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Green and clean: securing a sustainable future

Sticking with what currently works will not be as profitable when the broader environment changes. What seems valuable now, will not remain so.

ACOLA, SAF01 *Australia's Comparative Advantage*

Golden thread

Providing global leadership on environmental sustainability and adaptation is an area of great opportunity for Australia. With strengths in innovative research and a focus on community adoption consistent with a need to achieve a social licence to operate, Australia can seek to develop its own capabilities and give global advice on urban planning, transport and clean energy solutions. Achievement will protect our clean and green environment and international reputation.

Key findings

This ambitious and multifaceted objective draws on the research-based interdisciplinary evidence from ACOLA's Securing Australia's Future reports. Underpinning this objective are five detailed key findings for securing a sustainable future for Australia:

1. We must protect the environment servicing potential growth areas and industries to maintain our clean, green reputation and our global competitive advantage in agriculture and food, energy and minerals, tourism and other industries; and also develop information systems and marketing strategies to understand consumers' views on 'clean and green' attributes.

2. The century-old model of electricity generation requires a more radical update, using current and future developments in local energy storage, low-power wireless energy distribution, smart grids, and microgenerators to transform how electricity is distributed, drawing on alternative fuels such as shale gas and renewable energy sources wherever possible.
3. The structure of cities and their transport options needs to be reconsidered, with sustainable urban planning and a new approach to urban transport, including the establishment of areas such as innovation clusters, high-tech nodes and creative sectors.
4. There is an urgent need to equip the workforce of the future with scientific and technological knowledge, and to communicate the positive prospects and technological future of the agriculture sector, focusing on skills and innovation and complementary skills in humanities and social sciences.
5. Innovative and interdisciplinary approaches by Australian researchers, underpinned by sustained public investment and supportive, bipartisan government policies, could create opportunities for Australia to research, produce and deliver solutions – whether ideas, services or products, particularly for transport solutions and climate change adaptation – needed by countries around the world.

Introduction

Australians enjoy a relatively clean environment with unique biodiversity and plentiful resources, shared by a small population. We are known for products, particularly in the food industry, that are clean and green, sustainable and ethical, safe and affordable. There are potential growth areas but we need to protect the environment servicing these so that economic and environmental protection can proceed together sustainably.

This chapter looks at the clean and green environment and products that provide Australia with a market advantage in agriculture and other sectors; at the challenges to our internationally renowned green image; and at options to overcome these challenges through new energy sources, sustainable urban design, smart farming, and underpinning interdisciplinary research.

We begin with a description of Australia's relatively clean (by global standards) environment. Australia manages its forestry and water resources well, but can do better with its care of biodiversity and habitat, agriculture and fisheries, and climate, energy and associated greenhouse gas emissions. Any consideration of securing Australia's future needs to include an understanding of the risks and costs of the impacts of climate change and other changes to the environment. Climate change crosses international boundaries and Australia has an opportunity to apply its considerable climate knowledge to be an international leader in adapting to climate change.

The chapter proceeds to look at how to decarbonise our energy supply. The century-old, centralised, coal-powered method of supplying electricity requires a transformation in

light of increasing environmental concerns and higher energy prices, affordable energy storage, renewable energy technologies, and additional energy sources such as shale gas, which could become economically important in Australia.

We then examine urbanisation, transport, and sustainable urban design. Although our cities are renowned for being among the most liveable in the world, Australia is one of the most urbanised countries in the world. If roads, transport infrastructure and other urban planning activities are not properly managed, the cost of congestion in our capital cities could increase fourfold. Furthermore, increasing urbanisation will put pressure on water and energy resources.

As the Australian population increases, and is further concentrated in major cities with an increasing proportion of older people, a new approach to urban transport is needed. For truly sustainable urban design, the whole structure of cities and their transport options needs to be reconsidered. Sustainable urban planning can reduce or even avoid the need for travel by improving transport links between work and home, bringing workplaces and homes closer together. Increasing broadband speeds will enable a growth in telecommuting and shopping from home.

Australia has a large and rising number of motor vehicles, which are used inefficiently: the average car is parked 96 per cent of the time; the cost of moving freight by road is more than double the cost of transporting goods by train; and greenhouse gas emissions by road transport of goods are more than triple those of rail. Australians rely on cars, so it is surprising that we hold no more than three weeks' worth of oil and refined fuels onshore; this represents a significant fuel security risk. Research, new technologies and interdisciplinary studies of social barriers to change can address the country's fuel security risk, transport costs, inefficiencies in road transport, and environmental impact.

Australia's interdisciplinary research activities are important for the development and adoption of smart farming, and for providing the technologies, workforce and social understanding to enable a prosperous farming future. We need to change from concentrating on products low in the value chain to those higher. Furthermore, for Australia's future agriculture, energy and environment workforce, we will need a growing proportion of workers to be trained in scientific and technological literacy.

The chapter concludes with mention of the importance of social sciences playing a transformative role in dealing with the issues associated with energy, water, biodiversity, land use, urbanisation, and other environmental changes covered here, to secure a green and clean sustainable future. It echoes the themes from other chapters regarding the importance of investing in, and drawing on, Australia's interdisciplinary research capability, supported with adequate policies and business buy-in, to address environmental issues and enable Australia to contribute to the solution of global problems and maintain its clean and green competitive advantage.

Environment and energy

> *Avoiding unconstrained climate change would provide important benefits and opportunities to Australia.*
>
> – Australian Climate Roundtable, 29 June 2015

Protecting Australia's natural advantage

Australians are fortunate to benefit from a natural environment endowed with resources to use and land to enjoy. Australia's huge area, as the sixth largest country on the planet, provides a diverse variety of landscapes – from tropical rainforests in northern Queensland, to snowy alps in Victoria and New South Wales, rugged mountain ranges in south-west Western Australia and along the east coast, and deserts in central Australia. On the coastlines are pristine beaches perfect for surfing and swimming, and coral reefs.

The country enjoys a comfortable climate, is home to unique plants and animals in a wide range of habitats, and has extensive mineral resources. Our share of global natural assets is especially high relative to our number of residents, who enjoy relatively low population densities in urban centres hugging the temperate coastlines.

Against this natural background, Australia is world-renowned for agricultural products that are clean, green, safe, affordable, sustainable and ethical. Australian agricultural goods come from an unpolluted landscape, have a pest-free and disease-free status, and are produced within accountable and traceable processes such as the Maximum Residue Limits for chemicals in grains, and the National Livestock Identification System. Furthermore, Australian farmers have a reputation for looking after the land. Such an international image enables Australia to be very competitive in global markets.

Our natural environment provides opportunities for growth. Industries in areas such as farming, fisheries and forestry, as well as oil and gas, are likely to expand in coming years. For example, only ~3 per cent of the country's 761 million hectares of land available for agriculture is currently used for cropping and horticulture. This is mainly because of highly variable rainfall and low annual rainfall totals over much of the continent, and

Australians benefit from living in a country rich in natural assets. (Source: CSIRO)

limited access to water for irrigation in many regions. New areas of land, such as in northern Australia, could be farmed if there was substantial public investment in irrigation, energy and transport, as well as in new technology and skills.

Of course, such opportunities and potential for growth cannot be taken for granted, and our environment cannot be used without care and responsibility. We need to protect the environment, both for itself and for servicing these potential growth areas to maintain our global strengths in agriculture and food, energy and minerals, tourism and other industries. This is a significant challenge in the face of climate change, population growth and urbanisation, and other threats that impact on the environment and environment-related industries. Our excellent national and global reputation must be supported by evidence and accreditation, and be protected as production in sectors relying on the environment increases and improves.

A sustainable environment

Our rising and increasingly urbanised population combined with economic growth puts pressure on the sustainability of our environment. An awareness of environmental pressures, and the policies, technologies and community approaches that can manage such pressures, is vital for combined economic growth and environmental protection to proceed hand-in-hand – as so-called sustainable development.

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While we need to maintain our clean, green reputation to secure our future in agriculture, tourism and other areas, looking after nature for future generations is also important for a sustainable environment, to maintain diverse plants and animals, and to ensure human wellbeing. Compared with other countries, Australia manages its forestry and water resources reasonably well, especially in recent years. But it does not rank well in its care of biodiversity and habitat, agriculture, fisheries, climate and energy.

Since Australia signed the Convention on Biological Diversity following the Rio Earth Summit in 1992, there has been an increase in the number of areas on land and sea that are protected in order to conserve Australia's unique and irreplaceable biodiversity. However, biodiversity experts are pessimistic about how successful these measures have been in preventing loss of biodiversity. Gaps in data and measurements prevent a clear picture of the state or trends in biodiversity protection.

Australia has performed poorly compared with Organisation for Economic Co-operation and Development (OECD) countries for emissions of air pollutants since 2009. These air pollutants mainly come from fossil fuel burning, transport and other industrial processes. While carbon monoxide and volatile organic compounds decreased, sulfur oxides, nitrogen oxides and particulate matter have increased.

Similarly, Australia's total carbon emissions increased between 1990 and 2010 by more than 40 per cent. Contrast this with, for example, the group of 15 European countries whose emissions decreased by more than 10 per cent. Australia's increase can be explained by rising population and, more so, rising GDP per person. These rising greenhouse gas emissions lead to ever-increasing atmospheric concentrations of greenhouse gases, contributing to climate change.

The changing climate adds further threats to the Australian community, economy and environment. Australia is the driest inhabited continent on Earth so it is particularly vulnerable to changes to rainfall patterns. Any consideration of securing Australia's future needs to include an understanding of the risks and costs of the impacts of climate change, including changing rainfall patterns affecting water availability, increasing bushfire risk, rising sea levels, and more extreme weather events such as tropical cyclones and floods. This is particularly the case because most of the population, commercial activity and urban infrastructure is located near the coast.

It is already clear that southern Australia's rainfall is decreasing, particularly in the autumn when winter crops are germinating; this threatens Australia's international competitiveness in dryland farming. Irrigated agriculture uses between 50 and 65 per cent of the water consumed in Australia, with about half of this in the Murray–Darling Basin. Water use has become more efficient in recent years in both agriculture and urban areas (due to increases in technology, improvements in water-use efficiency to reduce water use, and policy responses, all partly in response to the Australian drought conditions of the 1990s and 2000s). However, the impact of climate change and climate variability on water resources will cause risks relating to prolonged drought that need to be managed. For example, in agriculture, less water, higher temperatures and different soil conditions will require research and development to provide transformational changes such as new types of seeds that can survive in the future climate. In urban areas, desalination plants could supply up to half the water needs of Adelaide, Melbourne and Perth.

Constitutional and political issues are a confounding factor in Australia's environmental performance. The different federal, state, territory and local government roles in environmental protection bedevil this area. For example, the separation of immigration responsibilities from infrastructure, and health and education responsibilities from zoning responsibilities, makes seamless government difficult. As well as leading to barriers for environmental health, such separation of roles also leads to disenchantment with political governance. Social science integrated with other disciplines could lead to improvement in understanding and outcomes about these importance issues.

Table 5.1. A summary of the impact of Australia's economic growth on the environment

Environmental impacts of growth
Environmental improvement (reductions) • Carbon monoxide (CO) • Volatile organic compounds (VOC) • Applied nutrients (water pollutants)
Mixed outcomes • Carbon dioxide (CO_2) • Particulate matter 2.5 (PM2.5) • Water in agriculture
Environmental deterioration • Particulate matter 10 (PM10) • Waste • Nitrogen oxides (NOx) • Sulfur oxides (SOx)
Inconclusive impact • Protected areas/biodiversity

Table 5.1 shows environmental indicators that have deteriorated as Australia's economy has grown, those that have improved with growth, and those not linked to growth. Despite the overall health of Australian ecosystems improving over the past decade or so, Australia's environmental ranking is well below global standards. This presents a problem in securing Australia's future.

While the threats of climate change are overwhelmingly negative, there are opportunities. Some sectors and regions may benefit from higher carbon dioxide levels, increases in temperature, and changes to the rainfall regime. More importantly, Australia has an opportunity to apply its considerable knowledge of living with extreme climates to be an international leader in adapting to climate change.

Indeed, climate change is a challenge that crosses international boundaries and is a research priority for many countries. It is also a research goal with a long history in many science, technology, engineering and mathematics disciplines – a major motivation for scientists is to improve human wellbeing on a global scale through understanding and subsequent improvement of environmental challenges such as land degradation, food security and low-carbon energy technologies.

If supported with appropriate policies, investment and commercialisation, our climate adaptation expertise could be applied to global advice and leadership in innovation that supports adaptation to climate change (particularly in agriculture), and reduction in emissions through new and renewable energy sources.

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Such global leadership in research advising adaptation to, and mitigation of, climate change would require a bipartisan approach and buy-in from industry. It is thus encouraging that major business groups, unions, research organisations, environment NGOs, investors, social groups and others came together in mid-2015 under the umbrella of the Australian Climate Roundtable.

Members of the roundtable include organisations as varied as the Australian Aluminium Council, the Australian Conservation Foundation, the Australian Council of Social Services, the ACTU, the Australian Industry Group, the Business Council of Australia, the Energy Supply Association of Australia, the Investor Group on Climate Change, the Climate Institute and WWF Australia. The Australian Climate Roundtable stated that 'Australia should play its part in global efforts', and noted that 'avoiding unconstrained climate change would provide important benefits and opportunities to Australia'.

This is particularly the case in the energy sector. The roundtable states that policy should 'be capable of achieving deep reductions in Australia's net emissions' and 'provide confidence that targeted emissions reductions actually occur'.

Decarbonising energy

Australia's electricity supply began in the late 1800s as isolated networks established by local governments. These networks became connected and supplied by central power stations as demand for power grew. As in most other countries, Australia's electricity generation relied on fossil fuels, especially coal. This centralised, coal-powered method of supplying electricity for immediate use has continued for more than 100 years. Coal is still our main source of electricity generation (73 per cent), followed by natural gas (13 per cent) and renewables (14 per cent, about half of which was hydro, as well as wind, solar and

bioenergy). With increasing environmental concerns, higher energy prices, more affordable energy storage (although large-scale energy storage is not yet affordable for most people), improving renewable energy technologies, and policies to reduce carbon emissions, the century-old model of coal reliance needs an update.

Over the period of fossil fuel generated electricity, carbon emissions have increased as more energy is used. However, the efficiency of energy production has risen – globally, carbon emissions per unit of energy produced have dropped by 0.3 per cent a year since 1850. This trend will need to continue, assisted by improvements in energy technologies.

While the current electricity infrastructure may continue to be used, local energy storage, low-power wireless energy distribution, smart grids, and microgenerators could transform how electricity is distributed to consumers in the future. Instead of using coal for the generation of electricity, alternative and renewable energy sources, and the increased and more efficient use of gas available in Australia (including shale gas: see below), would emit less carbon dioxide into the atmosphere, as long as the emissions associated with gas production are minimised. The generation of renewable energy will become more reliable and affordable, using advanced prediction and technologies that manage supply and demand, as well as benefiting from advances in the storage of energy.

Continuing to rely on current technology and processes because it works and does well fails to recognise that the evolution of global energy technology and processes will lead to the status quo being less profitable.

Storage of energy will play an increasingly important role in Australia's future electricity grid. Improvements in storage can address the variability between peak and low electricity demands, and provide the flexibility required due to the peaks and troughs in electricity generated by sources influenced by the weather (such as wind and solar power). Energy can be stored using technologies ranging from small rechargeable batteries to large pumped hydro systems, where water is pumped to a higher level dam at off-peak times and released to a lower level dam to drive turbines and generate electricity during peak demand. The specific type of energy storage depends on a location's infrastructure, energy resources and challenges.

However, while it is well recognised that carbon emissions need to be reduced, and apparent that improvements in technology can deliver such reductions, barriers to adopting new technologies exist due to inertia in the system and 'technological lock-in'. That is, there are delays in adapting current infrastructure and related systems, as well as community resistance to change (see below) and the influence of vested interests. These can cause a persistence of current and inferior technologies and approaches despite the availability of advantageous alternatives. Continuing to rely on current technology and processes (that is, using and exporting the world's primary source of energy, coal) because it works well fails to recognise that the evolution of global energy technology and processes will lead to the status quo being less profitable. There is the issue of cost, which should not be ignored and which has been highlighted by experiences in South Australia in recent times. Nonetheless, as affordability of new ways of generating and distributing electricity increases, what is valuable today will be devalued in future. As noted in ACOLA's SAF01 *Australia's Comparative Advantage*, 'sticking with what currently works will not be as profitable when the broader environment changes. What seems valuable now, will not remain so'.

Solar research facility, Newcastle, New South Wales, Australia. Renewable energy sources, including solar, provide ~14 per cent of our current energy generation. (Source: CSIRO)

Australia and indeed the world *can* overcome this inertia – but it takes commitment from government, acceptance by the community, and changing legal and regulatory requirements in addition to the changes in technology, performance and cost. Although these take time – sometimes decades – there are numerous past examples of global transitions from outdated and cumbersome technologies to new ways of doing things. These include the change from using inland canals to trains and then trucks for goods transportation, the evolution from vacuum tubes to microchips in electronics and computing, the move from analogue to digital broadcast technologies, and the change from fixed phone lines to mobile phones for telecommunications.

Natural gas: availability, technology and economic feasibility

> *There is great potential for shale gas in Australia but the benefits will not be easily won. It … will require great skill, capital and careful management of any impacts on ecosystems and natural resources.*
>
> – Peter Cook, ACOLA SAF06 Expert Working Group

The use of natural gas has increased over the past decade to represent about one-fifth of Australia's energy supply, with ~59 billion cubic metres of gas produced in total in 2012–13. The geology surrounding the gas and how the gas is trapped dictates whether it is

'conventional gas', such as natural gas in permeable subsurface sandstones, or 'unconventional gas' in relatively impermeable structures, such as shale gas and coal seam gas (CSG).

Australia has ~3.8 trillion cubic metres of shale gas, although this figure is based on just four known shale gas basins. Undiscovered resources could push the figure to over 1000 trillion cubic metres. Shale gas is found at depths more than a kilometre underground. Undiscovered shale gas resources in Australia may be large compared to conventional gas, but as yet there are no identified economic shale gas reserves in Australia.

Shale gas could be an economically important additional energy source in Australia, provided capital costs and the costs of extraction can be brought down. There is significant potential for shale gas in parts of Western Australia, Queensland, South Australia and the Northern Territory. Shale gas in the Cooper Basin (which straddles Queensland and South Australia) could be the first to be developed at a large scale because of the established infrastructure.

Australia is already a major producer of conventional gas and CSG. As technology and geological knowledge develop, we could be in a position to produce shale gas. Producing electricity using shale gas fired power stations produces less than half of the greenhouse gas emissions of black coal fired power stations (although shale gas produces ~20 per cent more emissions than conventional gas).

However, while there is no questioning the resource availability and potential for exploitation, the costs are currently relatively high (see the box, 'The economics of shale gas'). Also, the success of an Australian shale gas industry would require consideration of scientific, social, community, technological, environmental and economic issues and impacts.

Fracking rig in a Colorado field. Shale gas could be an economically important energy source in Australia, if it earns a social licence to operate. (Source: Lonny Garris/Shutterstock)

The economics of shale gas

ACOLA's study of shale gas in Australia (SAF06 *Engineering Energy: Unconventional Gas Production*, http://acola.org.au/wp/project-6/) concluded that any technical barriers to producing shale gas could be overcome. Shale gas is likely to be plentiful, with undiscovered resources in Australia larger than conventional gas.

However, shale gas won't be cheap in Australia. Costs to produce the gas are likely to be higher than in North America, where development of the shale gas industry over the past 15 years has benefited the US energy market and economy. Australia's lack of infrastructure will further add to costs. Nonetheless, if drilling costs could be significantly reduced through an innovative and large-scale effort (as in the United States), shale gas has every prospect of being a viable lower carbon energy source for Australia in the future.

World demand for natural gas is expected to increase over the first half of the 21st century, primarily due to industry's demand for electricity. The extent to which Australia's shale gas potential is realised will depend on the price of shale gas compared to the cost of other energy sources. In Australia, shale gas will require a price around $6–9 a gigajoule to make its production and transport profitable. By comparison, the Australian east coast wholesale gas price in 2013 was about $6 a gigajoule.

More information and exploration and favourable economics is required to turn the prospective resource estimates into proven reserves, but if momentum in this industry does indeed gather, it will affect the Australian gas market and gas prices, and have significant impacts on jobs and the economy.

This is particularly the case in farming areas. There are issues of contested land use in farming areas relating to ground water contamination and water use, and concern about unknown impacts.

The issues are also acute on land traditionally owned by Indigenous communities where exploration and extraction are planned or which will be crossed by pipelines. Much of Australia's potential shale gas development is likely to occur in remote locations on lands associated with Native Title or Aboriginal Lands. Development of shale gas projects on the lands of traditional owners must, from the start, include an understanding of Indigenous peoples' aspirations, land use and management. Informed understanding by all parties of the scale and expected impacts of a proposed project is required.

Shale gas extraction also would need careful management of impacts on ecosystems and natural resources due to its environmental impacts – although many impacts have a low likelihood of occurring and may be remediated, except for biodiversity impacts. Increased exploration and production of shale gas could adversely impact landscapes, ecosystems (including vegetation, flora and fauna species, and soils), surface water supplies and groundwater, and communities. It may result in habitat fragmentation and some environmental contamination. Water will need to be managed, to minimise the volume extracted from the surface and groundwater resources. Additionally, there will be a need to minimise contaminated water being discharged into streams and groundwater aquifers.

Hence a shale gas industry would need informed and supportive communities, and transparent and effective regulations and codes of practice. If the shale gas industry is to earn

and retain the social licence to operate, there must be a transparent, adaptive and effective regulatory system in place, backed by careful monitoring, and credible and high-quality baseline surveys. If best practice is followed, many of the potential problems can be avoided.

Cities and mobility

The lack of investment in transport over the past 40 years means Australia has a major infrastructure deficit.

– Bruce Godfrey, ACOLA SAF08 Expert Working Group

Liveable cities

Only 3 per cent of the world's population lived in urban centres 200 years ago. Today, 50 per cent of the world's population lives in cities. This is expected to increase to 75 per cent by 2050, when global population is likely to reach nine billion.

Australia is renowned for having some of the world's best and most 'liveable' cities, although the term is potentially a subjective one. The quality of Australian cities is partly due to investments in infrastructure during the 1800s that delivered one of the highest living standards in the world at the time, and which continues today. But this investment of wealth derived from the country's natural resources contributed to the building of cities that made Australia one of the most urbanised countries in the world from its very early stages of European development.

Significant congestion could harm the world-renowned liveability of our cities and quality of life.

Despite Australia's rural heritage and famed liveability, it is highly urbanised. Almost two-thirds of the population is concentrated in five state capital cities, each with populations surpassing 1 million: Sydney (4.8 million), Melbourne (4.4 million), Brisbane (2.3 million), Perth (2.0 million), and Adelaide (1.3 million). Today, Australia is one of the most urbanised countries in the world in terms of percentage of total population living in cities, and our trends of rising population and increasing urbanisation point to this not changing any time soon. Australia's population is forecast to increase 40 per cent in just 20 years, from 21.5 million in 2011 to 30.5 million in 2031. By the end of the century, Melbourne and Sydney's combined population is expected to exceed 14 million.

Planning is required to prevent this increasing population and urbanisation from causing significant congestion. If roads, transport infrastructure and other urban activities are not properly managed, the cost of congestion in our capital cities is forecast to almost quadruple from $13.7 billion in 2011 to around $53.3 billion in 2031. But planning to cope with this increasingly urbanised population is not just about reducing the economic costs. Significant congestion could harm the world-renowned liveability of our cities and quality of life for those large future populations. People will expect, and deserve, reliable and cost-effective ways to get around. Populations that live in outer urban locations (where transport options are usually limited to a car) should have equal transport choices to people in inner cities. This has implications for the design of urban centres, as described in more detail below.

Morning peak hour traffic, Melbourne. (Source: Soham Banerjee, CC BY 2.0)

Increasing urbanisation will also put pressure on water and energy resources. Cities cover less than 2 per cent of the Earth's surface, but use 78 per cent of world energy. Although Australian cities generally rate highly for liveability, they have unsustainable environmental footprints. The urban sprawl of Australia's largest cities affects water, air and ocean quality.

The expansive nature of our cities is related in particular to increasing transport of goods and people. This has led to road congestion, despite more and more land being appropriated for roads. Automotive transport contributes significantly to pollution of the water and air, and to greenhouse gas increases (as detailed above). Indeed, Australia has one of the highest levels of transport-related greenhouse gas emissions in the world. As well as the health impacts of increased pollution and climate change, reliance on road transport contributes to an increasingly sedentary lifestyle and a subsequent increase in mortality, not to mention the contribution to deaths, injuries and trauma by road accidents.

The relationship between cities and climate change is two-way, because as well as contributing to climate change, our cities and related infrastructure and transport systems are affected by the impacts of climate change. All of Australia's – and many of the world's – cities with populations of more than one million are on the coast and hence are vulnerable to sea-level rise combined with increasing extreme weather events. Furthermore, urban populations are susceptible to the impacts of extreme heat, with cities amplifying global warming through urban heat island effects. Adaptation to climate change is being considered, with many cities introducing trees and green spaces to reduce local temperatures, but cities have limited capacity to withstand the combined pressures of population expansion and climate change.

Cars *v.* horses

Not everything should be blamed on the technological progress of the car. As John McCarthy and Peter Wright note in their 2004 book, *Technology as Experience*, 'per vehicle and per mile, it seems highly likely that the environmental problems caused by the horse were far greater than those of the modern car'.

Values and beliefs influence whether people welcome technology as a saviour (in the case of cars, saving cities from being fouled by manure and dead horses, avoiding injuries and deaths, and alleviating animal welfare issues) or a destroyer (creating potential for new and unknown harms, such as injuries and deaths from road accidents, health impacts from pollution, environmental effects of greenhouse gas emissions, and challenges relating to the supply of fuels).

Sustainable urban design

Adapting to the increasing heat in cities by addressing the porosity of urban surfaces is just one aspect of urban design that is evolving sustainably. However, for truly sustainable urban design, the whole structure of cities and their transport options needs to be reconsidered.

Transport provides access to jobs, homes, and goods and services, and opens up isolated regions. Access to transport and the ability to move across cities influences perceptions of quality of life and plays an important role in economic and social development. There are some elements of Australia's city transport systems that are more than a century old. The urban sprawl of several Australian cities has caused them to extend well beyond the reach of public transport. Adding roads is not necessarily the solution to the problem of moving large urban populations of the future. As the population increases, and is further concentrated in major cities with an increasing proportion of older people, a new approach to urban transport is needed with a focus on people rather than particular modes of transport.

In cities around the world, people's average travel time is an hour a day – 30 minutes commuting in the morning, and then again in the evening. Of course, some people choose to travel more than this, while others travel less, but the average is 30 minutes. This leads to the concept of the 30-minute city. If people find they are spending more time than this travelling each day, they are likely to move to reduce their commute. Historically, cities extended only ~2 to 4 kilometres across when people could walk this far in 30 minutes; trains extended this spread to ~20 kilometres across; cars then created an urban sprawl of 40 to 50 kilometres across. However, cities such as Sydney and Melbourne, as well as Brisbane and Perth, have extended beyond 50 kilometres; hence the concept of the 30-minute city has become topical in urban planning.

Throughout the 1900s there were examples of urban planning in Australian cities that were forward-thinking and successful within the period's constraints and priorities, but in the past few decades the range of transport options required for long-term sustainability has not been delivered. Twenty-first century urban planning needs a rethink to ensure mobility is achieved with low environmental, social, and economic costs – for individuals and collectively.

Sustainable urban planning can reduce or even avoid the need for travel. For example, workplaces can be brought closer to homes, the number of homes can be increased in areas

with the greatest number of jobs, and transport links between work and home can be improved. A 'compact city' plan reduces urban sprawl by providing city centres that can be navigated on foot or by bicycle. Central business districts and the inner city traditionally have been the primary employment hubs, but there has been recent growth in employment in suburban locations. There is potential for future employment growth in suburbs away from the city centre, where there is bicycle-friendly land use and neighbourhoods with a mix of houses, businesses and industries. This can be further encouraged through the establishment of areas such as innovation clusters, high-tech nodes and creative sectors, similar to Silicon Valley in the United States.

> ***For truly sustainable urban design, the whole structure of cities and their transport options needs to be reconsidered … Twenty-first century urban planning needs a rethink to ensure mobility is achieved with low environmental, social, and economic costs.***

As the Federal Minister for Cities and the Built Environment observed in the launch of ACOLA's report SAF08 *Delivering Sustainable Urban Mobility* (http://acola.org.au/wp/8-delivering-sustainable-urban-mobility/), 'it is a matter of shame that 20,000 of our finest, smartest, and most entrepreneurial people base themselves in Silicon Valley in the United States … We need to continue to find ways to ensure that those people, and many thousands of others who leave our shores every day, are attracted to stay in our great cities, which are regularly rated as some of the most liveable across the globe'.

Online shopping and teleworking in Australia are rapidly increasing. These digital activities employ less than 10 per cent of Australia's workforce at the moment. As broadband speeds increase and enable a growth in telecommuting and shopping from home, cities will have less need for a central business district, and may head towards a decentralised design that reduces our reliance on cars and road transport.

Environmentally friendly future transport

There are ~1.2 billion cars in the world, a figure expected to double by 2030. In Australia there were 18.0 million motor vehicles registered in 2015, including more than 13.5 million passenger vehicles, with the number increasing at a rate of ~2.5 per cent each year. About three-quarters of Australians' journeys to work in 2011 were by car. However, car use is inefficient, with the average car parked 96 per cent of the time – 80 per cent of this at home.

Such inefficiencies extend to goods transport. The cost of moving freight by road is more than double the cost of transporting goods by train. Greenhouse gas emissions by road transport of goods are more than triple those of rail. Despite the obvious increased financial and environmental cost, the proportion of road freight compared to rail freight has steadily risen in Australia over the past four decades.

Furthermore, Australia lacks fuel security. Australians rely on cars for mobility within our urbanised population centres, as well as having a disproportionate reliance on heavy vehicles for goods transport. Therefore, it is surprising that Australia has small and declining fuel stock holdings. In fact, the country holds no more than three weeks' worth of oil and refined fuels onshore. In 2013–14, Australia's net import bill for crude oil and petroleum products was $30.7 billion, or 2 per cent of GDP. Australia's dependence on imported

fuel for transport is more than 90 per cent of our transport fuel demand, and it may well grow to 100 per cent. This leads to Australia having a significant fuel security risk.

It is surprising that Australia has small and declining fuel stock holdings. In fact, the country holds no more than three weeks' worth of oil and refined fuels onshore.

Development of more environmentally friendly transport options, as well as improved energy efficiency of transport, could address the country's significant fuel security risk, transport costs and environmental impact. Examples include increased uptake of electric cars, provided they recharge using renewable energy grids; the use of alternative fuels such as biofuels, gaseous fuels and synthetic fuels, especially for public transport; new and efficient powertrains for vehicles; and greater use of new energy technologies such as fuel cells.

Research also can address inefficiencies in road transport, which if improved will lead to reduced traffic congestion, decreased greenhouse gas emissions, and improved public health. For example, the efficient flow of people, vehicles and goods through cities could be facilitated by increased use of high-speed data transmission, digital sensors and data analytics that provide real-time information for management decisions – both computer-automated and human-assisted.

However, technology alone will not be enough to solve transport and urbanisation problems. Interdisciplinary research will be required to address problems such as social inertia to change (see below). Supportive government policies and sustained investment in innovative transport infrastructure also will be required.

Urbanisation and transport infrastructure are challenges around the world. New, efficient and renewable transport technologies are being adopted internationally. And, of course, many environmental problems, such as climate change, do not stop at international borders. Mobility and urbanisation are major long-term challenges for countries in Asia in particular. With global research priorities and societal challenges aligned to those in Australia, we could lead, or at least contribute more to, global transport solutions.

Collaborative research for sustainability

Questions such as food safety, product labelling, gene technology in plant and animal breeding, foreign investment and foreign workers, and farm ownership structures call for informed and respectful conversations.

– Joanne Daly, ACOLA SAF07 Expert Working Group

Australia's interdisciplinary research activities can contribute to global sustainability goals beyond those relating to transport. For example, science research has provided vital contributions to Australian agriculture over many decades, and still provides innovation input today. Science, innovation and technological research and development will continue contributing to future farming, with new technologies helping agriculture remain successful and sustainable, to adapt to climate change, and protect against the introduction of pests and diseases. Research that delivers anything from new types of seeds to new types of machines would be of value in Australia and beyond.

Australia can develop solutions to – or at least to help manage – our country's challenges such as climate change; the security of food, water and energy; and an ageing and growing population. Most challenges that we face require an interdisciplinary approach, drawing on humanities, arts and social sciences to address issues of change, technology adoption and quality of life in addition to technical and engineering solutions to sustainability challenges. Priorities relating to sustainability include:

- optimising food production and processing and agricultural productivity;
- improving the use of soils and terrestrial and marine water resources;
- increasing alternative fuels in transportation and lowering emissions;
- supporting development of reliable, low cost, sustainable energy supplies and enhancing the long-term viability of Australia's resources industries; and
- mitigating, managing or adapting to environmental changes.

All of these priorities are also global challenges. Innovative approaches by Australian researchers, underpinned by public investment, could create opportunities for Australia to research, produce and deliver solutions – whether ideas, services or products – needed around the world. This would improve our competitiveness, maintain our wealth and liveability, and help to secure our future (see Chapter 3).

Researchers already collaborate on global challenges relating to complicated problems such as energy security, food security, preventing and curing infectious diseases, and ensuring environmental sustainability. Here the scale of the problem and size of the associated research budgets are beyond the capacity of countries to address individually. Such research questions cross multiple disciplines and require the world's best knowledge, institutions and equipment to come together across international boundaries.

Just as opportunities should be sought to export Australian research to the world, we need to adopt international advances. The relatively small size of research and development investment in Australia – the majority of research and development is funded by federal and state budgets, and public spending on research and development has declined in the past few decades – is another reason for us to draw on international research. We need to put more emphasis on linking with other countries to obtain new research. Such thinking would provide opportunities across many sectors, a prime example being in agriculture.

Moving up the value chain with smart farming

> *Field robotics are becoming an integral part of many farming systems, reducing labour and input costs and increasing output quality and productivity.*
>
> – Salah Sukkarieh, University of Sydney

Farming is our oldest and still one of our most important sectors. However, agriculture's relative contribution to our economy has declined over the past century.

As introduced in Chapter 2, there are really two agricultural economies. One is highly productive and innovative, and includes the 25 per cent of farms that produce 80 per cent of production. They are innovative and adaptive, and are considered agribusiness. The other 75 per cent of farms consist of a mixture of lifestyle and hobby farms, and other farms that are sub-optimal in size and level of investment. The narrative in Australia about farming tends to reflect the latter, lifestyle farms rather than the vibrant agribusiness sector. The two should not be confused.

Population growth and rising standards of living here and overseas will drive an increased demand for agricultural products. Agricultural industries around the world will need to provide food for a world population of nine billion by the middle of this century. This population growth and changing dietary preferences – particularly in China, India, Indonesia and other parts of Asia – provide Australia with export opportunities worth many hundreds of billions of dollars over the next few decades. This should change the perception of agriculture being a sector in decline to one of renaissance in light of growing demand.

More than half of our exports in 2014 went to Asia, with eight of the top 10 destinations being Asian countries. Our historical capability in agriculture, combined with our global agricultural brand for pest- and disease-free produce from a clean and green environment, can be used to increase demand and create new value-added products. Already in the upper end of the food market, the Asian appetite is increasing for quality Australian primary produce, wine, craft beer and whiskey, and cottage industry speciality food products.

A traditional sector such as agriculture will remain an area of strength for Australia. But the current prosperity has partly been due to some low-value parts of the value chain; that is, growing and exporting basic agricultural commodities. Our current focus on commodities instead of value-added products needs to change for the longer term future. Our reliance on low-value agricultural exports leaves us vulnerable to currency fluctuations, commodity prices and global demand. Australian industries rarely focus on adding value to products, even though that is what a highly developed country with a highly skilled workforce should be doing. Rather than aiming to offer commodities at globally competitive prices in the face of competition from lower cost international markets, a better strategy would be to offer quality, environmentally friendly, clean and value-added products.

We can deliver specialised, high-value products for consumers who value safety, sustainable production, high quality and perceived health benefits over price (see Chapter 3). We can build a culture of high value-adding and technological innovation, especially in agriculture. However, it is crucial to develop sophisticated information systems and marketing strategies to get a better understanding of domestic and international consumers' views on 'clean and green' attributes, including nutrition and environmental impacts, and the premiums people are willing to pay for such products.

Rather than aiming to offer commodities at globally competitive prices in the face of competition from lower cost international markets, a better strategy would be to offer quality, environmentally friendly, clean and value-added products. Australia has the potential to deliver specialised, high-value products for consumers who value safety, sustainable production, high quality and perceived health benefits.

A move to more profitable commodities and an increase in productivity of traditional commodities will require existing and new technologies, improvements in breeding made possible through advanced genomics, and better management practices. Farmer-driven innovation has always been a feature of Australian agriculture, which has a long history of innovation, resilience, adaptability and productivity growth. New and continuing partnerships between farmers, researchers, communities and others will help provide the innovation to deliver to new niche markets.

Partnerships between farmers and researchers help to drive innovation. (Source: CSIRO)

Such advances can help Australia move further towards smart farming and value-added products, but require a higher level of research and development investment. Australian exports that have been traditional sources of strength and prosperity have tended to be unprocessed, including wheat, beef, cotton, wool, oilseeds, wine, lamb, sugar and barley. This has been driven by our natural endowment in these commodities, combined with the international trust in the quality and safety of Australian products.

Australia is now a net importer of processed food. Concentrating on products low in the value chain will not be a wise strategy. Innovative, value-added enhancements to food products, combined with links to global production networks, could create new

opportunities and employment in agriculture, as well as other sectors. We need to contribute more to products high in the value chain to provide growth potential for Australian industries linked to smart farming, such as advanced manufacturing and information and communication technologies.

The agriculture, forestry and fishing sector improved its productivity by 72 per cent between 1989 and 2013, in part because of investment in research and uptake of new technology. However, many of the current technologies and techniques used in Australian agriculture, as well as areas that support farming such as engineering, communication technologies, electrification and automobiles, are centuries or even millennia old. Paradigm shifts in technology can sometimes take decades, particularly when changes in infrastructure are required. Companies may not be able to adapt quickly, as agriculture has long lead times in growth and production processes, and organisations may be tied to contracts with equipment suppliers.

Nonetheless, new technologies are improving productivity, such as GPS-guided tractors to allow farmers to work on other tasks. There is potential to draw more heavily on technology, such as greater use of 'big data' and data analytics, precision agriculture, and smart water resource management. Developments in information and communication technologies can provide sensor networks and data to improve agricultural processes.

Furthermore, increasing demands for sustainability and environmental stewardship, and changes in cultural preferences and eating habits, are raising demand for organic foods grown in less polluted places with humane treatment of animals. Increased agriculture in future needn't lead to degradation of the environment through, for example, soil erosion and nutrient depletion. We could produce more from less by improving water use efficiency, or increasing productivity through innovation.

Botanical Resources Australia's high-value products for the world

Tasmanian company Botanical Resources Australia Pty Ltd (BRA) produces over 60 per cent of the world's pyrethrum, which is made from dried chrysanthemum flower heads and used in a range of pesticides. This puts BRA in a high-value part of an international chain of the world's consumer pesticide manufacturers. The high quality and reliability of BRA's products have maintained its position of supplying more than half of the global pyrethrum supply.

BRA undertakes research and development across all of its operations, and is the only company in the world that harvests the chrysanthemum crop mechanically. BRA originated from publicly funded research through the University of Tasmania and the Tasmanian Government in the early 1980s, where researchers bred plants suitable for local conditions. Ongoing close collaboration with the University of Tasmania and CSIRO has enabled BRA to develop new methods and processes, such as one for the analysis of a compound extracted with the pyrethrum that may provide more market share and commercial gains.

Funding support from the Commonwealth Government, research and development and highly focused management practices have contributed to BRA's success.

Preparing for the future

Global policy challenges must be addressed in a holistic way, drawing not only on science and technology, but also on economic, social, political and behavioural sciences. Interdisciplinary collaboration will be crucial.

– The UK Royal Society, *New Frontiers in Science Diplomacy*, 2010

Workforce for the future

Australia will need to train a future workforce to be equipped with skills for the new technology in smart farming, clean energy, natural resources management, and other sectors. Farms of the future will be unrecognisable compared with those of today. Robots will harvest and prune, while drones will survey fences and monitor high-value crops. Farmers will use real-time information to decide on levels of fertiliser, water and other inputs. Automation could see reduced demand for some labour while increasing the need for new skills; for example, engineers and computing experts will be needed to run machinery, which will place agriculture in competition with other sectors for these skills. With such developments in technology, and an ageing population, Australia faces shortfalls in skilled workers.

Farms of the future will be unrecognisable compared with those of today. Robots will harvest and prune, while drones will survey fences and monitor high-value crops.

For Australia's future agriculture, energy and environment workforce, we will need a growing proportion of workers to be trained in scientific and technological literacy. These industries will need increasing numbers of skilled workers who can work with and maintain complex equipment; for example, managing large farms remotely using information technologies, or using precision agriculture technologies.

However, current trends in education point in the opposite direction. In the first decade of the 21st century, enrolments in agriculture and environment undergraduate courses decreased to just 1.7 per cent of all domestic undergraduate enrolments. Enrolments in higher research degrees in agriculture, environment and related studies remained fairly steady, but at a low base of ~350. In 2010, there were ~285 000 course completions in all fields of education and at all levels (undergraduate and postgraduate), for domestic and international students together. Of these course completions, ~90 000 were in science-related fields but the smallest numbers completing courses were in agriculture and environmental sciences (approximately one-tenth of those completing studies in health).

These decreases in agricultural and environmental sciences may lead to shortages of skilled labour in these sectors, while on the other hand the requirement for unskilled labour is likely to decline as manual labour is replaced by technology. Already there is a decline in employment numbers in agriculture, which have dropped by 1 per cent a year on average from 1975 to 2013, despite the farm gross product increasing by 3 per cent over the same period. The education and subsequent labour shortages may be related to the negative image agriculture can have in Australia (contrary to the positive image Australian

agriculture has overseas). There is an urgent need to communicate the positive prospects and technological future of the agriculture sector, focusing on skills and innovation that can add to the country's natural advantage, historical track record and international reputation.

Furthermore, equipping students with scientific and technological knowledge and confidence provides the basis for participation in the most significant national and international debates of today, including climate change, ecological transformation, and new and renewable energy sources. Understanding of, and participation in, these discussions will enable the next generation to better shape the course of their own lives.

Growth in value-added agriculture industries will require increased skills and knowledge in humanities, arts and social sciences, and in science, technology, engineering and mathematics fields. These complementary skills will be essential to help communities adapt to the evolving industries and adopt new products and services.

Evolving communities

There are myriad social consequences when it comes to acceptance of changes in technology. For example, the evolutions and revolutions in agriculture greatly affect farming communities, where aspects of foreign ownership and an ageing population add to the changes. While Australian agriculture's history of resilience, innovation and adaptability encourages optimism, its future development – like other sectors – will require highly skilled and technically knowledgeable workers; access to high-quality transport, telecommunications and other infrastructure; and access to funds to enable change. The sector also will need to maintain healthy soil, water and biodiversity, including managing the risks associated with climate change and climate variability described above, in order to capitalise on increases in demand.

The Australian bush plays an important role in Australian lives and has a special place in the traditional Australian identity. Aligned to this identity is the contribution from farming, and managing on the land through droughts and flooding rains. But the sector is evolving, and there is potentially a tension between its past image and future role. Understanding the changes in Australia's agricultural sector is essential for securing its future wellbeing.

In 2013–14, some 270 000 people had farming-related jobs, representing ~2.3 per cent of Australia's workforce. This number is greater when forestry and fishing are included. However, it is just half of what it was in 2000. The median age of Australian farmers is increasing at a faster rate than that of the general population, although Australia still has the second highest proportion of farmers under 35 years of age (14 per cent) compared with other developed countries. As noted above, there has been a decline in employment numbers in agriculture and labour shortages remain a problem in rural areas.

The sector contains a wide variety of farms, including tiny lifestyle farms, long-run family farms and large corporate farms. Family-owned farms account for 95 per cent of farms and 77 per cent of farmland. Many people have concerns about the extent of foreign ownership and foreign labour in agriculture. But without more foreign investment in farms and agribusinesses, alternative models of farm financing will need to be developed to meet the needs for farm businesses faced with fluctuating incomes and reduced capacity to borrow. Local superannuation funds and other Australian funders may need to be encouraged to invest in potentially risky farming enterprises.

Communities and consumers are concerned about production methods (for example, pesticide usage) and technological innovations (for example, genetically modified crops

and foods). These views have attracted considerable political attention, in part because they are connected deeply to our perception of national identity and because food and its safety are fundamental parts of life. Media stories relating to animal welfare, food safety and labelling, combined with perceptions of agriculture as damaging to the environment and historically based romanticised views of agriculture and food production that are incompatible with modern technologies and processes, have all contributed to an erosion of farming's social licence to operate. These perceptions and concerns need to be addressed using humanities and social science skills to help understand how communities – and agriculture – can adapt. The industry itself needs to consider private regulatory structures, marketing and voluntary labelling practices relating to genetic modification.

Small family farm businesses may lack the ability to adopt advanced technologies and adapt to environmental and market changes. This, combined with the social and business inertia when it comes to paradigm shifts in innovation, raises issues associated with resistance to new technologies.

Are we ready for the future?

It is important to understand people's resistance to technological changes in the way we manage and interact with the environment, including our water, food and energy. Technology can be the catalyst for change, but is not necessarily always the answer to our problems.

Technology and its products often punctuate the record of historic cultural change. For example, the transition ~12 000 years ago between the Palaeolithic ('old stone') and Neolithic ('new stone') periods describes a change in the technology of stone tools and new activities such as animal husbandry, while the 'Green Revolution' from the 1940s to the late 1960s describes research, development and technology transfer that increased agricultural production. Other technological developments include the development of high-yielding cereal varieties, the expansion of irrigation, and the distribution of seed, synthetic fertiliser and pesticide. These changes improved the health and nutrition of billions of people, and probably saved more than a billion lives. While these developments were met with opposition at times, they led to profound social, economic, demographic and physiological changes.

The development of genetically modified 'Golden Rice' in the 2000s is an example of technology, health benefits, the influence of big business, and challenges to social acceptance linked to values, beliefs and perception of risk. Values relate to a person's principles and priorities in life; beliefs are firmly held opinions people accept as true and real; and these are reflected in a person's perception of risk. People opposed to genetically modified food focus more on 'tinkering with nature' and corporate power than on the scientific evidence and improvements resulting from research. Golden Rice was developed at the Swiss Federal Institute of Technology and the University of Freiburg to help address vitamin A deficiency in developing countries. Despite having been developed as a humanitarian tool and winning a Patents for Humanity award, there has been opposition from some environmental groups, with debate about the scientific evidence being a proxy debate about the influence of big business and commercial impartiality of scientists.

The advent of Golden Rice followed the increase in distrust of genetic engineering through the 1990s, particularly in Europe. In 1996, Monsanto introduced genetically modified soybeans without labelling them as GM, claiming that as there are no dangers associated with genetically modified soybeans there is no need for labelling. However, some groups saw this as concealing the origin of the product, and evidence of corporate manipulation.

Golden rice (right) is genetically engineered to biosynthesise ß-carotene, a precursor of vitamin A. (Source: International Rice Research Institute, CC BY 2.0)

Away from Europe, genetically modified crops have been received more favourably in developing countries due to their urgent need for food and improved nutrition. In Australia, while recycled drinking water was rejected by the Toowoomba community in 2006, a more recent study during severe drought found people more open to the idea.

Hence, before the introduction of technology, resistance to or uptake of new technologies needs to be seen in the social context of values and beliefs, as well as the environmental context.

Furthermore, the costs of a technology are not always clear when they are first introduced. For example, the impact of greenhouse gas emissions from fossil fuel generated electricity on the climate was not clear until decades after the technology was adopted. Coal drove the Industrial Revolution from the late 1700s and provided wealth and security to many millions of people, but coal mining led to mine accidents, and coal burning caused respiratory diseases and other long-term health effects for the ensuing two centuries, and will continue to cause climate change for decades to come.

As well as the social and economic perspective, an evaluation of technology using different, objective measures of costs can be helpful. For example, safety concerns relating to nuclear power could be crudely quantified as the number of deaths associated with the technology compared with the amount of energy generated. Although such a measure

may appear odd in light of environmental and other concerns, a comparison of deaths per unit of energy generated for a range of current primary energy sources generates some surprising results (see Table 5.2). By this measure, nuclear power is much safer than coal – by a factor of 4000, based on world averages. This kind of evaluation provides the opposite finding to what one would expect based on common community perceptions and social values.

Table 5.2. Number of deaths per unit of energy generated (terawatt-hours (TWh)) for various energy sources

Energy source	Percentage of world's energy	Deaths per TWh
Coal – world average	26	161
Coal (China)		278
Coal (US)		15
Oil	36	36
Natural gas	21	4
Biofuel/biomass/peat		12
Solar (rooftop)	0.1	0.44
Wind	1	0.15
Hydro	2.2	0.1
Nuclear	5.9	0.04

While the economic and other opportunities generated by the development of shale gas reserves will be widely welcomed, there are likely to be concerns about possible adverse impacts, as described earlier. Governments and industry must address these concerns while exploration is at an early stage, by engaging with affected and interested parties, building confidence in the science and technology, and demonstrating a preparedness to adopt and enforce strong regulatory and internal controls. Most, if not all, of the potential negative impacts could be minimised if these are in place. Robust and transparent regulation, underpinned by effective and credible monitoring, is key to public acceptability.

A 2009 report by the International Council on Science on the future of the Earth system highlighted 'the complex inter-relationships between biological, geochemical, climate and social systems' and suggested that 'natural science should no longer dictate the Earth system research agenda; social science will be at least as important in its next phase'. Indeed, many factors influencing our future are entwined, and these require a holistic, interdisciplinary approach to unpick, understand and prepare for. The social sciences can play a transformative role in dealing with issues associated with energy, water, biodiversity, land use, urbanisation and other environmental changes, to help secure a green and clean sustainable future.

Conclusion

> *The principle of decentralised concentration has long been advocated in Australian planning but rarely implemented with any will and therefore effectiveness. It guided the historical development of Canberra and has informed the planning of cities during periods of active metropolitan planning … This planning legacy has, arguably, been squandered in many of our cities.*
>
> – B Gleeson, J Dodson and M Spiller, quoted in SAF08 *Delivering Sustainable Urban Mobility*

This chapter on securing a clean, green and sustainable future for Australia draws on three key ACOLA reports (SAF06 *Engineering Energy: Unconventional Gas Production*; SAF07 *Australia's Agricultural Future*; and SAF08 *Delivering Sustainable Urban Mobility*), as well as incorporating cross-cutting themes about environmental sustainability that appear in the other eight ACOLA reports.

Similar to the approach of other chapters, and as noted in the introduction to this chapter, for a strong future we need to successfully address a range of findings identified through the interdisciplinary research and evidence of ACOLA's Securing Australia's Future reports.

We need to make choices and address challenges in the agriculture and energy sectors, and in cities, to enable sustainable growth in a changing market. This chapter presents opportunities to increase productivity, improve our competitiveness, protect the environment, and support communities during change.

We can realise opportunities for growth in local sectors while playing a global role in providing advice and leadership in sectors that depend on natural resources. This will require preparing the workforce for the future, focusing on skills in innovation, humanities and social sciences. We need to develop innovative new technologies that draw on scientific research, and on the humanities and social sciences to enable adoption.

We must improve our planning of urban centres and transport choices, such as establishing innovation clusters and high-tech nodes. We need to update our energy sources to protect our clean and green environment, for example by using local energy storage and smart grids to change electricity distribution and draw on alternative fuels where possible. In the production sectors, from agriculture to manufacturing, we need to look at producing more sophisticated, high-value products. That's where the markets will be; and that's where the profits lie.

If we recognise these findings and act on the implications, Australia will be able to balance its potential for growth with the protection of our environment and quality of life, achieving sustainable development in a secure future.