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doi:10.1038/nature16065

Australia is 'free to choose' economic growth and falling environmental pressures

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Over two centuries of economic growth have put undeniable pressure on the ecological systems that underpin human well-being. While it is agreed that these pressures are increasing, views divide on how they may be alleviated. Some suggest technological advances will automatically keep us from transgressing key environmental thresholds; others that policy reform can reconcile economic and ecological goals; while a third school argues that only a fundamental shift in societal values can keep human demands within the Earth's ecological limits. Here we use novel integrated analysis of the energy–water–food nexus, rural land use (including biodiversity), material flows and climate change to explore whether mounting ecological pressures in Australia can be reversed, while the population grows and living standards improve. We show that, in the right circumstances, economic and environmental outcomes can be decoupled. Although economic growth is strong across all scenarios, environmental performance varies widely: pressures are projected to more than double, stabilize or fall markedly by 2050. However, we find no evidence that decoupling will occur automatically. Nor do we find that a shift in societal values is required. Rather, extensions of current policies that mobilize technology and incentivize reduced pressure account for the majority of differences in environmental performance. Our results show that Australia can make great progress towards sustainable prosperity, if it chooses to do so.

Our analysis uses a new integrated multi-model framework developed for the Australian National Outlook[1]. Australia is globally relevant: a major exporter of energy, mineral and agricultural products, with high per capita income, greenhouse gas emissions, water extractions, and habitat loss. The framework assesses energy–water–food interactions (and links to ecosystem services) in the context of climate change[2], and uses more than 20 scenarios to explore a diverse range of factors shaping future Australian economic and environmental outcomes[1,2]. Interacting national trends and policies include energy and resource efficiency, agricultural productivity, consumption and working hours, and new land-sector markets for energy feed-stocks and ecosystem services (carbon sequestration and biodiversity conservation). These are modelled against four levels of national and global greenhouse gas emissions reduction effort (from no abatement to very strong abatement), and associated global climate trajectories (see Extended Data Fig. 9). As well as assessing the range of scenario outcomes, we identify the relative contributions of different types of choices. 'Collective choices' are defined as decisions that can only be implemented by groups of actors, and then constrain or empower 'individual choices' (particularly through changing rules and institutions). For example, individual choices about whether to drive or catch a train to work are strongly shaped by prior collective choices about transport infrastructure.

The framework accounts for detailed interactions across sectors and spatial scales. The focal scale is national (the continent of Australia), accounting for key processes at higher (global) and lower (sub-national) spatial scales. This cross-domain integrated approach is needed because partial assessments may not account for constraints or adverse impacts that would undermine an otherwise 'sustainable' trajectory[3–8]. The projections and indicators are fully consistent with the international System of National Accounts[9]. We provide more details in the Supplementary Methods (section 'Overview of modelling framework and scenarios') and results for more than 60 national and global indicators in the Supplementary Data.

Novel aspects of the analysis include assessing the potential for markets for ecosystem services to supply carbon sequestration and habitat restoration (and implications for agricultural output[7] and extinction risk)[10,11]; assessing future water stress rather than simple volume of water extracted[2,12]; exploring material extractions and environmental footprints[13]; and integrating these elements with established models for analysing energy, greenhouse gas emissions and economic performance[2,14–17]. We are not aware of any other future-looking modelling that integrates this range of issues and indicators (Supplementary Methods, 'Overview of modelling framework and scenarios').

Economic and physical decoupling is possible

We find that substantial economic and physical decoupling is possible[18]. Economically, Australia can achieve strong economic growth to 2050, indicated by rising gross domestic product (GDP) and gross national income (GNI) per capita, in scenarios where environmental pressures fall or are stable. Physically, we find the services derived from natural resources (energy (Extended Data Fig. 2), water (Extended Data Fig. 3), food (Extended Data Fig. 4)) can increase, while associated environmental pressures ease (greenhouse emissions (Extended Data Fig. 6), water stress (Extended Data Fig. 3), native habitat loss (Extended Data Fig. 5)). Importantly, these projected decouplings do not involve a reduction in the value of Australia's heavy industry (Extended Data

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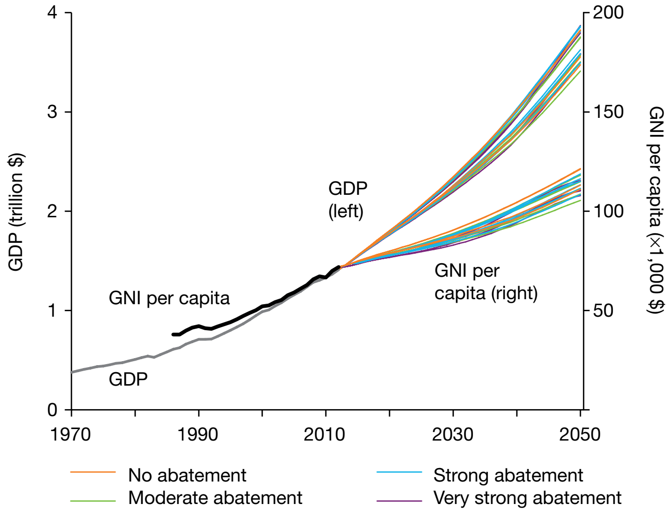

Figure 1 | Economic activity (GDP) and national income (GNI) continue to rise strongly in all scenarios. Projections for 20 scenarios. GDP measures the market value of goods and services produced. GNI here measures payments to national residents from domestic production (as foreign production is not modelled). All values are in real 2010 Australian dollars, adjusted for inflation; one trillion is defined as 1×10^{12}. Neither GDP or GNI is adjusted for changes in asset values, such as depreciation or the depletion of stocks of natural resources, and so do not measure pure income. More information on models and scenarios is provided in Supplementary Methods, 'Overview of modelling framework and scenarios'. Sources: Supplementary Data worksheets 1a and 1c.

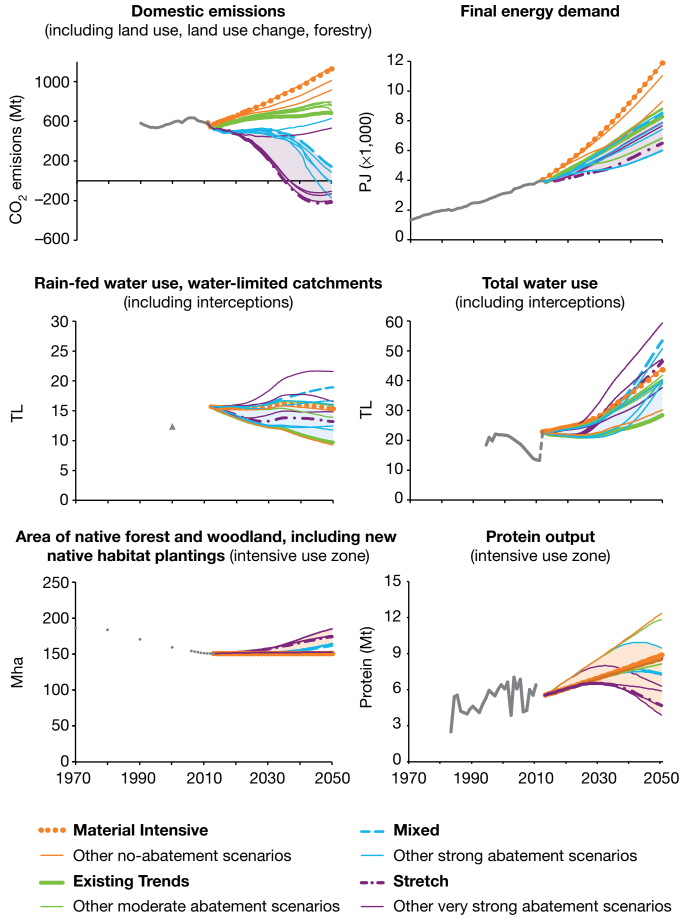

Figure 2 | Decoupling of emissions, water stress, and native habitat from the supply of energy, water and food, respectively, for 18–21 scenarios, 1970–2050. Each panel shows the scenario trajectories for a key indicator of resource use or environmental pressure. The shaded areas indicate scenarios in which environmental pressure decreases from current levels (in the left-hand panel), with the same scenarios shaded in the right hand panel of each row. Models and scenarios are described in Supplementary Methods, 'Overview of modelling framework and scenarios', and information on performance of multiple pressures across scenarios is provided in Supplementary Methods, 'Analysis of multiple pressures across scenarios'. Sources: Supplementary Data worksheets 6a, 2a, 3e, 3a, 5h and 4d.

Fig. 1g), or outsourcing its environmental footprint to other nations[13,19]. Instead energy- and material-intensive sectors are projected to increase their share of economic activity, even in scenarios with the strongest global abatement efforts[1,2].

In all scenarios, Australia's economy and living standards are projected to grow strongly (see Extended Data Fig. 1). As shown in Fig. 1, the value of economic activity (GDP) is projected to rise tenfold over the 80 years to 2050, driven by a 2.9-fold increase in population (Extended Data Fig. 8) and a 3.2–3.6-fold increase in GDP per capita (all values are in real 2010 Australian dollars, adjusted for inflation). National income (GNI) grows at a similar rate as GDP, with GNI per capita increasing by 58–82% from 2010 to 2050. Around two-thirds of the range of outcomes is explained by choices about working hours and consumption rather than environmental constraints. Average incomes rise by up to 66% if average working hours decline another 11% over the next four decades, in line with recent trends, and rise by 75% or more if there is no decline in working hours. The remaining income differential is accounted for by different assumptions and outcomes on resource efficiency, new land markets, agricultural productivity, and national and global abatement efforts.

Net greenhouse emissions show a clear decoupling from the growing economy, falling to zero or lower in some scenarios by 2040 (top row of Fig. 2). Australian emissions per capita could fall below the global average by 2050, from four times the global average today (Extended Data Figs 6b and 9f). One-third to one-half of Australia's projected emissions reductions are achieved through biosequestration from large areas of new carbon plantings (29–59 Mha in 2050, see Extended Data Fig. 5). The remainder is achieved by reducing the emissions- and resource-intensity of the economy. If there is a strong or very strong abatement effort, domestic emissions could fall by up to 33%, even as GDP grows more than 150%; and energy emissions could fall by up to 29% while energy use grows by 55–120%. Similarly, the total mass of fossil fuels, metals, non-metallic minerals and biomass[20] Australia uses is projected to decrease by 36% by 2050 in scenarios with very strong abatement and improved resource efficiency (Extended Data Fig. 1h). In other scenarios, total resource use is projected to increase by 69%[13].

National water extractions (by all sectors) are projected to increase by up to 101% by 2050. However, up to half (32–56%) of this water demand can be met by desalinisation in coastal cities and water recycling for industrial use. Water stress, indicated by rain-fed water use in water-limited catchments[12,21], improves or is stable in 7 of 18 scenarios (and is sensitive to governance of new carbon and biodiversity plantings, as noted below).

Pressures on biodiversity can also be reduced alongside economic growth and increased agricultural activity—resulting in increased native habitat and agricultural output volumes (including protein) in many scenarios[22] (bottom row of Fig. 2). Settings that give weight to biodiversity restoration could see mixed local native species plantings make up 36–47% of all carbon plantings in 2050 (against only 5% under a carbon-focused approach), increasing native habitat by up to 25% (37 Mha) in Australia's intensive use zone, and reversing the long-term trend. With strong abatement incentives, we find 11 Mha of habitat could be restored without large government outlays, reducing climate-related extinction risk by 7–9% (assessed for RCP 4.5 climate)[1].

However, these carbon and biodiversity plantings would reduce surface water flows, which could exacerbate pressures on river-based ecosystems in water-limited catchments (middle row of Fig. 2). Integrated

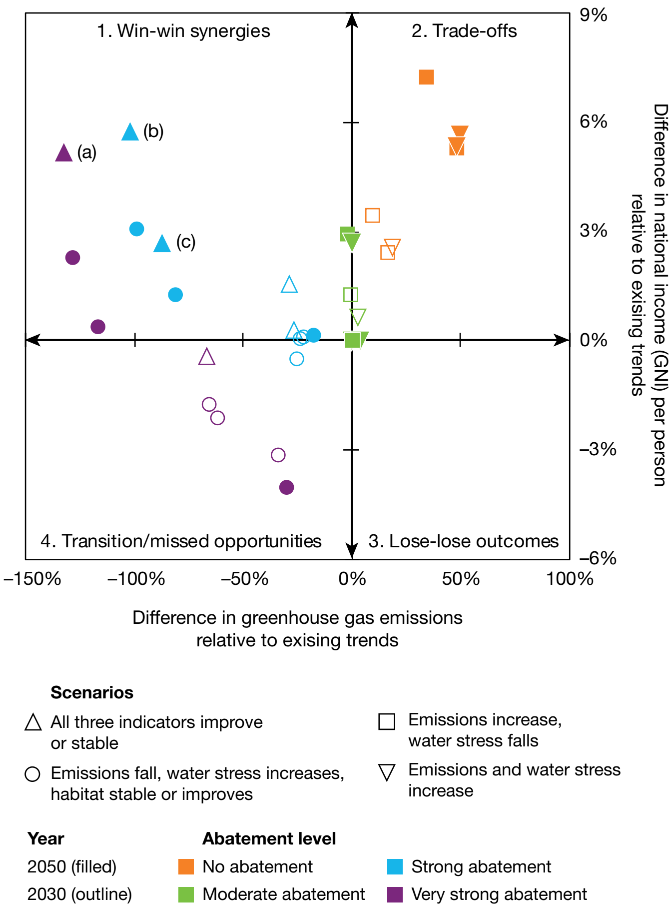

Figure 3 | Comparing living standards and emission outcomes across multiple scenarios. Differences in national income (GNI) and net greenhouse gas emissions in 2030 and 2050, relative to existing trends. Calculations based on 18 scenarios. Emissions, water stress and native habitat all improve or are stable in three scenarios, combining step change energy efficiency with very strong abatement (L1XI)—marked as (a)—or strong abatement (M3XI) (b), or trend energy efficiency with strong abatement (M3XR) (c). Differences shown are relative to existing trends (M2XR) controlling for working hours and consumption trends. Scenario assumptions and notation (such as M2XR) described in the text and Supplementary Methods, 'Calculations for Figure 3 and assessment of potential economic performance with different levels of global and national action to reduce greenhouse emissions'. Extended Data Fig. 6e shows time paths for each scenario from 2015 to 2050. Source: Supplementary Data worksheet 6e; see Extended Data Figs 1c and 6a.

governance is needed to properly balance their interceptions with competing extractive uses[23] (Supplementary Methods, 'Analysis of multiple pressures across scenarios'). Existing Australian governance arrangements cap extractions from water-limited catchments around current levels. The requirement to hold a water licence for new plantings embeds the price of water licences in these governance arrangements, as discussed below. Alternative governance assumptions could further restrain plantings, better safeguarding river health, but forgoing up to 0.5 Gt (5%) of cumulative national carbon sequestration by 2050.

Overall, two-thirds of the scenarios assessed (13 of 18) show improvement in at least one environmental indicator, but only three scenarios (all involving strong or very strong abatement and new land markets) show improvement or stable performance in all three environmental indicators, reflecting the tensions between reducing water stress and restoring terrestrial native habitat, and the importance of integrated governance (see Supplementary Methods Fig. 6 and Supplementary Methods, 'Analysis of multiple pressures across scenarios').

Policies to ease pressures extend established options

The scenario assumptions that result in reduced environmental pressures are all continuations of existing trends, combined with greater uptake of energy and water efficiency, and a shift towards stronger global and national greenhouse gas abatement (Supplementary Methods, 'Overview of modelling framework and scenarios'). Policy settings reflect market-based approaches that are already in place in Australia or other countries.

Greenhouse gas abatement is modelled as a uniform global broad-based carbon price, representing a variety of potential real-world mixes of regulation, standards, grants, taxes, or cap-and-trade arrangements. The carbon price in 2015 is US$15 (moderate scenario), US$30 (strong) and US$50 (very strong) per tonne of CO_2 emissions, and increases by around 4.5% per year in real terms (above inflation) to 2050. This drives a 90% reduction in the emissions intensity of Australian electricity from 2010 to 2050 in the stronger abatement scenarios (eliminating coal-fired electricity without carbon capture and storage before 2035 under the highest carbon price). Wholesale generation prices are 61–106% higher in 2050, and household electricity prices are 11–12% higher (strong) or 32% higher (very strong), compared to the no-abatement scenarios. However, affordability changes very little, owing to higher household incomes (in all scenarios) and higher energy efficiency in scenarios with higher prices[17].

Payments to Australian landholders for biosequestration are 15% below the global carbon price, with the forgone carbon revenue applied to increasing the share of native habitat plantings from 4–5% to 36–46% of total area in 2050. The resulting biodiversity 'top up payments' account for 22–30% of payments to habitat plantings in these scenarios over the decade to 2050, complementing carbon income. (These payments should be interpreted as a one-off payment for implementing a conservation covenant, for the area of new habitat added in that period.)

On water, we find that interceptions from new plantings result in increased water stress in many of the very strong abatement scenarios (which have the highest levels of new plantings). We find the profitability of carbon plantings is not sensitive to water licence prices: a doubling results in just a 4% reduction in the area of new plantings in water-limited catchments. Limiting the area of plantings to avoid this increased water stress would require a 200% increase in the water licence price (increasing the asset value of licences to existing owners).

Policy choices are crucial, not changes in values

These results provide insights into the contested relationship between economic growth and environmental sustainability[24], complementing historical analyses[18,25–27] (Supplementary Methods, 'Competing views on the prospects for sustainability'). A 'technological optimist' view considers market-driven technological advances will ensure that growth does not transgress key environmental thresholds[28–30]. Others suggest that institutional reform and new policies could achieve necessary changes within established values and paradigms[25,31–33], noting that environmental damage may occur during the long lags between problem identification and policy responses[18,25,34–36]. A third 'communitarian limits' view argues that sustainability will require a fundamental shift in societal values, often involving a rejection of economic growth[37,38], or a shift from consumerism to a values-based commitment to living within ecological limits[39].

We find that decoupling economic growth from environmental pressure before 2050 would not require a change in societal values, but is not automatic—contrary to both the communitarian limits and technological optimist positions. It is not projected to occur under existing trends, and requires, in our scenarios, collective choices to increase global and national abatement efforts.

The analysis explores potential behavioural change in several ways. The modelling simulates bottom-up individual choices on working hours and consumption that shape production and consumption as incomes rise (income elasticity) and relative prices change (price elasticity). These choices interact with different assumptions about policy settings (reflecting collective choices), such as incentives for greenhouse gas abatement, and about bottom-up trends, such as the uptake of energy and water efficiency. None of the scenarios assume a new social or environmental ethic. In particular, increasing Australia's abatement effort in line with emissions reductions by other countries would be consistent with Australian public opinion[40] and assessments of Australia's national interest[41–43] in limiting the rise in average global temperature to 2 °C[5,7,32,44], and so is not interpreted as implying a change in values. Rather, the analysis reflects how goal-oriented human behaviour can change with circumstances (including new information, or changes in the actions of others), without requiring any change in underlying goals and values.

We find collective policy choices are crucial, explaining 46–94% of differences in environmental performance and resource use across the scenarios examined (see Extended Data Fig. 7 and Supplementary Methods, 'Assessing the contributions of individual and collective choices'). Consistent with the institutional reform approach[25,32,45,46], we find top-down collective choices are particularly important in shaping 'public good' outcomes—accounting for 83–94% of the differential in scenario outcomes for net greenhouse gas emissions, and 69–89% for greenhouse emissions excluding land sector sequestration. Bottom-up individual choices play a greater role when private and public benefits are aligned, such as when improved resource efficiency delivers financial savings. Individual choices account for up to half of the differential in scenario outcomes for energy use (33–47%) and non-agricultural water consumption (16–53%).

Giving value to natural assets can build new advantage

Economic analysis of climate change mitigation typically finds that limiting emissions involves near-term costs, but can yield net benefits over the long term (well after 2050) through avoided climate impacts[5,32,41,44]. Near-term co-benefits such as improved air quality and human health are also identified[47,48]. However, our analysis identifies additional near-term economic benefits for nations with a comparative advantage in ecosystem services, particularly carbon sequestration from reforestation. For these nations, stronger action to improve resource efficiency and environmental performance could unlock new sources of economic opportunity and growth, boosting near-term income while protecting natural assets essential to long-term well-being.

Figure 3 compares national income and net emissions outcomes in 2030 and 2050 for 18 scenarios. All seven stronger abatement scenarios (blue and purple) with land sector markets have better economic performance to 2050 than those with moderate abatement (green scenarios). National income (GNI) in 2050 in these scenarios is up to 6% higher than under existing trends (see quadrant 1). These win-win outcomes occur because carbon sequestration becomes more profitable than beef and other agricultural production across large areas of Australia (up to 58 Mha, or 70% of the intensive-use zone), in a world taking stronger action to reduce emissions. Stronger abatement incentives also promote electrification and the use of biofuels in road transport, reducing oil imports. These economic gains outweigh the costs of more stringent national emissions targets, as well as the impacts of lower global demand for (and value added from) Australia's emissions-intensive exports, relative to moderate national and global abatement (see Supplementary Methods, 'Calculations for Fig. 3 and assessment of potential economic performance with different levels of global and national action to reduce greenhouse emissions' and Extended Data Fig. 1i).

Across the scenarios explored, we find land-sector markets are needed to exploit these shifts in comparative advantage. Quadrant 4 reflects missed opportunities, including the scenario where very strong abatement action without land-sector markets leads to the worst relative economic performance (solid purple circle). Other scenarios in this quadrant involve transitions: pathways where emissions reductions generate net costs around 2030, but net benefits by 2050, relative to existing trends (see Extended Data Fig. 6e for time paths).

Quadrant 2 shows the scenarios in which there is no global or national action to reduce emissions, reflecting a decline from current modest abatement efforts. Here, national income in 2050 is projected to be 5–7% higher than for existing trends, while emissions are projected to be 35–51% higher. These scenarios illustrate the classic 'unsustainable development' trade-off, where higher near-term living standards are achieved at the cost of increased risks and future damage to the Earth's natural capital and life-support systems[5,46]. Adverse environmental feedbacks might see these scenarios shift towards quadrant 3 after 2050, combining worse economic performance and higher emissions. Limitations of the current modelling framework suggest that the analysis is likely to overstate the relative economic performance of the no-action scenarios (orange) and understate that of the very strong abatement scenarios (purple), because it does not fully account for all potentially significant climate impacts[1,2].

Making progress towards sustainable prosperity

In summary, we find that Australia could materially ease environmental pressures while enjoying strong economic growth. Many of the 20 scenarios we explored would represent substantial progress towards sustainable prosperity[46]. Australia could begin to repair past damage; restoring significant areas of native habitat and achieving negative emissions (net sequestration) of greenhouse gasses. But none of these scenarios would guarantee sustainability, or eliminate future threats to Australia's natural capital and the Earth's life-support systems[6,46]. Instead, each implies a different portfolio of risks and opportunities, which we have not fully modelled beyond 2050. For example, new native habitat established before 2050 could provide a permanent flow of biodiversity benefits and other ecosystem services, while the flow of carbon sequestration provided will peak and eventually decline to zero, drawing attention to challenges and opportunities beyond our modelling horizon, such as the possibility of using carbon plantations to generate negative emission bioenergy with carbon capture and storage[49].

Reducing environmental pressures will not require a shift in societal values, but neither will technology deliver it automatically. Collective choices and public policy settings have a crucial contribution, and well-designed markets can boost national income by exploiting new areas of comparative advantage in some circumstances. However, these scenarios may present new longer-term risks and opportunities, and the synergies and trade-offs involved will be influenced by global circumstances. We also find an important threshold effect: moderate global action to reduce greenhouse emissions may diminish Australia's traditional comparative advantage (particularly in fossil fuel-based sectors) without creating new areas of advantage; while stronger global action that places tangible value on emissions reductions could create new opportunities for creating value, providing win-win economic and environmental benefits relative to existing trends. While Australia could dramatically reduce environmental pressures across a wide range of global contexts, the economic costs of doing so will be smaller (and benefits larger) in global settings that support the stable functioning of key Earth systems, including through promoting clean energy. As these global circumstances emerge, Australia's opportunities will multiply.

Sustainable prosperity is possible, but not predestined. Australia is free to choose.

Online Content Methods, along with any additional Extended Data display items and Source Data, are available in the online version of the paper; references unique to these sections appear only in the online paper.

Received 22 May; accepted 9 October 2015.

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Supplementary Information is available in the online version of the paper.

Acknowledgements The authors thank CSIRO Land and Water, CSIRO Energy, CSIRO Agriculture, and CSIRO Oceans and Atmosphere for funding and support, and J. Dowse of Clarity Thought Partners for assistance in preparing this paper and the National Outlook report.

Author Contributions S.H-D. led the National Outlook project and oversaw all analysis, and led the drafting of this paper. All authors contributed to the analysis and interpretation, and commented on the draft paper, focusing as follows: S.H-D., study design, integration, and interpretation; H.S., material flows; P.D.A., CGE modelling; T.M.B., efficiency potential; T.S.B., transport; B.A.B. and M.N., land use; F.H.S.C. and I.P., water; P.W.G., stationary energy; M.G., agriculture; T.H., biodiversity; R.McCa., model linking, data integrity, analysis and charts; R.McCr., historical consumption trends; L.E.M., data integrity, analysis and charts, land and water analysis; D.N., global economics and climate; A.W., interpretation.

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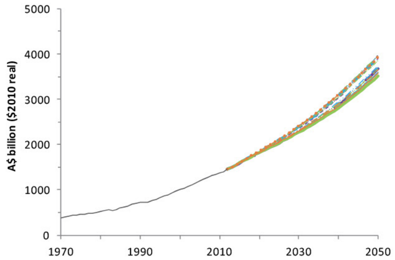
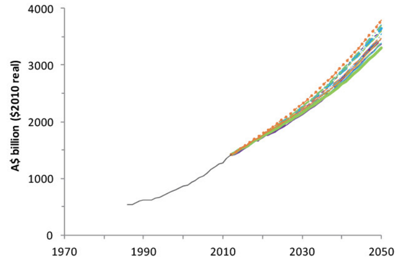
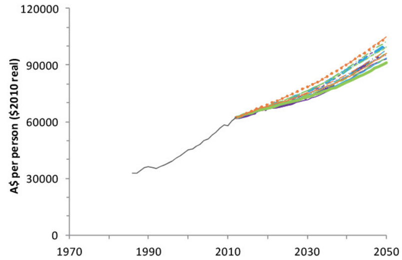
1a Australian Gross Domestic Product (GDP), 20 scenarios, 1970-2050



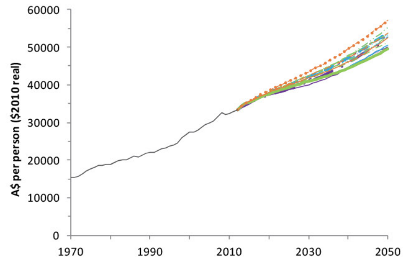
1b Australian Gross National Income (GNI), 20 scenarios, 1986-2050



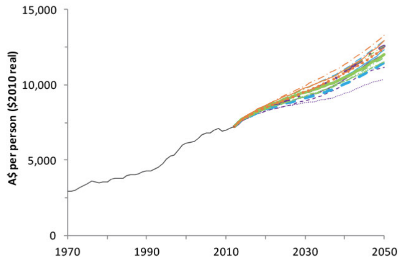
1c Australian Gross National Income (GNI) per person, 20 scenarios, 1986-2050



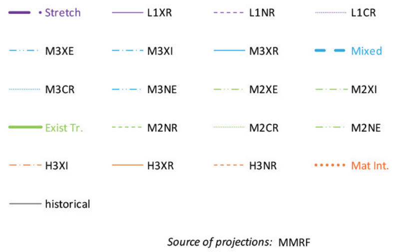
1d Australian Private Final Consumption (PFC) per person, 20 scenarios, 1970-2050



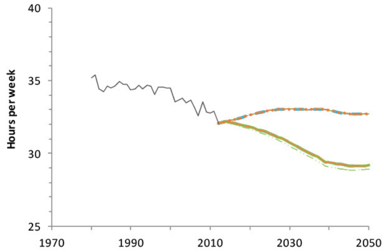
1e Australian Experience Oriented Private Consumption (EOC) per person, 20 scenarios, 1970-2050



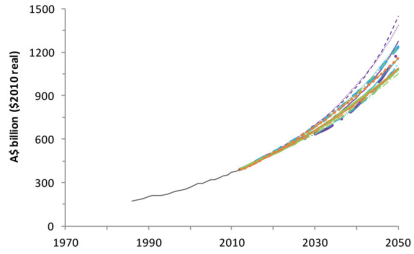
Scenario Key



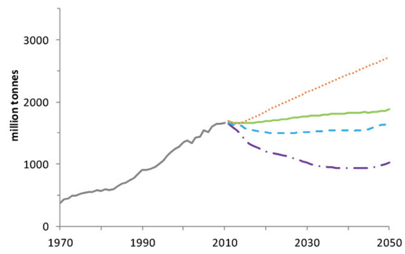
1f Australian Average Working Hours (per person in the workforce), 20 scenarios, 1980-2050



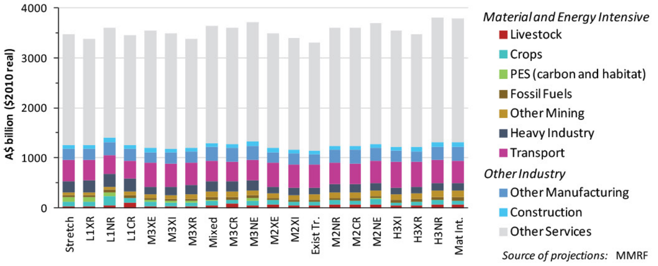
1g Australian material and energy intensive industries, total gross value added, 20 scenarios, 1986-2050



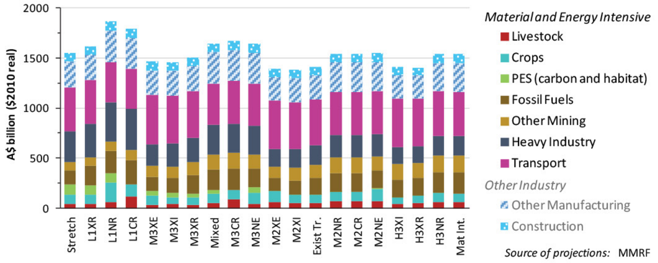
1h Australian Domestic Material Extractions (DME), touchstone scenarios, 1970-2050



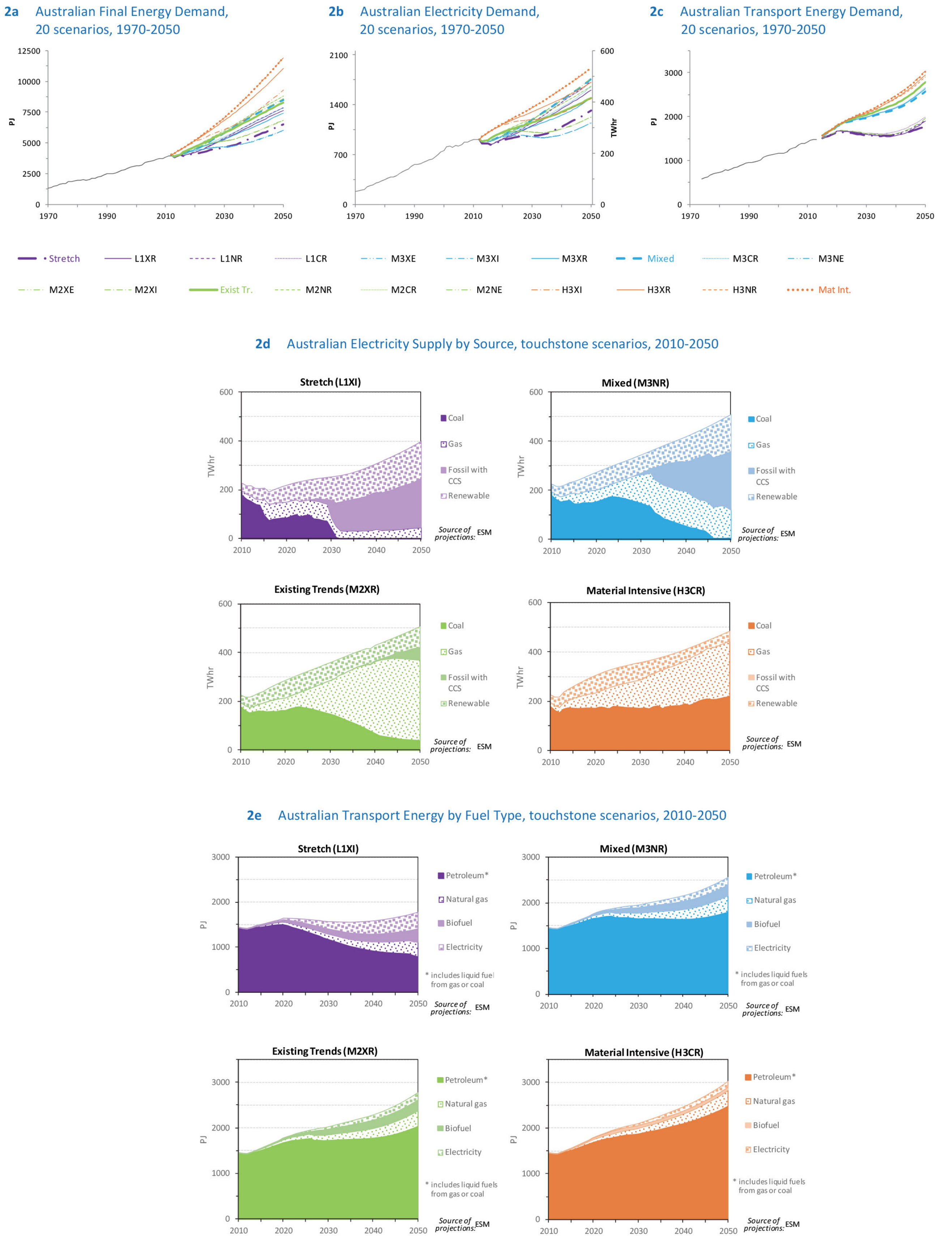
1i Contributions to Australian Gross National Income (GNI) by sector, 20 scenarios, 2050



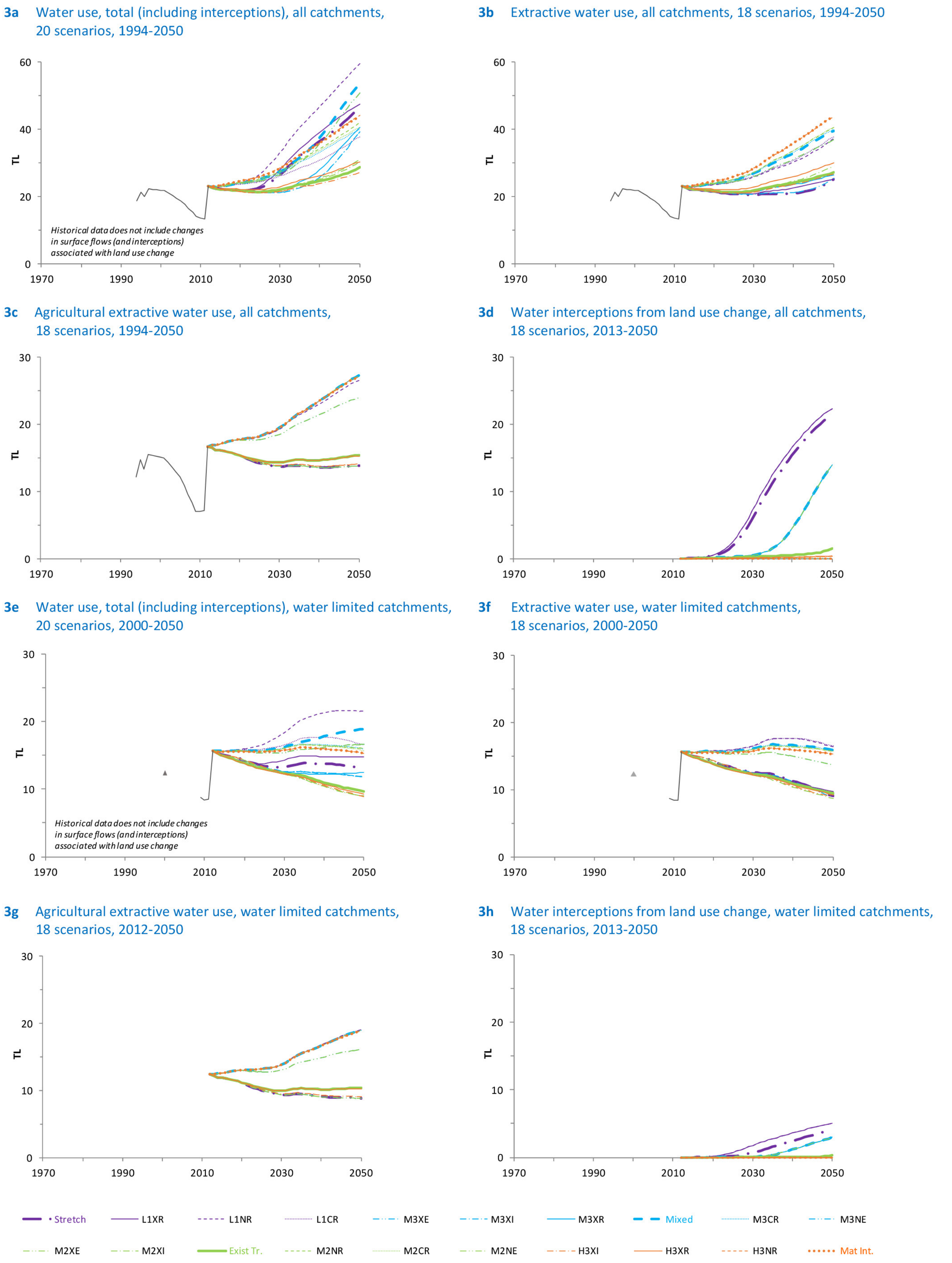
1j Australian material and energy intensive industries, gross value added by sector, 20 scenarios, 2050



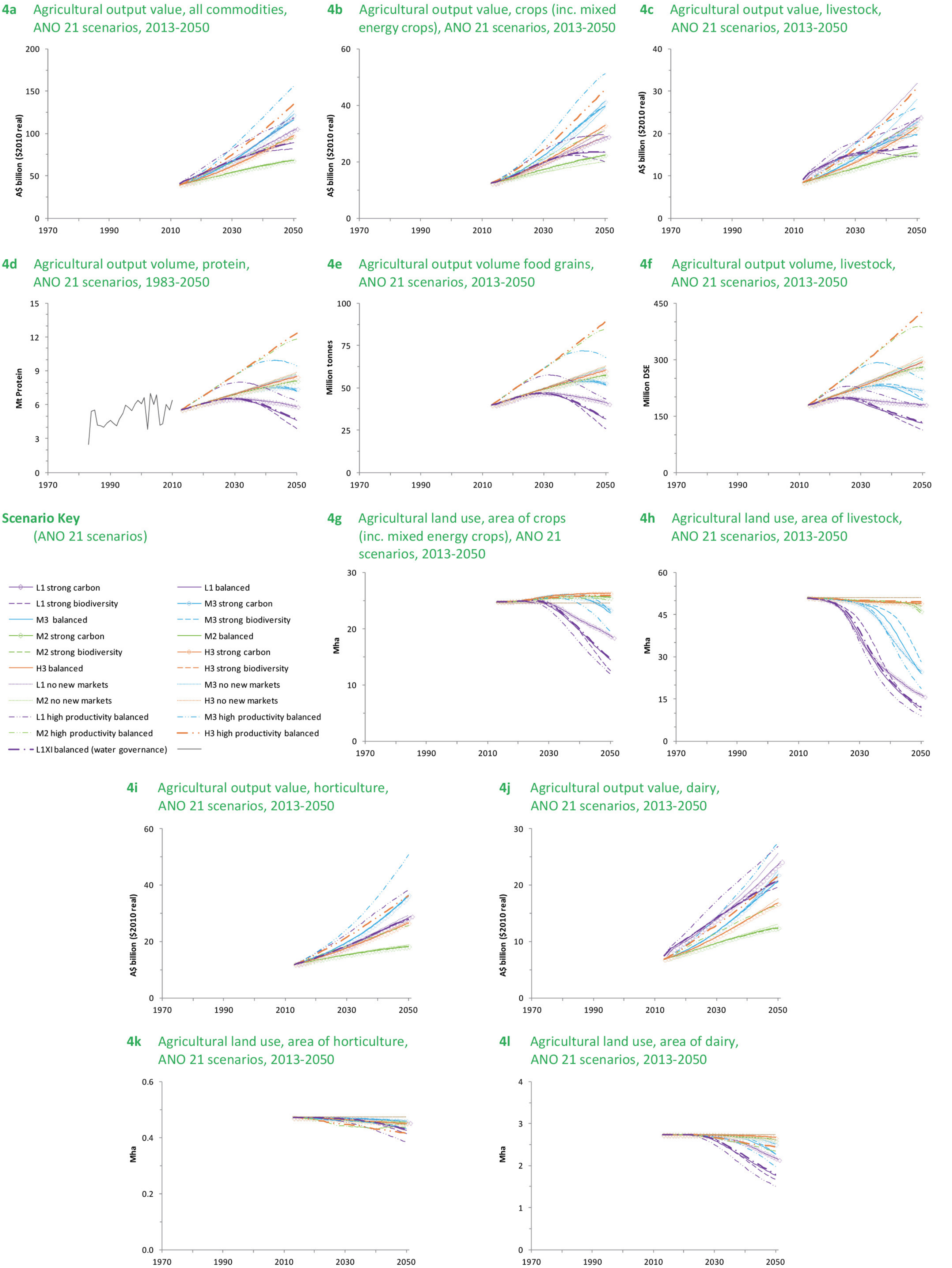
Extended Data Figure 1 | Australian economic activity, income and living standards, and material and energy intensive industries to 2050. Projections for 20 scenarios for nine indicators, and touchstone scenarios for one indicator. Income, consumption, and average working hours provide indicators of living standards. PES refers to payments for ecosystem services (carbon sequestration and habitat restoration). Definitions of scenarios and scenario assumptions, details of scenario sets, a full list of indicators, and references for historical data are provided in the Supplementary Information.



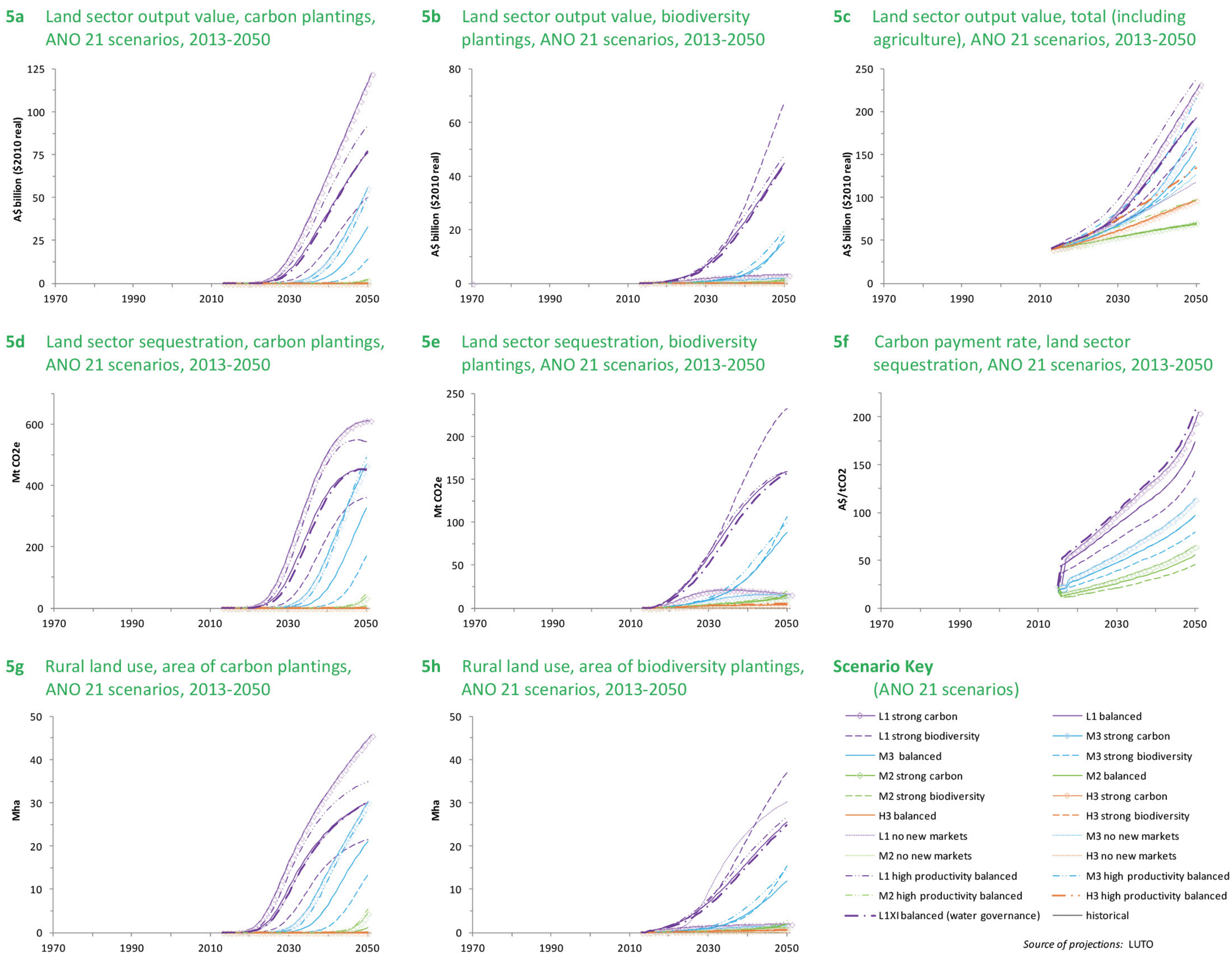
Extended Data Figure 2 | Australian energy use to 2050. Projections for 18 or 20 scenarios for three indicators, and touchstone scenarios for two indicators. Definitions of scenarios and scenario assumptions, details of scenario sets, a full list of indicators, and references for historical data are provided in the Supplementary Information. CCS, carbon capture and storage.



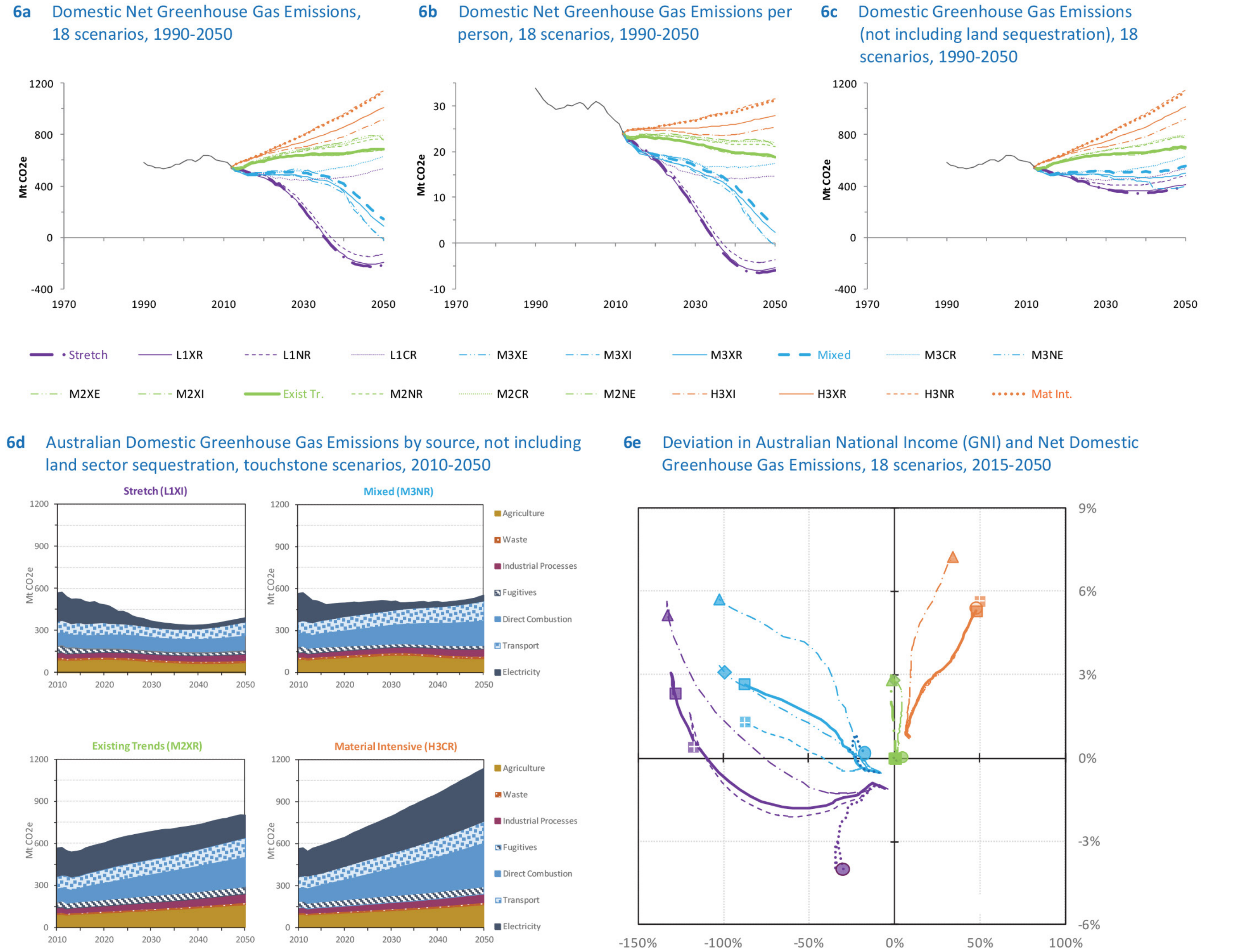
Extended Data Figure 3 | Australia water use to 2050. Projections for 20 scenarios for two indicators and 18 scenarios for six indicators. Total water use is made up of extractive use plus interceptions of surface flows by new plantings that would otherwise contribute to streamflow. Water use in water-limited catchments provides an indication of water stress. Definitions of scenarios and scenario assumptions, details of scenario sets, a full list of indicators, and references for historical data are provided in the Supplementary Information.



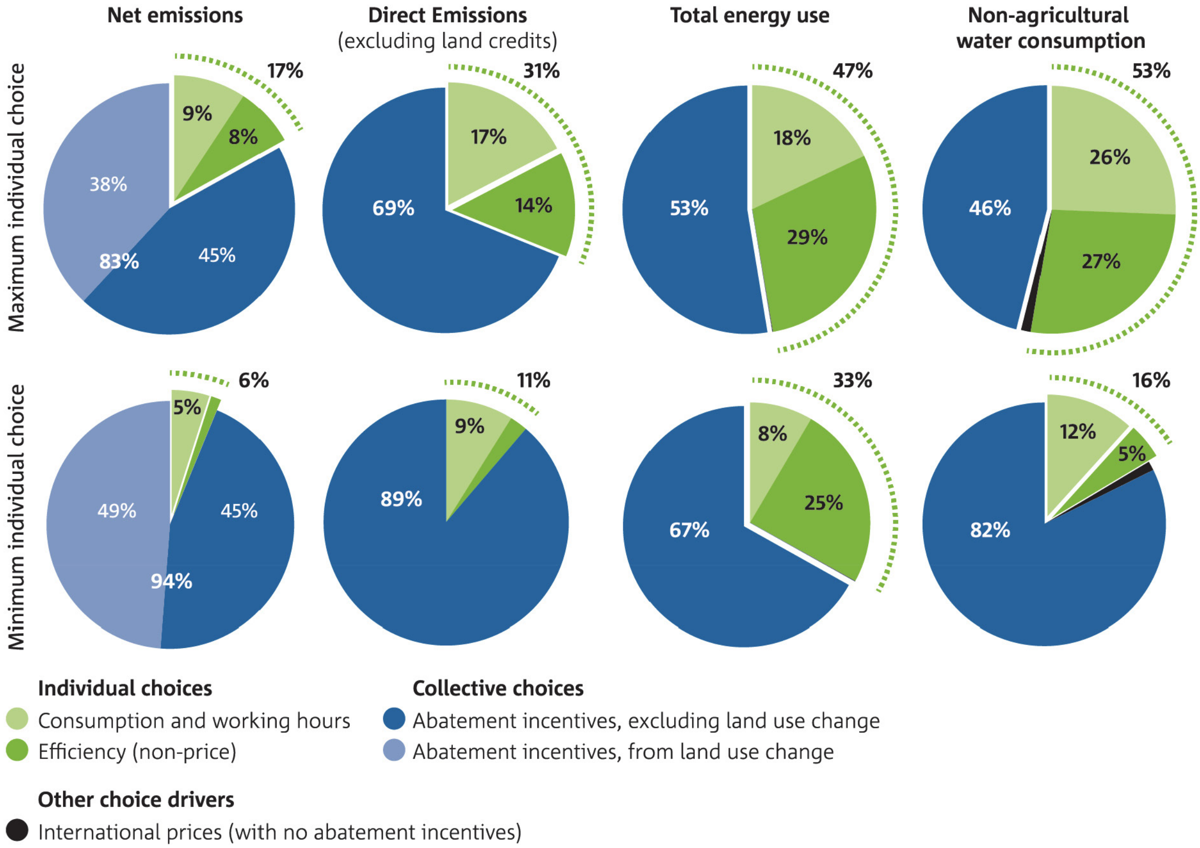
Extended Data Figure 4 | Australian agriculture output values, volumes and land use to 2050. Projections for 21 scenarios for 12 indicators. Food grains are a sub-set of crops. Protein calculation based on agricultural output volumes for all food commodities (including cereals, beef, sheep, legumes and dairy milk), weighted using USDA (2014). Definitions of scenarios and scenario assumptions, details of scenario sets, a full list of indicators, and references for historical data are provided in the Supplementary Information.



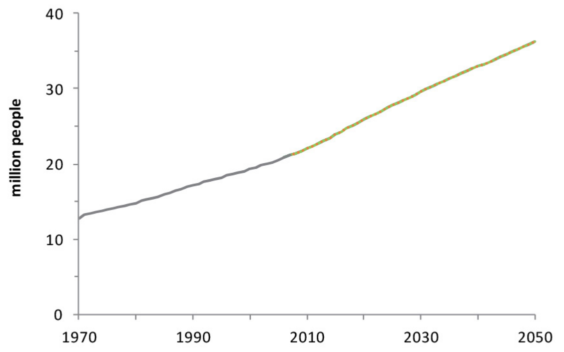
Extended Data Figure 5 | Australian land sector output values, volumes and land use to 2050. Projections for 21 scenarios for eight indicators. Total land sector activity is made up of agriculture (detailed in Extended Data Fig. 4) and payments for ecosystem services (carbon sequestration and habitat restoration) (see Extended Data Fig. 1i, j). Definitions of scenarios and scenario assumptions, details of scenario sets, a full list of indicators, and references for historical data are provided in the Supplementary Information.



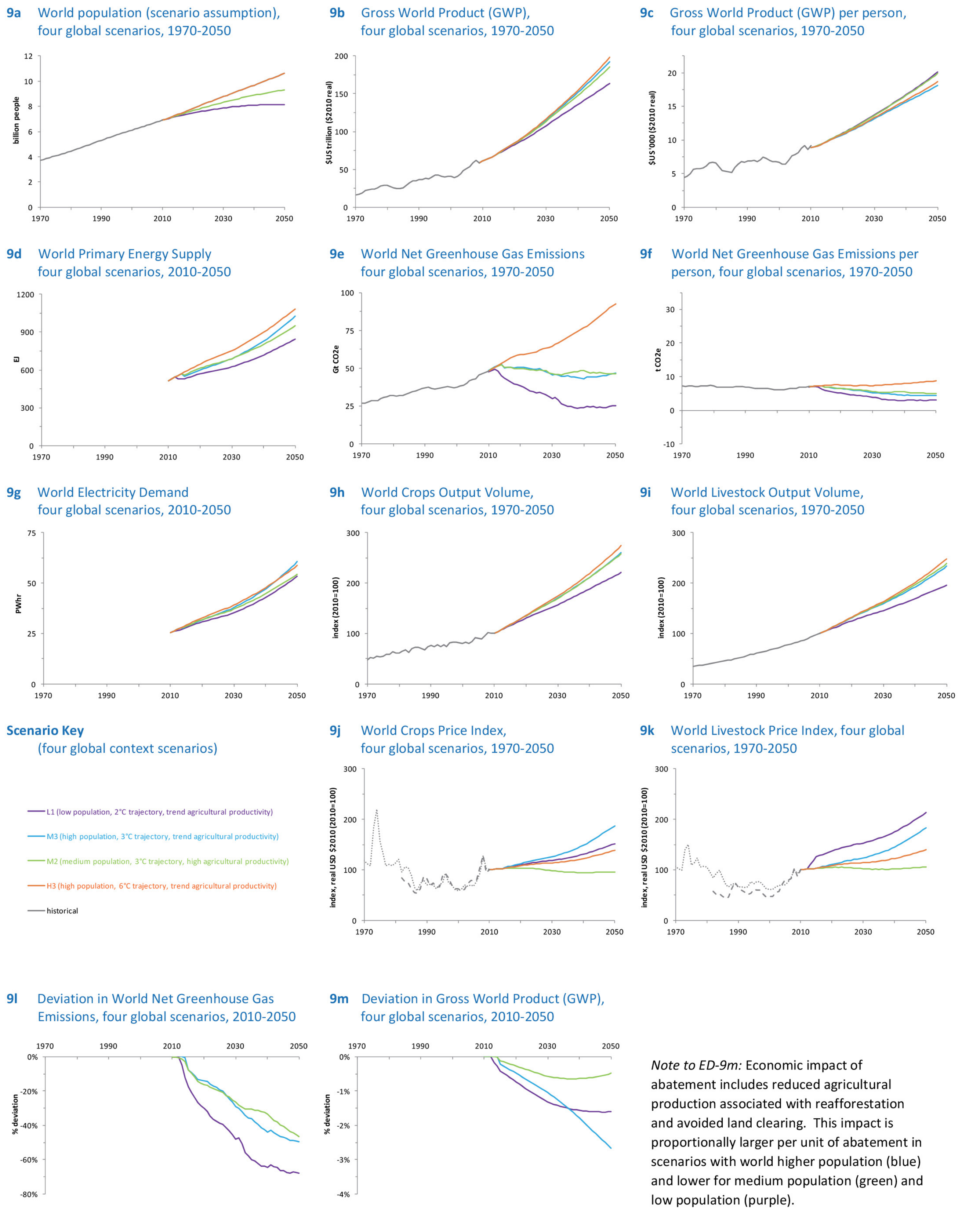
Extended Data Figure 6 | Australian greenhouse gas emissions and abatement to 2050. Projections for 18 scenarios for four indicators, and touchstone scenarios for one indicator. Domestic net emissions are defined as direct emissions less carbon sequestration (CCS and biosequestration) before trade in international emissions units. Calculations for Extended Data Fig. 6e are set out in Supplementary Methods, 'Calculations for Fig. 3 and assessment of potential economic performance with different levels of global and national action to reduce greenhouse emissions'. Definitions of scenarios and scenario assumptions, details of scenario sets, a full list of indicators, and references for historical data are provided in the Supplementary Information.



Extended Data Figure 7 | Maximum and minimum contributions of individual and collective choices to differences in projected greenhouse gas emissions, energy use, and non-agricultural water use in 2050. Calculations based on 20 scenarios, as described in Supplementary Methods, 'Assessing the contributions of individual and collective choices', drawing on data from Extended Data Figs 6a, b, 2a and 3b, c. Scenario assumptions and characteristics of the modelling framework prevent meaningful analysis of other indicators of environmental pressure for this purpose, such as total water use including agricultural extractions. Definitions of scenarios and scenario assumptions, details of scenario sets, a full list of indicators, and references for historical data are provided in the Supplementary Information.



Extended Data Figure 8 | Australian population, 1970–2050. Population trajectory assumed in all domestic National Outlook scenarios. Information on age structure and dependency ratios is provided in ref 1. Definitions of scenarios and scenario assumptions, details of scenario sets, a full list of indicators, and references for historical data are provided in the Supplementary Information.



Extended Data Figure 9 | World population, economic activity, energy, emissions and agriculture to 2050. Projections for four global context scenarios for 11 indicators, and for three global context scenarios for two indicators. The global scenarios assume different combinations of population and cumulative greenhouse gas emissions, implying different levels of global abatement effort as well as different patterns of global demand and supply of energy and agricultural products. To give a wider range of contexts, the M2 (medium population, moderate abatement) global scenario also assumes higher global agricultural productivity, resulting in lower agricultural prices than would be projected otherwise. Definitions of scenarios and scenario assumptions, details of scenario sets, a full list of indicators, and references for historical data are provided in the Supplementary Information.