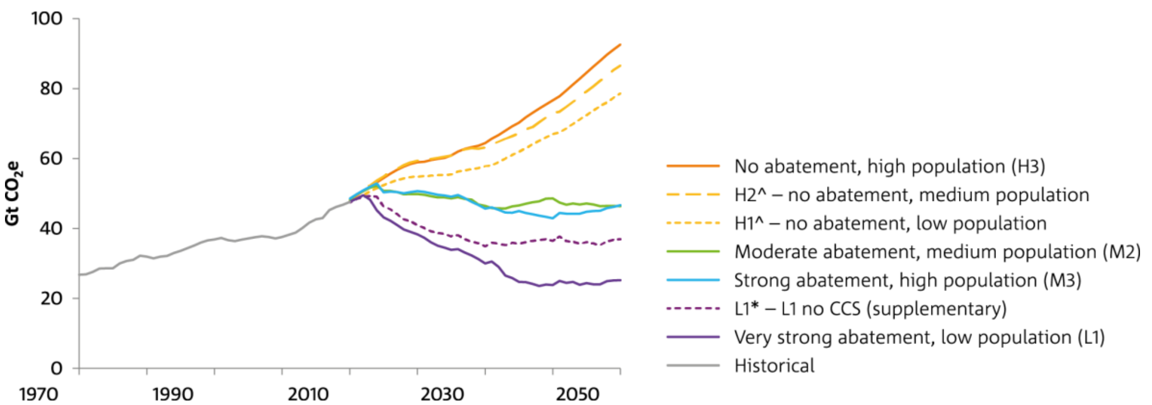
18% and 54% from 2010–2050. For consistency with the international literature, the global modelling maintains the UN projections for Australian population when modelling the global context scenarios. The scenarios are also benchmarked to the climate change literature, through links to three representative (GHG) concentration pathways.

The first step in modelling the set of scenarios was to calibrate the model to produce the H3 scenario, with high global population, no global action to limit GHG emissions, and cumulative emissions to 2050 that are consistent with the RCP 8.5 representative concentration pathway, while working within typical assumptions for labour productivity, energy efficiency, technological change and results for global GDP growth per capita. This scenario forms the anchor point for the set of global scenarios and is the reference case (with no abatement incentives) for the high population outlook.

Next, the modelling developed references cases for the medium and low population outlooks, maintaining exactly the same settings for all other variables, while letting cumulative emissions vary.

The L1, M2 and M3 scenarios were then developed by calculating the levels of abatement incentive (represented as a global carbon price trajectory) that results in the cumulative emissions specified for each scenario (see Table 1 **Error! Reference source not found.** and Section 2.3 above) when applied to the reference case for each population trajectory. The abatement incentive was applied to all energy and industrial emissions across all three scenarios, and to livestock emissions in the L1 (2°C) scenario. The analysis assumed that global abatement incentives and effort increase proportionally over time, reflecting the cost of capital and a margin for investment risk. The rate of increase in the abatement incentive (in USA dollars) declines from 6% per year to 4% from 2015 to 2035, resulting in an average annual increase of 4.5% per year to 2050. Given this rate of increase, the analysis identified the initial level of abatement incentive required to achieve the cumulative abatement task for each of the L1, M2 and M3 scenarios. Land sector abatement from reafforestation and avoided deforestation was estimated for each global carbon price (as detailed below) and applied to projected land sector emissions for each scenario. We made minor adjustments to cumulative land sector abatement to reconcile the total emissions budget for initial carbon prices in 'round number' values. The resulting emissions projections for all scenarios are shown in Figure 56.

Figure 56. Global emissions for core and supplementary global scenarios, 1970–2050



Notes: Figure 56 shown global emissions from all sources, including land sector emissions, for the four core global scenarios, the two additional references cases (for low and medium population) and a supplementary scenario exploring the impact of failing to deploy CCS.

Source: GIAM.GTEM, GALLM and global land sector emission analysis (see Section 8.2, Table 3 for modelling references).

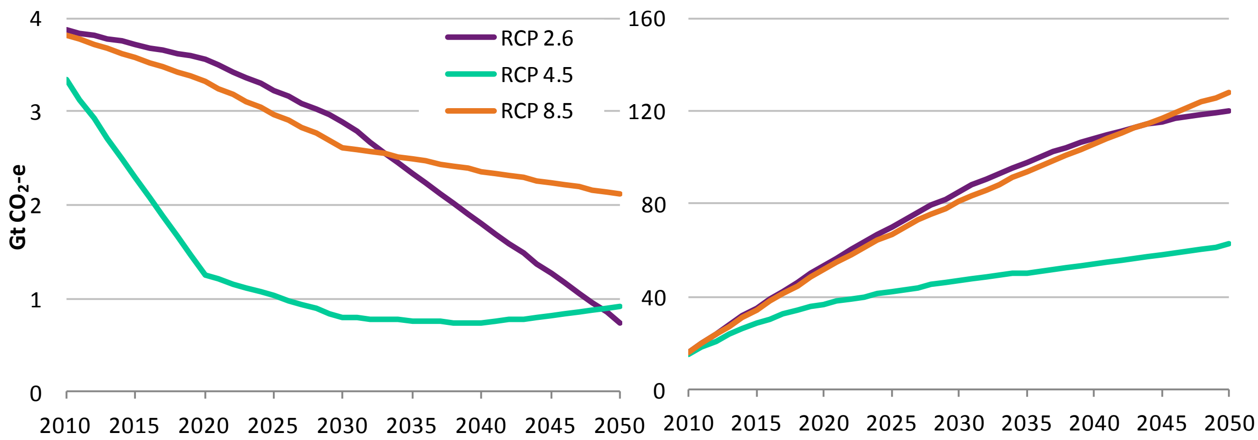
This process reconciled the different combinations of population, economic growth and cumulative emissions through initial carbon prices of US$15 in the M2 scenario (modest abatement), US$30 in M3 (strong abatement), and US$50 in the L1 scenario. (All prices in the report are real 2010 values, adjusted for inflation.) Differences in exchange rates over the scenarios result in the carbon price increasing at around 6% per year in Australian dollars the L1 scenarios, 5% per year in the M3 scenarios and 3% per year in the M2 scenarios, increasing the range of abatement incentives somewhat over time. This is consistent with a projected depreciation in the real exchange rate over the period to 2050 (from historically high levels in 2012) of 8% and 9% in the *Stretch* (L1XI) and *Mixed* (M3NR) scenarios, and of 12% and 16% in the *Existing Trends* (M2XR) and *Material Intensive* (H3CR) scenarios.

Estimating global land sector abatement

Developing projections of total global greenhouse emissions required an internally consistent set of projections for land sector emissions (accounting for differences in population and global abatement effort), along with estimates of the implications of land sector abatement for land availability and agricultural productivity in each scenario. These projections of land sector emissions were developed in a three step process, denoted as [M] in Figure 47and Table 3 above.

The first step is to establish consistent land sector emissions for different population trajectories, in the absence of global abatement action. This is necessary because the published land sector emissions for RCPs 2.6 (3PD), 4.5 and 8.5 are not mutually consistent. In particular, cumulative land sector emissions for RCP 2.6 (3PD) are significantly higher than those in RCP 4.5, and similar to RCP 8.5, as shown in Figure 57. This conflicts with the definition of the L1 scenario (based on RCP3PD emissions) as having significantly lower population growth and thus lower underlying demand for land clearing than H3 (based on RCP 8.5) with high population growth. This inconsistency across the RCPs does not seem to be explained by the underlying population assumptions for these representative concentration pathways, with RCP 3PD assuming population rises to around 8.8 billion in 2050, RCP 4.5 around 9 billion and RCP 8.5 around 10.3 billion (van Vuuren et al., 2011).

Figure 57. Global land sector emissions for three RCPs, 2010–2050



Source: Calculated from van Vuuren et al. (2011)

To resolve this inconsistency, the *National Outlook* analysis adopts the RCP 8.5 land sector emissions for the H3 scenario (assuming high global population and no global abatement efforts).[11] To establish land sector emissions for other population levels, the project adopts the RCP 4.5 land sector emissions trajectory for the low population reference case with no abatement efforts (H1^). Land sector emissions for the UN mid population trajectory with no abatement efforts (H2^) were interpolated on the basis of population relative to H1^ and H3. This approach results in a pattern of land sector emission that is proportional to rates of population growth across the scenarios. Population growth from 2010–2050 in the low population reference case (H1^) is 32% of the increase in H3 scenario over the same period, while assumed land sector emissions are 34% of H3. Population growth to 2050 in the medium population reference case (H2^) is 65% of the increase in H3, while land sector emissions total 67% over the period. The pattern of land sector emissions across scenarios is thus considered consistent with the underlying land use pressures for different levels of global population growth, particularly deforestation and land clearing for agricultural production. The logic adopted also provides a clear scenario anchor to RCP 8.5 and a secondary link to RCP 4.5. The resulting emissions trajectories are shown in Figure 58 below.

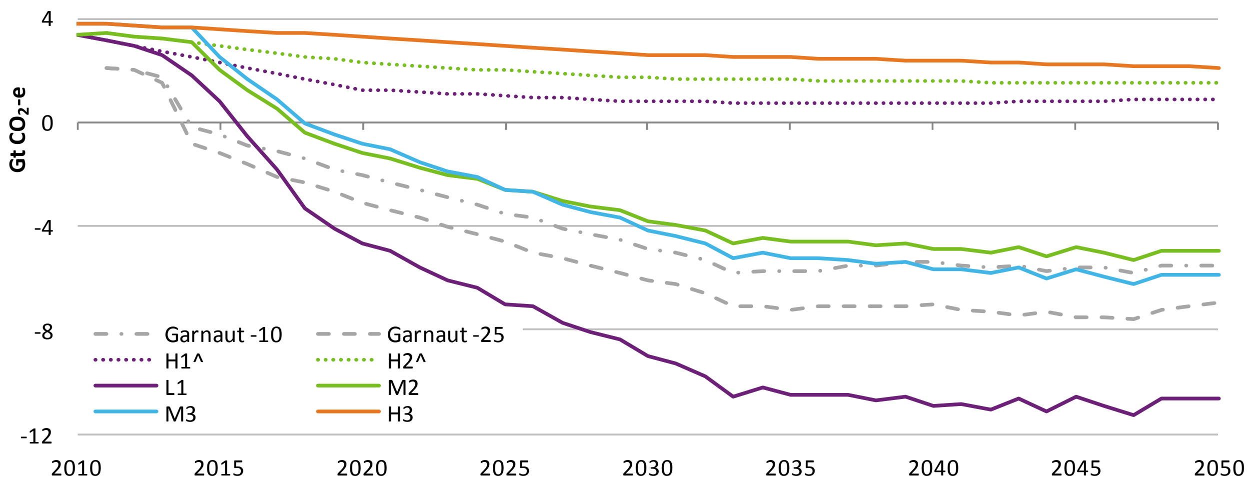
The second step in developing global land sector emissions was to estimate land sector abatement for each global abatement trajectory based on results reported in Treasury (2011), which used a previous version of the GTEM model, drawing on data and inputs from the Lawrence Berkley Labs. This calculation is anchored to the carbon price for the Garnaut-10 scenario ($27.48 in 2015 (US$2010 real) and rising at 4% above inflation). Abatement estimates for higher prices are consistent with the additional abatement implied for the Garnaut-25 price (relative to the Garnaut -10 price), while the abatement for lower prices are estimated on a linear pro rata basis. This process gives 'raw abatement potential' for each year to 2065, with abatement volumes smoothed for the first three years to reflect differences in the start date for carbon pricing in the *National Outlook* scenarios relative to the Treasury (2011) analysis.

To allow the *National Outlook* analysis to use 'round number' initial carbon prices, the projected land sector abatement is then used as a balancing item in ensuring that cumulative composite global emissions (from all sources) matches the cumulative RCP emissions (from all sources), calculated from 2010–2050. To achieve emissions within +/- 1% of the cumulative RCP total required relatively modest adjustments to the raw abatement estimates. Land sector abatement required is in the range of 115%–123% of the raw abatement estimated, equal to an additional 30–56Gt cumulative adjustment over the period 2010–2050. The H3 scenario does not involve any land sector abatement. The resulting abatement estimates are subtracted from land sector emissions in the reference case to give emissions for the L1, M3 and M2 scenarios, as are shown in Figure 58.

This process gives land sector emissions and abatement estimates that are consistent with the carbon prices and other parameters for each scenario, such as population.

[11] The UN (2013) high population projection of 10.6 billion in 2050 is slightly higher than the 10.3 billion assumed population in the RCP8.5 pathway (van Vuuren et al 2011).

Figure 58. Global land sector emissions for *National Outlook* global context scenarios and reference cases



Source: Calculated from van Vuuren et al. (2011), Treasury (2011) and GIAM.GTEM projections analysis as described in the text.

The third component of the analysis was to estimate the implications of the avoided deforestation or reafforestation involved in achieving this projected land sector abatement for the area of land available for food production (agricultural output for crops and livestock). All else equal, a smaller area of land for agricultural production will reduce supply, and thus put upward pressure on agricultural prices, increasing the profitability of food production relative to carbon abatement and reducing the incentive for additional land use change.

We assessed the scale of potential impacts on land availability through the following steps:

1. A number of reports relating to the Generalised Comprehensive Mitigation Assessment Process (GCOMAP) were identified as potential data sources for re-estimating mitigation potential. Results presented in Sathaye et al. (2005) were found to be most relevant and was used to determine the distribution of abatement from avoided deforestation and from reafforestation by each major region, for two carbon prices.

2. GCOMAP data on average carbon abatement per hectare (from the same source) was used to estimate land use change for deforestation and for reforestation for each region. Estimated abatement potential from avoided deforestation was reduced in Africa and South America to ensure global reference case emissions are consistent with the H1^, H2^ and H3 land sector emissions trajectories. The resulting trajectories were also cross checked against the Garnaut reference case (Treasury, 2011), and found to be consistent.

3. FAO data (Alexandratos and Bruinsma, 2011) on arable and harvested land was aggregated to broadly match GCOMAP regions.

4. The GCOMAP-based estimates of land use change were compared to FAO projections of total available land to calculate proportion of arable land ‘not available for agricultural production’ relative to the reference case (for the supply of arable land).

The results of this calculation are shown in Table 8. As shown in the table, the analysis finds that for a rising global carbon price of US$16 in 2015, the projected GCOMAP abatement would result in a 3%–5% reduction in available arable land in 2030 (for low to high population scenarios), and a 7%–8% reduction in arable land by 2050.

Table 8. Land sector abatement potential, and implications for the availability of arable land

			H1^ REFERENCE			H2^ REFERENCE			H3^ REFERENCE		
			2010	**2030**	**2050**	**2010**	**2030**	**2050**	**2010**	**2030**	**2050**
Carbon price	US$ (2010)		12.7	34.2	88.6	12.7	34.2	88.6	12.7	34.2	88.6
Land sector sequestration											
Forestation		Mt C	340	3819	10122	340	3819	10122	340	3819	10122
Avoided deforestation		Mt C	1127	720	810	1127	1530	1350	1127	2340	1890
Total		Mt C	1467	4539	10932	1467	5349	11472	1467	6159	12012
Implied change in land use (relative to reference)											
Forestation		Mha	4	41	108	4	41	108	4	41	108
Avoided deforestation		Mha	17	11	12	17	23	20	17	35	28
Reduction in land area		Mha	20	51	120	20	63	128	20	75	136
Share of harvested land		%	1.4%	3.5%	7.9%	1.4%	4.3%	8.4%	1.4%	5.1%	8.9%
Share of arable land		%	1.3%	3.1%	7.2%	1.3%	3.9%	7.7%	1.3%	4.6%	8.2%

Source: Analysis as described in the text, drawing on Sathaye et al. (2005) and Alexandratos and Bruinsma (2011).

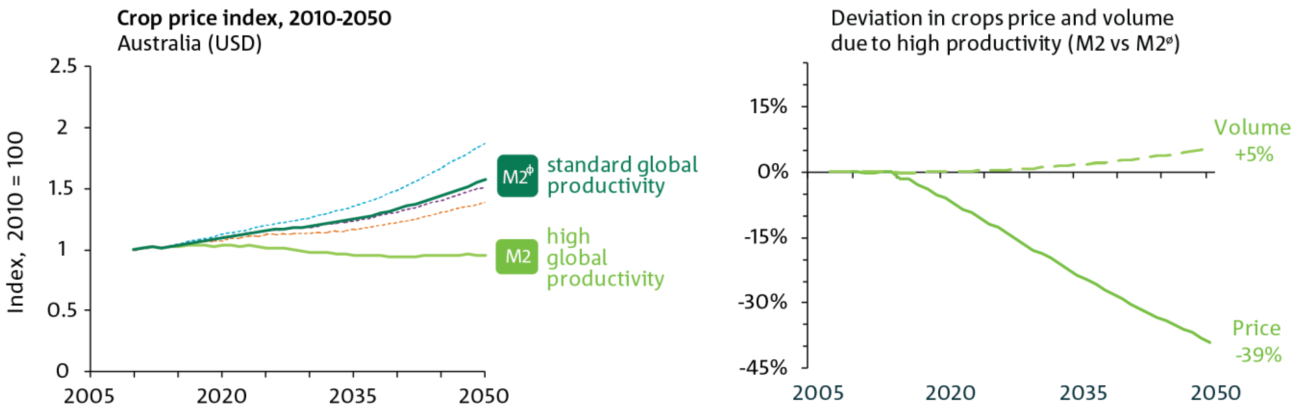
Interpreting these results and using them to inform the calibration of feedbacks from land sector abatement to global agricultural productivity and output is subject to several caveats. First, the estimates rely on the compatibility and consistency of the data and land areas that underlie the GCOMAP and FAO databases. The degree of this consistency is difficult to judge, suggesting that the resulting estimates should only be treated as indicative. Second, the calculations relate to land area, not land productivity. In general, the reduction in the area of available land would be expected to be larger than the reduction in average productivity of land, as there will be incentives to withdraw (or avoid clearing) the least productive land from an agricultural perspective. (This assumes that differences in agricultural productivity within the pool of potential arable land outweigh the differences in the supply of carbon abatement per hectare.) Third, the estimates are for one carbon price trajectory ($16 in 2015 to $89 in 2050). This trajectory closely matches the carbon price in the M2 scenario, which rises from $15 in 2015 to $71 in 2050. But it is significantly lower than the carbon price trajectories for other global scenarios. One perspective for comparing these trajectories is what year the lower price path reaches 2015 price of the other scenarios. The low price path reaches $30 (the starting price for M3) around 2030, and $50 (the 2015 price for L1) around 2040. This perspective is consistent with the view that higher carbon prices may ‘bring forward’ abatement and associated land use change, but not necessarily provide a proportional increase the long run global land sector abatement achieved.

Taking these considerations into account, the *National Outlook* analysis assumes relatively large reductions in agricultural productivity (relative to the reference case) as a result of projected land sector abatement. The calibration of these productivity losses was also informed by the early results from the detailed Australian analysis of potential land use change, particularly that abatement achieved increases less than proportionally (to price) for carbon prices above $40/CO_2$. For these reasons, the global analysis assumes that the M2 carbon price results in cumulative global reduction in land productivity of around 8% by 2030, and that the M3 and L1 carbon prices results in a cumulative reduction of around 12.5% by 2030.

Achieving a spread of agricultural export price outlooks

To achieve an appropriate range of agricultural export prices across the set of scenarios, the analysis assumed a higher rate of global agricultural productivity in the M2 scenario, reducing the projected trend increase in agricultural prices (and increasing output volumes). This variation results in crop and livestock prices in 2050 that are around 5% above or below 2010 prices in the final M2 scenario, in real Australian dollars, rather than 55%–60% higher without the higher productivity assumption. Crop prices in 2050 are 40%–80% higher than 2010 in the other scenarios (Figure 59, and see Figure 23).

Figure 59. Deviation in crop prices and output volumes from assumed higher agricultural productivity for M2 global scenario



Notes: Figure 59 shows projected change in real world grain prices from 2010–2050 across the global context scenarios, based on a USA dollar index ($2010). The left panel is the same as Figure 23, but shows what the raw M2 price trajectory would have been without the higher agricultural productivity as a dark green line. The right panel shows the deviation from the raw price trajectory (M2ᶲ) to the final M2 trajectory for price (lower) and output volume (higher).

Source: GIAM.GTEM (see Section 8.2, Table 3 for modelling references).

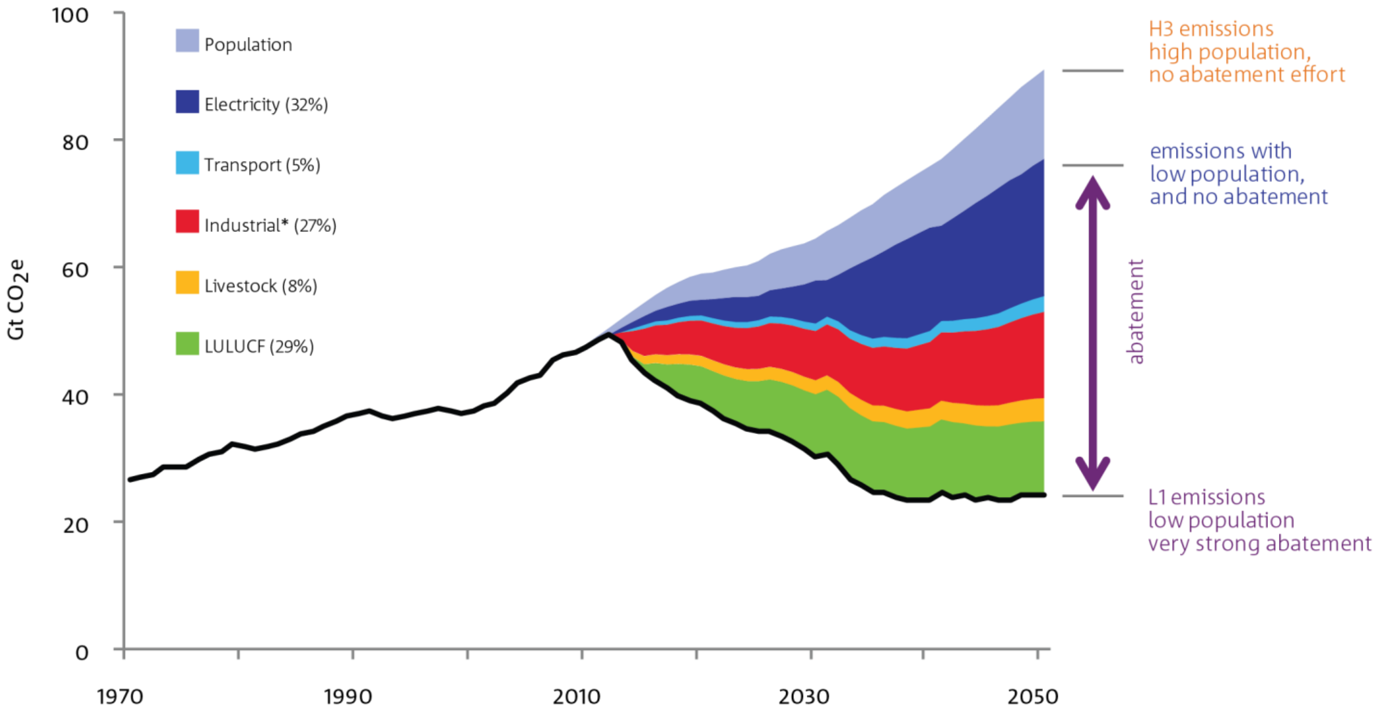
Comparison of global abatement impacts with previous studies

The modelling results are consistent with previous studies using the same core global economic model (GTEM, developed by ABARE), and similar models. With no action on climate change, annual global per capita emissions are projected to rise from 7 tCO_2e in 2010 to 9 tCO_2e in 2050 in the H3 scenario. Different levels of abatement incentives reduce global emissions by 45%–68% relative to projections with no abatement action (controlling for other factors), with per capita emissions in 2050 falling from current levels to 3 tCO_2e in L1, 4 tCO_2e in M3 and 5 tCO_2e the M2 scenario (see Figure 41Viewed on a per person basis, direct emissions in 2050 (before accounting for land sector credits) are projected to range from 31tCO2e per person (a 16% increase from current levels), to 15tCO2e per person (a reduction of up to 45%) in the very strong abatement scenarios. When land sector credits are included, emissions per person fall to -6tCO2e per person in the very strong abatement scenario, and 4tCO2e per person in the strong abatement scenario – implying a potential transformation from being one of the world's highest rates of emissions per person to matching the global average in the strong abatement (M3) global context scenario, or well below the average with very strong national and global abatement.

Figure 41 above). Cumulative emissions increase by 87%–186% across the four scenarios. Lags between emissions and changes in temperatures mean that differences in physical climate across the scenarios are relatively modest before 2050, but lock in major differences in climate outcomes over following decades. The analysis does not account for potential changes in climate variability of extreme events, and so understates the likely long term economic costs of climate change.

The analysis finds that around two thirds of the projected cumulative abatement comes from energy and industrial sources, and one third from land sector abatement and livestock emission, shown Figure 60. The analysis also finds that differences in population growth have a substantial impact on emissions in the reference case, which assumes no global abatement efforts (see Figure 60 below and Figure 56 above).

Figure 60. Global emissions and abatement by sector, selected scenarios, 1970–2050



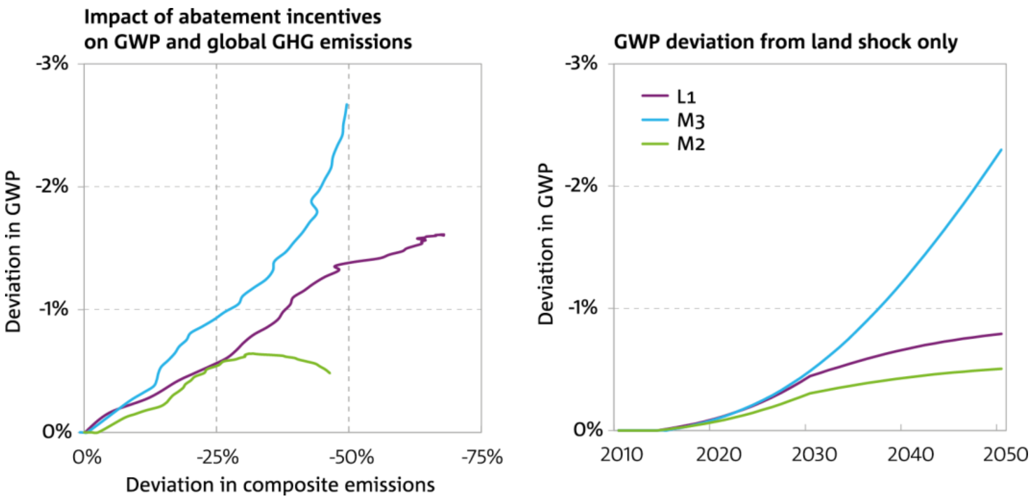
Notes: Population contribution shown in Figure 60 reflects the difference in global emissions under the high and low population trajectories. The abatement shown is for L1, and is calculated as the difference in emissions relative to low population reference case (with no abatement incentives). *Includes industrial gas use and non-energy industrial emissions.

Source: GIAM (see Section 8.2, Table 3 for modelling references).

The value of global economic activity (GDP) per person increases by around 110% in the H3 scenario from 2010–2050, with higher trend growth in global per capita income in scenarios with lower population growth (Figure 8 above). We find that global abatement efforts reduces the rate of economic growth, with global economic activity 1.4–2.9% lower in 2050 than it would be in the absence of action to reduce emissions, all else equal (see Figure 8 above). The effects for the Australian region in the global model are broadly similar, with abatement action reducing Australian GDP by 0.7%, 1.8% and 2.6% in 2050 in M2, M3 and L1 relative to H3. (As the global modelling does not allocate land sector abatement to nations or account for potential trade in international units, the global scenarios can be considered similar to CR domestic scenarios.)

The global economic impacts of abatement are broadly proportional to the volume of abatement achieved, as shown in Figure 61, with each 20%–25% reduction in emissions resulting in GDP being around 1% lower than it otherwise would be. We find that the impact of emissions reductions are larger in the high population scenario, particularly from 2040–2050, when global population in the M3 and H3 scenarios is 20%–30% higher than in the L1 scenario. These higher economic impacts reflect flow on effects of higher levels of competition for land (reflecting impacts of land sector abatement on food production, which are more significant with a higher global population), as shown in the right panel of Figure 61.

Figure 61. Impact of abatement incentives on global emissions and economic activity, deviation from reference case, 2015–2050



Notes: Analysis of abatement impact controlling for other factors, as measured by deviation from reference scenario. The abatement incentive is applied to livestock emissions in L1, but not in in M2 and M3. The dotted purple line provides a sensitivity analysis for L1 scenario excluding livestock emissions.

Source: GIAM, GALLM and analysis of land sector abatement (see Section 8.2, Table 3 for modelling references).

B.4 Analysis underpinning the domestic scenario assumptions

Implementing the *National Outlook* required analysis of untapped energy and water efficiency potential, and historical trends for working hours, consumption trends and agricultural productivity (denoted as [N], [P] and [Q] in Table 3 above). This analysis is summarised below.

Estimating untapped potential for improved energy and water efficiency

It is well known that households and businesses do implement all economically cost effective options for using water and energy efficiently. And thus, that greater uptake of resource efficiency options could reduce costs, improve productivity, and potentially reduce environmental pressures. Not all technically possible efficiency options are cost effective, however.

For this reason, the *National Outlook* analysis sought to identify the scope for implementing a step change in energy and water efficiency, defined as substantial uptake of all available options that would pay back any up-front capital expenditures through reduced energy and water costs over a period of three to five years.

The analysis was undertaken using the MEFISTO model, which uses a flexible accounting structure that parallels established data bases hosted by the ABS and Bureau of Resources and Energy Economics (Stark et al., 2012). Resource use and the uptake of efficiency options are driven by turnover of the stock of energy and water using assets for each sector. Projections were developed for energy and water intensity, defined as energy and water use (in physical units) per dollar of real value added for eight non-agricultural industry sectors and the residential sector. (Sector definitions are based on ANZSIC industry divisions.) Baynes (2015) provides more detail. The treatment of agricultural water efficiency is outlined at the end of this section.

The MEFISTO analysis drew on early access to the Industrial Energy Efficiency Analysis Tool (ClimateWorks Australia, 2013) originally developed by ClimateWorks in the context of the Industrial Energy Efficiency Data Analysis Project (IEEDAP). This data allowed identification of recent trends (or ‘business as usual’ projections) and the potential scope for a more ambitious step change in energy use, based on self-identified energy use and efficiency opportunities by industry.

The analysis found that recent trends would see modest continuing reductions in the energy and water intensity of most sectors, and the economy as a whole (excluding agriculture). The difference in overall energy intensity by 2050 is small (2.5%), but larger improvements are projected for water intensity (with cumulative reductions in water intensity of 20%). These trend improvements are small relative to projected economic growth, however, and total energy and non-agricultural water use will continue to increase.

The analysis of a potential step change found there is significant potential for improving the efficiency of energy and water use. The data and methods that underpin these estimates are focused on identifying realistic savings with a three to five year payback period for any additional capital costs involved in achieving these physical efficiency gains, after which the efficiency measures can be interpreted as saving money and improving overall productivity, as well as reducing the use of energy, water and other resources. The sectors with largest identified absolute energy savings are in transport (681 PJ/year) and manufacturing (469 PJ/year). For water, the largest absolute savings are in the commercial and services (1993 GL/year) and residential (1764 GL/year) sectors. In these sectors and the water supply and waste services sector, the water efficiency savings are larger than projected trend growth in value added, resulting in absolute decreases in water use to 2050.

Overall, as shown in Table 9and Table 10, the analysis suggests that achieving a step change in energy and water efficiency would reduce the demand for water and energy resources by up to 20% and 2% in 2020, and 48% and 17%, respectively, in 2050, relative to recent intensities. More detailed results are provided in Baynes (2015).

Table 9: Projected energy savings by 2020 and 2050 relative to sectoral energy intensity in 2011

ENERGY (PJ/YEAR)	2020		2050	
	Recent trends	*Step change*	*Recent trends*	*Step change*
Mining	0.8 (0.11%)	2.5 (0.36%)	34.8 (3.1%)	127.2 (11.3%)
Manufacturing	4.2 (0.28%)	10.1 (0.68%)	154.9 (8.3%)	468.6 (25.0%)
Construction	0.0 (0.10%)	0.3 (1.2%)	1.2 (3.0%)	3.3 (8.2%)
Transport	3.4 (0.18%)	100.8 (5.3%)	166.3 (5.2%)	681.1 (21.1%)
Commercial and services	0.0 (0%)	6.4 (1.7%)	0.0 (0%)	315.3 (48.9%)
Residential	5.3 (0.96%)	21.1 (3.8%)	-98.8 (-11.4%)	202.0 (23.4%)
Water supply and waste services	0.0 (0.13%)	0.04 (~0%)	0.6 (3.9%)	1.9 (13.3%)
Electricity generation	0.0 (0%)	0.0 (0%)	0.0 (0%)	0.0 (0%)
TOTAL	**14 (0.19%)**	**141 (2.0%)**	259 (2.5%)	1800 (16.9%)

Source: MEFISTO analysis, as set out in Baynes (2015)

Table 10. Projected water savings by 2020 and 2030 relative to sectoral water intensity in 2011

WATER (GL/YEAR)	2020		2050	
	Recent trends	*Step change*	*Recent trends*	*Step change*
Mining	-4 (-0.6%)	-3 (-0.4%)	-8 (-0.75%)	53 (5.0%)
Manufacturing	-59 (-8.2%)	-46 (-6.4%)	-93 (-10.2%)	383 (41.9%)
Construction	2 (7.7%)	2 (7.7%)	13 (28.3%)	13 (28.3%)
Transport	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Commercial and services	129 (8.51%)	165 (10.9%)	273 (10.7%)	1993 (77.7%)
Residential	634 (30.6%)	843 (40.7%)	1242 (38.3%)	1764 (54.4%)
Water supply and waste services	435 (26.7%)	436 (26.8%)	645 (33.4%)	691 (35.8%)
Electricity generation	14 (4.2%)	14 (4. %)	25 (5.3%)	25 (5.3%)
TOTAL	**1151 (16.5%)**	**1412 (20.2%)**	2097 (20.5%)	4921 (48.1%)

Source: MEFISTO analysis, as set out in Baynes (2015)

It is important to note that these estimates are of potential savings assuming a continuation of recent trends, or widespread adoption of cost effective efficiency measures. Achieving substantial improvements in energy efficiency would require actions by households, businesses and governments. Useful reviews of barriers to the uptake of energy efficiency, and potential constructive responses to these barriers, are provided in reports by ClimateWorks Australia (2013); Energetics (2004) and others (Petchey, 2010; Rickwood et al., 2008).

Water use trends in agriculture were treated in a different way in the scenario framing, focusing on total water use rather than water intensity. In the *Existing Trends* scenario, agricultural water use is capped in water limited states (NSW, Vic and SA), consistent with current policies), and follows previous trend growth in other regions. In the Step Change scenario, agricultural water use in water limited states is reduced by 15% over 30 years from 2020. Settings for new plantings ensure that water interceptions from new plantings in water limited catchments do not result in total water use exceeding current levels as share of available water. There are several reasons for this focus on total use. Total water use is already ‘capped’ or limited in many important irrigation areas (and varies from year-to-year as a result of rainfall). In practice this results in a different pattern of decision making, motivated by a desire to make the best use of available water, given a finite supply. This can be achieved by using water to produce different commodities, or by improving irrigation techniques and (on and off farm) water management. Water intensity can vary significantly due to differences in the value of output, both across different agricultural commodities and from year-to-year for specific commodities. The factors suggest that turnover in water using assets is not a suitable proxy for exploring agricultural water efficiency.

Assessing historical trends in consumption patterns and working hours

There is a widespread view that rising incomes are likely to see a shift from consuming tangible goods towards consuming services (see Hajkowicz et al., 2010), particularly 'experience oriented' services such as entertainment, hospitality (food and drink outside the home) and tourism. A more contested associated issue is whether rising incomes will see an accompanying shift towards increased leisure, and reduced average working hours, over people's working lives as a whole.

The *National Outlook* scoping process identified these issues as significant potential drivers of resource use and environmental pressure that would be interesting to explore. In particular, in high income countries lower working hours would – all else being equal – be expected to slow the rate of economic growth, and reduce resource use. (This logic might not apply in low income countries where use of natural resources is driven more directly by basic needs, and may not occur through markets.) But anecdotally, many people associate a shift towards greater leisure with increased tourism and travel – which can be very energy and emissions intensive, and potentially increase pressures on fragile ecosystems.

The ABS collects extensive data on working hours, and others had already used this data to assess recent trends in average working hours (NSC, 2012). They found that a clear decline in average working hours, falling 7% over the two decades to 2010 (see Figure 17). This was driven primarily by an increase in the share of people working part time, and supported by a decline in average hours worked by full time employees (from 41 to 39 hours per week from 2000 to 2012). The analysis also helps to explain why these trends are hard to observe anecdotally (rather than through statistical data). For example, while Australians work shorter hours than the OECD average, more than 15% of Australians work long hours (more than 50 hours per week), which is well above the OECD average. Also, while the share of people in part time employment has increased (decreasing average hours overall), the average hours of part time employees increased.

The ABS also collects extensive data on household expenditure and consumption, but this data has not been previously analysed to identify potential shifts towards experience oriented consumption.

Our analysis found that experience oriented consumption currently accounts for one fifth to one quarter of total household expenditure, and that lower income households spend proportionally less on experience oriented goods and services while higher income households spend proportionally more, as shown in Table 11. We define 'experience oriented consumption' to include expenditures on holidays, recreation, food and drink away from home, and recreation equipment (including for sport, photography and the like).

Table 11. Household consumption patterns, 1989–2010

		EQUIVALISED DISPOSABLE INCOME QUINTILE					TOTAL
		Lowest (a)	*Second*	*Third*	*Fourth*	*Highest*	
1998–99	Total consumption	578	809	1,049	1,206	1,500	1,020
	Experience oriented	88	136	200	249	335	200
	Share of total	15.2%	16.7%	18.8%	20.4%	22.0%	19.4%
2003–04	Total consumption	606	892	1,160	1,343	1,648	1,112
	Experience oriented	94	166	231	269	391	227
	Share of total	15.5%	18.6%	19.8%	19.9%	23.5%	20.3%
2009–10	Total consumption	684	1,026	1,267	1,556	2,029	1,296
	Experience oriented	125	205	284	348	515	292
	Share of total	18.2%	19.8%	22.3%	22.3%	25.2%	22.4%

Notes: Values are real AUD$ 2010, adjusted for inflation. (a) Excludes households with zero or negative income, quintiles are calculated on the basis of all households.

Source: Calculated from ABS (2013f) Customised report: HES data from 1998–99, 2003–04 and 2009–10, and ABS (2013e) 6401.1 Consumer Price Index, Australia

We then analysed unit record data from the ABS Household Expenditure Survey (HES) for the years 1998–99 and 2009–10 (ABS, 2013g), providing sample sizes of 6,800 and 9,700 for these years.[12] The HES collects household expenditure on over 600 goods and services (see ABS, 2012b, Appendix 6). These were combined to form 12 expenditure categories, which we report as three higher level categories: experience oriented consumption (EOC), material oriented consumption (MOC) – divided into 'shelter' and 'other'. Most, but not all, categories of EOC are services – such as tourism expenditure on holidays in Australia or overseas. But some EOC categories include goods, including sporting, leisure and recreational goods (surfboards, golf clubs, photographic equipment) and items that represent a mix of 'goods' and 'services' (such as restaurant meals). In the same way, some MOC categories include services, such as household maintenance or car repairs.

The analysis of unit record data examined the proportion of household consumption across each of the 12 expenditure categories as a function of household disposable income and time (survey year). Total household expenditure was used rather than disposable income due to concerns about the relationships between income and consumption in HES-style data. Expenditure amounts were adjusted to account for inflation and weighted to normalise the sample to the Australian population (ABS, 2000b; 2012b). The analysis used a fractional multinomial logit model, which is a multivariate generalisation of the fractional logit model proposed by Papke and Wooldridge (1996). This technique has several advantages over other regression techniques, including that it models multiple proportions simultaneously; ensures that the estimated proportions sum to one; and, accounts for interdependencies between proportions (that is if one proportion increases another must decrease).

[12] Further information on the samples, survey methodology and weighting procedures for 1998–99 and 2009–10 can be found in the relevant HES user guides for these years (Australian Bureau of Statistics 2000, Australian Bureau of Statistics 2012).

The analysis found that EOC had increased substantially as share of total expenditure over the decade to 2010, and that this is best explained as a combination of changes in income and a time based change independent of income. (Changes independent of income are likely to reflect shifts in consumer attitudes and social norms, and could also be influenced by changes in available technologies and consumption goods, and by shifts in relative prices of different types of goods and services.) As shown in Table 12, the analysis found that the consumption share of all seven categories of EOC were predicted to increase with income, and six of the seven were predicted to increase with time. (The exception was the share of expenditure on 'self-drive' holidays within Australia, which increase in real terms, but fall slightly as a share of consumption.) The last key finding was that expenditure trends relating to shelter (including furniture and household appliances, as well as rent, renovations and purchase of homes) are markedly different from the trends for other MOC. Expenditures on 'shelter' were essentially stable, growing in proportion to total household consumption, while other material consumption declined, driven primarily by a fall in food expenditure as a share of total consumption.

Table 12. Historical consumption patterns as a function of total expenditure and time

PROPORTION OF CONSUMPTION	CHANGE IN PROPORTIONS FOR AN ADDITIONAL DOLLAR OF CONSUMPTION				CHANGE IN PROPORTIONS OVER TIME (11 YEARS BETWEEN SURVEYS)			
	Mean Total Household Consumption		75th percentile		Mean Total Household Consumption		75th percentile	
	Coefficient	**z**	**Coefficient**	**z**	**Coefficient**	**z**	**Coefficient**	**z**
Experience oriented consumption (EOC)								
EOC – Meals out and fast food	0.0007%	15.5	0.0006%	13.1	0.8700%	7.9	0.8800%	7.3
EOC – Education	0.0005%	15.2	0.0006%	12.7	0.6200%	7.3	0.7300%	7.3
EOC – Recreation holiday: Australia transport	0.0002%	6.7	0.0002%	5.7	-0.0200%	-0.3	-0.0300%	-0.4
EOC – Recreation holiday: Australia other	0.0002%	10.6	0.0002%	9.5	0.0400%	0.7	0.0400%	0.6
EOC – Recreation holiday: overseas transport	0.0003%	11.8	0.0003%	10.4	0.3600%	4.9	0.3900%	4.8
EOC – Recreation: overseas other	0.0001%	11.7	0.0001%	10.0	0.2700%	8.4	0.3100%	8.4
EOC – Recreation: other experience	0.0009%	13.2	0.0008%	11.3	1.2000%	7.5	1.1800%	6.9
Material oriented consumption (MOC) – shelter								
MOC – Shelter house	-0.0044%	-25.9	-0.0042%	-30.0	1.2700%	4.5	1.0200%	3.9
MOC – Shelter contents	0.0005%	4.9	0.0003%	3.3	-1.3100%	-6.6	-1.4200%	-7.1
Material oriented consumption (MOC) – food, mobility, other								
MOC – Food	-0.0032%	-34.4	-0.0031%	-38.8	-4.3900%	-23.1	-4.0900%	-24.1
MOC – Mobility	0.0028%	25.5	0.0028%	21.5	1.3600%	5.4	1.3900%	5.2
MOC – Other	0.0015%	10.0	0.0014%	8.8	0.2700%	-1.1	-0.4000%	-1.5

Source: Calculated from ABS (2013g) HES CURF data, as described in text.

In practice, these shifts in historical trends in consumption shares occur through differences in the growth of different consumption categories. As shown in Table 13, household consumption increases in each of the three major categories (at rates that are further increased by population growth). Experience oriented consumption is projected to rise three times a quickly as total consumption, while overall MOC rises at less than half the total rate.

Table 13. Predicted change in levels of experience and material oriented consumption as a function of total expenditure and time

	CHANGE IN LEVEL (PER HOUSEHOLD)	
	per decade	***per 10% increase in income***
Experience Oriented Consumption (EOC)	42%	35%
Material Oriented Consumption (MOC)	5%	4%
MOC–shelter	10%	8%
MOC–food, mobility, other	1%	1%
Total	**12%**	**10%**

Source: Calculated from ABS (2013g) HES CURF data, as described in text.

The final component of the analysis involved two steps. First, the MMRF.H_2O modelling imposed 'neutral consumption' on the baseline domestic scenario (H3CR) to offset drift that would otherwise occur as a result of changes in income and relative prices (in the absence of specific model calibration). Second, the modelling imposed a conservative interpretation of the historical findings, calibrated to be around one third of the projected shift in consumption as a function of income. Results are reported in the section on living standards above. Analysis of the implications of the implications of these shifts in consumption for material flows and other indicators of environmental pressure will also be reported in research papers.

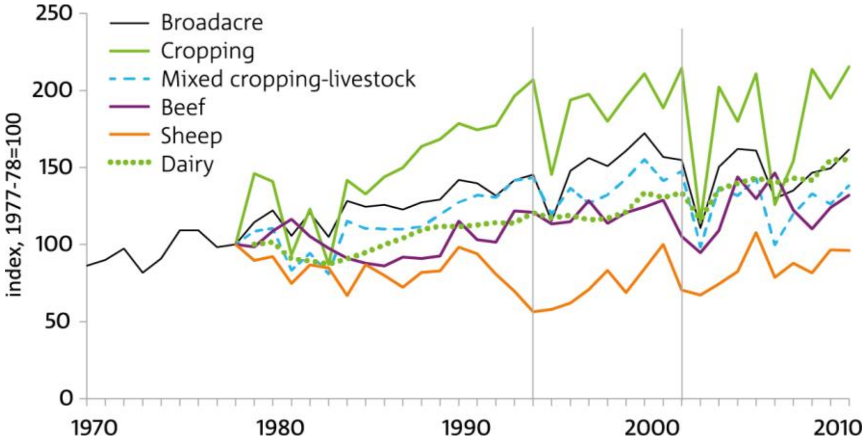
Identifying appropriate values for trend agricultural productivity

The development of the *National Outlook* scenarios identified agricultural productivity as a key driver of food production, adaptation to climate change, and rural land use choices – but also indicated that future trends in productivity are highly uncertain. One of the reasons for this uncertainty is that it is difficult to disentangle the impact of the recent prolonged drought on agricultural output to allow an estimate of productivity in the absence of climate variability.

This section reports the analysis of sector level agricultural productivity trends from 1978–2010, undertaken to inform the calibration of scenarios representing a continuation of existing trends and a step change improvement in agricultural productivity.

Total factor productivity compares the total outputs produced (various agricultural commodities) with total inputs consumed (land, labour, capital and other resources) to determine how effectively or efficiently inputs are converted to outputs. Data collected and aggregated by the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES) aggregates multiple inputs and outputs using a Fisher index (price index) to estimate historical changes in productivity over time (Grey et al., 2012). These results suggest that productivity growth over the past five decades accounts for more than half of the gross value of Australian agricultural production. Sector level productivity estimates are available from 1977/78, and are shown in Figure 62 and Table 14

Figure 62. Australian agricultural total factor productivity index by enterprise classification, 1970–2010



Source: Grey et al. (2012)

Table 14. Average Australian productivity growth for different periods, and the implications of the choice of period end points

COMPOUND ANNUAL RATE OF CHANGE	1977/78 TO 1993/94	1978/79 TO 1994/95	1993/94 TO 2001/02	1994/95 TO 2002/03	2001/02 TO 2009/10	2002/03 TO 2010/11
Cropping	4.6%	0.0%	0.4%	-2.9%	-1.2%	8.2%
Mixed cropping-livestock	2.3%	0.6%	0.4%	-2.4%	-1.9%	4.4%
Beef	1.2%	0.9%	-1.7%	-2.2%	2.1%	4.2%
Sheep	-3.5%	-2.7%	2.8%	1.9%	4.0%	4.6%
Dairy	1.3%	1.0%	1.3%	-0.1%	1.9%	3.7%
Broadacre	**2.4%**	**0.0%**	**0.8%**	**-0.5%**	**-0.4%**	**4.8%**

Source: Calculated from Grey et al. (2012)

This data indicates that there has been a clear long run trend improvement in agricultural productivity from 1978, but with substantial variability in productivity between years, and relatively modest improvements in broadacre productivity from 1993.

The data presented in Table 14 shows that this year on year variability means that average productivity rates over specific periods are highly sensitive to the choice of end points, with a one year change in the end points flipping average productivity from an increasing to a decreasing trend in many cases. The data also indicates that sector level productivity growth is far from smooth – sectors perform well for a period, then experience little or even negative productivity growth, or vice versa – and that productivity growth rates across sectors do not move together.

In light of these findings, the *National Outlook* analysis applies uniform productivity assumptions across all agricultural sectors within each scenario set, consistent with the goal of understanding the impacts of productivity changes on agriculture as a whole, rather than the change in relative shares of agricultural subsectors (as influenced by sector-specific productivity growth assumptions). As a result, and because subsectors grow at different rates in different time periods, it was decided that a stylised set of productivity assumptions would be most valuable.

The available data summarised above indicates that recent agricultural productivity trends are uncertain, but appear to be in the range of 0.5%–1.0% per annum. With this in mind the core *National Outlook* scenarios representing a continuation of recent trends assume agricultural productivity growth of 1.0% per annum. The step change scenarios assume a very ambitious sustained 2.8% annual productivity growth. These productivity rates are applied uniformly across all agricultural sectors, with lower rates applied to forestry and perennial crops (where cultivars are not able to be replaced or updated annually). This range both reflects uncertainty, and exploring the possibilities for land use and agricultural output if Australia can achieve a consistent high trend growth in productivity.

The detailed land use analysis undertaken in the LUTO model provided supplementary analysis of this issue, bracketing the recent trends estimate with analysis of the implications of 0%, 0.5% and 1.5% productivity growth, with results reported in the *National Outlook* science papers.

Insights into economic impacts on Australia of greenhouse gas abatement

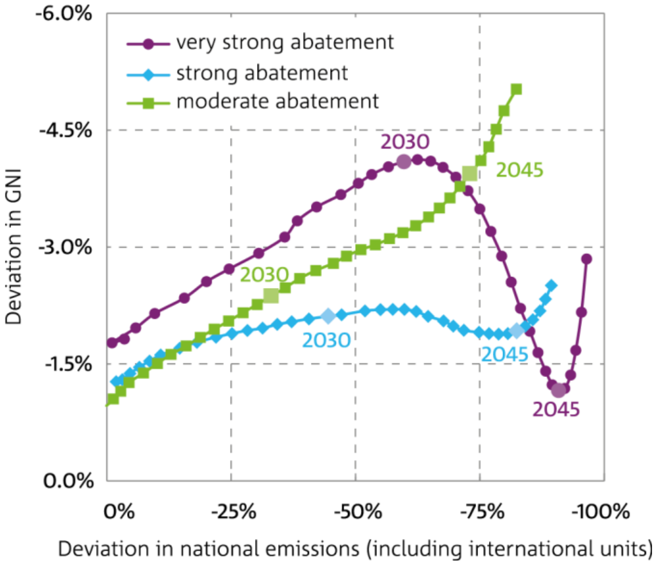
The set of *National Outlook* scenarios were not designed to support a detailed assessment of the impacts of different levels of abatement. Rather, they are designed to provide information on the outlook for Australian industry across a wide range of potential global contexts. These global contexts involve different levels of global population (effecting overall demand) and abatement effort (effecting the mix of specific supply options within sectors).

To allow comparisons to other analysis we provide results for the deviation in national emissions and national income for the three levels of abatement, relative to no national or global abatement action. The deviation in national income shown in Figure 63 represents the combination of two effects: the impact on Australia of other countries taking on more stringent emissions targets; and, the impact of Australia itself taking on more stringent targets. The *National Outlook* also does not assess any scenario where Australia takes on a more or less stringent target, with no corresponding change in the emissions reductions by other nations. To ensure a 'like-with-like' comparison, the analysis for this figure uses national emissions including the purchase or sale of international emissions units (as these capital flows are included in the definition of GNI). The relative magnitude of impacts on national income is not strongly affected by these capital flows.

A distinctive finding of the analysis is that strong action has lower economic impacts than moderate abatement in 2030 (and very strong abatement has a lower impact after 2035 – implying that an increase in global abatement effort could provide net economic benefits relative to *Existing Trends*. The reasons for this are complex and reflect a potential shift in comparative advantage where carbon plantings provide higher economic returns than livestock on less productive land (as discussed in Section 7.2). In particular, strong and very strong abatement settings result in new supply of domestic land sector sequestration before 2030, which does not occur under moderate abatement settings until after 2040. The benefits of this cost-effective abatement outweigh the more stringent national responsibility targets assumed for in 2030 and 2050, relative to moderate abatement with a lower target but a higher reliance on the use of international units. The time profile of yearly carbon sequestration from these plantings (after they are established) is the primary driver of the dramatic peak and trough in the economic impact of very strong abatement shown in Figure 63. The peak and trough effect for strong abatement is less dramatic due to a more gradual uptake of plantings up to 2035.

Relative to the hypothetical scenario where there is no global or national abatement, the economic impact of moderate abatement action is -2.4% of national income (GNI) in 2030. The impact of strong abatement is -2.1% in 2030 (less than the impact of moderate abatement), while the impact of very strong abatement is -4.1%. These figures overstate economic impact relative to a business as usual scenario (such as *Existing Trends*), which accounts for national and global abatement that is already occurring.

Figure 63. Deviation in national emissions and national income, relative to no global or national abatement, 2015–2050



Notes: The figure shows the deviation in national emissions (including import or export of international emissions units) against the deviation in national income (GNI). These deviations are for three XR scenarios relative to H3XR, with no global or national abatement action. In these scenarios, with no abatement national emissions are projected to increase by 79% from 2000 levels by 2050. With moderate abatement they fall by 68% below 2000 levels by 2050, while with strong and very strong abatement they fall by 81% and 94% below 2000 levels by 2050, respectively.

Source: National emissions from MMRF, ESM and LUTO; National income from MMRF (see Section 8.2, Table 3 for modelling references).

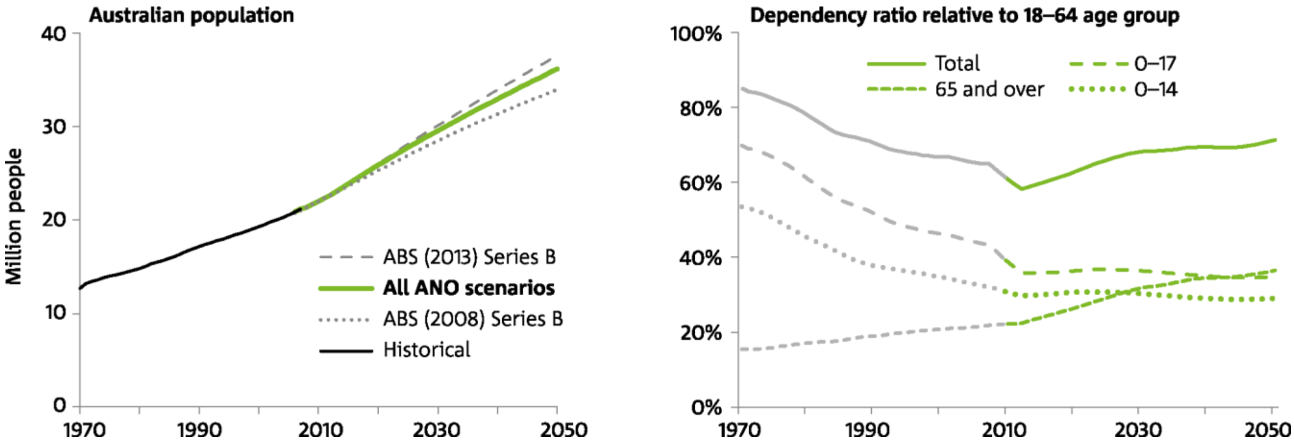
Population projections used in the *National Outlook* analysis

The domestic scenario analysis and projections are based on a single population scenario for Australia, and do not vary with global population growth. This population projection was commissioned by CSIRO from the ABS on the basis that the ABS (2008) projections were considered out-of-date but the new ABS population projections would not be available in time to be incorporated into our analysis.

The population projection (ABS, 2013a) is based on the 2011 Census and the medium fertility and mortality assumptions from the ABS (2008). It assumes net migration stabilises at 210,000 people per annum to 2050, driving population growth and slowing the aging of the population relative to what would occur without migration (as migrants are younger than the average population age).

The projection used in the *National Outlook* has since been superseded by the official projections published in September 2013 (ABS, 2013c). As shown in Figure 64, total population increases from 22 million people today to 36 million in 2050. This is an increase of 64% over four decades, a little slower than the 76% increase experienced from 1970–2010. Young dependents are projected to be stable as a share of population, at historically low levels, while the share of people 65 years and over rises from around one in five people today to around one in three people in 2050.

Figure 64. Population trajectory used in the domestic *National Outlook* scenarios, 1970–2050



Notes: Figure 64 shows the Australian population trajectory assumed for all *National Outlook* scenarios. The left panel shows total population in the context of ABS projections published in 2008 and 2013. The right panel shows the 'dependency ratios' for the population projection: the ratio of the number of people aged 65 and over, and aged 17 and under, in proportion to the number of people aged 18–64 (generally considered to be 'working age).

Source: ABS (2008; 2013a; 2013c)

Appendix C Guide to *National Outlook* papers

Supporting documents and materials

The key findings and results presented in this report are supported by more than 10 science papers, all of which are available on line at www.csiro.au/nationaloutlook. The data for all the charts in this report is also available online in spreadsheet format.

Reports	
Australian National Outlook 2015 Economic activity, resource use, environmental performance and living standards, 1970-2050	Main report, highlighting our key findings.
Australian National Outlook 2015: Technical report	Technical report, explaining methods and results in more detail.
Key science papers – Reporting *National Outlook* results and analysis	
Free to choose: Australia can achieve economic growth and dramatically reduce environmental pressure	Underpins Section 7. (see Hatfiield-Dodds, Shandl et al., 2015)
Australian retail electricity prices: Can we avoid repeating the rising trend of the past?	Underpins Sections 4.2 and 5.3 and analysis of emissions reductions from stationary energy. (see Graham et al., 2015; published in Energy Policy)
Australian self-sufficiency in transport fuel: Potential contribution of biofuels	Underpins Section 4.2 and 5.3 and analysis of emissions reductions from transport. (see Brinsmead et al., under review)
Potential for Australian land – sector greenhouse gas abatement and implications for land use, food, water and biodiversity	Underpins Sections 5 and 6 and analysis of land use trade-offs. (see Bryan et al., 2015; published report for the Australian National Outlook)
Land use and sustainability under intersecting global change and domestic policy scenarios: trajectories for Australia to 2050	Underpins Sections 5 and 6 and analysis of land use trade-offs. (see Bryan et al., under review)
Scenarios for Australian agricultural production and land use to 2050	Underpins Sections 5.1 and 5.2. (see Grundy et al., under review)
Outlooks for adaptive conservation of Australian biodiversity under global change	Underpins Section 6.1. (see Harwood et al., under review).

Foundation science papers – Documenting the *National Outlook* modelling capacity	
Integrated multi-model projections of Australian economic activity, resource use and environmental performance: New methods and insights	Describes the *National Outlook* modelling and analytical framework and advantages and disadvantages. (see Hatfield-Dodds, McKellar et al. under review)
A hybrid energy-economy model for global integrated assessment of climate change, carbon mitigation and energy transformation	Describes the global modelling framework (GIAM) and reports key results. (see Cai et al., 2015; published in Applied Energy)
Shrinking window of climate mitigation	Describes enhanced global modelling framework including climate damages (GIAM), and reports scenarios from which the global scenarios were developed. (see Newth et al., under review)
Modelling continental land use change and ecosystem services with market feedbacks at high spatial resolution	Describes land competition in the land use trade-offs model (LUTO), and reports key results. (see Connor et al., 2015; published in Environmental Modelling and Software)
Supply of carbon sequestration and biodiversity services from Australia's agricultural land under global change	Describes the treatment of carbon and biodiversity in the land use trade-offs model (LUTO), and reports key results. (see Bryan et al., 2014) published in Global Environmental Change.
Assessing the potential for a step change in energy, water and resource efficiency, 2010–2050	This report outlines the data and methods used to estimate implications of a continuation in current trends in energy and water intensity over the period to 2050, and the potential impact of widespread uptake of cost effective efficiency measures. (see Baynes, 2015; published report for the Australian National Outlook).
Decoupling global environmental pressure and economic growth: scenarios for energy use, materials and carbon emissions	Describes the analysis of global material and energy use and carbon emissions, on a production basis and footprint (consumption) basis, and reports key results. (see Schandl et al., 2015; published in Journal of Cleaner Production)

Appendix D Contributors and Acknowledgements

This report has been prepared by CSIRO in collaboration with our university partners.

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Glossary

TERM	DEFINITION
Abatement incentives	Incentives to reduce greenhouse emissions or to supply sequestration from reafforestation. The incentives apply to covering all sources of emissions (fossil fuel combustion, industrial emissions, fugitive emissions from coal and gas extraction, and livestock) in the very strong abatement scenarios, and all sources other than livestock emissions in the moderate and strong abatement scenarios.
Agricultural productivity	The ratio of output value (or volume) achieved from given inputs. Improved productivity allows more output from the same inputs.
Arable land	Land suitable for use in agriculture. Does not include arid land.
Bioenergy	Energy produced from crops or plant-based feed stocks, including bioelectricity and biofuels.
Biofuels	Transport fuels produced from crops or plant-based feed stocks.
Biophysical flows	Annual extraction, use and return of non-renewable resources, biomass, and wastes (including minerals, energy, agricultural products, and greenhouse gas emissions) associated with economic activities.
Biophysical processes	Biological and physical processes, usually measured in physical terms such as tonnes of grains, megalitres of water, or joules of energy used as inputs or outputs in a specified period of time. Often contrasted with monetary processes, measured in dollars.
Business cycle	Refers to deviations in the rate of economic growth, sometimes called ‘booms’ and ‘busts’ or ‘recessions’. A key goal of macroeconomic policy is to reduce the extent of these deviations to avoid unnecessary economic disruption.
Carbon capture and storage (CCS)	Capture of carbon dioxide emissions from fossil fuel combustion and long term storage, usually in underground reservoirs, avoiding or reducing emissions to the atmosphere.
Carbon farming	Reforestation of cleared land to sequester carbon. See ‘carbon plantings’ and ‘habitat plantings’.
Carbon plantings	Reforestation using single species plantations of native trees (usually eucalypts) chosen to maximise carbon sequestration rates at a given location.
Carbon sequestration	Carbon dioxide withdrawn from the atmosphere and stored in plants. Can refer to carbon stored in soils, or carbon capture and storage (CCS).
Economic decoupling	Refers to an outcome where the value of economic activity increases (in dollar terms), while environmental pressures decrease. Relative decoupling refers to a reduction in environmental pressure per dollar of economic activity, while pressures are increasing.
Economic drivers	Key assumptions or trends that shape the patterns and character of future economic activity and performance.
Economic growth	Refers to the increase in the value of economic activity over time, usually as measured by Gross Domestic Product (GDP) in real terms, adjusted for inflation.
Ecosystem services	Refers to the multiple ways that native plants, animals and natural systems are of value to people. Healthy ecosystems are likely to provide or maintain a wider range of services, and higher quality services, than degraded systems.
Energy efficiency	The ratio of energy service provided (such as passenger kilometres travels) from a given energy input. Improved energy efficiency implies the value of energy saved over time is larger than the associated cost.
Energy intensive industry	Industry sectors that use high levels of energy inputs per dollar of output, including aluminium smelting, iron and steel production, pulp and paper, mining, water supply and transport.

TERM	DEFINITION
Environmental pressures	Refers to states or trends that put natural assets and ecosystems under stress, and are likely to damage or degrade these assets and systems if pressures continue or are not managed appropriately.
Extractive water use	Water taken from rivers, lakes, dams or groundwater storages. Does not include supply from desalination or water recycling, or interceptions of surface water by plantings and land use change.
Greenhouse gas abatement	Reductions in net greenhouse gas emissions (including carbon sequestration), measured or assessed relative to a specific scenario or reference case. Abatement may refer to lower growth in emissions than occurs in the reference case.
Habitat plantings	Reforestation using mixed species plantings to restore local ecosystems, providing biodiversity benefits and carbon sequestration. In the National Outlook analysis most plantings are located to maximise biodiversity benefits.
Historical data	Statistical information based on observations and measurements, generally for the period 1970-2012.
Hydropower	Electricity generated from water, such as by the Snowy Mountains Hydro-Electric Scheme.
Institutional settings	Policies, practices and regulations – particularly implemented by government and government agencies – that shape the operating context of business decision making and resource allocation.
Intensive use zone (with respect to agriculture)	Agricultural land cleared for cropping, horticulture and livestock production, accounting for 85 million hectares of land across south-western Western Australia, the south eastern States including Tasmania, and eastern Queensland.
Land-sector	Agricultural activity and other industries based on rural land, including forestry and carbon and habitat plantings.
Land sector credits	The supply (and sale) of emissions offsets from carbon sequestration associated with carbon and habitat plantings.
Low emissions technology	Capital assets that deliver services (such as electricity) with lower greenhouse emissions than alternative approaches (such as wind power relative to coal fired power).
Material intensive industry	Industry sectors that use high levels of material inputs per dollar of output, including agriculture, energy commodities (coal, gas), mining, water supply, and most energy intensive industries.
Megatrends	A megatrend is considered to be a long term shift in technology or social, economic, and environmental conditions that could substantially change the way people live.
Natural assets	Biophysical systems and processes that underpin the supply of ecosystem services and natural resources, and contribute to human health and well-being.
Natural resources	Commodities extracted from nature-based systems that provide inputs to economic processes, such as grains, meat, water, timber, minerals, coal, and gas. Does not include non-consumptive use, such as tourism in national parks, or ecosystem services.
Negative emission energy	Potential technologies that supply energy and achieve net decreases in greenhouse gas concentrations (the stock of gases in the atmosphere).
Non-petroleum powered road transport	Road transport powered by biofuels, gas (LPG, CNG), or electricity.
Peak demand (energy)	The level of maximum demand for electricity over the course of a day, or during the year (such as in heat wave conditions, due to air use of conditioners).
Per capita income	Average income per person, usually measured by Gross National Income (GNI) per head of population.
Physical decoupling	Outcomes involving a simultaneous increase in services derived from national resources (such as energy, water, food) while pressures on those resources decline.
Physical economy	Economic activity and change understood in physical terms (flows of materials and energy, tonnes of resource extraction). See also ‘biophysical processes’ and ‘economic decoupling’.

TERM	DEFINITION
Policy settings	The rules and institutions that shape economic and social activity, including resource use, the generation and disposal of wastes, and modifications to natural ecosystems.
Projections	Quantified future trajectories of key variables for one or more scenarios, representing possible futures.
Representative Concentration Pathway (RCP)	Four benchmark scenarios of greenhouse gas concentration trajectories used in IPCC (Intergovernmental Panel on Climate Change) modelling and research, to allow comparisons across studies assessing climate change projections, impacts, and adaptation options. The RCPs were adopted by the IPCC for its fifth Assessment Report (AR5) in 2014, and supersede Special Report on Emissions Scenarios (SRES) scenarios published in 2000.
Resource intensity	Quantities of energy, water and other material inputs used per dollar of economic activity in a sector or nation.
Resource efficiency	The ratio of resource inputs to the value of outputs. Inputs can be defined in physical units or terms of economic value or cost. Improved resource efficiency implies that the costs involved are more than outweighed by the benefits.
Scenario based approach	Approaches that explore a range of potential futures, rather than focusing on one (most likely) future. Can be used to identify the implications of different choices or pathways.
Scenario projections	Model-based descriptions of potential futures, including indicators of key variables, to allow detailed quantitative comparisons across alternative outlooks.
Sensitivity analysis	Analysis of the implications of varying specific modelling assumptions or parameters or inputs – including assumptions about scenario drivers – to test and understand their significance.
Social drivers	Societal trends or circumstances that are expected to have a significant influence on future risks, opportunities and outcomes.
Sustainable prosperity	Economic development that improves human wellbeing and social resilience, while significantly reducing environmental risks and damage to scarce natural resources and ecosystem services
Synergies	Refers to ‘win-win’ situations where two or more desirable things can be achieved simultaneously, without an increase in an undesirable outcome. Often contrasted with ‘trade-offs’.
Tipping points	Situations where a small incremental change triggers a disproportionate (or non-linear) response in a system, including situations where the change is difficult or impossible to reverse.
Trade-offs	Refers to situations where achieving more of a good thing involves an increase in an undesirable outcome. Often contrasted with ‘synergies’.
Voluntary conservation payments	Payments to landholders who choose to restore and protect native plants and animals, and native habitat and ecosystems.
Water-energy-food nexus	Refers to the multiple interactions and feedbacks among water, energy and food systems, and between those systems and the people, landscapes and ecosystems who depend on nexus resources.
Water limited catchments	Catchments where current levels of water use are close to, or exceed, levels that are needed to maintain key ecological functions. In the National Outlook analysis ‘water limited catchments’ are defined as Class C and D catchments, as identified by the National Water Commission (2012).
Water security	Refers to the reliability of access to water, particularly in drought or other dry periods.

Acronyms

ACRONYM	DEFINITION
ABARES	Australian Bureau of Agricultural and Resource Economics and Sciences
ABS	Australian Bureau of Statistics
CCS	Carbon capture and storage
CGE	Computable general equilibrium model, also referred to as a an economy wide model (covering all sectors)
CO_2e	Carbon dioxide equivalent
DSE	Dry (non-lactating) sheep equivalent, in relation to meat output or feed requirements
ESM	CSIRO's Energy sector model
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
GALLM	CSIRO's Global and Local Learning Model, which provides projections of electricity generation technology costs
GCOMAP	Generalised Comprehensive Mitigation Assessment Process
GDM (biodiversity Assessment)	Generalised dissimilarity modelling, modelling to analyse and predict patterns of beta diversity in regional biodiversity assessment
GDP	Gross domestic product
GIAM	Global integrated assessment model
GIAM.GTEM	Global trade and environment model
GIAM.SCCM	Simple Climate Change Model
GNI	Gross national income
GNP	Gross national product
Gt	Gigatonne (1 Gt = 1,000,000,000 tonnes)
GWP	Gross World Product
GWyr	Gigawatt-year (1 GWyr = 1,000,000,000 Wyr = 8,760,000,000 kWh)
LULUCF	Land use, land-use change and forestry
LUTO	CSIRO's Land Use Trade Offs model
MEFISTO	CSIRO's Material and Energy Flow Integrated with Stocks model
Mha	Million hectares
Million DSE	Million dry (non-lactating) sheep equivalent
MMRF/MMRF.H_20	Monash Multi-Regional Forecasting model of the Australian economy, now maintained by Victoria University
Mt	Megatonne (1 Mt = 1,000,000 tonnes)
NIAM	CSIRO National Integrated Assessment Model
NIAM.FLOW	CSIRO's model used to assess and project surface water flows
ppm	Parts per million
Solar PV	Solar photovoltaic
TL	Teralitre (1 TL = 1,000 GL, 1 GL = 1,000,000,000 litres)
UN	United Nations
USA	United States of America
USD	United States dollars

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