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Australian National Outlook 2015

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

October 2015

Foreword

The *National Outlook* is a ground-breaking attempt to model and analyse Australia's physical economy and natural resource use many decades into the future.

It provides the most comprehensive analysis of its kind yet undertaken, including several advances in scientific capacity, and identifies a number of areas for future public deliberation and scientific exploration.

National Outlook focuses on the emerging water-energy-food nexus, and the prospects for Australia's energy, agriculture, and other material intensive industries in the context of multiple uncertainties and opportunities, with particular attention to potential synergies and trade-offs within and across economic sectors.

National Outlook is a unique tool to help us navigate to prosperity through an uncertain future, by providing a scientific assessment of the complex connections and interactions between economy activity, resource use and the environment.

CSIRO is sharpening its focus on innovation. With this report we build upon our analysis of key global megatrends, to give a sharper focus on implications and opportunities for Australia, as a precursor to helping create market roadmaps for – and with – each of the industries we serve.

This report presents key findings, with further detail provided in a technical report and scientific papers published in peer-reviewed journals, including Nature. To help ensure that the *National Outlook* modelling and interpretation are rigorous and based on the best available science, CSIRO marshalled a distinguished external review panel from Australian and international institutions, representing a broad range of relevant disciplines, in addition to rigorous internal review.

While science can provide new evidence and insights, how we respond is the decision of individuals, firms and communities.

Our hope is that this *National Outlook* is just the beginning. Future directions for this integrated capacity might include deepening our analysis of economy-wide interactions, and better incorporating aspects of our urban systems, such as the interactions between nutrition, mobility and health.

We entrust these findings to our national discussions and open them to private decision-making, and hope above all that this analysis will enrich the ongoing conversations between policy makers, market analysts, and the public, as we navigate our nation to a prosperous future.

Dr Larry Marshall
Chief Executive, CSIRO

Statement by the External 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, by no means exhaustive, of 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 *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 non-indigenous 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, and 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.

Professor Alan Randall

Chair, External Expert Review Panel
University of Sydney, Australia
Ohio State University, USA

Professor Peter Bridgewater
Australian National University, Australia and Beijing Forestry University, China

Professor Neil Byron
University of Canberra, Australia

Professor Pavel Kabat
International Institute for Applied Systems Analysis (IIASA), Austria

Dr John Radcliffe
Honorary Research Fellow, CSIRO, Australia

Professor Matthias Ruth
Northeastern University, USA

Professor Sangwon Suh
University of California Santa Barbara, USA

Executive summary: *Australian National Outlook 2015*

Scope and purpose: helping to navigate the future

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 consideration and action. The investments and other changes required will not happen overnight. There is no overstating of the challenges for policymakers, industries and communities in navigating the transitions needed to secure our future prosperity.

Key messages and findings

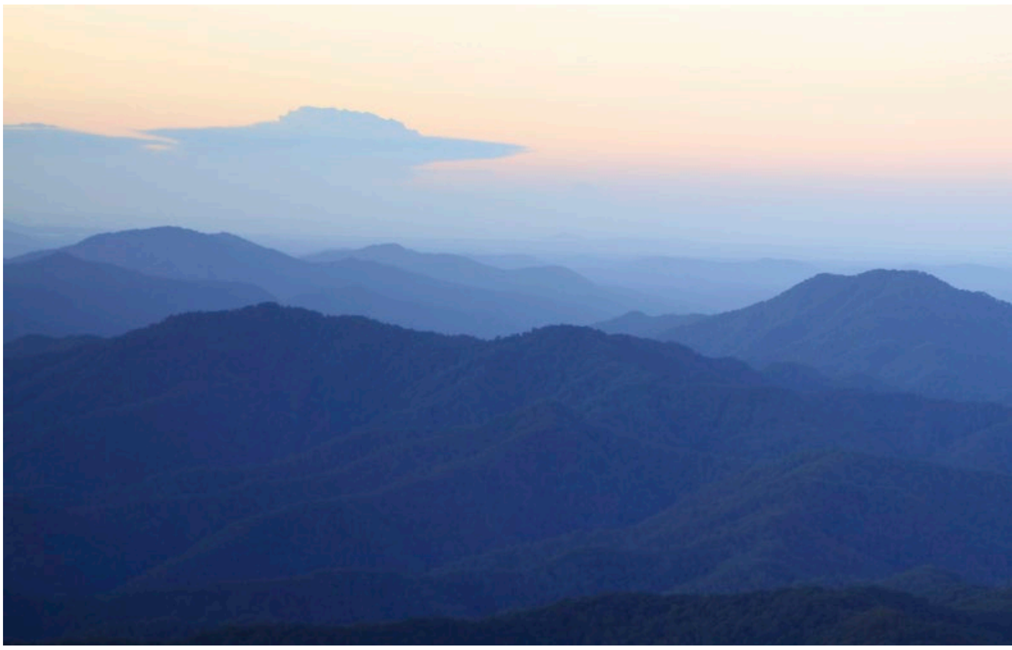
Australia has the capacity to pursue economic growth, sustainable resource use and reduced environmental pressures simultaneously. Policies and institutions will be essential to realise Australia's full potential and manage the associated trade-offs and risks. Australia can benefit from the positive 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 to 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 reducing costs, improving air quality, and reducing greenhouse gas 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.

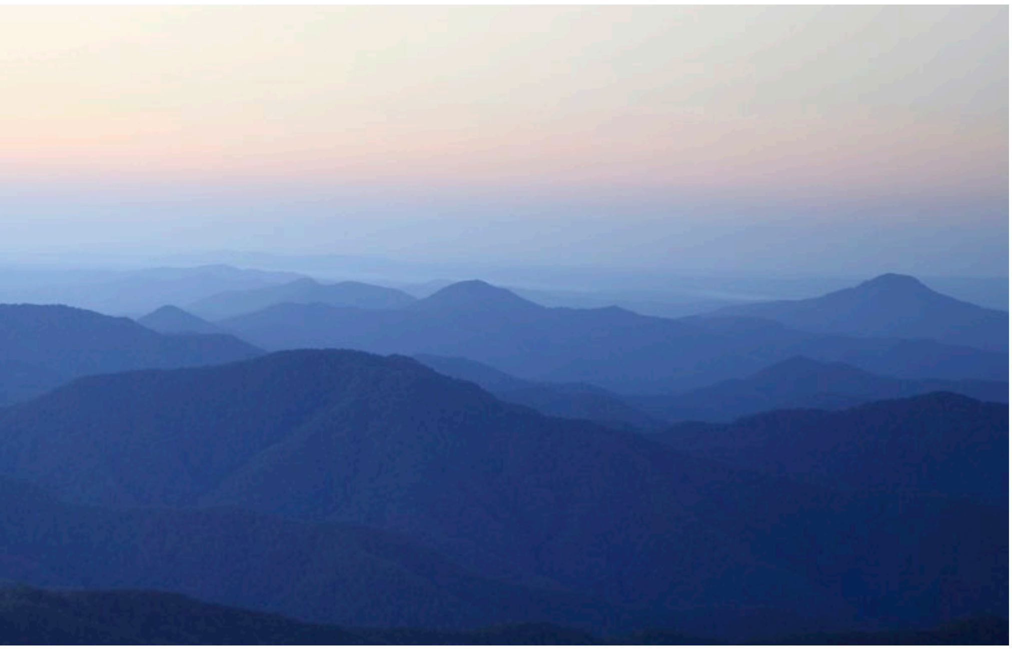
Policies and institutions are central to unlocking potential benefits and managing trade-offs and risks. Collective decisions account for 50-90% of the differences in resource use and natural assets across the scenarios in the *National Outlook*, resulting in synergies in some cases and trade-offs in 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, 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 A$40-60 per tonne of CO_2e 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.




DETOUR
BRIDGE
TUNNEL

Contents

Introduction:
Helping to navigate Australia's future

Australia is unique. A small, stable democracy responsible for a vast island continent; a significant exporter of food, minerals and energy; and host to more diverse species and ecosystems than any other nation. In coming decades, all of these attributes are likely to be in short global supply. The demand for them will put pressure on Australian land, water, energy resources and ecosystems – and on how we make decisions about them. Australia already has one of the most variable climates in the world, and this variability will increase with climate change. We need reliable analysis and insights to help navigate that future, though none will be complete.

This first Australian *National Outlook* seeks to provide a better understanding of Australia's physical economy, with a particular focus on two things. The 'water-energy-food nexus' (and the links between these essential resources and wider human and natural systems – see box on page 3), and the possibilities 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 (see Figure 2).

Over 40 researchers have applied nine evidence-based physical and economic models to develop this understanding, exploring more than 20 potential trajectories for Australia over the next 35 years. Those trajectories reflect different potential private and public choices – in Australia and overseas – and their implications for Australian income, resource use, and natural assets in a complex and uncertain world. The results and our interpretations have been reviewed by a panel of external experts, and tested with diverse stakeholders.

It is CSIRO's role to help the Australian community navigate an uncertain future, and enhance Australia's long term prosperity.

We find that sustainable resource use and economic growth can be partners not competitors. Australia has the technology to pursue both at the same time, and with sound policies and institutions, can benefit from the positive outlook for its living standards, natural resources, and environmental assets.

Beneath this finding there are many insights relevant to Australian policy makers, businesses, and citizens. These are summarised in this document and in *National Outlook – Technical Report,* and more than ten supporting articles written for peer-reviewed scientific journals.

As extensive as our work has been, it is only a first step. We plan further *National Outlooks* every three to five years, likely focusing on different issues, but always seeking to integrate and distil the best available data and analysis.

It is CSIRO's role to help the Australian community navigate an uncertain future, and enhance Australia's long term prosperity.

We find that sustainable resource use and economic growth can be partners not competitors. Australia has the technology to pursue both at the same time, and with sound policies and institutions, can benefit from the positive outlook for its living standards, natural resources, and environmental assets.

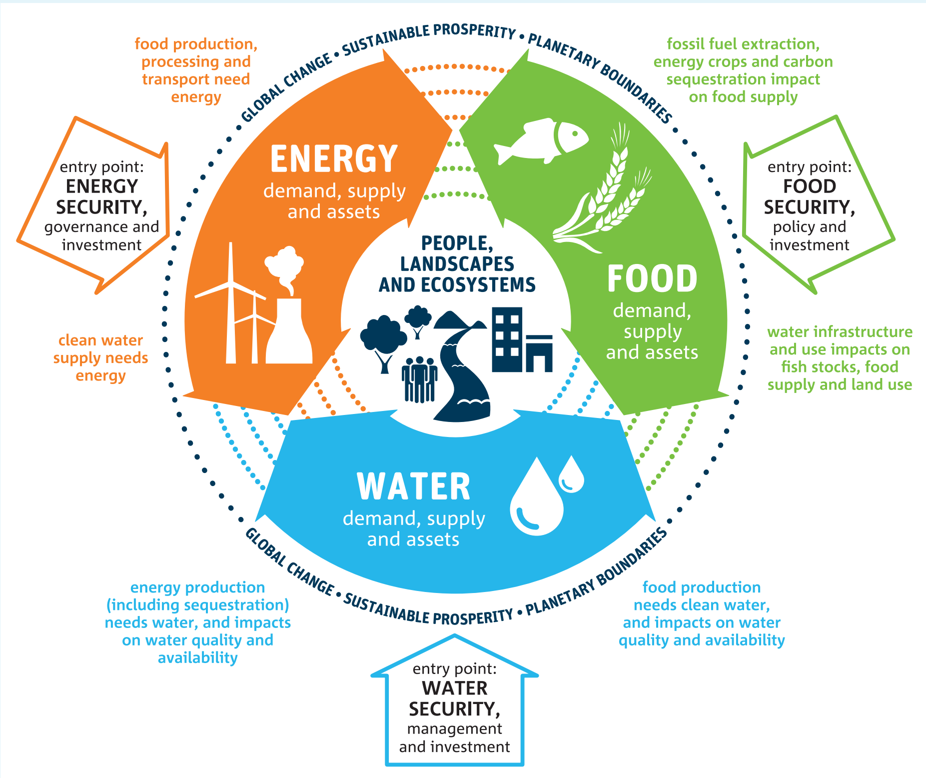
Exploring the "Water-Energy-Food nexus"

Recent years have seen growing attention to the complex interactions between water, energy and food systems – often motivated by concerns about potential conflicts between meeting the water, energy and food needs of an increasing global population, while maintaining the health of often already stressed natural assets. The World Economic Forum identifies these interactions as a major emerging global risk,[1] and explains crisply that "Any strategy that focuses on one part of the water-food-energy nexus without considering its interconnections risks serious unintended consequences."

The literature on the nexus is still evolving, and there is no single agreed definition or approach. The National Outlook analysis treats the nexus as having four interconnected elements: water, energy and food systems, each interacting with the people, landscapes and ecosystems that support and depend on nexus resources. As shown in Figure 1, these interconnected elements are located in the wider context of global change (including population growth, urbanisation and climate change), planetary boundaries (referring to the safe operating limits of crucial natural systems[2]) and aspirations for sustainable prosperity.

One of the attractions of applying a 'nexus approach' is that it provides a series of practical entry points for exploring universally relevant issues around resource security, access and management – and connects these to the everyday circumstances and needs of specific communities. For example, policies to support the production of biofuels can improve energy security and reduce net greenhouse emissions, but may have adverse impacts on food security. Or shifts to best practice farm management may reduce soil erosion and nutrient runoff into streams, providing win-win improvements in water quality and food output (as well as increasing farm income). Analysing these issues from a nexus perspective helps ensure that wider interactions like these – and associated trade-offs and synergies – are properly accounted for in decision making.

FIGURE 1 **ELEMENTS OF THE WATER-ENERGY-FOOD NEXUS, AND KEY NEXUS LINKAGES**



Source: Adapted from Smajgl and Ward 2013.

1 World Economic Forum (2011) *Global Risks 2011 (Sixth Edition)*, World Economic Forum, Geneva: page 7

2 Griggs, D., M. Stafford-Smith, O. Gaffney, J. Rockstrom, M.C. Ohman, P. Shyamsundar, W. Steffen, G. Glaser, N. Kanie and I. Noble (2013). Policy: Sustainable development goals for people and planet. *Nature* 495 (7441), 305-307

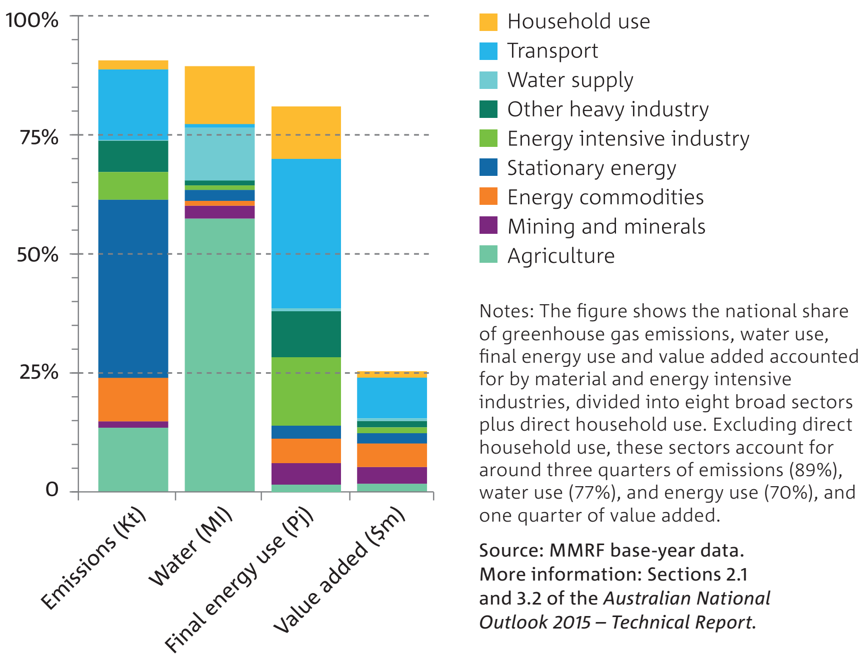
Purpose and scope of the *National Outlook*

CSIRO is focused on delivering new technologies and science-based solutions that benefit industry, society and the environment. The *National Outlook* is a new initiative, 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.[3]

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 over another. Rather, we hope this report will provide an evidence base for a series of national conversations about our opportunities and challenges, and how Australia might position 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, businesses, and policy makers. 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 uniquely Australian context in relation to plausible technological and policy settings we must consider as a nation to secure our future prosperity.

Consistent with CSIRO expertise and mandate, the *National Outlook* focuses on the physical economy, particularly the water-energy-food nexus and the prospects for material and energy intensive industries – which account for around three-quarters of our use of energy, water and materials, but one-quarter of Australian economic value and employment (see Figure 2). No analysis can account for every issue – see the box on page 7 for a discussion of issues that are outside the scope of the *National Outlook*.

FIGURE 2 **CONTRIBUTION OF MATERIAL INTENSIVE SECTORS TO AUSTRALIAN GREENHOUSE GAS EMISSIONS, WATER USE, ENERGY USE, AND VALUE ADDED, 2012**



Notes: The figure shows the national share of greenhouse gas emissions, water use, final energy use and value added accounted for by material and energy intensive industries, divided into eight broad sectors plus direct household use. Excluding direct household use, these sectors account for around three quarters of emissions (89%), water use (77%), and energy use (70%), and one quarter of value added.

Source: MMRF base-year data.
More information: Sections 2.1 and 3.2 of the *Australian National Outlook 2015 – Technical Report*.

3 This report uses 'sustainable prosperity' to refer to economic development that improves human wellbeing and social resilience, while significantly reducing environmental risks and damage to scarce natural resources and ecosystem services. This notion is similar to the ideas of 'sustainable development' and more recent articulation of 'green growth economy' (see O'Connell et al. 2013, Griggs et al. 2013).

> **The analysis for the *National Outlook* adopts a scenario based approach to explore multiple uncertainties.**

Our analytical framework

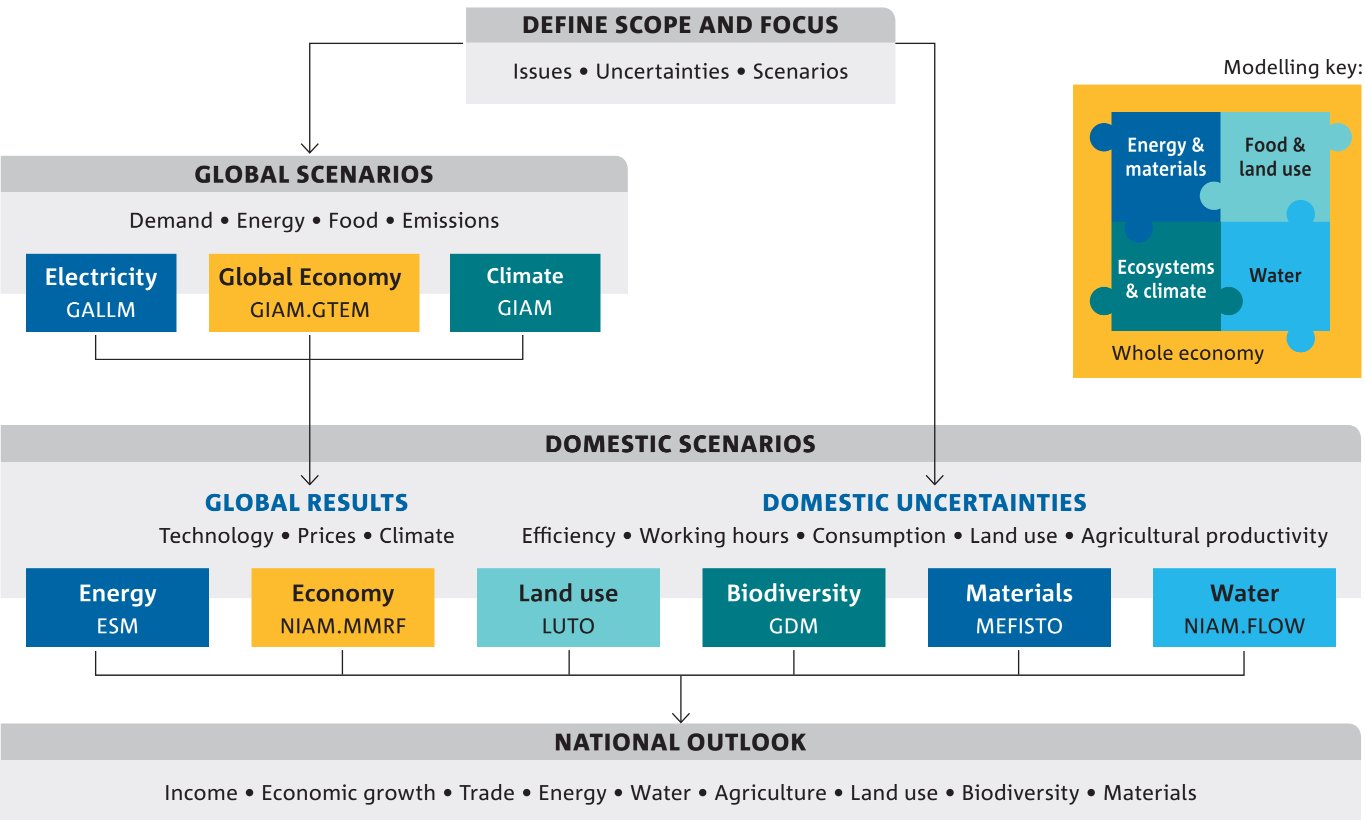
All decisions involve a view about the future, and about the implications or merits of choosing one thing over another. However, social and economic systems are complex, and their trajectories and consequences are notoriously difficult to predict. So the analysis for the *National Outlook* adopts a scenario based approach to explore multiple uncertainties.

Our approach is summarised in Figure 3 below. We first established the range of global and national issues and uncertainties to be explored: see the section on 'issues and scenarios' on page 6. We 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 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 this report and the 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).

The models vary in their scope, purpose, structures, variables, spatial resolution and dynamics. Many are the current versions of models that have been used to analyse national and global policy issues for more than 20 years. The coloured rectangles in Figure 3 show their primary focus (global or national economy, food and land use, water, ecosystems and climate, energy and materials). 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 model multiple complex interactions between biophysical processes and economic activities, to obtain a more holistic picture.

For further details on our modelling see Appendix A of this report and Section 8 of the Technical Report.

FIGURE 3 **OVERVIEW OF THE NATIONAL OUTLOOK ANALYTICAL FRAMEWORK, AND PROJECT FLOW**



Source: *National Outlook* project team. More information: See Appendix A, including box on summary of models.

The issues and scenarios explored

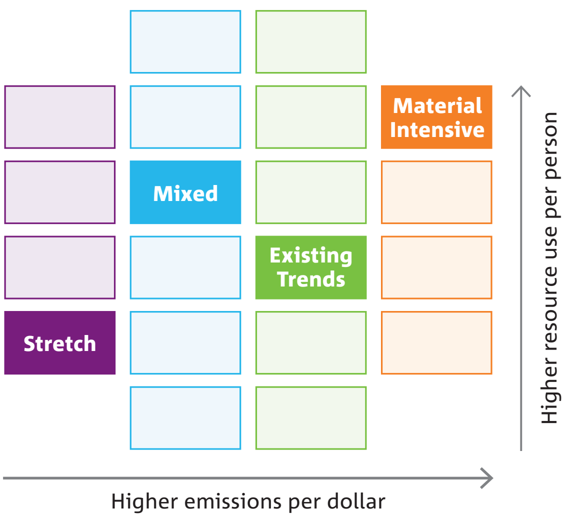
The analysis for the *National Outlook* explores the implications of different interacting social and economic drivers. These drivers underpin our projections of what Australia might be like in the future, and range from how agricultural land might be used, to trends in working hours and household consumption, to different potential levels of greenhouse gas abatement effort. Because the future is uncertain, we model multiple trajectories for each driver: one that assumes Australia continues in line with the recent trend, and one or more that follow a different trajectory to 2050. The drivers and possibilities explored are:

- **Global economic demand –** exploring three different outlooks for global population (based on UN projections), which see the 2050 global economy being from 2.6 to 3.2 times larger than today's.
- **Global climate, and greenhouse gas abatement effort –** four combinations of global economic demand and action to reduce emissions, which see global temperatures rising by 2 to 6°C by 2100 (benchmarked to three Representative Concentration Pathways used by the IPCC – see Section A.3 on the global scenarios, page 38). The analysis assumes that national abatement effort matches global effort in each scenario.
- **Australian resource efficiency –** continuing recent trend reductions in the quantities of energy and water used per dollar of economic activity, or a step-change to even higher energy and water efficiency (through uptake of options with a three to five year payback period).
- **Australian working hours and consumption mix –** continuing the recent trends towards consuming more 'experiences' (such as holidays and eating out) and working shorter average hours, or maintaining the current consumption mix and working hours, with no decline in hours.
- **Australian land sector markets –** new markets emerge to supply energy feedstocks, carbon sequestration and biodiversity benefits from rural land, or current agriculture is maintained with no land use change.
- **Australian agricultural productivity –** continuing our long term (40 year) improvement in productivity, or achieving high agricultural productivity through a threefold increase in trend.

To make the analysis tractable, the modelling focuses on around 20 scenarios, each defined by a specific combination of drivers (selected from hundreds of potential combinations), as shown in Figure 4.

In presenting the results we often focus on the implications of specific drivers, such as the impacts of new land markets (compared to no land use change) or shorter hours (compared to no decline in hours), as well as the interactions between drivers.

FIGURE 4 **OVERVIEW OF THE NATIONAL OUTLOOK SCENARIOS**



- Each row is a different combination of domestic drivers
- Each column is a different combination of global drivers
- These combinations present 20 core scenarios that we have modelled in detail
- The four touchstone scenarios (in solid colours) illustrate a clear range of outcomes

Notes: Touchstone scenarios shown in solid colours are explained on page 7.

Source: *National Outlook* project team. More information: See Appendix A and Figure 23.

We also report the full range of outcomes for key indicators across all scenarios, and bring this to life through four 'touchstone scenarios' that illustrate iconic combinations of drivers:

- **Material Intensive** assumes no national or global policies to reduce emissions beyond those in place a few years ago, with no changes to working hours, consumption patterns, and land use.
- **Existing Trends** assumes everything continues in line with recent national trends, including energy and water efficiency, declining working hours, emerging land sector markets, and moderate (and gradually increasing) efforts to reduce global and national greenhouse gas emissions.
- **Mixed** assumes strong greenhouse gas abatement effort, together with new land-sector markets and no changes to working hours or consumption. This results in lower emissions intensity but higher resource use than existing trends.
- **Stretch** assumes higher energy efficiency effort and very strong action to reduce greenhouse gas emissions, resulting in the lowest resource use and greenhouse gas emissions per dollar of economic activity (referred to as emissions intensity) of the four touchstone outlooks.

More details of our analytical framework and the *National Outlook* scenarios are provided in Appendix A, including the key modelling assumptions for each scenario (see Figure 23 and Table 1).

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 is the most integrated and evidence-based national scenario assessment of these issues yet attempted, providing projections of a very broad range of indicators. The modelling 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 24).

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 US and 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, or changes to taxation, or policies that would influence productivity growth (such as industry or education policy).

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The *National Outlook* ... is the most integrated and evidence-based national scenario assessment of these issues yet attempted, providing projections of a very broad range of indicators.

1 The global economic outlook is positive for Australia, but our choices will shape our prosperity

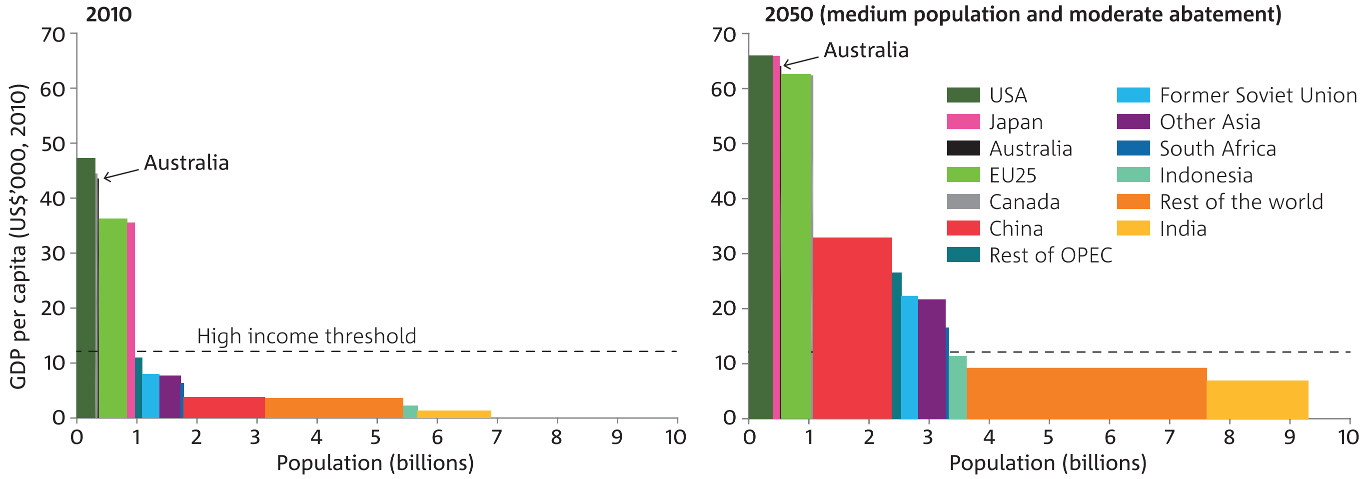
We project strong demand for Australia's commodity exports to 2050, underpinning continued trend growth in living standards, much of which we may choose to enjoy as increased leisure. Overall global demand for our exports is projected to treble by 2050.

1.1 Projected global demand for our exports trebles to 2050

Global per capita income is projected to treble through to 2050, rising much faster than population growth.

Global population is projected to rise by 14 to 56% by 2050, from 7 billion people today, in line with UN projections. However, the transformational shift will be the projected *tripling* (from one billion to three billion) of the number of people in nations with annual income comfortably above the World Bank's high income threshold of US$12,000 per capita (see Figure 5). As a result, the size of the global economy and its global demand for food, energy and energy-intensive materials is projected to more than double. Due to that demand, agriculture, energy commodities, aluminium and steel will remain important export earners for the Australian economy. Meanwhile, Australia's population is projected to grow by 64% to reach 36 million in 2050 – a slightly slower rate than the four decades to 2010 (where population increased 76%), but still significantly higher than the global rate.

FIGURE 5 **THREE BILLION PEOPLE LIVE IN HIGH INCOME NATIONS BY 2050, UP FROM ONE BILLION TODAY**



Notes: The figure shows population (horizontal axis) and the value of economic output (Gross Domestic Product (GDP)) per person by thirteen 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 26 in Appendix A. The high income threshold of US$12,000 GDP per person is consistent with World Bank (2014a) classifications, in 2010 real international dollars.

Source: UN (2013) GIAM. More information: Section 3.1 of the *Australian National Outlook 2015 – Technical Report.*

1.2 Demand for our materials and energy-intensive exports will be strong, but prospects for specific commodities are uncertain

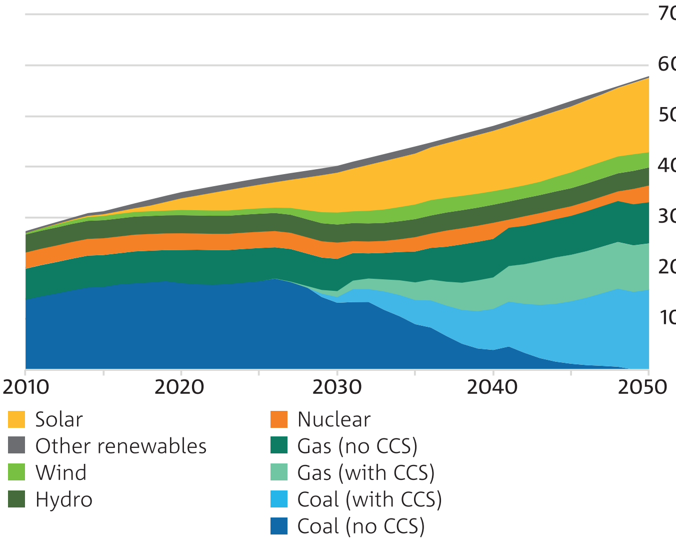
While overall global demand is strong, demand for specific resources will depend on international developments. Australia must be flexible, but has the natural and institutional resources to prosper across a diverse range of global scenarios.

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 these commodities is therefore less certain, particularly for coal,[4] which is sensitive both to the pace of action to reduce carbon emissions, and to the relative competitiveness of coal and gas 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%) by 2050, with even larger differences in outlook for coal (see Figure 6). Achieving successful deployment of carbon capture and storage technology (CCS) 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 emissions reductions on the demand for Australian coal.

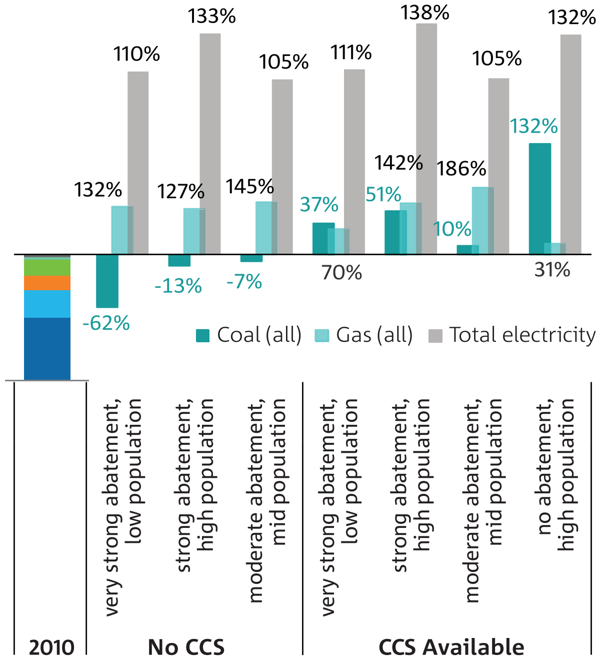
Australia has the natural and institutional resources to participate in any global energy future, and to prosper in any scenario for global energy demand and action on greenhouse gas emissions. Australia should therefore position itself to take advantage of a range of opportunities and global trends (see Section 3.1).

FIGURE 6 **GLOBAL ENERGY DEMAND GROWS, BUT PROSPECTS FOR SPECIFIC ENERGY RESOURCES ARE UNCERTAIN**

Global electricity generation (GWyr) by energy source
moderate abatement and medium population (M2) with CCS



Change in coal, gas, and total electricty generation from 2010 to 2050 (GWyr)



Notes: The figure shows changes in projected global electricity supply, by fuel or technology. The panel on the left shows supply for the period 2010 to 2050. The panel on the right shows the change in global coal, fossil fuel, and total electricity generation in 2050 relative to 2010 levels for the four global scenarios, which all assume carbon capture and storage (CCS) technology is available, and three supplementary scenarios where CCS technology is not available. The height of the columns reflects change in generation output (GWyr) from 2010 on the same scale as the left hand panel, with percentage change provided using labels.

Source: GALLM. More information: Section 5.3 of the *Australian National Outlook 2015 – Technical Report*

> **The outlook for coal and gas is uncertain … the global outlook for fossil fuel based electricity generation ranges from a small decline to a doubling from current levels, with larger differences for coal.**

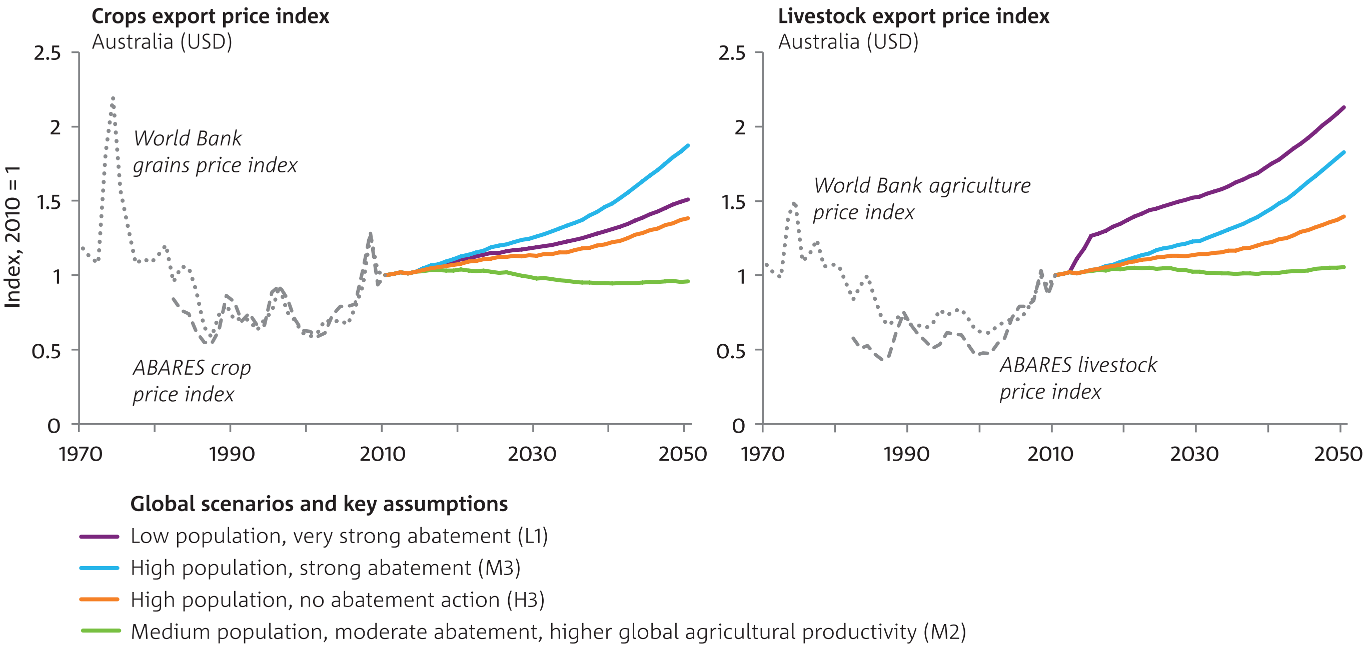
4 IEA (2012) World Energy Outlook 2012. OECD / IEA, Paris. http://www.iea.org/publications/freepublications/publication/WEO2012_free.pdf

1.3 Agricultural prices are projected to trend upwards, and Australia can increase output

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.

As producers know, real prices for agricultural commodities fell over the 60 years to 1999, as global supply outstripped global demand. The expansion of farmed land area was amplified by strong productivity growth from the 1960s 'green revolution'. Now, growth in global supply is falling behind growth in demand, and the last decade saw weather events cause a series of food price spikes. Looking ahead, we consider an upward trend in commodity prices is likely (see Figure 7). Globally, we are approaching the limits of arable land, and we are observing increased 'climate variability': the frequency and severity of extreme events such as drought, fire, storms and floods. These trends will continue. Stronger global action on greenhouse gas emission reduction could also see land increasingly used for bioenergy and carbon sequestration, competing with the use of land for food production globally. Improving agricultural productivity (including yields per unit of land) will thus be central.

FIGURE 7 **GLOBAL AGRICULTURAL PRICES COULD TREND UP, REVERSING THE LONG TERM TREND**



Notes: The figure shows projected change in grains and livestock prices from 2010 to 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, which reduce 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, which reduces agricultural prices and increases output relative to the levels with no adjustment to productivity. Projected prices with no productivity adjustment are provided in the technical report. 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. More information: Section 5.2 of the *Australian National Outlook 2015 – Technical Report*.

"

Looking ahead, an upward trend in agricultural prices is likely as global supply falls behind the growth in global demand.

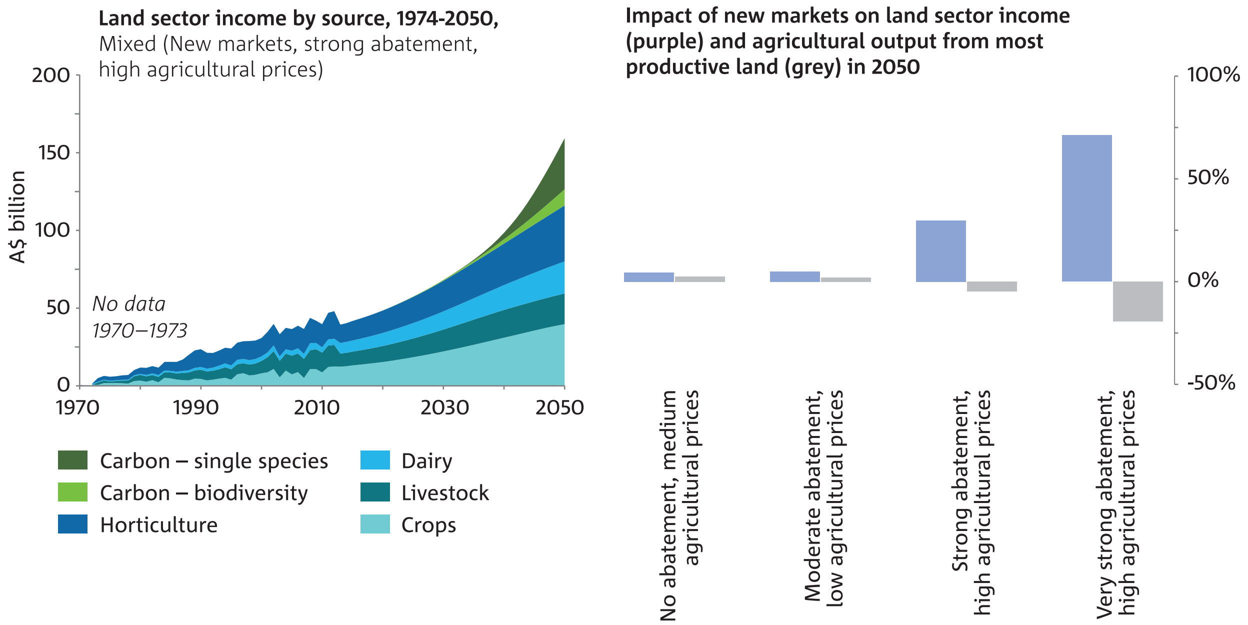
With productivity improvements in line with long-term trends, Australian agricultural output volumes are projected to rise by at least 50% by 2050 – even in scenarios where food production is giving ground to bioenergy and plantings for carbon sequestration. This is possible because there is little change in the use of Australia's most productive agricultural land: the one third of agricultural land that accounted for two thirds of output value in 2010 (see Figure 8). New markets and policy settings that enable carbon farming would allow many rural landowners to diversify their incomes, particularly from less productive land, even while they benefit from the projected higher prices for agricultural commodities.

Improving global food security will require a significant increase in agricultural productivity, and innovation along the whole food supply chain, to offset the effects of population growth, urban expansion, and climate change. Public investment in agricultural research and development has a crucial role.[5]

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. At this stage, our modelling accounts for trend changes in temperature and rainfall, but does not fully capture the impacts of changes in the frequency and severity of extreme weather events (see Figure 25). Yet we know that the impacts of changed frequency and severity of extreme weather and climate events may be very significant[6], and may outweigh the benefits of productivity improvements in some regions.

> **"With productivity improvements in line with long-term trends, Australian agricultural output volumes are projected to rise by at least 50% by 2050.**

FIGURE 8 **NEW MARKETS BOOST AND DIVERSIFY LAND SECTOR INCOMES, PARTICULARLY FROM OUR LESS-PRODUCTIVE LAND**



Notes: The figure 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). The right hand panel also shows 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 agricultural land in the intensive use zone. Results are scenarios assuming trend agricultural productivity and a balanced approach to carbon and biodiversity, across different levels of abatement effort (rows CR and NR in Figure 23).

Source: historical data, GIAM (prices) and LUTO (volumes and spatial detail). More information: Section 5.2 of the *Australian National Outlook 2015 – Technical Report.*

5 P.G. Pardey, J.M. Alston ad C.Chan-Kang (2013) Public agricultural R&D over the past half century: An emerging new world order. *Agricultural Economics* 44, 103-113.

6 CSIRO and Bureau of Meteorology (2015) *Climate Change in Australia, Information for Australia's Natural Resource Management Regions: Technical Report. CSIRO and Bureau of Meteorology, Australia.* http://www.climatechangeinaustralia.gov.au/en/publications-library/technical-report/

2 Economic growth and sustainable resource use can be partners not competitors

The forces that shape the next four decades are difficult to predict, but it is unlikely they will be the same as those that shaped the last four. As a developed nation with strong education and governance institutions, Australia's economy is flexible and resilient. The biggest determinant of our future prosperity is not the sectors which have served us in the past, but how we choose to prepare for and respond to future trends and opportunities.

> **Our findings highlight opportunities from resource efficiency, agricultural productivity, low-emissions technology, and land-sector markets.**

2.1 Energy, water and food output can increase, while pressures decline

The *National Outlook* finds that we can continue to enjoy strong growth in national income, while reducing pressures on natural resources and ecosystems. Across the scenarios we explore, higher living standards and economic growth are propelled by strong global demand for our exports, improved technology, household consumption and leisure trends, and taking advantage of new opportunities. Consistent with the focus of the *National Outlook* on the water-energy-food nexus and material-intensive industries, our findings highlight opportunities from resource efficiency, agricultural productivity, low-emissions technology, and land-sector markets enabled by national and global action on climate change.

While we analyse a wide range of scenarios, we do not consider every potential possibility. All of the scenarios explored would involve challenges as well as opportunities, and would have different impacts on different regions and sectors. Many scenarios see incentives for reducing greenhouse emissions providing a range of co-benefits – such as higher and more diverse farm incomes, and improved biodiversity and ecosystem services – as well as presenting challenges, such as lower growth in agricultural industries, and higher water interceptions. The new carbon plantings that underpin this mix of outcomes would be physically and economically feasible across a wide range of global contexts, but the detailed economic implications would be different in scenarios where Australian action to reduce emissions is not broadly consistent with the pace and level of wider global efforts (as is assumed in the *National Outlook* analysis). In addition, each of the twenty scenarios we model in detail implies a different legacy of challenges and opportunities after 2050, which we do not explicitly explore. For example, scenarios with strong abatement incentives have higher emissions than scenarios with very strong abatement, but have a larger potential for carbon plantings after 2050 (spreading Australia's land sector abatement potential over a longer period). And scenarios where the world fails to slow the growth of greenhouse emissions risk very significant negative impacts on natural systems and human wellbeing after 2050. These considerations do not, however, undermine the finding that Australia can achieve economic growth while reducing pressures on our natural resources and ecosystems.

The *National Outlook* also finds that the relationship between economic growth and the environment is not an even one, however. Choices by government, business, and households

> **We find Australia can continue to enjoy strong trend growth in national income, while reducing pressures on natural resources and ecosystems.**

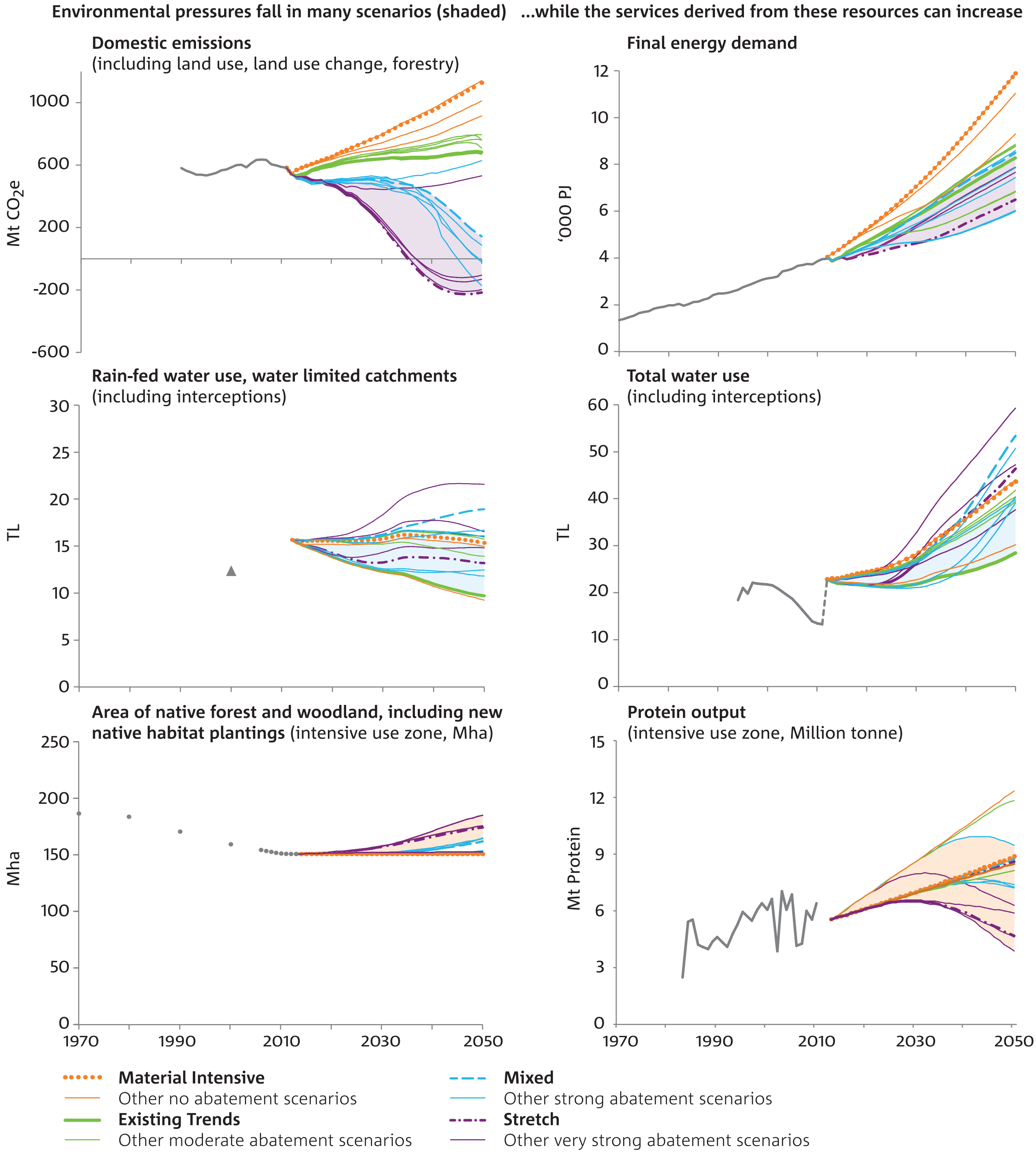
with major implications for the health and productivity of natural resources and assets – such as for climate, water supplies and native habitats – have only relatively small implications for the rate of economic growth before 2050 (see Figure 10 and Figure 11 in Section 2.2).

Across the scenarios we explore, 50 to 90% of the differences in environmental outcomes are due to policy choices that frame technology and resource use decisions, the remainder being due to household and business choices. Private choices play a greater role where reductions in resource use and environmental pressure also provide private benefits, such as the uptake of water and energy efficiency (see Figure 15 below).

Technology and institutional settings enable 'physical decoupling': allowing us to increase the services derived from natural resources (energy, water, food), while 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 (see Figure 9).[7] 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.

7 The analysis that underpins the findings in this section, including policy assumptions and impacts, are set out in more detail in Hatfield-Dodds, Schandl et al. (2015) Australia is 'free to choose' economic growth and falling environmental pressures, *Nature* DOI 10.1038/nature16065

FIGURE 9 **ENERGY, WATER AND AGRICULTURAL OUTPUT INCREASES, WHILE PRESSURES DECLINE**



Each panel shows trajectories for a key indicator of environmental pressure and an associated 'service' derived from these resources 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 greenhouse gas emissions or water extractions and an increase in area of native habitat, with the same scenarios shaded in the right hand panel of each row. The top two rows show projections for 18 scenarios (all except rows VR and XE in Figure 23). The bottom row shows 21 land use scenarios: trend agricultural productivity and new markets (NR) for three market settings (carbon focused, balanced and biodiversity focused); new markets high productivity (NE) balanced; and no new markets trend productivity (CR); all for each of the four abatement levels, plus L1XI reflecting integrated water governance settings. Water use is shown relative 2000/01 levels, representing a typical year, rather than 2010 levels when agricultural water use was historically low due to a severe drought in south-eastern Australia. Historical water use excludes interceptions. Protein output reflects all food commodities (including cereals, beef, sheep, legumes, and dairy milk). Protein output increases in all but three L1 scenarios. Livestock output value increases but volume falls below 2010 levels by 2050 in the same three scenarios. (Livestock value and volume both increase in L1 scenarios with high agricultural productivity, or carbon focused new markets, or no new markets.) Forgone agricultural income is more than offset by new income from carbon plantings, as shown in Figure 8.

Source: Hatfield-Dodds, Schandl et al. (2015) *Nature*, based on historical data and MMRF, ESM, and LUTO projections.
More information: Sections 1.3, 3.2 and 3.7 of this report, and Section 7.1 of the *Australian National Outlook 2015 – Technical Report*.

2.2 Australian average income is projected to rise in line with historical trends

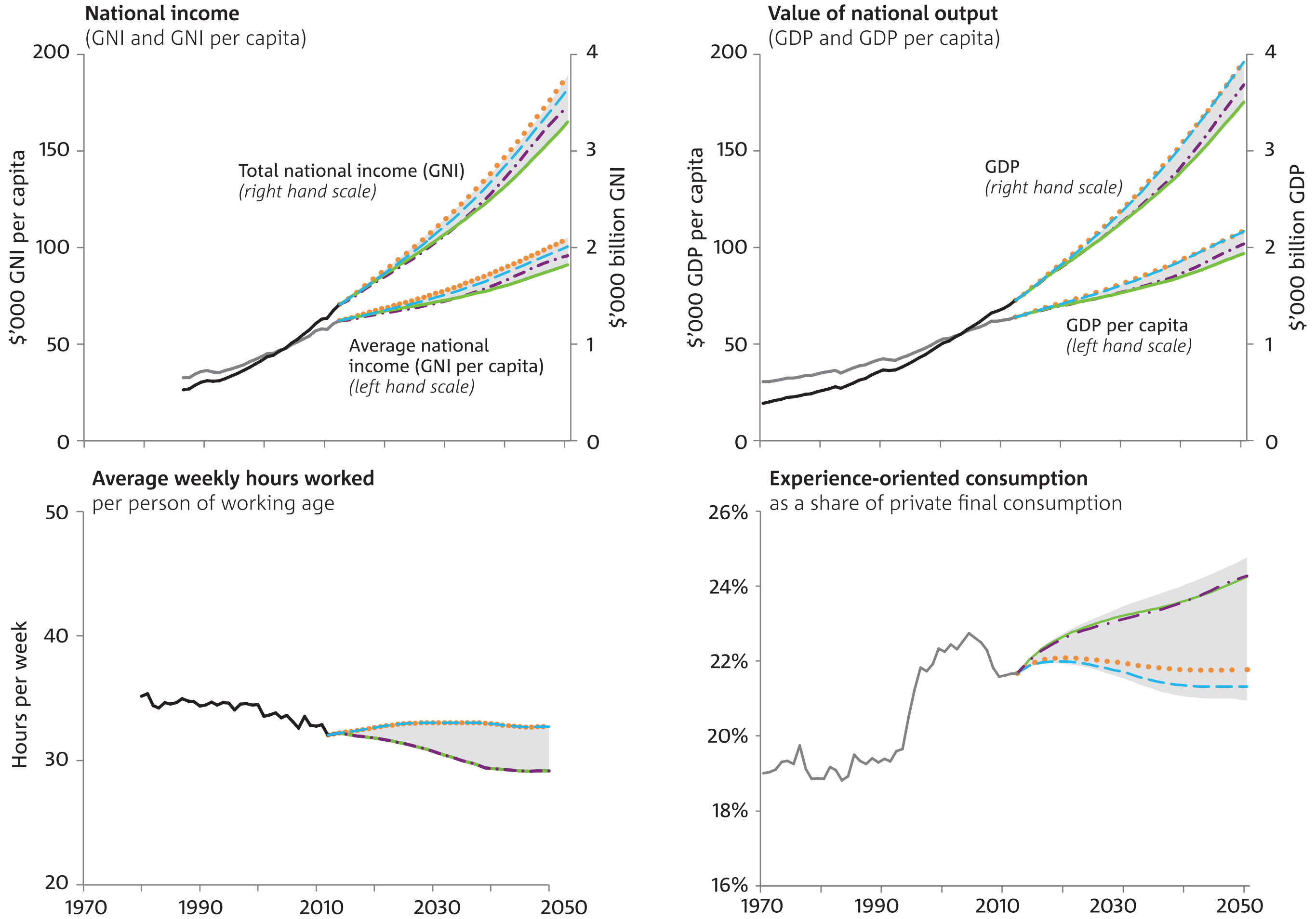
Average income per person is projected to increase by 12 to 15% above inflation per decade to 2050, subject to major disruptions, with choices about working hours making up two-thirds of the differences in income.

Supported by global demand, responsive export industries and domestic choices, our national GDP is projected to treble from 2010 to 2050 (see Figure 10). Australia's real per capita income (measured by gross national income or GNI) 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 ten 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 (see Figure 10). Alongside changes in working

FIGURE 10 **AVERAGE INCOME INCREASES BY 12 TO 15% PER DECADE OVER THE FOUR DECADES TO 2050, EVEN WITH DECLINING WORKING HOURS, AND THE VALUE OF ECONOMIC ACTIVITY INCREASES TEN-FOLD FROM 1970 TO 2050**



Notes: The figure shows the range of projections for national income, the value of national output, working hours and experience-oriented consumption across the 20 *National Outlook* scenarios, highlighting the four touchstone scenarios within this range (see Figure 4 and Figure 23). All values real A$ 2010.

Source: historical data, ABS (2008, 2013a, 2013b) MMRF. More information: Introduction in this report and Sections A.2 and B.4 of the *Australian National Outlook 2015 – Technical Report*.

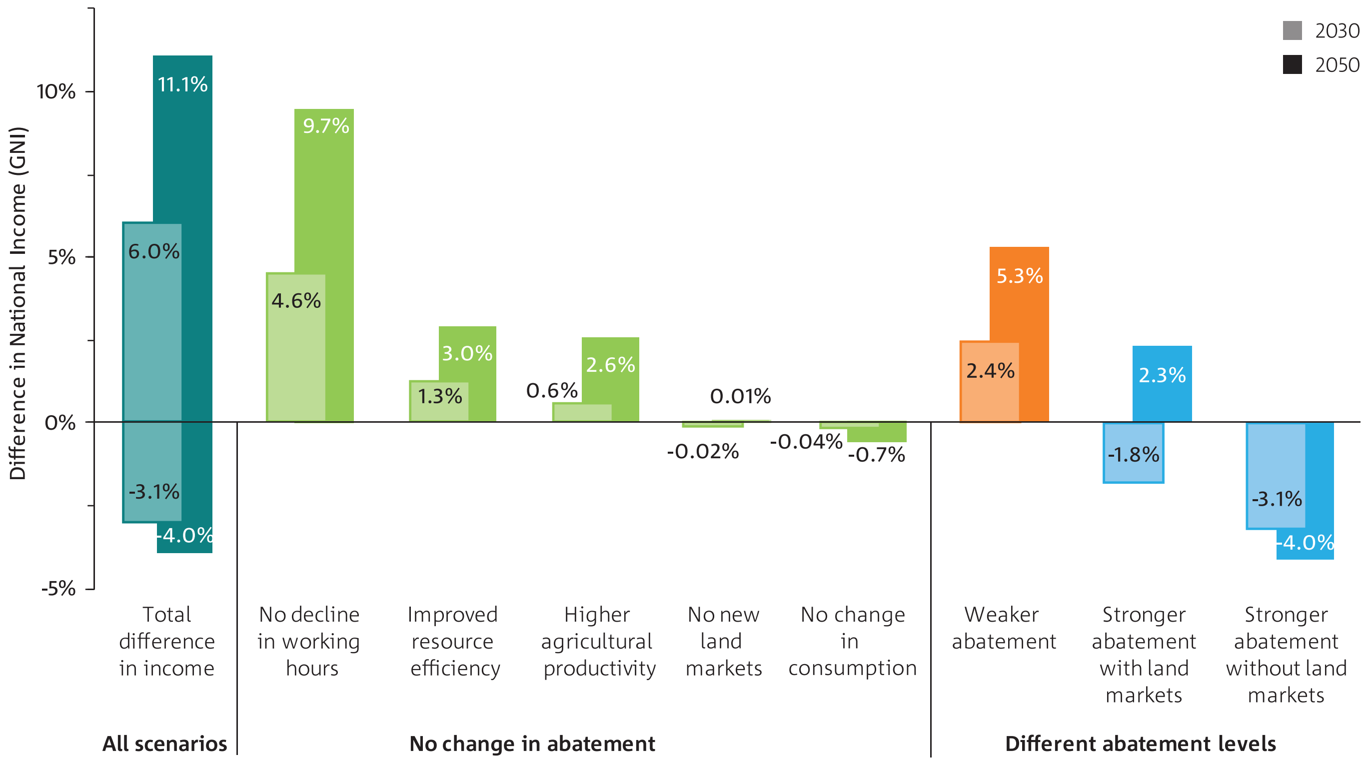
hours, recent decades have seen consumer spending shifting towards experiences and away from durable goods, a trend that is expected to continue.[8] This would see consumer spending on experiences growing around one-third faster than total private consumption (such as in the Existing Trends and Stretch 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 (see Figure 11).

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 (see Section 3.2). Appendix A provides more detail on the scope of the analysis and key assumptions.

> **We project that the total value of Australian economic activity will increase by a factor of ten over the 80 years to 2050.**

FIGURE 11 **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 23).

Source: MMRF. More information: Section 4.2 of the *Australian National Outlook 2015 – Technical Report*.

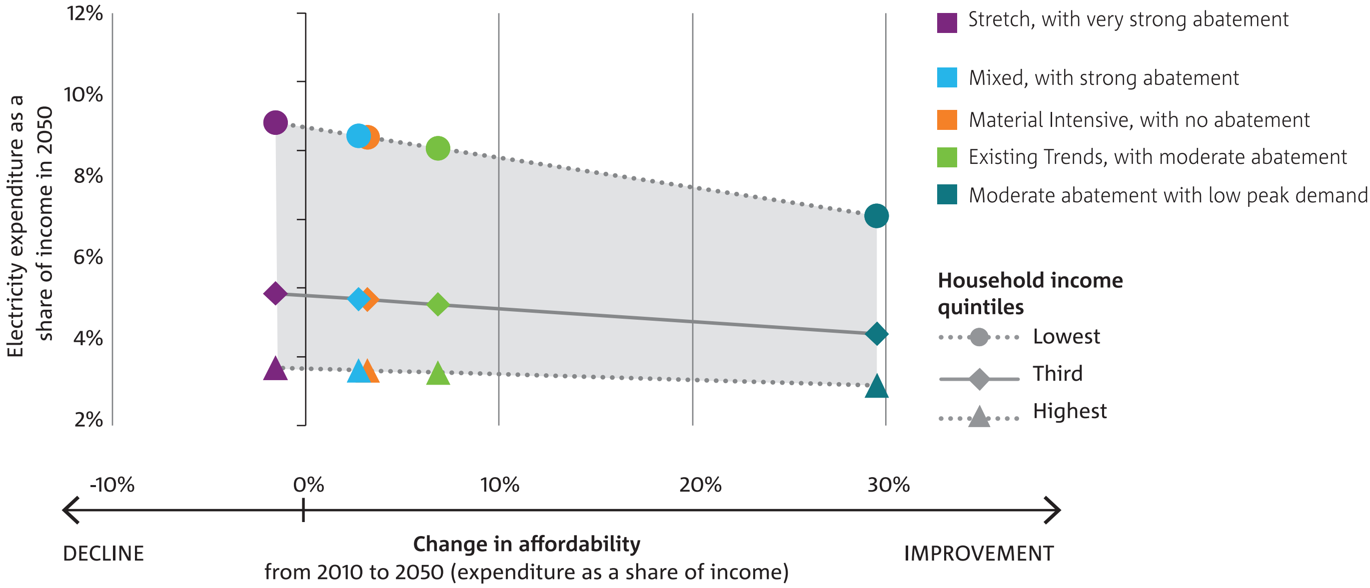
8 Hajkowicz, S.A., Cook, H., Littleboy, A. (2012) *Our Future World: Global megatrends that will change the way we live. The 2012 Revision*. CSIRO, Australia.

2.3 Energy and transport affordability can be maintained or improved

Energy efficiency can help offset higher unit electricity prices, but we find better management of peak demand and our transmission and distribution networks could yield the greatest benefits. By 2050, electric vehicles and biofuels could reverse our mounting transport fuel imports, as well as reducing costs, improving air quality, and reducing greenhouse gas emissions.

Energy prices, the mix of electricity generation, and the mix of vehicle fuel and engine technologies vary widely across scenarios. Despite rising unit prices and demand across all scenarios, energy affordability for Australian households changes only modestly, with greater energy efficiency more than offsetting higher electricity prices over the long term in most cases.[9] Achieving these gains would involve a mix of actions, some of which involve higher up-front capital costs but lower total costs over the operating life of these new assets. Much larger improvements in the affordability of electricity could be achieved through better managing peak demand, and associated network infrastructure costs (see Figure 12). We find Australian energy demand is very sensitive to different scenario assumptions, with annual demand growth ranging from 1 to 3% per year across different national and global outlooks.

FIGURE 12 **ENERGY EFFICIENCY CAN MAINTAIN AFFORDABILITY OF ELECTRICITY IN THE FACE OF HIGHER PRICES – BUT THE BIGGEST GAINS COME FROM REDUCING NETWORK AND DISTRIBUTION COSTS**



Notes: The figure 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. More information: Section 4.3 of the *Australian National Outlook 2015 – Technical Report*.

9 Unit electricity prices for households and industrial users are projected to increase in all scenarios due to higher costs of generation, transmission and distribution. The main sources of cost increases for generation are the eventual recovery from current excess supply, adoption of low emissions technologies, and higher fuel costs. Transmission and distribution network costs increase due to declining network utilisation associated with increasing distributed generation. Together these result in average residential prices rising by 50-100% across different scenarios.

Road transport costs as a share of income are projected to fall by 30 to 55% across all scenarios, primarily due to shifts to electric vehicles, which are expected to have dramatically lower operating costs. By 2050, electric vehicles account for one third of road passenger transport in scenarios with very strong abatement incentives or high uptake rates (combined with moderate abatement incentives), and up to one tenth in other scenarios. Biofuels could displace up to 10% of liquid petroleum fuels that would otherwise be used for passenger road transport, while vehicles using grid-sourced electricity are projected to displace up to 45% of liquid fuels, together helping reduce greenhouse gas emissions, improve air quality, and reduce future oil imports (see Figure 13). These projections are highly uncertain, however, as vehicle choices may also be influenced by potential shifts in attitudes and technology breakthroughs – such as new vehicle sharing models, and a potential shift to driverless cars – which are not explored in the *National Outlook* scenarios.

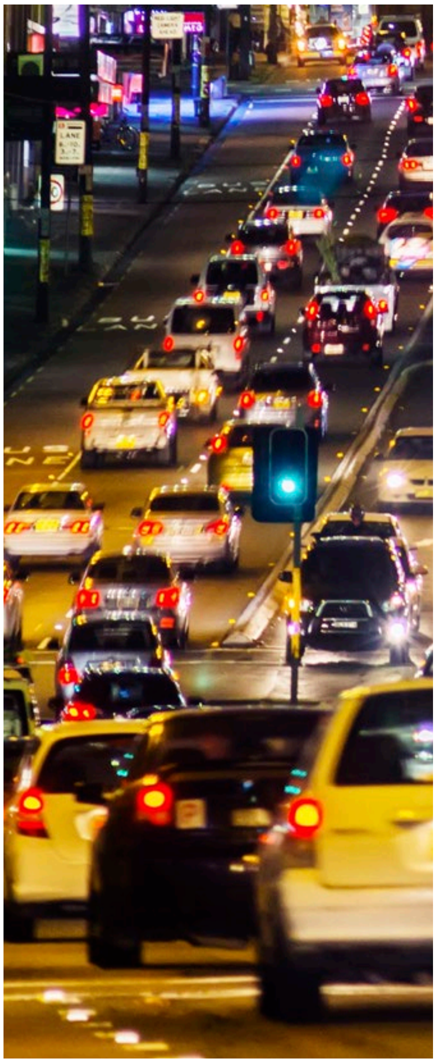
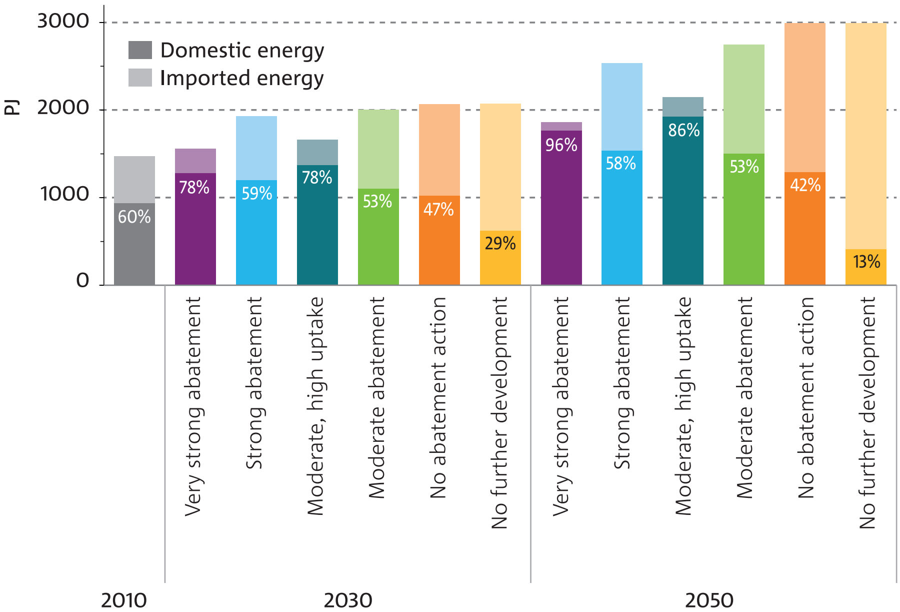


FIGURE 13 **ELECTRIC VEHICLES AND BIOFUELS COULD REVERSE DECLINE IN TRANSPORT ENERGY SELF-SUFFICIENCY**



Notes: The figure 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. More information: Section 4.3 of the *Australian National Outlook 2015 – Technical Report*.

“ Improvements in the affordability of electricity could be achieved through better managing peak demand, and associated network infrastructure costs.

3 Policy choices and institutional settings will play a central role in delivering reductions in environmental pressures while enhancing economic performance

The 20th century saw sustained increases in national and global pressures on water catchments, landscapes, and ecosystem services. In this century, those pressures are likely to mount as we supply food, fibre and energy to a global population that is growing in both number and wealth, while also seeking to protect planetary functions and life-support systems essential to human well-being.[10]

The extent to which these challenges and opportunities will be addressed will be significantly influenced by policy choices and institutional settings. An effective global response to climate change will require a diverse range of local and national initiatives, many of which could also provide wider benefits. For example, paying landholders for 'carbon farming' (sequestering carbon from the atmosphere by restoring vegetation on cleared land) could also assist in controlling erosion, addressing dryland salinity, and restoring native habitat. The analysis assumes the level of payments to landholders is largely determined by the pace of global abatement efforts. We find that once payments reach a 'sweet spot' of \$40-\$60 per tonne of CO2e sequestered, 'carbon farming' becomes attractive across large areas of Australia (see Figure 14), while supply of land sector abatement is projected to be more modest and targeted at lower payment levels.[11]

We find land sector credits could be instrumental in reducing Australia's greenhouse gas emissions, accounting for 30 to 40% of abatement in the strong and very strong scenarios, and that carbon incentives could also be harnessed to restore significant areas of native habitat. Yet land sector credits are not a silver bullet. In the most ambitious abatement scenarios, for example, they account for less than half of Australia's emissions reductions over the decades from 2030 to 2050, and their need for water will require careful integrated catchment management.

3.1 Meeting 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.

New markets for carbon sequestration, energy feed stocks, and nature conservation have the potential to diversify and increase on-farm incomes. Markets that support carbon sequestration could benefit farmers and rural communities (particularly in New South Wales and Queensland), increasing farm incomes by more than 30%, and national income (GNI) by up to 3% above existing trends. (And, by contributing to an effective global response to climate change, could help reduce the risk and severity of extreme weather events.) For example: policy settings that strike a balance between carbon sequestration and promoting biodiversity could also increase native habitat by 17% and reduce species extinction risk by 10% in scenarios with strong abatement incentives (see Figure 15 and section 3.6 below). And biofuel production on the land could boost transport fuel security, and put downward pressure on fuel costs – including in scenarios that assume no further national or global action to reduce greenhouse gas emissions (see Section 2.3).

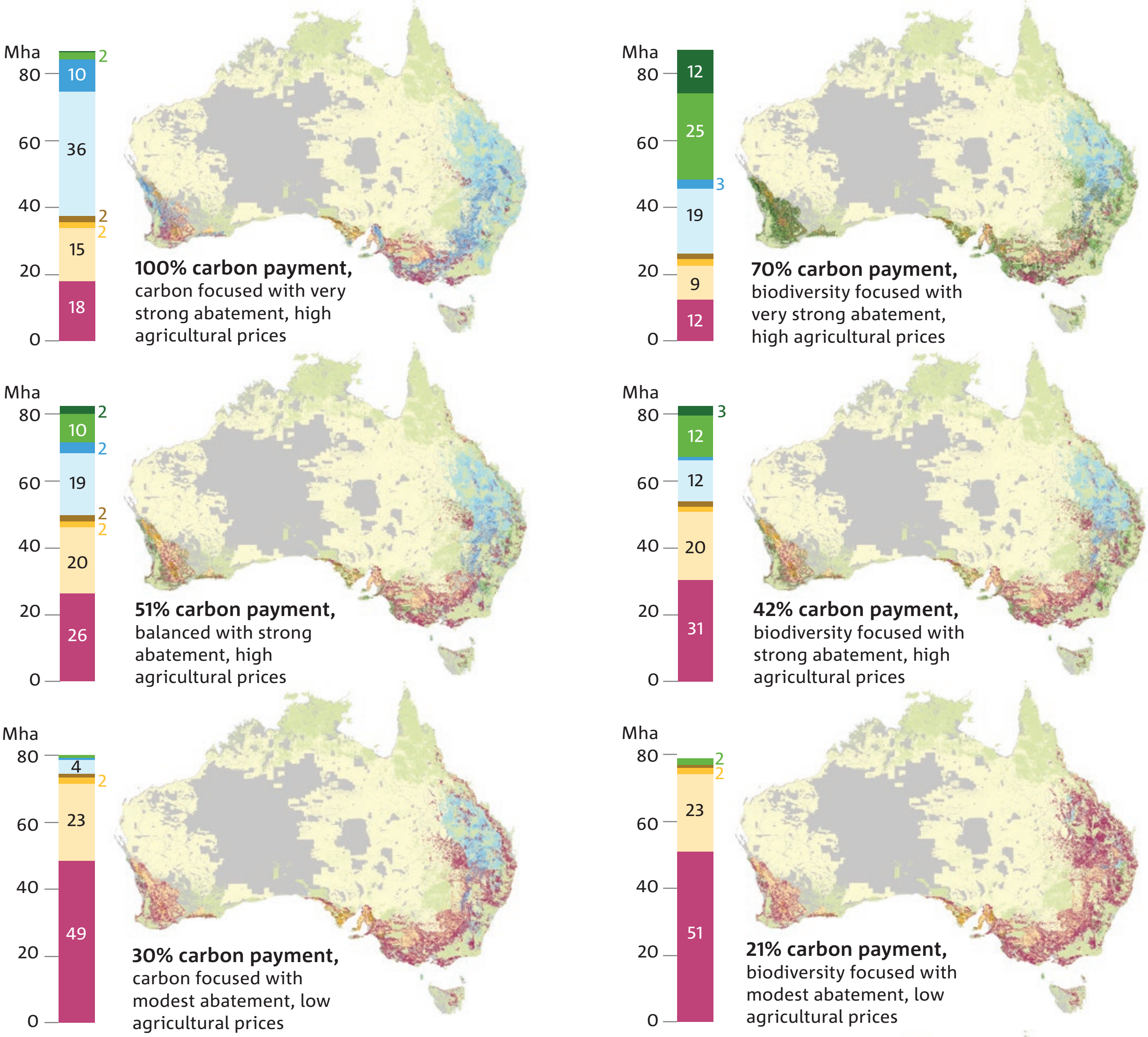
> **Decisions we make as a society matter – and will shape Australia's future more than decisions we make as businesses or individuals.**

Managed well, these new land sector markets could be nationally transformative, and deliver significant regional benefits. Action would be required by different players to unlock financial, business, and on-farm innovation so that landholders can 'do well by doing good'. However, stronger global action to reduce greenhouse gas emissions could shift the economic foundations of some rural communities, as forestry and ecosystem services become more profitable than production of food and fibre in some locations. While these changes will not happen overnight, the scale and multiple complexities of the potential changes could raise unprecedented challenges for landowners and regional communities.

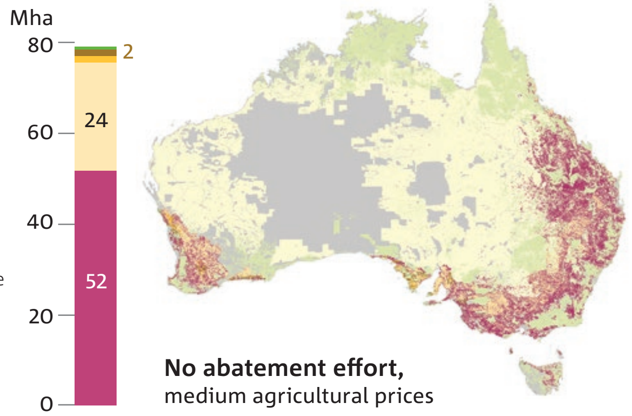
10 See Griggs, D., M. Stafford-Smith, O. Gaffney, J. Rockstrom, M.C. Ohman, P. Shyamsundar, W. Steffen, G. Glaser, N. Kanie and I. Noble (2013) Policy: Sustainable development goals for people and planet. *Nature* 495 (7441), 305-307

11 Evans, M.C. et al. (2015) Carbon farming via assisted natural regeneration as a cost-effective mechanism for restoring biodiversity in agricultural landscapes. *Environmental Science and Policy* 50: 114-129

FIGURE 14 **PROFITABLE RURAL LAND USE COULD SHIFT DRAMATICALLY, RAISING CHALLENGES AND OPPORTUNITIES**



Notes: The figure 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 2Mh 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, as described in Section 3.6. 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. 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.**



Change in use or most profitable use by 2050
- Native habitat from crops and horticulture
- Native habitat from livestock and dairy
- Carbon plantings from crops and horticulture
- Carbon plantings from livestock and diary
- Energy feedstocks or mixed food and energy, from livestock or dairy
- Energy feedstock or mixed food and energy, from crops and horticulture

No change
- Crops and horticulture
- Livestock and dairy
- Native forest and woodland
- Native shrubland and grassland
- Other

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

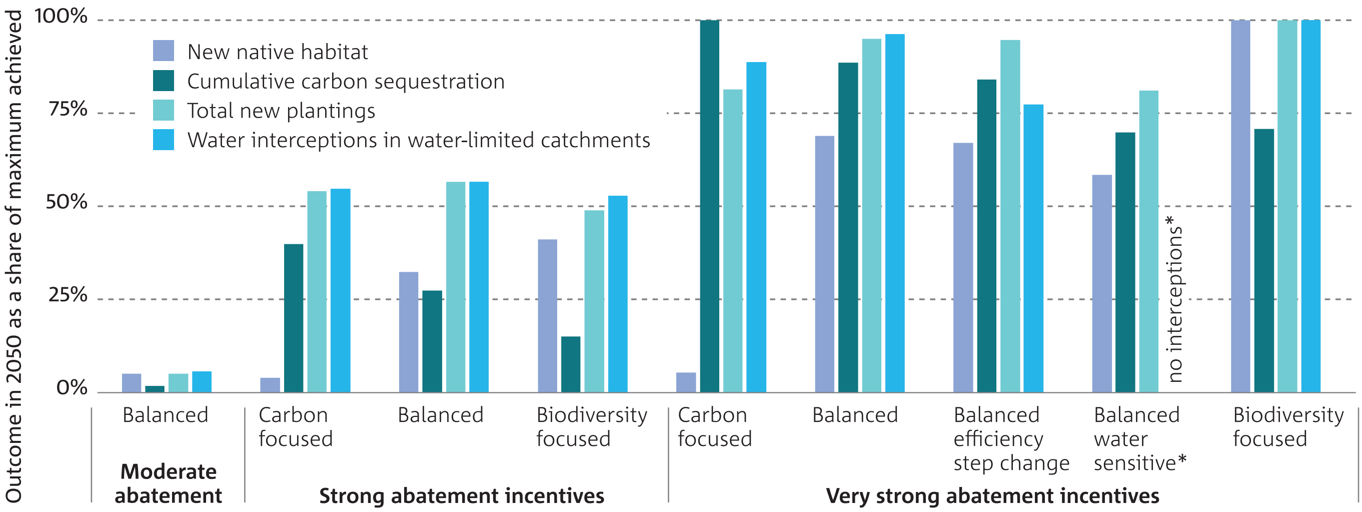
Policy choices (in Australia and globally) and institutional settings account for 50 to 90% of the range of projected resource use and environmental outcomes. The detailed design and implementation of policies will have significant implications for resource use and environmental outcomes – implying a need to understand the synergies and trade-offs involved.

Our physical economy has complex thresholds, tipping points and cross-sector interactions, implying 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.[12] 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 15 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.

Collective choices about policy settings shape individual decisions by households and firms, and are the primary driver of projected differences in resource use and environmental outcomes (see below). Policy settings will also shape our electricity and water supply choices, 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. The 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).

FIGURE 15 **POLICY SETTINGS AND CHOICES DRIVE DIFFERENT OUTCOMES FOR CARBON, NATIVE HABITAT, AND WATER – EVEN WITH THE SAME LEVEL OF ABATEMENT INCENTIVE**

Native habitat, carbon sequestration and water interceptions from new plantings



Notes: The figure 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 to 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 23). Two scenarios assume new markets, very strong abatement, and a step change in water efficiency (row XI in Figure 23). The figure also reports the implications of carbon focused, balanced and biodiversity focused policy settings (see Section 3.6). 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. More information: Section 3.7 of this report and Section 7.2 of the *Australian National Outlook 2015 – Technical Report.*

12 The analysis assumes that all new plantings in catchments with average rainfall above 600mm per year are required to purchase a water licence to cover interceptions of surface water.

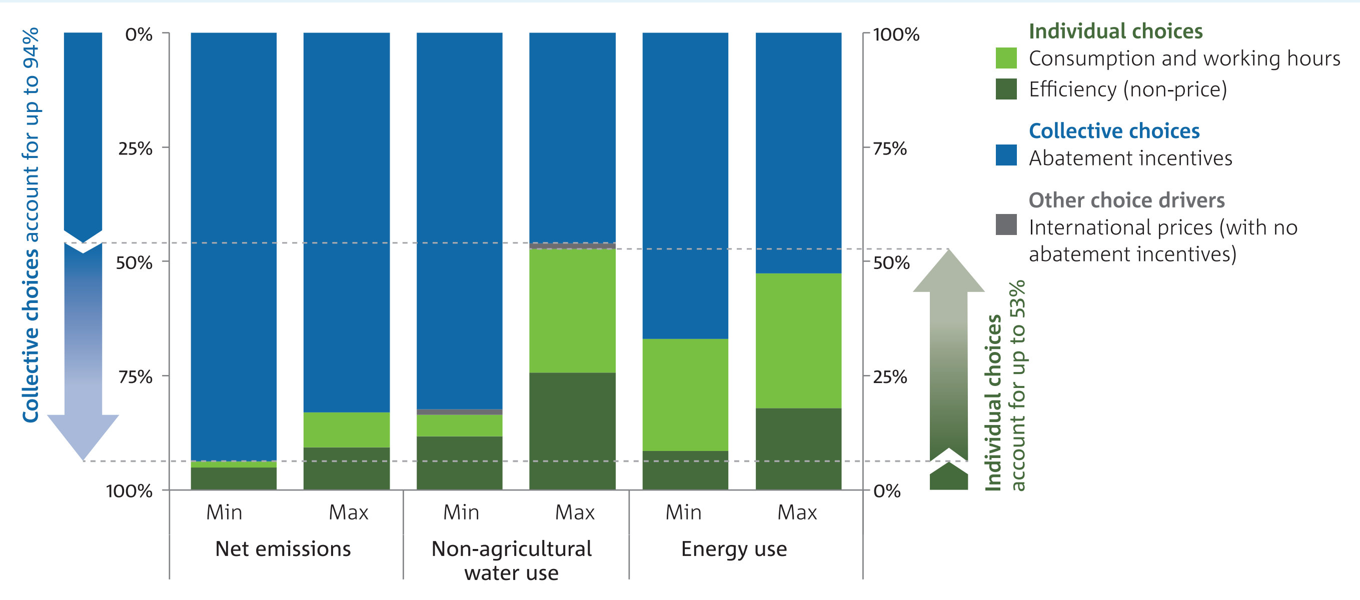
Calculating the contribution of individual and collective choices

Individual (private) choices involve decisions by individuals and firms within existing rules and institutions, while collective (public) choices can only be implemented by groups of actors (such as through government policy), and then constrain or empower individual choices. For example, individual choices about alternative transport options – such as whether to drive or catch a train to work – are strongly shaped by prior collective choices about transport infrastructure.

The relative contributions of individual versus collective choices across the *National Outlook* scenarios are calculated by constructing a chain of steps from the highest scenario to the lowest for different performance indicators. Each of these steps varies the setting for a specific driver (see Figure 23), which can be classified as representing either an individual or a collective choice. This process can be used to estimate a maximum and minimum contribution for each type of choice, as there are many possible chains of steps between the maximum and minimum scenarios.

Individual choices by households and businesses account for only a small share of the difference in 'public good' environmental performance across the set of *National Outlook* scenarios, contributing up to one sixth (6 to 17%) of the difference between the maximum and minimum levels of greenhouse gas emissions. Individual choices are more significant where they provide private benefits (such as financial savings to decision makers), accounting for up to half the differences in energy use (33 to 47%) and non-agricultural water consumption (16 to 53%). This is consistent with individual choices having a larger contribution where there are synergies between individual benefits (such as financial savings) and public benefits, while policy settings will be more important where individuals do not directly benefit from changes that improve community wellbeing (such as where upstream technology choices shape environmental outcomes).

FIGURE 16 **COLLECTIVE CHOICES ACCOUNT FOR THE MAJORITY OF PROJECTED DIFFERENCES IN RESOURCE USE AND ENVIRONMENTAL PRESSURES IN 2050**



Notes: The figure shows the relative contribution of different scenario drivers to difference between the maximum and minimum levels of net emissions, total energy use, and non-agricultural water consumption across 18 *National Outlook* scenarios (all rows except VR in Figure 23). As noted in the text, differences attributed to assumptions about working hours and consumption patterns are treated as the result of individual choices, and differences associated with different abatement levels and the use of new land sector markets are treated as collective. (Global and national abatement incentives effect national water demand through impacts on energy-intensive industries, which are significant water users). Different levels of energy and water efficiency could arise either through bottom-up individual action, or be influenced by government policies, but are treated as individual choices for this analysis. The only other factor identified as contributing to the difference between the maximum and minimum levels of these indicators is international prices (reflecting responses to global demand with no change to abatement level), which accounts for 1 to 2% of differences in non-agricultural water consumption across the scenarios. Scenarios with high agricultural productivity do not account for the maximum or minimum levels of these variables across the set of scenarios, and so differences in agricultural productivity are not included in this analysis. In practice, achieving a step change in agricultural productivity would be likely to involve a combination of collective and individual choices.

Source: MMRF, ESM, LUTO. More information: Section 7.3 of the *Australian National Outlook 2015 – Technical Report*.

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

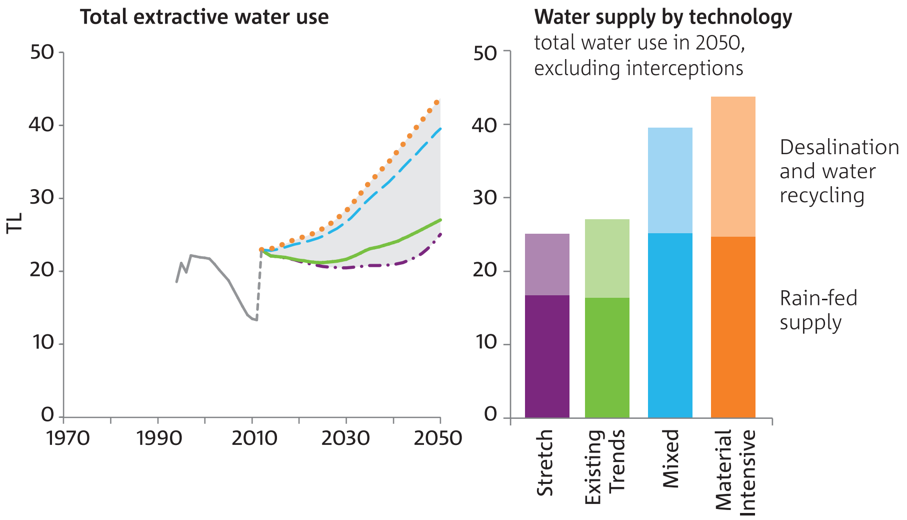
National water use is projected to double by 2050 (increasing by 80 to 120% in most scenarios), driven by increased population, economic growth, and new carbon plantings. This growth in demand can be met while enhancing non-agricultural water security, without increasing pressure on water-limited catchments, through water recycling, desalination and integrated catchment management.

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.

Non-agricultural water use is projected to increase by 65 to 150% by 2050, while the value of national economic output grows 156 to 186%. Energy-intensive industries are significant water users, and so water demand grows most strongly in scenarios with high energy use. The combination of improved water and energy efficiency in those industries would improve their competiveness, reducing national energy use but increasing non-agricultural water use by 4 to 13% (relative to scenarios without improved efficiency). Agricultural water use is projected to increase by up to 80% over the 35 years to 2050,[13] driven by increases in catchments outside the Murray Darling Basin where water resources are not yet fully allocated.

With appropriate settings and technologies, the projected increases in water demand need not lead to increased pressure on water-limited catchments. Instead, this additional water can be supplied by increased water recycling and desalinisation, which is projected to account for 3 to 15% of national water use in 2030, rising to 32 to 56% by 2050.

FIGURE 17 **NON-TRADITIONAL SUPPLY OPTIONS PLAY A SIGNIFICANT ROLE IN MEETING FUTURE WATER DEMAND**



Notes: The figure shows historical and projected total water consumption from 1990 to 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 18 *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, whilst 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 caps water extractions at 50% of projected average annual flows, with the shortfall supplied by water recycling (for industrial water use) and desalination. Water demand is effected by population, income, the growth of energy-intensive industries (which are also significant water users), water supply costs, and the uptake of energy and water efficiency. The modelling does not account for potential impacts of climate change on water demand (such as due to higher temperatures).

Source: historical data, MMRF. More information: Section 5.4 of the *Australian National Outlook 2015 – Technical Report.*

"

Projected increases in water demand need not lead to increased pressure on water-limited catchments

13 We assess change in water use against 2000/01 levels, as agricultural water use in 2010 was historically low due to the Millennium Drought in south-eastern Australia.

These options are cost competitive relative to building major new water storages[14] – and more practical where surface water resources are already fully developed. The energy implications of alternative water supply are noticeable but manageable, with desalination and water recycling projected to account for 5-7% of national electricity use in 2050 under *Existing Trends*. This suggests potential to meet growing demand while enhancing the security of non-agricultural water supplies, even with projected future declines in rainfall.

New plantings for carbon sequestration could have significant additional impacts on surface flows, depending on institutional settings. We find planting decisions are not sensitive to water prices, and that interceptions of surface flows in high rainfall areas could account for more than a quarter of total national water use in 2050. This implies that in water-limited catchments, plantings have the potential to entirely offset projected water use reductions in other sectors. Restricting carbon plantings in water-limited catchments would reduce potential stress on river health and ecosystems, but would also forgo the environmental benefits of new plantings for dryland ecosystems and up to 2.2Gt of potential land sector carbon abatement (around a third of the national potential) by 2050 in the very strong abatement scenarios (see Figure 15).

These findings illustrate the potential scale of changes to water flow, and the need for integrated planning and governance that considers social, ecological, agricultural, and carbon dimensions of water use. Improvements in national and state water governance and markets over the past 25 years have allowed Australia to address over allocation of water in the Murray Darling Basin, while accommodating population growth and supporting increased agricultural production. Future events and trends will bring both challenges and opportunities that will call for integrated analysis and decision making.[15]

14 Burn, S., 2011, Future urban water supplies, in Prosser, I. (ed), 2011, *Water: Science and Solutions for Australia*, CSIRO Publishing, Melbourne, pp 89-104

15 Hobday, A.J., and J. McDonald (2014) Environmental Issues in Australia. *Annual Review of Environment and Resources* 39: 16.1–16.28

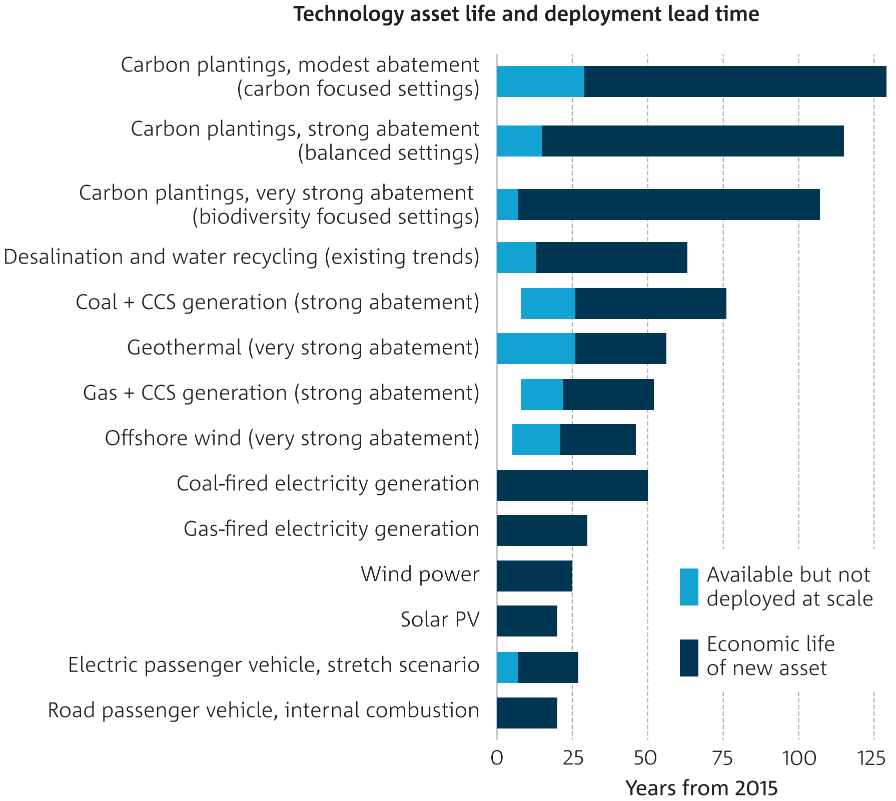
3.4 Technology is crucial to achieving sustainable prosperity

Policy settings and market factors will drive the deployment of a portfolio of technologies for energy, water, transport, agriculture and other industries, and to support continuing innovation.

Existing and emerging technologies are available to meet needs in all sectors, including in energy and transport (see Section 2.3) and water (Section 3.3). Achieving the efficiency improvements and cost reductions assumed in our projections will require continued effort and innovation, however, and should not be taken for granted. Further innovation is particularly needed in agriculture, to boost productivity and resilience (Section 1.3), and across multiple sectors to achieve cost-effective emission reductions (Section 3.5).

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. But it would generally take a decade or more to decide on and build significant new water and energy infrastructure assets, and a long operational life is needed to repay large capital investments (see Figure 18). Confidence in long-term policy settings is therefore essential to minimise investment risks and release cost-effective solutions.

FIGURE 18 **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/tCO2e. Economic life represents typical expected life, and actual asset life may be shorter or longer as influenced by operating costs and other factors.

Source: Modelling assumptions and results from LUTO and ESM, water supply asset life based on author judgements. More information: Section 3.3 of the *Australian National Outlook 2015 – Technical Report*.

Further innovation is needed to boost agricultural productivity and resilience, and to achieve cost-effective emission reductions across all sectors.

3.5 We can reduce our greenhouse gas emissions significantly through actions across all major sources, while maintaining strong economic growth

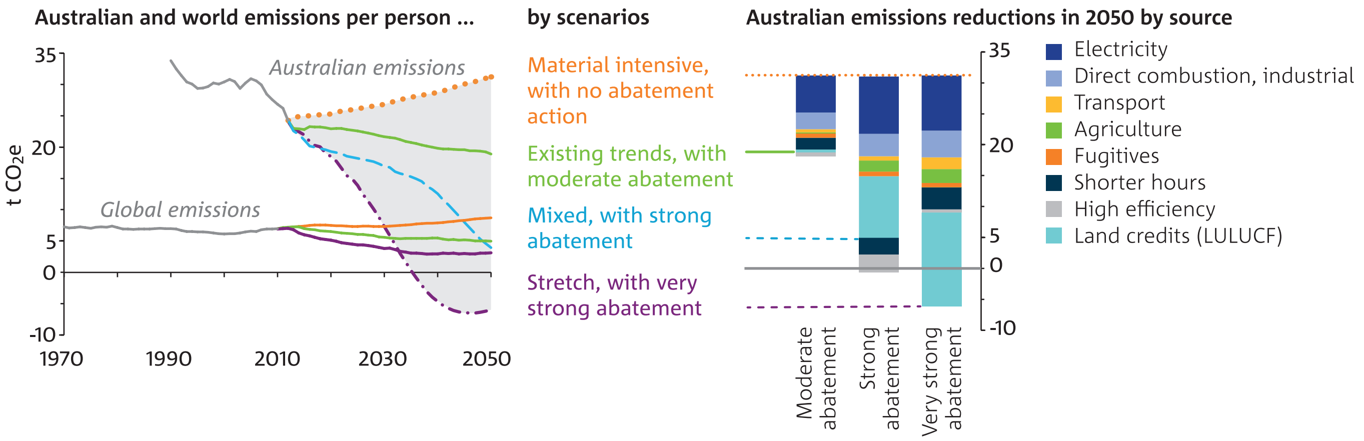
Australia can reduce its per capita emissions to below the global average by 2050, down from five times the average in 1990, by pursuing a mix of policies including energy efficiency, carbon capture and storage, renewable energy, and large-scale land-based sequestration.

We find Australia can reduce its per capita emissions to the world average by 2050, while maintaining strong economic growth and increasing exports from our energy-intensive industries. Australia could meet even the most stringent of long term targets, such as zero net emissions by 2050, without relying on international offsets[16]: see Figure 19.

Doing so will require policy settings and institutional arrangements that unlock emissions reductions across all sectors. Electricity, industrial emissions and transport deliver 40 to 75% of cost-effective national abatement by 2050 (assuming successful deployment of carbon capture and storage technologies), involving actions by a relatively small group of actors. Personal choices on energy efficient vehicles and appliances, as well as increased leisure, can also help reduce emissions. We find that achieving higher levels of cost-effective abatement requires settings that unlock land-based sequestration, which supplies 30 to 40% of total abatement in the strong and very strong scenarios. We find this only becomes attractive to landowners at significant scale when payments reach a 'sweet-spot' of A$40-60 per tCO2e or more – a threshold reached before 2020 with very strong global abatement (on track to 2°C) and before 2030 in the strong global abatement scenarios. Stable and predictable policy settings are also required, as to be effective in reducing emissions carbon plantings must be maintained for a 100 years or more.

Modelling confirms that successful global deployment of carbon capture and storage (CCS) has a crucial role in limiting the rise in global average temperature to 2°C. It would also significantly reduce the global costs of action, and cushion the impact of ambitious global action on Australian coal exports. Beyond 2050, there may be potential to combine bioenergy with CCS to generate energy with 'negative emissions', which could help reduce the stock of greenhouse gases in the atmosphere if deployed globally – a possibility warranting further assessment and research.

FIGURE 19 **AUSTRALIAN PER CAPITA EMISSIONS CAN FALL BELOW THE GLOBAL AVERAGE, WITH CONTRIBUTIONS FROM ALL SECTORS**



Notes: The figure 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 2.7 tCO2e and 2.2 tCO2e respectively, together resulting in projected emissions just below zero in 2050 for scenario M3XI.

Source: historical data, GIAM, GALLM, MMRF, ESM, LUTO, and estimates of global land sector abatement.
More information: Section 6.2 of the *Australian National Outlook 2015 – Technical Report*.

16 Consistent with our focus on the physical economy, the *National Outlook* focuses on domestic emissions before any trade in international offsets, and does not comment on potential emissions targets for Australia (which could be met through different combinations of domestic abatement and international offsets). International emissions offsets, or credits, provide valuable flexibility and allow countries and firms to meet their emissions commitments by supporting cost effective abatement in whatever country it occurs, with appropriate monitoring and verification.

3.6 Stronger global action to reduce greenhouse gas emissions could provide net benefits to Australia before 2050

Participating in stronger, coordinated global action to reduce greenhouse gas emissions could provide net benefits to Australia before 2050, in addition to longer term benefits. Actual costs and benefits would be highly dependent on the details of domestic policies, and how these interact with international actions. This analysis assumes abatement is achieved across all sectors, including carbon farming, transport, agriculture and other stationery energy industries, with settings that support continuing innovation.

Across all scenarios analysed, we found that those scenarios where Australia and the world take stronger action to reduce greenhouse gas emissions show higher long-term economic growth and better environmental outcomes compared to scenarios that continue current trends. Increased global efforts to reduce emissions could dampen demand growth for coal and minerals exports. However commercially available CCS technologies could significantly mitigate these impacts on Australia's export industries. At the same time, increased global efforts could boost the profitability of gas, uranium and agricultural production – and may even enable Australia to become a net exporter of emissions credits before 2050. We project Australian per capita income would continue to rise around the long term trend, between 1.2 and 1.5% per year. Over longer timeframes, growing global demand for education and tourism may play a larger role, and emerging energy technologies may provide new sources of comparative advantage. Synthetic solar gas and other zero-carbon energy might, for example, underpin Australia's future energy and energy-intensive exports, similar to the way that low-cost hydropower favours other countries today.

Other analysis has 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 economic benefits to Australia after 2050.[17] We find the additional benefits of stronger global action to reduce greenhouse gas emissions could outweigh the additional costs before 2050, due to projected shifts in national competitiveness rather than reduced physical climate impacts (which would largely occur after 2050).[18]

Figure 20 captures these results graphically, showing the economic and environmental trajectories of different scenarios, relative to existing trends. We find scenarios with strong abatement action (blue) or very strong abatement action (purple) nationally and globally would deliver win-win outcomes of higher economic growth combined with better protecting our natural assets over the medium to long term – delivering *synergies* (shown Quadrant 1). In our analysis, only the very strong global action scenarios limit the increase in global average temperature to 2°C. While this would achieve the greatest reduction in climate risks, it would also be expected to involve the highest national costs in the next two decades, all else equal. A number of scenarios involve a *transition*, with net costs in 2030 (as projected national income is lower than under existing trends), but net benefits relative to existing trends by 2050. We identify one outlook with lower projected emissions that represents *missed opportunities*

> **Shifting from current global efforts to stronger global emissions reductions could yield economic and environmental benefits for Australia. Weaker global emissions reductions are projected to boost near term economic performance, but would risk damaging assets that underpin our long term wellbeing and economic security.**

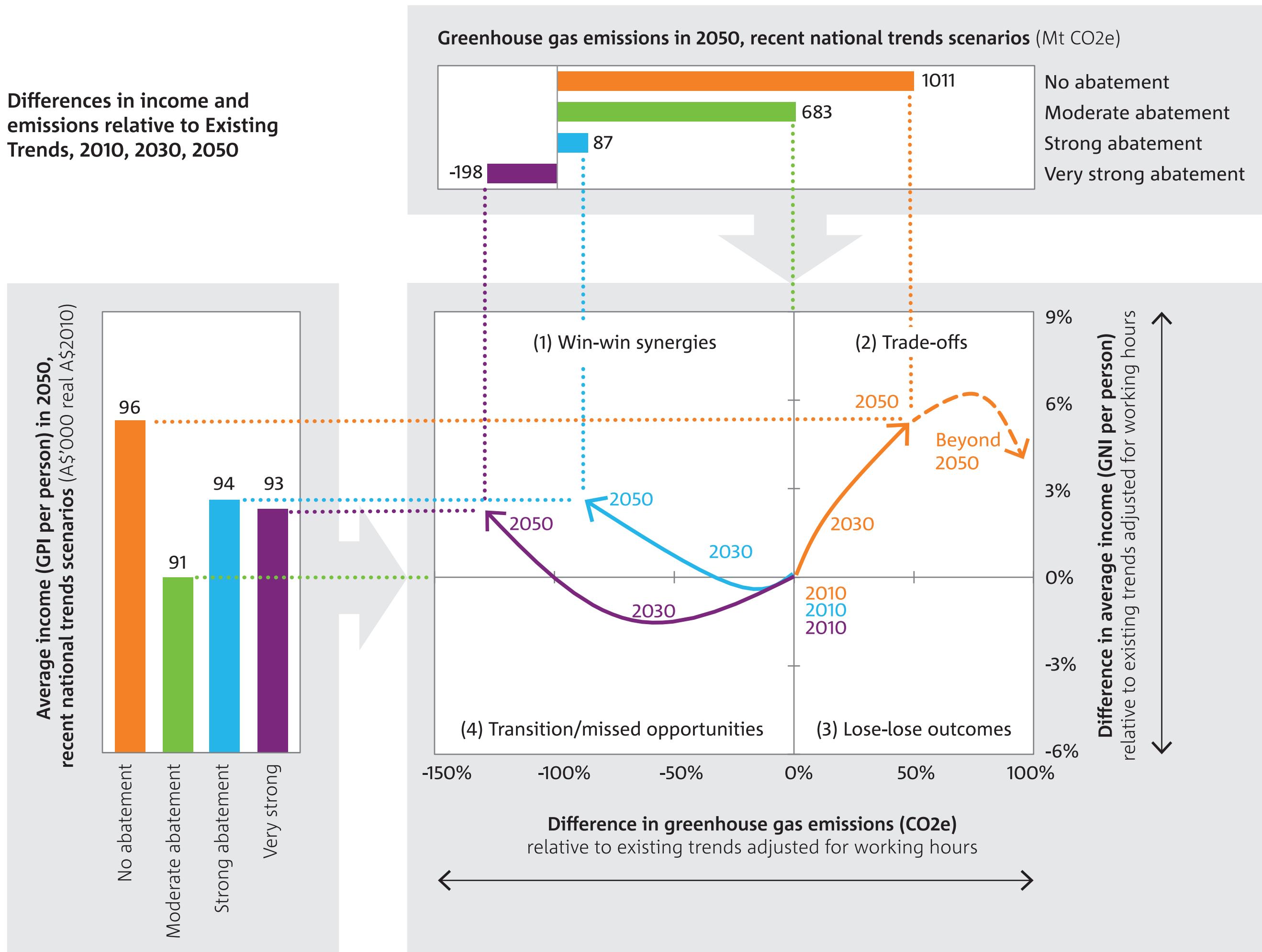
17 Garnaut, R. (2008) *The Garnaut Climate Change Review: Final Report.* Cambridge University Press, Port Melbourne. Climate Change Authority (2014), *Reducing Australia's Greenhouse Gas Emissions – Targets and Progress Review Final Report*, Climate Change Authority, Melbourne.

18 Moving to strong or very strong abatement involves higher abatement costs than moderate abatement, but the additional costs involved are more than offset by shifts in prices and production patterns that deliver greater value added from Australia's natural endowments than under moderate national and global abatement. In global scenarios with stronger action to reduce emissions, supplying carbon sequestration becomes more profitable than beef and other agricultural production across large areas of Australia – with carbon plantings at least five times more profitable than existing use on more than 60% of this land. The stronger abatement incentives in these scenarios also promote greater electrification and use of biofuels in road transport, and lower oil imports. These economic gains outweigh the costs of more stringent national emissions targets, as well as the impacts of lower global demand and value added from Australia's emissions-intensive exports, relative to scenarios assuming moderate national and global abatement. Scenarios with strong and very strong abatement thus involve net costs before 2050 when compared to no abatement action (nationally and globally) but net benefits when compared to modest abatement scenarios. S. Hatfield-Dodds, Schandl et al. (2015) Australia is 'free to choose' economic growth and falling environmental pressures, *Nature* DOI 10.1038/nature16065.

(Quadrant 4) in 2050, where a lack of land-sector markets both reduces living standards and foregoes economically attractive emissions reductions.

However, we also find potential for *trade-offs* (Quadrant 2), where weaker action (orange) is projected to result in better near-term economic performance, but risks damaging the natural assets and life-support systems on which our long-term wellbeing and economic security depend. At this stage, our modelling does not fully account for the economic impacts of climate variability and extreme events – including droughts, floods, and storms – and so is likely to understate the economic performance of scenarios involving very strong action, and overstate the economic performance of scenarios with weaker action, relative to existing trends. Improved energy efficiency and agricultural productivity could boost economic growth across all abatement scenarios, including those with modest abatement, but makes only a modest additional contribution to reducing emissions.

FIGURE 20 **STRONGER GLOBAL ACTION TO REDUCE GREENHOUSE GAS EMISSIONS PROVIDES WIN-WIN ECONOMIC AND ENVIRONMENTAL OUTCOMES BEFORE 2050**



Notes: The figure shows the differences in average national income (GNI per person) and net greenhouse gas emissions for different scenarios to 2050, relative to existing trends with moderate national and global abatement. The column and bar charts show projections for recent national trend scenarios for four abatement levels in 2050 (row XR in Figure 23), including the Existing Trends touchstone scenario. The pathways shown on the quadrant diagram by the coloured arrows are based on results for 2010, 2030 and 2050 for recent national trends. Modelling limitations imply that the economic performance of the no abatement scenarios is overstated and very strong abatement scenarios is understated relative to Existing Trends.

Source: Hatfield-Dodds, Schandl et al. (2015) *Nature*, MMRF (income) and MMRF, LUTO, ESM (emissions).
More information: Section 7.2 of the *Australian National Outlook 2015 – Technical Report*.

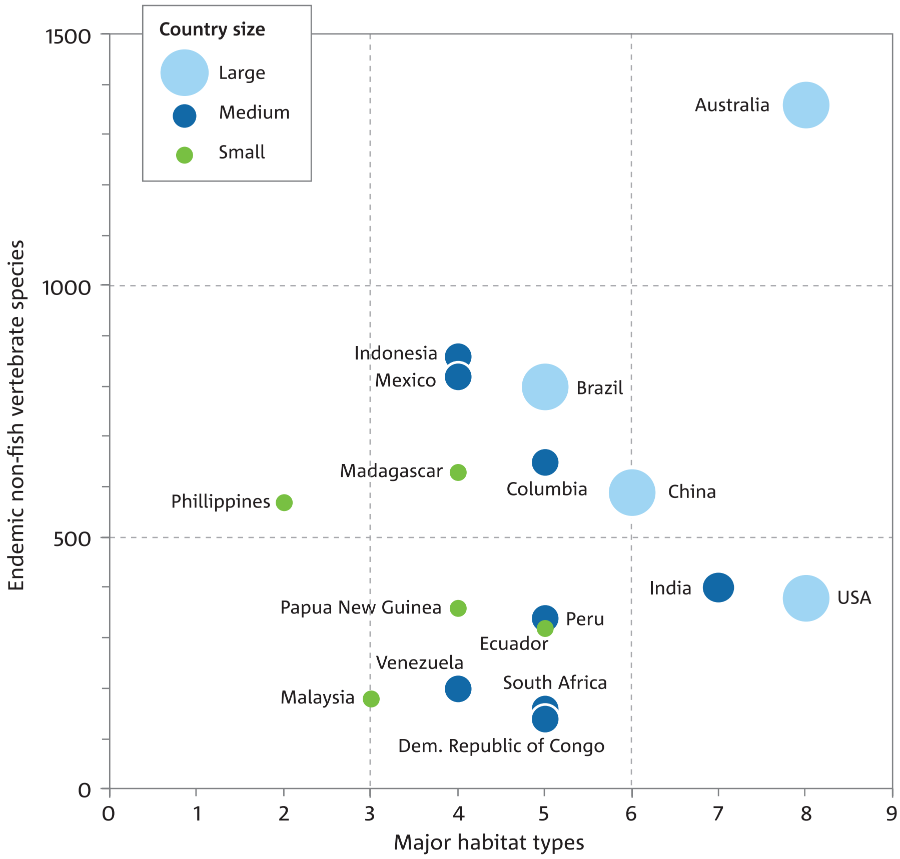
3.7 Abatement incentives can be harnessed to restore Australia's globally significant ecosystems

Australia's ecosystems are unique and globally significant. Harnessing markets for carbon sequestration would be the first opportunity in Australia's history as a nation to reward landowners for restoring and conserving those natural assets at national scale, without large government outlays.

Few countries have the number and diversity of habitats and species that Australia hosts (see Figure 21). Multiple waves of human settlement have reduced our biodiversity with the last two centuries seeing extensive reductions in the area of native habitat, and significant modification of our ecosystems. Climate change will exacerbate the impacts of these past changes – but climate policies can be harnessed to protect our biodiversity.[19] Providing incentives for restoring native habitat as well as carbon sequestration could significantly reduce the impacts of climate change on Australia's unique ecosystems and native species.

> **Carbon payments can be harnessed to protect our biodiversity.**

FIGURE 21 **AUSTRALIA HAS GLOBALLY DISTINCTIVE BIODIVERSITY**



Notes: The figure 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 km^2, medium are 0.8-3.0 million km^2 and large are 7.5-9.5 million km^2.

Source: Figure 12.1 in Morton and Sheppard (2014).

19 We find harnessing carbon payments could provide biodiversity benefits without large government outlays. The modelling assumes that governments provide a base level of funding for voluntary conservation across all scenarios. But this funding is very small in comparison to the resources provided directly and indirectly by payments for carbon sequestration, which are assumed to come from firms who wish to offset their greenhouse emissions (consistent with the general polluter pays principle). The key findings on the synergies and trade-offs between carbon and biodiversity outcomes presented in this section are not sensitive to these specific assumptions about whether land sector carbon credits and biodiversity benefits are purchased by public or private agents.

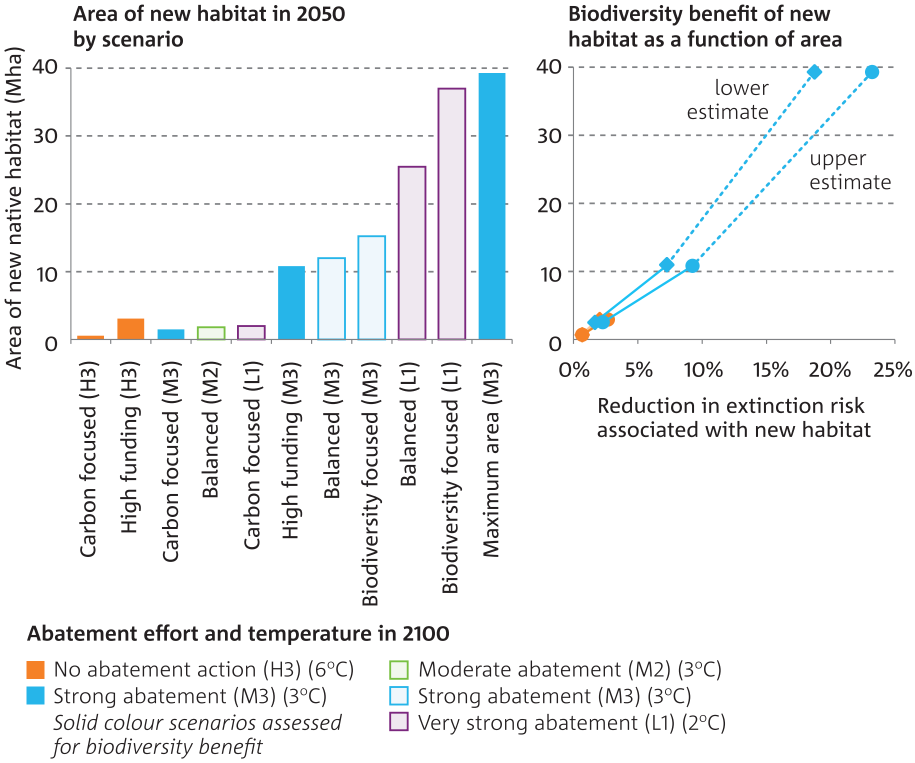
We find the benefits of restoring native habitat is broadly proportional to the area of native habitat, and so the benefits are strongly influenced by the total area of carbon sequestration plantings and the relative share of mixed species plantings versus single species forestry plantations.

The *National Outlook* explores this by modelling 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 ten 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 GtCO2e) over the period to 2050. We find a middle-ground 'balanced approach' could increase native habitat around eight-fold, for a one third reduction in carbon sequestration (1.3-1.4 GtCO2e) 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 22), while providing 3.1Gt GtCO2e of carbon abatement.

However, even restoring all cleared land to native vegetation (which is not modelled in any *National Outlook* scenario) would not eliminate very significant extinction risks under the current global emissions trajectory. We find no level of ecosystem restoration would offset the impacts of climate change where global average temperatures increase by 3°C to 6°C by 2100. This implies that stronger global action on greenhouse gas emissions is essential to effective protection of Australia's terrestrial and marine biodiversity for future generations.[20]

> **Biodiversity benefits – including reductions in extinction risk – are broadly proportional to the area of new native habitat restored.**

FIGURE 22 **RESTORING NATIVE HABITAT COULD SIGNIFICANTLY REDUCE THE IMPACTS OF CLIMATE CHANGE**



Notes: The figure 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 difference between the economic returns to mixed species plantings and the next most profitable land use.) The 'carbon focused' scenarios assume government funding of around A$125m per year. The 'biodiversity focused' and 'high funding' scenarios assume payments of around A$125m and A$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: LUTO (area of habitat) and GDM (biodiversity benefits), drawing on other model inputs (see Figure 14). More information: Section 6.1 of the *Australian National Outlook 2015 – Technical Report.*

20 Poloczanska, E.S. et al. (2007) Climate Change and Australian Marine Life. *Oceanography and Marine Biology Annual Review* 45: 409-480; Hobday, A.J., and J. McDonald (2014) Environmental Issues in Australia. *Annual Review of Environment and Resources* 39: 16.1–16.28

4 There is more we should talk about

This has been a first attempt by CSIRO and our partners to model and analyse potential trajectories for Australia's physical economy many decades into the future. While our approach and models have limitations, we consider the strong grounding in scientific theory and observed data helps identify several important areas warranting further public discussion and scientific research.

4.1 A partial outlook, no matter how extensive

No scientific project or report can address all issues. This first *National Outlook* is focused on interactions within the water-energy-food nexus, and the prospects for our export-oriented materials intensive industries to 2050 – particularly energy and agriculture. The analysis is framed around a set of key uncertainties that could materially impact on Australian living standards, resource use and environmental performance over the long term (see introduction, above). We do not explore the global business cycle, such as how or when Europe and the United States might deal with persistent low demand and structural economic problems. Nor do we explore significant Australian policy issues such as the patterns of government taxes and expenditures. Our analysis assumes Australia's long-term average productivity growth continues a little below that of recent decades (as the benefits of the previous reforms taper off), and a gradual decline in the relative value of the Australian dollar.

4.2 Significant issues to debate and explore

Some of our findings challenge accepted views. Others land decisively on one side or the other of contemporary debates. In many cases the findings point to a need for public dialogue and discussion, as well as continued scientific exploration.

We find stronger global action on reducing greenhouse gas emissions could result in net economic benefits for Australia before 2050, several decades earlier than suggested by previous studies. But this finding is for a specific set of assumptions, and rests heavily on the performance metric of economic activity measured by GDP or GNI. Further research and analysis is required, including of the risks and opportunities of climate change for agriculture, coastal settlements, and other vulnerable sectors. Also warranted is further evidence-based assessment of the potential effects of a global clean energy transition, identifying transition pathways for particular sectors and regions, and how Australia can best manage uncertainties as it pursues its national interests.

We find potential for very substantial land use change, driven by the relative market rewards for agriculture and carbon sequestration plantings. Relatively minor changes in settings and incentives can have major impacts on the mix of carbon, water flows, and river and dryland ecosystem health across different areas of Australia. But with great opportunities come great challenges. Ignoring these opportunities would deny landholders the ability to earn substantial additional income, and neglect a potentially transformative chance to restore our globally significant ecosystems. The insights and approaches Australia develops will be relevant and valuable to other countries facing analogous challenges.

We find that Australia remains a country of opportunity, but that we need to create our own future. Empirical evidence suggests that while some trends and underlying drivers will be similar, many of the trends that shape the world over the next forty years will be different to those that shaped the last four decades. This raises questions about how Australia can best capitalise on our natural assets: for tourism, food and fibre, energy, materials and our own quality of life – and do so in a way that is ecologically responsible?

Given the focus of the *National Outlook* on the water-energy-food nexus and material-intensive industries, it is not surprising that technology deployment and innovation emerge as key issues in shaping our future, drawing attention to policy and institutional settings. Australia's long term policy frameworks are often world leading – including in water governance, retirement incomes, and public health. But there are always opportunities for continuous improvement, such as in the governance of electricity networks and managing peak demand. How do we build on what we do well, to turn challenges into opportunities, and help navigate Australia's future?

"

We find that Australia remains a country of opportunity, but that we need to create our own future.

4.3 Scientific advances and future research needs

Several aspects of the integrated analytical framework used for the first *National Outlook* represent significant advances in Australia's scientific capacity. The framework builds on established practice in assimilating large complex data sets, nesting national economic models within global models, and in linking national economic models (providing a high level view of the whole economy) with engineering based electricity and transport models (simulating investment and operating decisions with rich technology detail). The major advance comes from linking multiple models to provide an integrated framework that accounts for interactions and impacts across sectors that are normally analysed in isolation. This allows the framework to explore and assess (i) the evolution of economic structure, sectoral interactions, and cross scale effects (working within the UN national accounts framework); (ii) potential land use change across diverse economic and policy scenarios, including implications for agricultural output, carbon sequestration, terrestrial native habitat and associated changes in extinction risk; (iii) future water stress (rather than simple volume of water use); (iv) flows of materials and energy through national and global supply chains, and associated environmental footprints; and (v) combine these assessments with established indicators including energy and water use, greenhouse emissions, national income, and economic activity in a coherent integrated framework.

The analysis for the *National Outlook* draws attention to numerous gaps in our data, scientific knowledge and capacities. It highlights the need to improve the productivity and resilience of Australian agriculture, and to explore opportunities arising from global shifts towards clean energy – including possibilities to deliver 'negative emission energy' that might help reduce global greenhouse gas emissions concentrations.

Several priorities have been identified for improving our integrated analytical framework, at both national and global scales. These include developing the capacity for fully-linked multi-model ensemble analysis (using large sets of scenarios to explore uncertainties, and the impacts of specific events as well as different trends), enhancing the representation of water supply and demand, and improving analysis of sector-level climate impacts (particularly for agriculture and built assets). Over the longer term, we are interested in deepening our capacity to analyse the urban systems in the context of regional, national and global supply chains, including the relationships between the built environment, mobility, energy use, food systems, nutrition, and health.

> **Several aspects of the integrated analytical framework used for the first *National Outlook* represent significant advances in Australia's scientific capacity.**

Appendix A: Our analytical framework

A.1 Detailed scenario and modelling assumptions

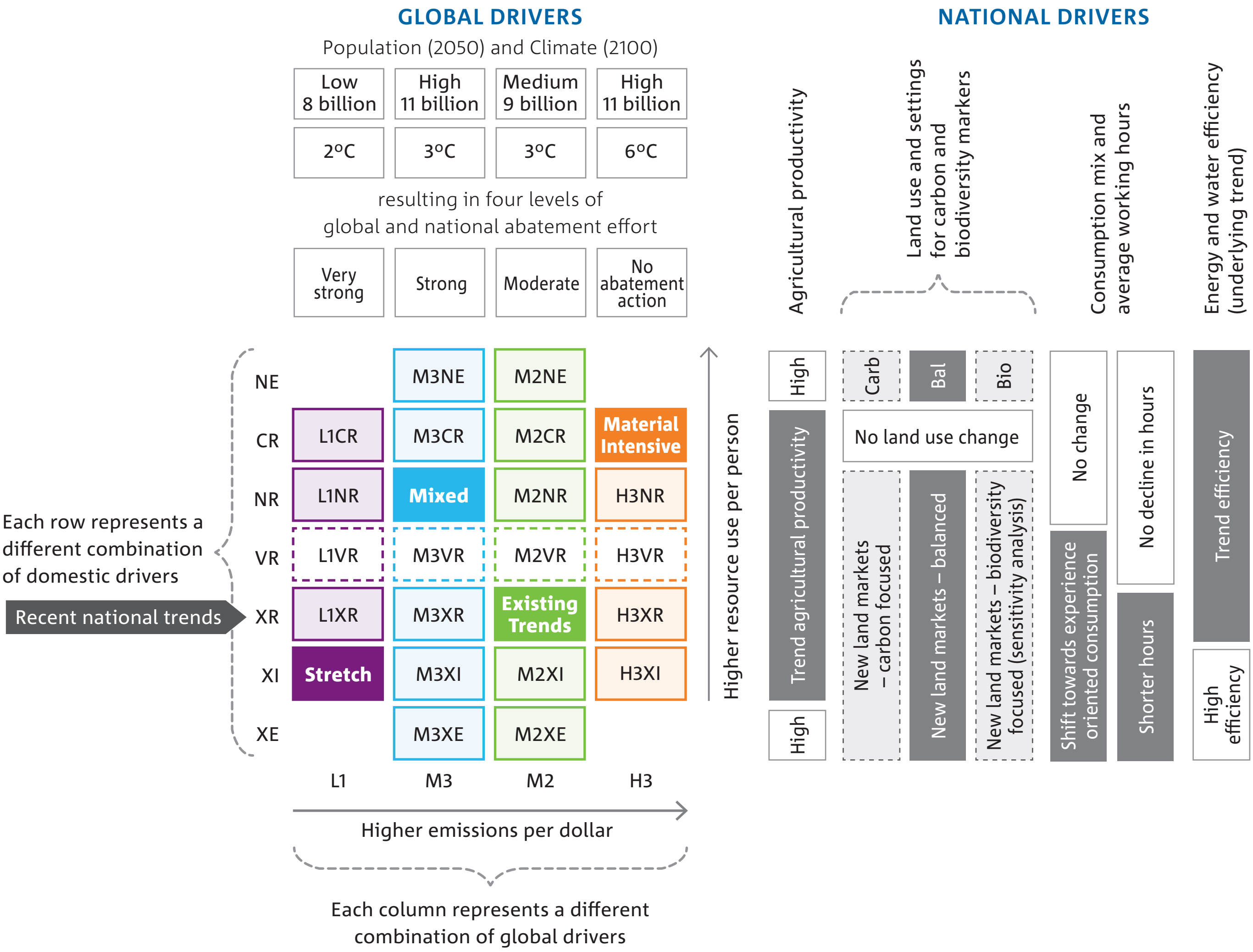
Scenario definitions and construction

The set of scenario issues and drivers explored in the *National Outlook* was chosen after a series of expert workshops in late 2012, drawing on the CSIRO megatrends analysis.[21] (See introduction for a summary of the scenarios). To test the implications of these uncertainties, three levels were identified for each of the two global drivers, and two levels for each of the national drivers. In addition, three settings were identified for the relative weight given to carbon and biodiversity in implementing new land markets. This implies 864 unique potential combinations of drivers, each representing a potential scenario.

To make the analysis tractable, we have focused on modelling the 20 core scenarios shown in Figure 23 (following page), supplemented by targeted sensitivity analysis. Though not exhaustive, this set covers a wide range of plausible socio-economic and biophysical outcomes, and allows us to assess the effects of each scenario driver. The specific assumptions for each driver are shown in Table 1, and the main scenario pairs used to assess the impact of the drivers are shown in Table 2. Sensitivity analysis was undertaken to separate the effects of global population growth from the level of abatement effort (as discussed below), and to explore different settings for new land markets. Most of the supporting science papers also define and model additional scenarios to explore specific issues of interest in the context of each paper.

21 Hajkowicz, S.A., Cook, H., Littleboy, A. (2012) *Our Future World: Global megatrends that will change the way we live. The 2012 Revision*. CSIRO, Australia.

FIGURE 23 **THE SET OF NATIONAL OUTLOOK SCENARIOS, IN RELATION TO GLOBAL AND NATIONAL DRIVERS**



Notes: The figure 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 greenhouse gas 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.

Source: *National Outlook* project team, see Section 2.4 in the *Australian National Outlook 2015 – Technical Report.*

TABLE 1: SUMMARY OF THE MAJOR UNCERTAINTIES EXPLORED IN THE NATIONAL OUTLOOK

Global context	Four global context scenarios (a)			
Global climate	**Low climate (L) on track to 2°C**	**Mid climate (M) 3°C by 2100**	**Mid climate (M) 3°C by 2100**	**High climate (H) 6°C by 2100**
economic demand and population growth (a)	**Lowest economic demand (1)** Population rises to 8.1 billion in 2050.	**Strong economic demand (3)** Population rises to 10.6 billion in 2050.	**Moderate economic demand (2)** Population rises to 9.3 billion in 2050.	**Strong economic demand (3)** Population rises to 10.6 billion in 2050.
greenhouse gas emissions to 2050 (a)	Very strong abatement is required to limit cumulative emissions to 3,100 GtCO2e.	Strong abatement is required to limit cumulative emissions to 3,800 GtCO2e.	Moderate abatement is required to limit cumulative emissions to 3,800 GtCO2e.	No abatement action sees cumulative emissions of 4,600 GtCO2e.

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 all 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 increases 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. Energy demand growth in strong and very strong abatement scenarios is reduced by higher prices.	**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 in 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 thirty 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 above current levels.
Emerging land-sector markets	**New Markets (N):** (Experience oriented (X) consumption scenarios all also assume new markets.) 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 agricultural 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 in crops, livestock and other sectors, and 1.0% in forestry, implying substantial innovations in agricultural techniques.

Notes: (a) The abatement effort in each global scenario has been calculated to result in cumulative global greenhouse gas emissions from 1861 to 2050 that match RCP 2.6, 4.5 and 8.5 (Moss et al., 2010). Temperature for 2100 is based on the upper bound of the 66% range for the increase from pre-industrial to 2090-2099, rounded to the nearest whole degree (Rogejl et al., 2012). Population matches UN (2012) projections.

TABLE 2: SCENARIO PAIRS USED TO ANALYSE THE IMPACTS OF DIFFERENT DRIVERS

Driver	**Primary comparison** (see Figure 23)	**Additional comparisons** (see Figure 23)
National and global abatement effort	Column L1 vs M3 vs M2 vs H3	
Resource efficiency	Row XR vs XI	
Working hours and consumption mix	Row XR vs NR	
– *Working hours*		Row VR vs XR
– *Consumption mix*		Row NR vs VR
Land use	Row NR vs CR	
Settings for new markets	Balanced vs carbon focused vs biodiversity focused (all NR)	
Agricultural productivity	Row NR vs NE	Row XI vs XE Row CR vs no land use change and high productivity (not shown in Figure 23)

Source: *National Outlook* project team.

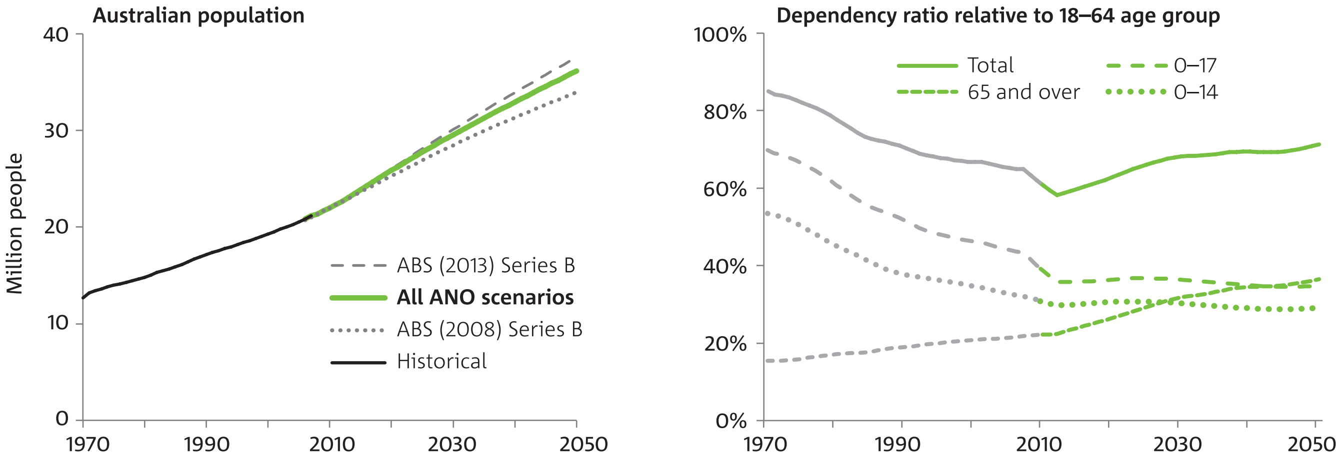
Population assumptions

The global scenarios incorporate the low, mid and high UN population projections, which see population increasing between 18 and 54% from 2010 to 2050. For consistency with the international literature, the global modelling maintains the UN projections for Australian population when modelling the global context scenarios.

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 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 has now been superseded by the official projections published in September 2013 (ABS 2013b).

As shown in Figure 24, 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 to 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 24 **AUSTRALIAN POPULATION AND DEPENDENCY RATIOS, 1970-2050 (ALL SCENARIOS)**



Notes: The figure 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: historical data, ABS (2008, 2013a, 2013b).

A.2 Modelling framework and implementation

Modelling linkages and implementation

The analysis for the *National Outlook* is implemented through linking the different models in the framework to provide consistent multifaceted projections, drawing on the different scope and strengths of each model. 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

Summary of models used in the *National Outlook*

GIAM (Global Integrated Assessment Model) is a set of linked models of the global economy and climate system, accounting for emissions from energy, industrial activity and agriculture (impacting on climate) and for climate impacts on economic activity.

GIAM.GTEM (Global Trade and Environment Model) is a multi-region dynamic economic model with up to 57 sectors. This model was originally developed by ABARE and has been adapted and rebuilt by CSIRO using the latest GTAP database.

GIAM.Climate includes the SCCM, CCAM and ACESS models, providing ensemble climate projections with regional resolution to match GIAM.GTEM, MMRF.H2O and NIAM.FLOW requirements.

GALLM (Global and Local Learning Model) is a multi-region global electricity model that projects change in generation supply mix and technology costs for alternative scenarios. This model has been developed by CSIRO.

ESM (Energy Sector Model) is a set of interconnected CSIRO models of the Australian energy sector, including electricity generation, transmission and distribution, and transport sector. These models have been developed by CSIRO and provide detailed projections of electricity prices, system costs, and the mix of electricity and transport technologies and associated fuel use.

MMRF.H2O (Monash Multi-Regional Forecasting model) is a dynamic economic model of Australia, with seven state regions and up to 110 sectors. It has been used extensively for assessing greenhouse emissions and policy options, and has recently been extended to include water trading and three water supply options (rainwater, desalination, and recycled waste water). 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.

LUTO (Land Use Trade Offs) is a spatially detailed model of Australian rural land use that combines data on existing land use, production functions, input and output prices, and physical variables (including climate) to calculate the relative profitability of a wide range of potential land uses. This model has been developed by CSIRO.

Biodiversity Assessment using **GDM** (Generalised Dissimilarity Modelling) provides spatial analysis of biodiversity and its relationship with the physical environment over time. The GDM approach has been developed by CSIRO and allows for biological scaling of the pace of climate change, informing adaptive prioritisation.

MEFISTO (Material and Energy Flows Integrated with Stocks) is a multi-scale flexible modelling framework used for analysis of historical energy and environmental pressures and supply chain or 'footprint' analysis of economic production and consumption. This model has been developed by CSIRO.

NIAM.FLOW (National Integrated Assessment Model – Surface Flows) is a module that provides climate-linked projections of water availability in rivers and storages. This has been developed by CSIRO.

used as an 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.

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 25). Changes in climate variability – the intensity and frequency of droughts, floods, storms – will have impacts for agriculture (potentially outweighing productivity improvements in some regions), infrastructure and built assets, and human health. Better representation of these impacts would have implications for the projections presented in this report, but may not have significant implications for relative performance across different scenarios before 2050 because of the lag times to differences in climate, and thus in climate impacts.

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 (see Section 4.3), 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:

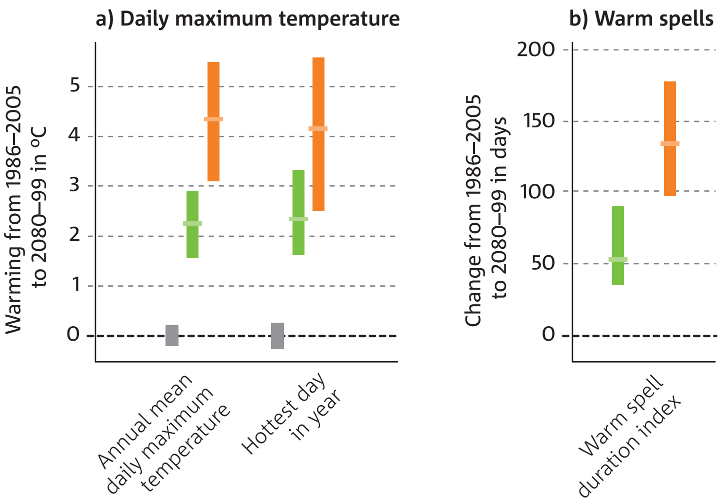
Energy system: Analysis of dynamic land use constraints for bioenergy supply, and whole of electricity system analysis of efficiency and costs, including transmission and distribution network utilization under different policy settings and demand scenarios, and the implications of different rates or 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

FIGURE 25 **EXTREME HEAT EVENTS ARE PROJECTED TO BECOME MUCH MORE COMMON**



Notes: The figure 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).

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 projected economic and biophysical flows through national and global supply chains, to assess the materials, energy and carbon footprints of different nations and scenarios, and associated patterns of production and consumption (applying established techniques used for historical data to forward looking projections).

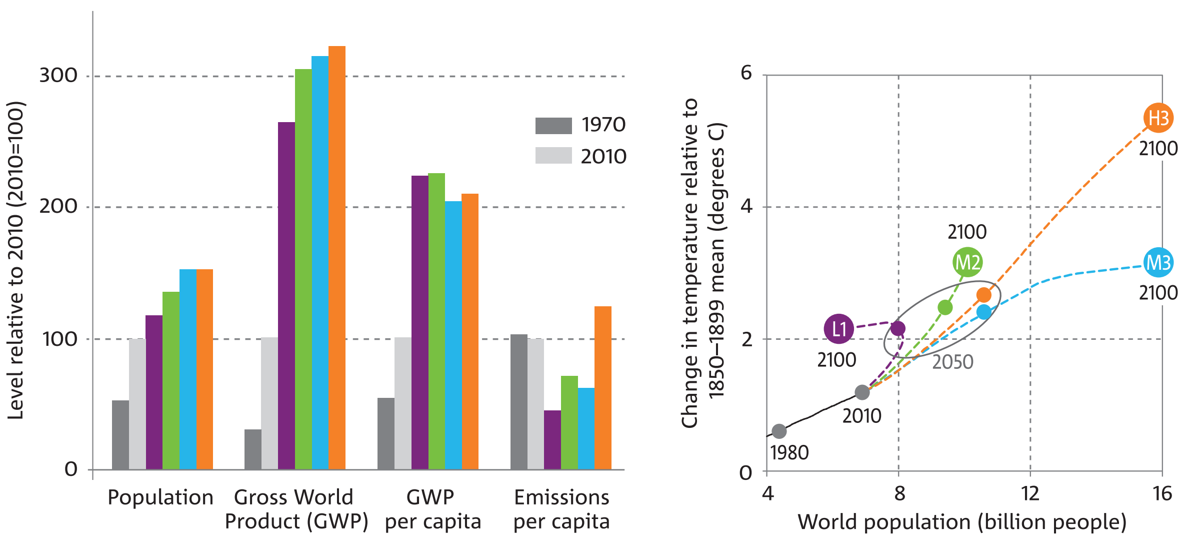
Environmental pressures: Analysis of multiple environmental pressures, and their relationships with Australian population, economic growth, technology, and consumption patterns across different scenario outlooks.

A.3 Key results for the global context scenarios

The four global context scenarios are designed to provide an internally consistent set of contrasting outlooks for global economic demand, abatement action, physical climate trends, and agricultural prices. We assume global population follows UN projections,[22] rising from 6.9 billion in 2010 to 8.1 billion (L1 scenario), 9.3 billion (M2 scenario) or 10.6 billion (M3 and H3 scenarios) in 2050. Consistent with other studies, we find that by 2050 world economy is projected to grow to be around three times larger than it is today, with average global income per person more than doubling from 2010 to 2050 across all scenarios.

The abatement effort in the scenarios has been calculated to result in cumulative global emissions from 1861 to 2050 that match RCP 2.6 (scenario L1), RCP 4.5 (scenarios M2 and M3), and RCP 8.5 (scenario H3)[23], requiring moderate abatement effort to achieve RCP 4.5 with medium global population growth (M2) and strong abatement effort to achieve the same RCP with high global population growth (M3). The different levels of global abatement effort have a significant impact on per capita emissions in 2050, but the full climate implications – and impacts – of the different emissions trajectories do not occur until later in the century (see Figure 26).

FIGURE 26 **KEY INDICATORS FOR THE FOUR GLOBAL CONTEXT SCENARIOS, 1970, 2010, 2050, OR 1980-2100**



Notes: The left hand panel shows population, real world economic output (GWP), average income (GWP per person), and net greenhouse gas emissions per capita (CO2e from all sources) for 1970, 2010 and 2050, for the four global context scenarios (as described in the text and Figure 23). The right hand panel shows population and indicative change in average global temperature for 1980-2100, relative to the 1890-1899 mean.

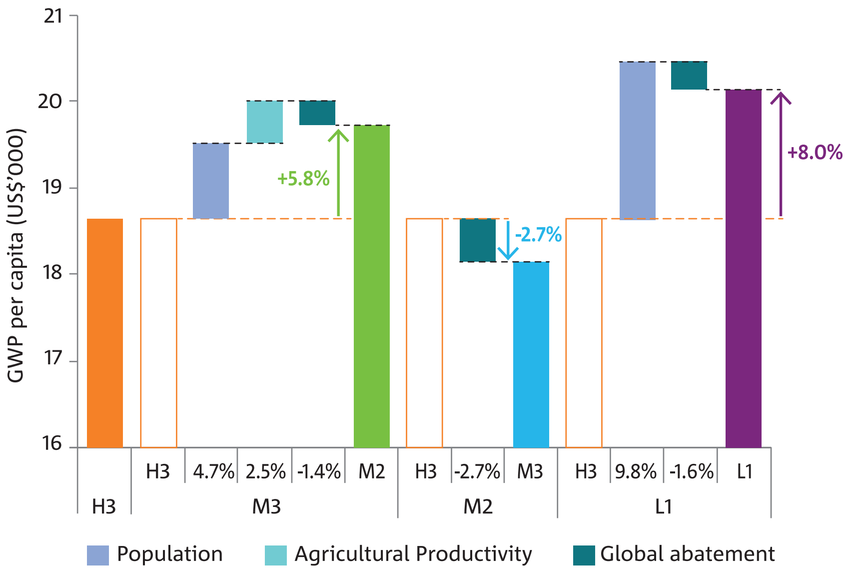
Source: historical data, UN (2013) (population projections), GIAM.GTEM and GIAM.Climate. More information: Section 3.1 of the *Australian National Outlook 2015 – Technical Report*.

22 United Nations (2013) *World population prospects. The 2012 revision. Volume I: comprehensive tables.* New York, United Nations.

23 Moss et al. (2010) The next generation of scenarios for climate change research and assessment. *Nature* 463:747-756. (See the *National Outlook – Technical Report* for more details.)

Average global income in 2050 varies by 8% across the different global context scenarios. Differences in population growth account for most of this difference, with lower population growth resulting in higher average global incomes. Stronger levels of global abatement effort slow the rate of economic growth, resulting in average income in 2050 being 1.4 to 2.7% lower than it would be otherwise. This abatement impact is more than offset by population growth, as shown in Figure 27. We also find that greenhouse gas reductions involve relatively greater costs in scenarios with higher global population, largely due to interactions between higher demand for food and increased competition for land (from reforestation and reduced levels of land clearing). The last factor influencing the range of average global incomes is agricultural productivity, where the analysis assumes higher agricultural productivity in the medium population moderate abatement (M2) scenario in order to achieve a wider range of agricultural prices for the domestic scenario analysis. This boosts average income in the M2 scenario by 2.5% in 2050.

FIGURE 27 **IMPACT OF POPULATION, AGRICULTURAL PRODUCTIVITY AND ABATEMENT INCENTIVES ON GLOBAL GDP PER CAPITA, RELATIVE TO THE SCENARIO WITH HIGH POPULATION AND NO GLOBAL ABATEMENT, 2050**



Notes: The figure shows the impact of key assumptions on average global income for the four global context scenarios, stepping out the effects of population, abatement effort and global agricultural productivity, as discussed in the text.

Source: GIAM. More information: Section 3.1 of the *Australian National Outlook 2015 – Technical Report.*

Appendix B: References and further information

B.1 Supporting documents and materials

The key findings and results presented in this report are supported by a technical report and more than ten 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 and Summaries	Notes
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 – Chart overview.	A3 poster and infographic.
Australian National Outlook 2015 – Technical report.	Technical report, explaining methods and results in more detail.
Key science papers – Reporting *National Outlook* results and analysis	
Australia 'free to choose' economic growth and falling environmental pressures.	Underpins Sections 2.1, 3.2 and 3.6. See Hatfield-Dodds, Schandl et al. (2015) published in *Nature*.
Australian retail electricity prices: Can we avoid repeating the rising trend of the past?	Underpins Section 2.3 and analysis of emissions reductions from stationary energy (including Section 3.5). See Graham et al. (2015) published in *Energy Policy*.
Australian self-sufficiency in transport fuel: Potential contribution of biofuels.	Underpins Section 2.3 and analysis of emissions reductions from transport. See Brinsmead et al. (in review).
Potential for Australian land-sector greenhouse gas abatement and implications for land use, food, water and biodiversity.	Underpins Sections 1.3, 3.1, 3.2 and 3.7, and analysis of land use trade-offs (in review).
Land use and sustainability under intersecting global change and domestic policy scenarios: trajectories for Australia to 2050.	Underpins Sections 1.3, 3.1, 3.2, 3.7 and analysis of land use trade-offs. See Bryan et al. (2015) published report for the *Australian National Outlook*.
Scenarios for Australian agricultural production and land use to 2050.	Underpins Sections 1.3 and 3.1. See Grundy et al. (in review).
Outlooks for adaptive conservation of Australian biodiversity under global change.	Underpins Section 3.7. See Harwood et al. (in 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. Underpins Sections 2.1, and 3.4. See Hatfield-Dodds, McKellar et al. (under review for *Economic Systems Research*).
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. (in 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.	Outlines the data and methods used to estimate implications of trends in energy and water intensity and potential impact of efficiency measures. See Baynes (2015) published report for the *Australian National Outlook*.
Decoupling global environmental pressure and economic growth: scenarios for energy use, materials use 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 the *Journal of Cleaner Production*.

B.2 Figures and tables in this report

Figures in this report

Tables in this report

B.3 References

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B.4 Glossary of key terms

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.
Bio-physical 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.
Bio-physical 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 travelled) 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 use of air conditioners).
Per capita income	Average income per person, usually measured by Gross National Income (GNI) per head of population.

Term	Definition
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 'bio-physical processes' and 'economic decoupling'.
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) 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.

B.5 Acronyms

ABARES	Australian Bureau of Agricultural and Resource Economics and Sciences
ABS	Australian Bureau of Statistics
CCS	Carbon capture and storage
CO2e	Carbon dioxide equivalent
EU	European Union
ESM	CSIRO's Energy Sector Model
DSE	Dry (non-lactating) sheep equivalent, in relation to meat output or feed requirements
GALLM	CSIRO's Global and Local Learning Model, which provides projections of electricity generation technology costs
GDP	Gross Domestic Product
GDM (biodiversity assessment)	Generalized Dissimilarity Modelling, which analyses and projects patterns of beta diversity in regional biodiversity assessment
GIAM	Global Integrated Assessment Model
GIAM.GTEM	Global Trade and Environment Model of the global economy
GNI	Gross National Income
Gt	Giga-tonnes (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
Mha	Million hectares
MEFISTO	CSIRO's Material and Energy Flow Integrated with Stocks model
MMRF	Monash Multi-Regional Forecasting model of the Australian economy, now maintained by Victoria University
Mt	Million tonnes
NIAM	CSIRO's National Integrated Assessment Model
NIAM.FLOW	CSIRO's model used to assess and project surface water flows
Solar PV	Solar photovoltaic
UN	United Nations
US	United States of America
USD	United States dollars

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BRIEF CITATION
CSIRO, 2015, *Australian National Outlook 2015: Living standards, resource use, environmental performance and economic activity, 1970-2050.* CSIRO, Canberra.

FULL CITATION
Steve Hatfield-Dodds, Phillip D. Adams, Thomas S. Brinsmead, Brett A. Bryan, Francis H.S. Chiew, John J. Finnigan, Paul W. Graham, Michael J. Grundy, Tom Harwood, Rebecca McCallum, Lisa E. McKellar, David Newth, Martin Nolan, Heinz Schandl, and Alex Wonhas, 2015, *Australian National Outlook 2015: Economic activity, resource use, environmental performance and living standards, 1970-2050.* CSIRO, Canberra.

ISBN 978-1-4863-0587-2

15-0019