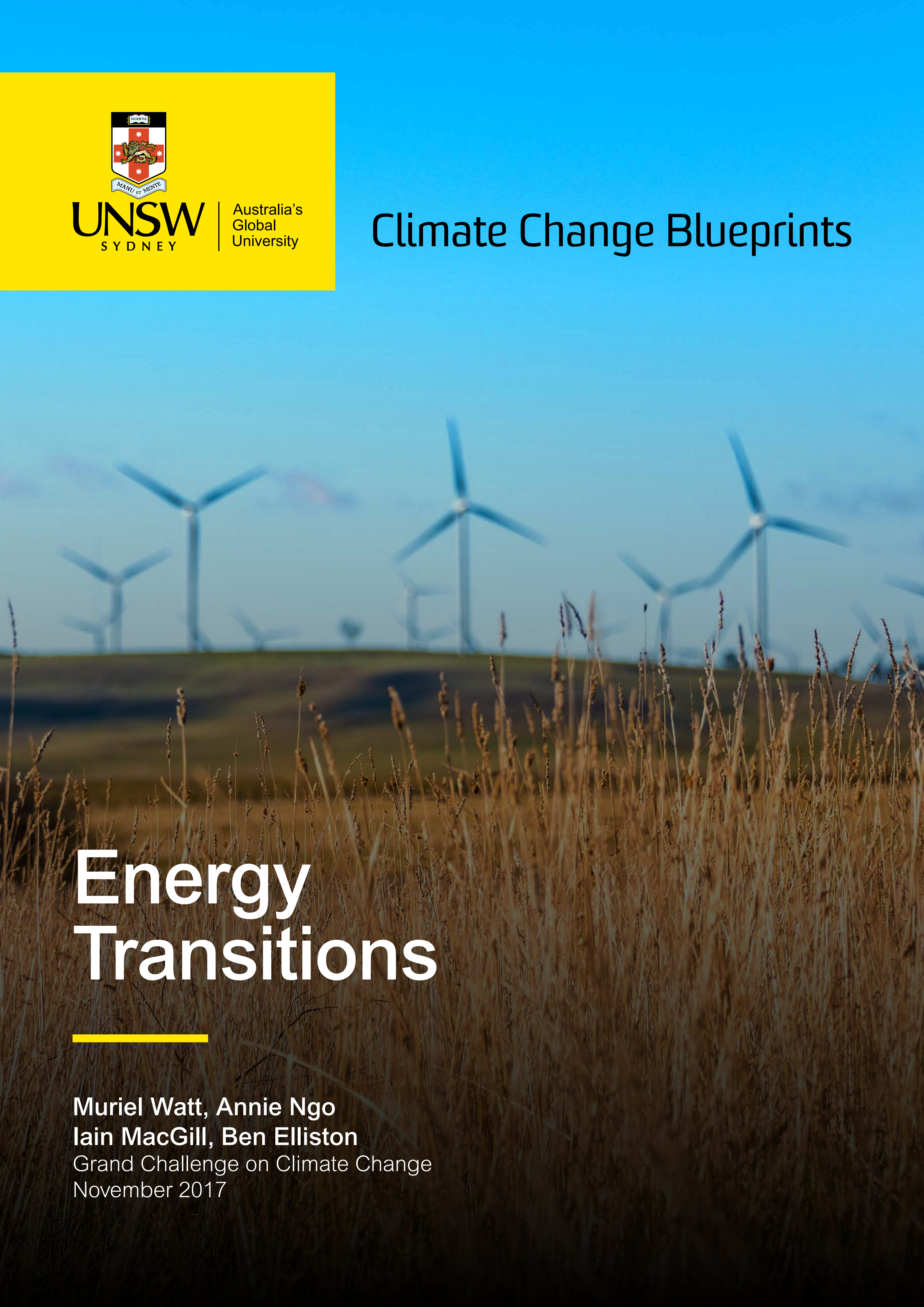

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Climate Change Blueprints

Energy Transitions

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Grand Challenge on Climate Change
November 2017

Preface

Increased greenhouse gases are already transforming our climate system. The world is warming, the oceans are acidifying, ice is melting and sea-levels are rising at an accelerating rate. Costly extreme events such as hurricanes, storms, floods, and heatwaves are becoming more frequent and more intense. Growing food and managing freshwater supply is becoming more challenging in some regions. Here in Australia drought and declining rainfall in the southwest has led to costly adaptation measures to secure a safer climate future. Insurance premiums are on the rise globally and infrastructure is being re-engineered for what lies ahead. The costs are expected to be crippling, especially when factoring in the massive scales of migration and resettlement from upcoming multi-metre sea-level rise.

The only viable way to stop climate change is to stop our emissions of greenhouse gases. This means we need to rapidly transform the way we produce energy and the way we power our transport systems, at an unprecedented rate. This might sound like hard work, but the challenge also presents an enormous opportunity to innovate and redesign the way we do things; how we generate electricity, how we build our cities, and the way we transport people and produce.

This report, *Energy Transitions*, is one of three Climate Change Blueprints launched in November 2017. The aim of the *Energy Transitions* blueprint is to set out the options available and actions required to meet our energy demands while also curbing our reliance on fossil fuels. The report was compiled by leading experts in the field and produced under the auspices of the UNSW Grand Challenges program.

The UNSW Grand Challenges program, an initiative introduced in the UNSW 2025 Strategy, aims to address the biggest issues facing humanity. The program leads the debate and facilitates critical discussions and actions with researchers, government, policymakers, business and the wider community; on areas such as refugees and migration, inequality, technology in the 21st century, and climate change.

Since its inception in 2015, the UNSW Grand Challenge on Climate Change has hosted lectures, events, and facilitated discussions on topics ranging from impacts and security to intergenerational consequences and adaptation. These Climate Change Blueprints represent a major effort to inform the community of the challenges and opportunities facing society in the areas of energy, human health, and justice.

I commend the *Energy Transitions* blueprint as a landmark report outlining the ways we need to reengineer our systems and practices in the energy sector. Because of the intrinsic link to greenhouse gas emissions, this is the sector uniquely placed to minimise climate change and avoid the worst impacts of climate disruptions. By transforming our energy systems in a clever, timely and sustainable way, we can help deliver a safer climate future for the generations ahead.

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Executive Summary

Background

The global energy sector is highly fossil fuel based and currently accounts for at least two-thirds of greenhouse gas emissions. Carbon dioxide concentration in the atmosphere has reached levels at which global average temperatures are predicted to rise by 1.5°C. A temperature increase of this magnitude is at the lower end of the 2015 Paris Agreement commitment to a 1.5ºC to 2ºC increase above pre-industrial levels. To achieve the Paris target, emissions need to fall to net zero by 2050. The urgency for action is now palpable.

The global energy system has evolved as a complex, world-scale system of energy extraction, delivery and end-use. Only 100 years ago, energy was mostly locally sourced. Fossil fuel resources (oil, gas, coal) are concentrated in particular countries. In addition, there is a large differential between per capita energy use in developed versus developing countries.

This means that any transition to new energy sources, services and applications has very large, global ramifications and, therefore, strong multi-national corporate and government interests. The transition to a more sustainable energy system, based on locally available resources, has the potential to reduce the political power of the fossil fuel sector and the differential in world-wide per capita energy use.

The global climate impacts of fossil fuel use will be experienced by all communities. However, the early impacts are being felt disproportionately by communities in developing countries, far removed from those that are most benefitting from the fossil fuel industry or end-use services provided.

Societies are reliant on low priced, reliable energy for all economic activity. Industrialised countries, as prosperous nations, have a role in the energy transition. They can fund the research, development and demonstration needed to rapidly develop low emission energy technologies. Furthermore, they can assist developing countries to move directly to renewable and distributed energy systems without the legacy of fossil fuel based supply.

Australia's geographic presence in the Asia-Pacific region provides the opportunity to apply Australian expertise to the broader region and to assist developing nations with their energy and economic development.

Climate change and energy in Australia

The energy market developed in the 1990s provides the basis for Australia's own energy transition. Australia now faces the challenge of transitioning to an energy system which is affordable to all, secure and environmentally sustainable.

In the past, energy in Australia has been produced using low cost fossil fuel sources, providing a competitive advantage for Australian industries and the economy. The associated high emissions are not monetised. This mode of growth is unsustainable for Australia and also for other newly advancing economies which are seeking to raise living standards to those of developed countries.

Under the Paris Accord, Australia has committed to reduce emissions to 26-28% of 2005 levels by 2030. This target represents a 50-52% reduction in emissions per capita and a 64-65% reduction in the emissions intensity of the economy between 2005 and 2030. It will become increasingly challenging to meet the Paris targets without carbon pricing signals in the economy.

Global trends

The future is renewable

Global investment in renewable energy generation has surpassed fossil fuel generation for the past three years with higher levels of investment in developing countries than developed countries. Small scale solar and distributed energy systems have been deployed rapidly in established economies like Australia, and in emerging economies with low levels of electrification. These trends are changing energy markets and projected energy mixes into the future.

The future is electric

The deployment of renewable electricity generation world-wide has accelerated over the past decade. As technologies mature and the costs continue to fall, it is becoming apparent that the easiest way to decarbonise some of the more difficult sectors, such as heat, transport and industrial processes is to shift these sectors from direct fuel combustion to electricity. Sustainable electrification of these sectors is now more feasible due to the readily available supply of zero emissions renewable electricity.

The future is distributed

The future grid will be more distributed, with consumers the driver of this transition. The technologies contributing to this trend are photovoltaics (PV), smart controllers and, increasingly, energy storage and electric vehicles. A new "Prosumer" market is developing, where end-use customers are also involved in energy production, storage and supply.

The future is digital

Enormous potential exists for new types of customer engagement, customer empowerment, grid management and electricity trading using information technology. Developments in information technology that are spurring innovation in the distributed energy sector include the "Internet of Things", low cost digital electronics and communications networks. Innovations allowing appliances to be controlled by utilities, aggregators or customers and the development of technologies such as blockchain or similar applications of public key cryptography are also driving innovation.

The future is flexible

Under the old supply-focussed paradigm, inflexible power generation was seen as being reliable. As a system incorporates higher levels of variable renewable generation, power is delivered from a greater range of fuel sources with faster rates of change in output. Power delivery must operate at more flexible levels, and the system overall needs to balance supply and demand more actively, meeting variable demand from a mix of flexible and dispatchable sources[1] that can increase or decrease levels of power to complement variable renewable energy sources.

The future is more global and more local

The rapid rate of solar PV uptake globally shows the extraordinary rate at which technology can be adopted across the world – particularly if scalable, adaptable and targeted at local consumer markets. A future with high levels of renewable and distributed energy, assisted by new models of social interchange and new market mechanisms, seems likely to replace global fuel supply chains with global technology chains. There will be an associated return to local energy production at the point of consumption.

Energy sector transitions

A range of energy transitions are required. Some of the transitions are already underway in different parts of the world and their timing will vary depending on local circumstances and policy settings. Some span a discrete timeframe, others are ongoing.

There is broad based agreement on a number of features of an energy transition to meet the climate challenge. These include: carbon pricing and complementary measures; dramatically reduced reliance on coal and oil; and a wide portfolio of clean energy technologies, with renewables playing a key role. There is a need for more engaged and informed energy users and integrated planning across related sectors to achieve social objectives. Further, there is a significant role for energy efficiency, appropriate policy and regulation, and planning and investment to prevent long-term lock-in of inefficient energy use. These can form the basis for government policy and facilitation.

However, issues remain where there is still disagreement. Among these are the future roles for nuclear and carbon capture and storage, the role of gas as a transition fuel and the role of hydrogen as another energy vector. Also important are the extent of the challenges posed by the integration of variable renewables, the extent to which a change in energy markets is needed and the outlook for future cost reductions for different renewable energy technologies. In these instances, there is a role for further research, investigation, analysis and/or policy debate to assist in developing consensus.

Recommendations for Australian Action

1. The new energy system must be affordable to all, secure and environmentally sustainable.
2. Australia must use its resources and institutional arrangements to reduce its own emissions and to assist others to do the same.
3. Independent and enduring governance arrangements must be in place to ensure the success of the energy transition.
4. The national electricity market design must change to accommodate distributed and renewable energy technologies and changes in end-use behaviour.
5. To address uncertainty regarding the impacts of climate change, there must be disciplined analysis and no-regrets action, not delay.
6. There must be coherence between domestic policy and global agreements.
7. To be sustained, the global transition must be consistent with prosperity and equity.

1 Flexible sources help a power system to be responsive to changes in demand and supply. They can originate from the supply or the demand side. Dispatchable sources are those that can respond to the command of a plant or system operator to vary its output up or down.

Background

The climate change imperative

The global energy sector is highly dependent on fossil fuel (oil, gas, coal) energy sources. These are high in energy density and have been cheap to extract, transport and use. However, the environmental and social impacts of burning fossil fuels have largely been seen as externalities. A key externality is changes to the composition of the Earth's atmosphere. The world is currently undertaking a global experiment by adding around 100 million tonnes of CO_2 to the atmosphere each day, as shown in Figure 1.

In 2016, the carbon dioxide concentration in the Earth's atmosphere reached 400ppm, a level at which global average temperatures are predicted to rise by 1.5°C. The Paris Agreement, adopted by 196 countries in December 2015, aims to hold the increase in global average temperatures to 2ºC above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5ºC.

To achieve the Paris target, emissions of greenhouse gases need to fall to net zero by 2050.[3] The emission cuts agreed to by most nations are only to 2030 and fall well short of what is required.

The energy sector currently accounts for at least two-thirds of greenhouse gas emissions.[4] Combustion of fossil fuels is the major contributor in both the electricity and transport sectors. The urgency for action is now palpable amongst communities everywhere, but appears yet to be felt by all political and business leaders.

Action over the past decade has seen global emissions stabilise over the past three years, at a time when economic growth continued. This indicates that emissions reduction does not need to threaten GDP, as illustrated for Europe in Figure 2. Many countries, including China, are rapidly developing new industries, and increasing their energy use but not their emissions, via the manufacture and deployment of renewable energy technologies.

The role of energy

Energy is an essential component of a modern economy. It is a critical input to our housing, industry, transport and communications systems, all of which have become increasingly, in some cases totally, reliant on readily available, low cost electricity or fossil fuels. In turn, a complex, world-scale system of energy extraction, delivery and end-use has developed. Only 100 years ago energy was mostly locally sourced.

Key aspects of the current energy system include:

- High dependence on fossil fuels.
- Concentrations of fossil fuels in certain countries, with implications for trade, investment and local development.
- Large differential between per capita energy use in developed (>200 GJ/capita/year) versus developing countries (<20 GJ/capita/year)[6]

Figure 1: Historical CO_2 levels[2]

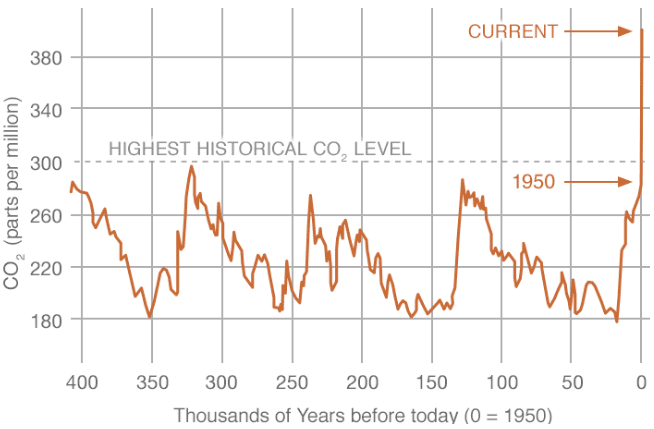
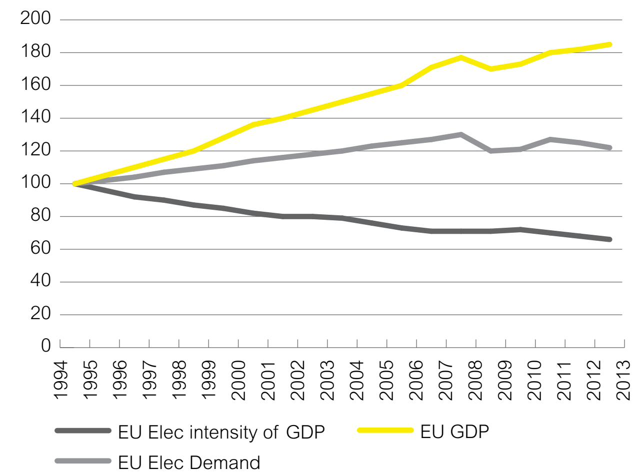


Figure 2: European electricity demand since 1995, compared with GDP and electricity intensity of GDP[5]



2 National Oceanic and Atmospheric Administration (NOAA) cited on https://climate.nasa.gov/vital-signs/carbon-dioxide/.
3 Figueres et al, 2017, Nature – News and comment, 28 June 2017.
4 International Energy Agency, World Energy Outlook, 2016.
5 Based on figure published in Carbon Tracker, 2015, Coal: Caught in the EU Utility Death Spiral
6 Energy Transitions Commissions, 2017, Better Energy: Greater Prosperity

Credit: iStockphoto

This means that any transition to new energy sources, services and applications has very large, global ramifications and therefore strong multi-national corporate and government interests. Any changes which impact current supply chains have implications for trade, balance of payments, industry, employment and local energy prices. Nevertheless, transition to a more sustainable energy system, based on locally available resources has the potential to reduce the political power of the fossil fuel sector and also reduce the differential in world-wide per capita energy use.

It is also becoming increasingly clear that energy-water-carbon are interconnected challenges.[7] This interdependency is expected to become more apparent in the transition to a clean energy system, as parts of the energy sector, particularly those using turbines, are reliant on water and the water sector is also reliant on energy for purification and distribution.

The amount of energy used to extract, distribute and treat water is around 4% of global electricity consumption and this is expected to more than double by 2040 due to wastewater treatment demand in emerging economies.[8] Careful management of this interdependency is important, otherwise the risk is the achievement of one target at the expense of another, thus compromising overall outcomes sought in terms of resilience, adaptation and transition.

Implications for the developing world

The global climate impacts of fossil fuel use will be experienced by all communities. The early impacts are, nonetheless, being felt disproportionately by communities in developing countries far removed from those that are most benefitting from the fossil fuel industry or end-use services provided.

Societies are reliant on low priced, reliable energy for all economic activity. To equalise living standards of developing nations with those of developed nations, it is forecast that their annual energy use needs to increase from around 20 gigajoules (GJ) to between 80 and 100 GJ per capita per year.[9]

At the same time, global greenhouse gas emissions need to reduce from annual 36,000 metric tons (Mt) in 2015 to 20,000 Mt by 2040. That is less than half the 47,000 Mt expected in business as usual. To achieve this, energy productivity improvements must increase from historical rates of 1.7% per year to 3% per year.[10]

THE GLOBAL CLIMATE IMPACTS OF FOSSIL FUEL USE WILL BE EXPERIENCED BY ALL COMMUNITIES

The role of the industrialised world

Industrialised countries, as prosperous nations relative to developing counterparts, have a role in funding the research, development and demonstration needed to rapidly develop low emission energy technologies to market maturity so they can be widely deployed. Opportunities exist for the industrialised world to assist developing countries to bypass fossil fuel and associated infrastructure for energy supply needs, particularly as financing options for new technologies become more viable as costs and track records improve. Industrialised nations can assist developing countries to adopt renewable energy, distributed energy and efficient, electrified energy systems without the legacy of fossil fuel based supply.

Australia’s role in the Asia-Pacific region

Australia’s geographic presence in the Asia-Pacific region provides an opportunity to apply Australian expertise to the broader region. China, India, South-East Asia and the Pacific represent growing market opportunities as they transition their old energy systems and develop new ones to meet increasing development targets. Examples include: use of pioneering Australian solar cell research in Chinese manufacturing; use of Australian patented renewable integration technology in projects in the region; and Australian project implementation and service expertise in control systems and integration in off-grid and mini-grids in the Asia-Pacific region.

7 Prime Minister’s Science, Engineering & Innovation Council, Challenges at Energy-Water-Carbon Intersections, 2010.
8 Ibid.
9 Energy Transitions Commission, Better Energy, Greater Prosperity, 2017.
10 Ibid.

Climate Change and Energy in Australia

Energy sector 'reform' in Australia over the past three decades

Australia was one of the pioneering nations to transform its energy sector from a largely government owned and operated model, with vertical integration and regulated prices, to a more disaggregated, market oriented one. It largely focussed on the establishment of the national electricity market (NEM) which aimed to increase competition and private investment in the east-coast's electricity sector.

The reform agenda in the mid-1990s centred on introducing market mechanisms as part of broader structural changes for more transparent and competitive electricity and gas markets. Despite environmental sustainability being one of the key underlying principles when establishment of the NEM was being discussed, it was dropped from the list of legislated aims during the final negotiations. This has meant that environmental implications of energy sector decisions are often overlooked.

During the 2000s, the focus shifted to implementation of energy market governance and institutional arrangements to support the market sectors (generation and retail). Economic regulation of the non-contestable sectors (distribution and transmission) was also in focus.

An independent review of the strategic directions for energy market reform in 2002 found reform had brought significant benefits, including electricity and gas prices becoming competitive with other OECD countries.[11] However, the overriding conclusion was that energy reform was incomplete and serious deficiencies remained. These included lack of emissions pricing which, without being addressed, risked losing the valuable benefits to Australia's energy market gained over the previous decade.

The inability to obtain bipartisan support for emissions pricing, despite the widely accepted need to decarbonise the electricity sector, has persisted in Australia. Various mechanisms, operating in parallel with the main energy markets, have been introduced by different governments.
One such mechanism has been the national Renewable Energy Target, a scheme under Federal legislation to increase the proportion of electricity generated in Australia from renewable energy sources.

In 2006, a further broad review of energy markets found Australia was respected internationally for past reforms and for producing one of the most competitive and efficient energy sectors in the world.[12] It also reiterated the recommendation from the earlier review for the implementation of an economy wide carbon price signal. While a carbon pricing mechanism was legislated and become operative in 2012, it was subsequently repealed following a change of government in 2014.

Recent events

After an initial period where affordability was assisted by generally low wholesale prices, Australian electricity and gas prices increased steeply. They are now some of the highest in the world.[13]

The most recent review of the NEM (Finkel[14] June 2017) has focussed on regional approaches to system security and strategic government intervention. In relation to climate change, the review recommended orderly transition of the NEM to low emission sources. This included using a Clean Energy Target as a compromise proposed policy mechanism for emission reduction.

This recent review also concluded that existing NEM investment pricing signals are no longer a dependable mechanism to ensure reliability.[15] In relation to energy generation, a long-term measure recommended was for new generators to bring forward dispatchable capacity in instances where these levels have fallen below pre-assessed minimum levels for a given region.

11 Parer Review: Towards a Truly National and Efficient Energy Market, 2002.
12 Energy Reform Implementation Group, Energy Reform: The Way Forward for Australia, 2007.
13 European Commission, Directorate-General for Energy, Market Observatory for Energy, 2015.
14 http://www.environment.gov.au/energy/national-electricity-market-review
15 Expert Panel, Independent Review into the Future Security of the NEM, 2017.

Since the review, there has been discussion of strategic reserve procurement by the market operator as a potential mechanism compatible with NEM design.[16] The review also recommended government undertake transmission investment if the market is unable to deliver the investment required to meet development of renewable energy projects needed to meet emission reduction targets.

In October 2017, the Federal Government announced energy retailers and some large businesses making wholesale purchases from the grid, would be obliged to source dispatchable electricity from a mix of generation, storage and demand response. This was in order to meet regional reliability requirements under the 'National Energy Guarantee'.[17] The electricity purchased would also need to meet a specified emissions level in line with Australia's international commitments and regionally predetermined minimum dispatchable levels. Liable parties under the scheme could meet their obligations by either directly investing in dispatchable sources, contracting with generators or retailers, or purchasing international emissions permits to an certain level. Priority has been placed on implementation of dispatchability guarantees by no later than 2019.

The emissions obligation is to be implemented in 2020 to replace the Renewable Energy Target. The setting of the emissions target and trajectory under the National Energy Guarantee will have emissions implications and also influence the mix of dispatchable sources that will be incentivised under the scheme.

Australia's emission trajectory and commitments under the Paris Accord

Under the Paris Accord, Australia committed to reduce emissions to 26–28% of 2005 levels by 2030. This target represents a 50–52% reduction in emissions per capita and a 64–65% reduction in the emissions intensity of the economy between 2005 and 2030.

Australia is starting from one of the highest levels of per capita emissions in the world, as shown in Figure 3, and emissions have been growing rather than falling, as shown in Figure 4.[18] Meeting the Paris targets will become increasingly challenging without clear carbon pricing signals in the economy.

Figure 3: Per capita emissions - Australian and international[19]

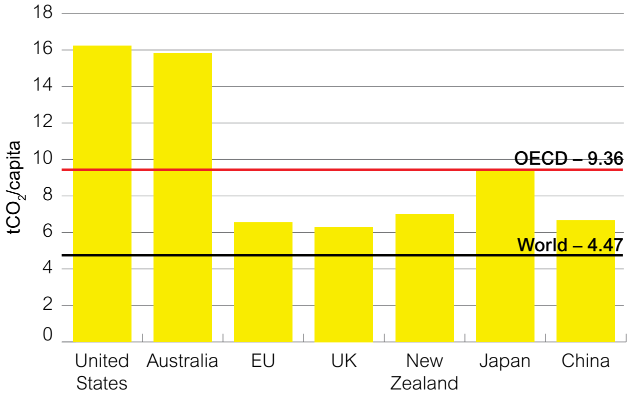
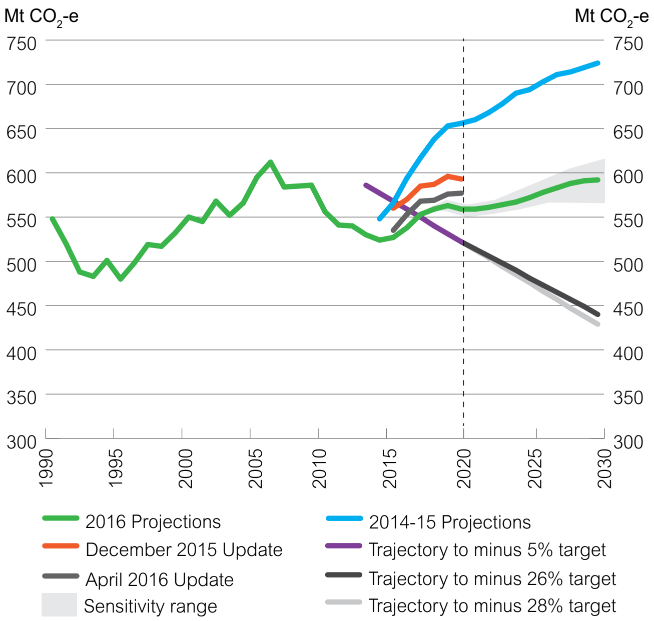


Figure 4: Australia's emissions growth 1990-2015, and targets for 2030[20]



16 Australian Energy Market Operator, Advice to Commonwealth Government on Dispatchable Capability, 2017.
17 Energy Security Board, Overview: Retailer Reliability and Emissions Guarantee, October 2017.
18 http://www.news.com.au/national/breaking-news/greenhouse-gas-emissions-up-in-2016/news-story/8535cf8d9a18f94d52460141fad7a953
19 Based on IEA data from Key world energy statistics © OECD/IEA 2016, www.iea.org/statistics, Licence: www.iea.org/t&c; as modified by IT Power (Australia) Pty Ltd.
20 Department of the Environment and Energy projections chart data cited in Australia's emissions projections 2016, Commonwealth of Australia 2016.

Production of wind towers, Kilburn South Australia. Credit: RenewablesSA, Government of South Australia

Global Trends

The future is renewable

Over the past decade, renewable energy technologies, particularly photovoltaics and large wind generators, have undergone rapid development and have begun to compete on costs with fossil fuels.

In the electricity sector, global and Australian investments in renewable energy generation have surpassed those in fossil fuels for the past three years. The year 2015 was record breaking for global renewable energy investment, with increased capacity in 2016, but lower prices, as shown in Figure 5.

For the first time, more than half of all new power generation capacity came from renewables, with investment higher in developing economies than in developed countries[21], as shown in Figure 6. Many countries or regions have examined 100% renewable energy scenarios and, in many cases, both the technical and economic feasibility have been confirmed.

Emerging economies, where electrification levels are still relatively low, have seen rapid deployment of small-scale solar, at levels far exceeding utility-scale deployments in these regions.[22] Pay-as-you-go solar service providers of solar lanterns and household stand-alone power systems have attracted significant investments by private equity firms.

Larger scale renewable energy deployment is also increasing rapidly in transition economies such as India and China, as well as in developing nations, both for central and distributed energy services. These trends are rapidly changing energy markets and projected future energy mixes.

The future is electric

Electricity, once generated, can be distributed and used irrespective of its original energy source, hence the transition from fossil fuels to renewable generation can be implemented incrementally in the electricity sector. The transport sector, where the 'fuel' is loaded and carried, has different challenges. Still, a technology-driven transition is interconnecting various energy use sectors. This blurs the lines between electricity, transport and other end use sectors, such as building services and industrial processes.

21 Frankfurt School-UNEP Centre, BNEF, Global Trends in Renewable Energy Investment 2016, 2016
22 Bloomberg, Quarter 1 2017 Off-grid and mini-grid market outlook, 2017.

The deployment of renewable electricity generation world-wide has accelerated over the past decade.[23] As wind and solar PV technologies mature and costs continue falling, it is becoming apparent that the easiest way to decarbonise some of the more difficult sectors, such as heat, transport and industrial processes, is to shift these sectors from direct fuel combustion to electricity.

While there are some options available to decarbonise these sectors, they have not yet been scaled up (e.g. biofuel production) and do not convey the benefits of electrification. Nevertheless, in the longer term there are significant opportunities for renewable fuels and biofuels in aviation and freight.

The forecasts are for electricity to comprise a larger share of final energy consumption, increasing from 25% to almost 40% of consumption by 2040.[24] Electrification offers a range of benefits over direct combustion technologies:

- Electric motors are much more efficient than engines which burn fossil fuel. For instance, the tank-to-wheel efficiency of electric vehicles (EVs) is around 85% compared with 19–21% for internal combustion engines. The well-to-wheel efficiency, which includes the efficiency of production of the end-use energy source, gives EVs approximately double the energy efficiency of internal combustion engine vehicles.

  Electrification of transport can be applied to trains, trucks, buses, passenger vehicles, motorcycles and bicycles. Options include direct connection to the grid (trams) and on-board batteries or hydrogen fuel cells. There is large scope for further improvement in the performance of electric motor systems, which account for more than half of current electricity consumption in a range of end-use applications (e.g. fans, compressors, pumps, vehicles, refrigerators).[25]
- In the heat sector, efficient electric heat pumps offer significant improvement in energy efficiency over gas boilers/furnaces and resistive electric heating in residential and commercial applications. Heat pumps use a refrigerant cycle to move heat from outdoors to indoors (or vice-versa in cooling mode). In the Australian climate, heat pumps can operate at high levels of performance.
- Increasing the number of electric appliances will increase electricity demand, but it also offers new kinds of flexible load that will assist in balancing supply and demand in grids with high shares of variable renewable energy. For consumers, greater electrification supports more distributed and resilient energy supply. For example, an electric vehicle can be charged at home by an onsite solar PV system without an extensive fossil fuel supply chain.
- There are some applications in the industrial process sector where direct electrification may not be feasible. However, through the creation of renewable fuels from electrically driven processes, there is the potential for zero emissions liquid and gaseous fuels. For instance, hydrogen gas can be created from renewable powered electrolysis and used in a hydrogen fuel cell. The enormous potential to export renewable fuels is also being explored by forward thinking companies.

RENEWABLE ENERGY TECHNOLOGIES HAVE UNDERGONE RAPID DEVELOPMENT AND HAVE BEGUN TO COMPETE ON COSTS WITH FOSSIL FUELS

Figure 5: Global investment in clean energy technologies 2004–2016[26]

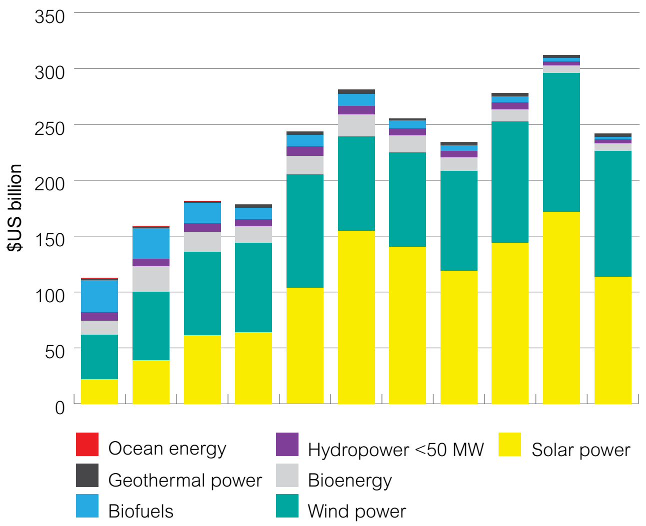
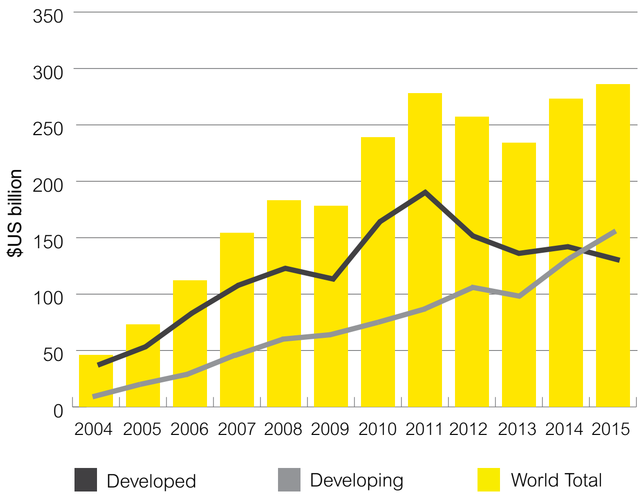


Figure 6: Global investment in clean energy, developed and developing countries, 2004–2015[27]



23 REN21, Renewables Global Futures Report, 2017
24 International Energy Agency, World Energy Outlook 2016, 2016.
25 Ibid.
26 Prepared from data in REN21, 2017, Renewables 2017 Global Status Report
27 Based on Frankfurt School Centre-UNEP, Bloomberg New Finance cited in UNEP, Global trends in renewable energy 2016, 2016.

Figure 7: Past, present and future of electricity generation.

The future of electricity is distributed

The future grid will be more distributed, with consumers the driver of this transition.[28] The evolution to a future grid is shown in Figure 7. The technologies contributing to this trend are PV, smart controllers and, increasingly, storage and electric vehicles. This is developing a new "prosumer" market, where end-use customers are also involved in energy production, storage and supply.

The main hurdles are regulatory and institutional rather than technical. These are inappropriate tariff settings, lack of clear rules for consumers and inflexible markets. In Europe, an estimated 50% of residential customers have the potential to become prosumers by 2050.[29] The customer drivers are reduced costs, increased power reliability, low carbon electricity generation and other grid benefits, including reduction in demand charges and provision of back-up power during emergencies.

Rapid take up could encourage defection away from the grid. Under existing utility models, defection would increase tariffs, thus making self-generation and grid defection even more economic[30] and triggering the so-called 'death spiral' of the grid. This is a particular issue in the US and Australia, because of the structure and regulation of their grids.[31]

If customer defection is widespread, it could mean costly stranded assets, with traditional utility cost recovery models – based on kWh sales, recovery of costs and allowable returns – being undermined. It is possible to ameliorate these risks through: planning focused on distributed energy; and regulatory approaches which incentivise networks to pursue distributed energy and fairly recognise the grid benefits of customer supply.

For the developing world, the opportunity of distributed energy changes the drivers for grid connections to the remaining unelectrified regions, most of which are remote and low density. Even in the developed world, grid connections have traditionally been seen as a key driver for socio-economic development. As cheaper, more reliable options for self-supply become available, the large cross subsidies required to maintain network supply to remote and sparsely populated areas will increasingly be questioned.

Linked to the uptake of distributed energy is the rapid increase in mini-grids, both for remote communities and for groups of customers within existing grids[32]. Mini-grids aim to utilise the investments made by customers and the local utility in generation, storage and load control to form self-contained grids which can operate autonomously during emergencies, during peak periods, or all the time. The low costs of wind and solar technologies, and the reducing costs of storage offer significant potential to displace diesel fuel in remote areas, and to reduce the need for expensive grid investments in other regions.

Distributed energy in Australia

CSIRO has estimated that 30 to 45% of Australia's electricity consumption could be supplied from consumer-owned generators by 2050[33], the highest in the world.

The degree to which Australia can smoothly transition from central supply to more distributed supply will be strongly influenced by technology developments and the extent to which related policies are coordinated, strategically driven and relevant to consumers. Australia must plan ahead to build on its research capabilities and develop new energy system control and management platforms.

The ability of Australia's institutional energy structures and policy frameworks to adapt, become fit-for-purpose and remain technology agnostic as it responds to new technology developments is also vital to the energy transition ahead.

28 Expert Panel, Independent Review into the Future Security of the NEM, 2017
29 Solar Power Europe, 2017, Global Market Outlook for Solar Power 2017- 2021.
30 RMI, 2014, The Economics of Grid Defection.
31 Edison Electric Institute, 2013, Disruptive Challenges
32 IRENA, 2016, Innovation Outlook: Renewable Mini-grids
33 Energy Networks Australia and CSIRO, Electricity Network Transformation Roadmap: Final Report, 2017.

The future is digital

The transition from central to distributed energy systems provides opportunity for digitally based innovation – for instance, new technologies that integrate variable renewable energy and new data systems which, in turn, support new modes of energy delivery and consumption.

Such innovations will be needed to fully harness the benefits of distributed energy resources like rooftop solar PV and battery storage systems without prompting unnecessary grid defection. It will be necessary to implement smart grids, intelligent meters, energy and data management, control and communication technologies, as well as clear data ownership rules to promote new ways of trading value.

Deployment of distributed energy technologies will promote greater end user participation in energy supply. As a result, energy institutions must develop strategies for managing demand side data, keeping pace with rapidly changing technology developments and taking into account user preferences in planning approaches.

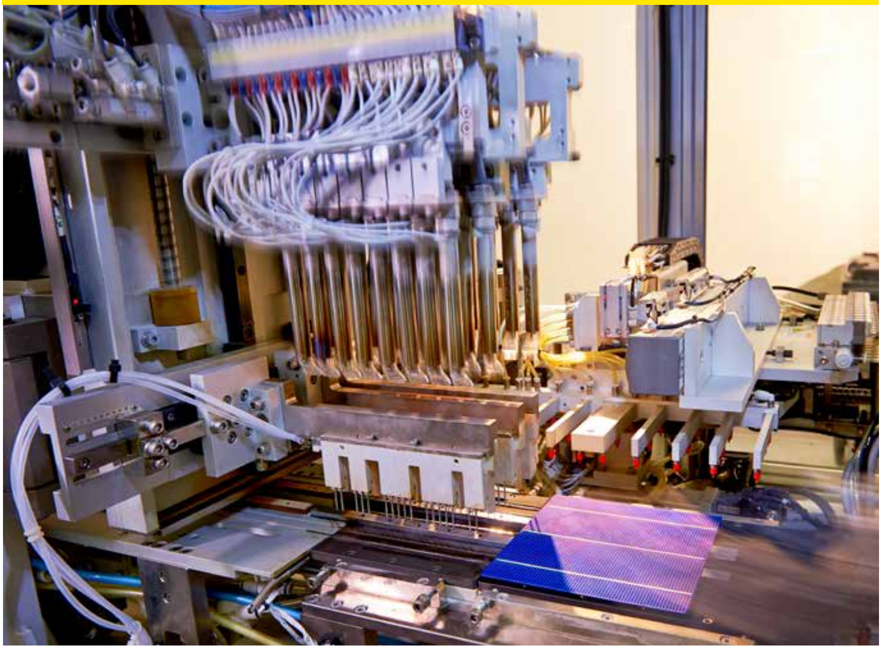
Institutions must also ensure benefits of consumer participation are within reach of all energy consumers. They must also make certain that developments are accompanied by greater transparency in energy data. This would broaden the base of stakeholders involved in energy policy and market development processes.

Enormous potential exists for new types of customer engagement, customer empowerment, grid management and electricity trading using information technology. The number of digital technologies and products in this space is increasing rapidly. Numerous start-up companies have emerged, although there are few established players.

The entire existing electricity retail model used worldwide could be substantially altered by so-called peer-to-peer electricity trading between small-scale distributed producers and nearby consumers, using new technologies. At present, electricity retail market structures and regulated components, which were designed to meet the needs of technology and demand in past decades, pose major barriers to new options.

Alternatively, new technologies may supplant the existing infrastructure by providing superior solutions in a less regulated environment. Examples include home energy control systems, with more features than the high cost “smart” utility meters.

PV module manufacture, South Australia. Credit: RenewablesSA, Government of South Australia



Developments in information technology are spurring innovation in the energy sector. They include:

- the "Internet of Things".

  This consists of low cost, low power radios that can transmit sensor data or receive commands to servers on the Internet.

- low cost digital electronics and communications networks.

  Various devices can be connected at low cost to the data network or mobile phone network of household or commercial premises. They can provide functions such as: PV system performance monitoring; load scheduling that incorporates solar radiation forecasts; control of resistive electric hot water systems for fast frequency management; and remote control of appliances such as air conditioners.

- development of standards such as Demand Response Enabling Device (DRED), allowing variable control of appliances by utilities.

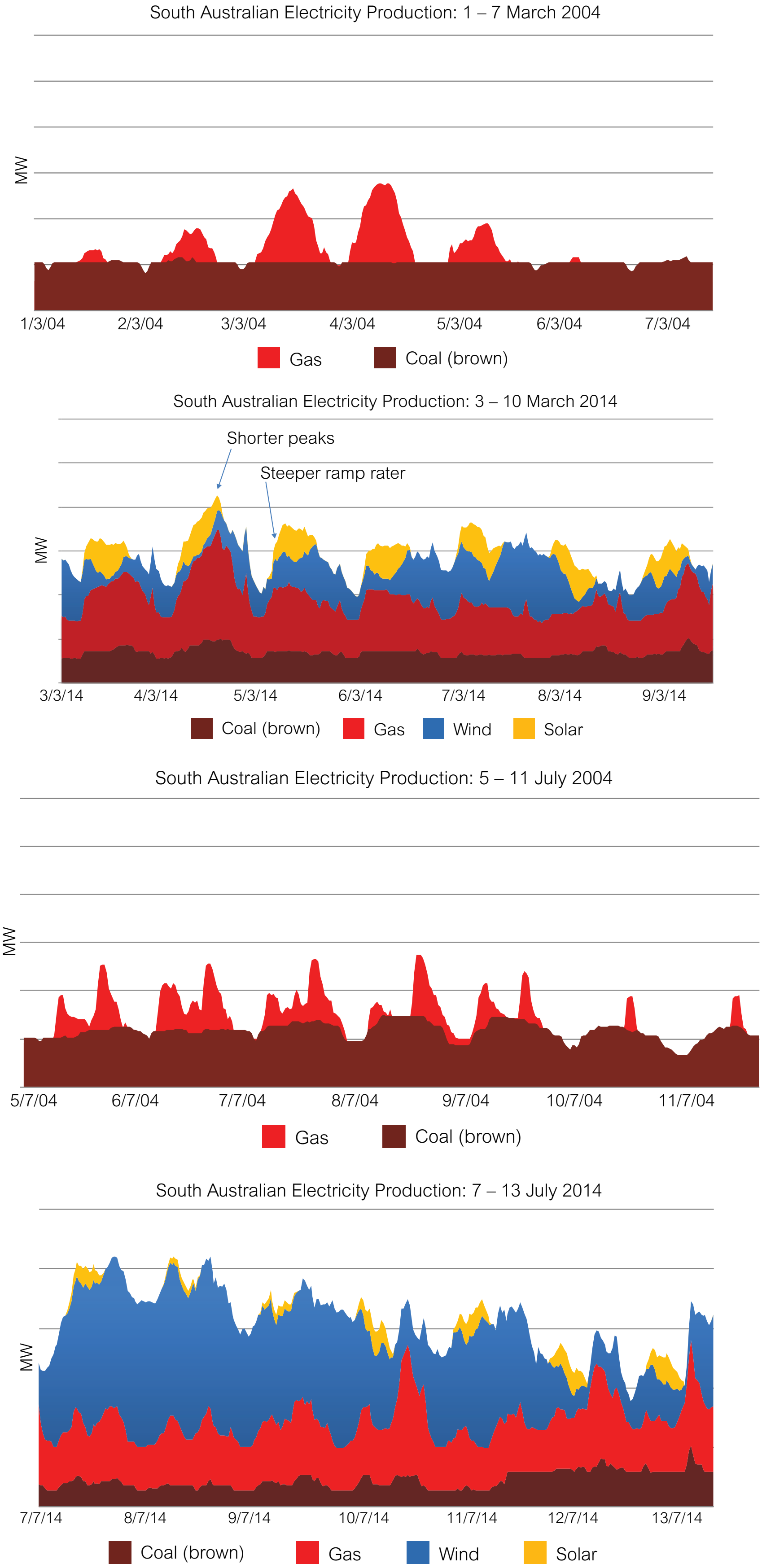
  This enables utilities to control the load of appliances such as air conditioning while minimising the inconvenience to end-users. Indeed, with an air conditioner being limited to 75% of rated power for a short period, a customer is unlikely to even notice.

- development of blockchain, an application of public key cryptography.

  Blockchain allows a ledger of transactions — for example, the amount of energy flowing from one customer location to another over 24 hours — to be maintained by a group of users who do not necessarily trust each other. The users can, however, verify each transaction in the ledger without the possibility of forgery. Blockchain has been promoted as a way for energy users across the grid to trade electricity with each other, allowing users to purchase electricity from the generation sources they choose, say solar power.[34]

34 It should be noted, however, that blockchain is well suited to a sparse network of participants with low levels of trust (for example, two Internet users exchanging digital currency). In many applications proposed for the energy sector (eg peer-to-peer trading in an apartment building), blockchain is probably unnecessary. A bank of utility-grade electricity meters, which cannot be tampered with, could be inspected by any resident at any time. Reconciliation of accounts can occur periodically without blockchain. In many instances, energy system vendors appear to be confusing blockchain with the need for digital signatures or simply metering.

Figure 8: Graphs of South Australian power supply profiles – Summer and Winter 2004 and 2014 showing the dramatic change in supply profiles over a decade.[36]



The future is flexible

Prior to the addition of variable renewable generation to modern power systems, power came from large scale, inflexible fossil or, occasionally, nuclear generation with more flexible fossil generation or large hydro as intermediate and/or peaking generation. Inflexible power generation was seen as reliable. Under this system of delivery, power system operators match supply to variable demand, as well as managing planned or unplanned outages.

As a system incorporates more variable renewable generation, power is delivered from a greater range of technologies with faster rates of change in output in response to the varying fuel sources such as sun and wind. Consequently, the nature of power delivery must evolve. Output and consumption levels of remaining generation and demand must operate at more flexible levels. The system overall must minimise peak demand periods in order to reduce capital investment and price volatility.

Internationally, it has been found that some power systems have more technical potential for higher flexibility than is being used. These systems must be incentivised to deploy it in the most cost-effective way.[35]

The transition in supply profiles is clearly evident in South Australia. Figure 8 shows changes in the instantaneous generation mix from 2004 to 2014 in a low wind/high solar month (March) and a low solar/high wind month (July). In 2004, coal and gas were the predominant fuel sources for electricity generated in the state. By 2014, wind and solar energy has dramatically changed the state's electricity generation by fuel type, and also altered the supply profile. While this analysis is for a single week during a year, it shows that in July 2014, renewable energy contributed to more than 50 per cent of electricity generation in one week.

35 Agora Energiewende, Understanding the Energiewende, 2015.
36 The Government of South Australia, Low Carbon Investment Plan, sourced on 3 October 2017, http://www.renewablessa.sa.gov.au/files/93815-dsd-low-carbon-investment-plan-for-sa-final-web-copy.pdf

Clearly, the whole energy system must move to meet variable demand from a mix of flexible and dispatchable sources – sources able to increase or decrease power levels to complement variable renewable energy sources and load. As variable renewable energy increases, flexibility becomes more important to achieve deep decarbonisation and to utilise renewable generation to its full extent, without curtailing too much energy from these sources.

Figure 9 shows the current situation in South Australia, where wind can take over as 'baseload' power, but is significantly curtailed[37] by the market operator, in order to maintain sufficient gas operating as a reserve.

Changes in output and demand over several days are shown in Figure 9, with the blue line showing price, which is correlated with demand and increases when gas fired generation increases.

The concept of dispatchable capacity is as applicable to both the demand side and the supply side. Electricity demand patterns are also flexible. In fact, they are often the cheapest form of flexibility, as they need little or no investment to activate. New technologies will increasingly enable flexibility on the demand side.[39] The options and their costs are system-specific and will evolve over time, as shown in Figure 10.

In the Australian context, responsive load[41] is an area under active development. It is a concept offering a range of benefits to customers, vertically integrated generator-retailers and network owners. The Australian Energy Market Operator is trialling a range of new 'Demand Response' options over the coming two summers. This is to better gauge the value customers place on provision of this new service, and to test the extent of demand reduction possible from residential, commercial and industrial users during high demand or emergency situations[42].

Some technical solutions to increase power system flexibility are available in the short to medium term. In general, though, the institutional, legislative, and market options to increase and incentivise flexibility will take longer to implement. All approaches are essential to allow power systems to develop and integrate technology advances, new operating procedures, evolved business models, and new market rules.

Figure 9: Wind acting as 'baseload' power in South Australia, operating under current system curtailments dictated by reserve gas availability[38]

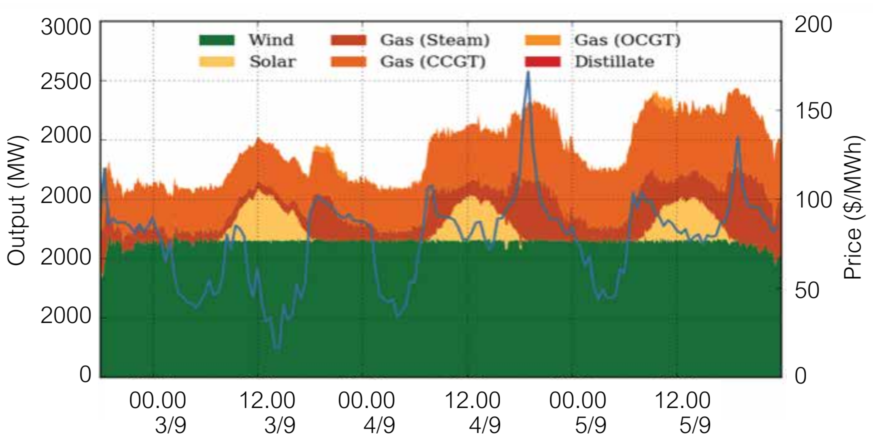
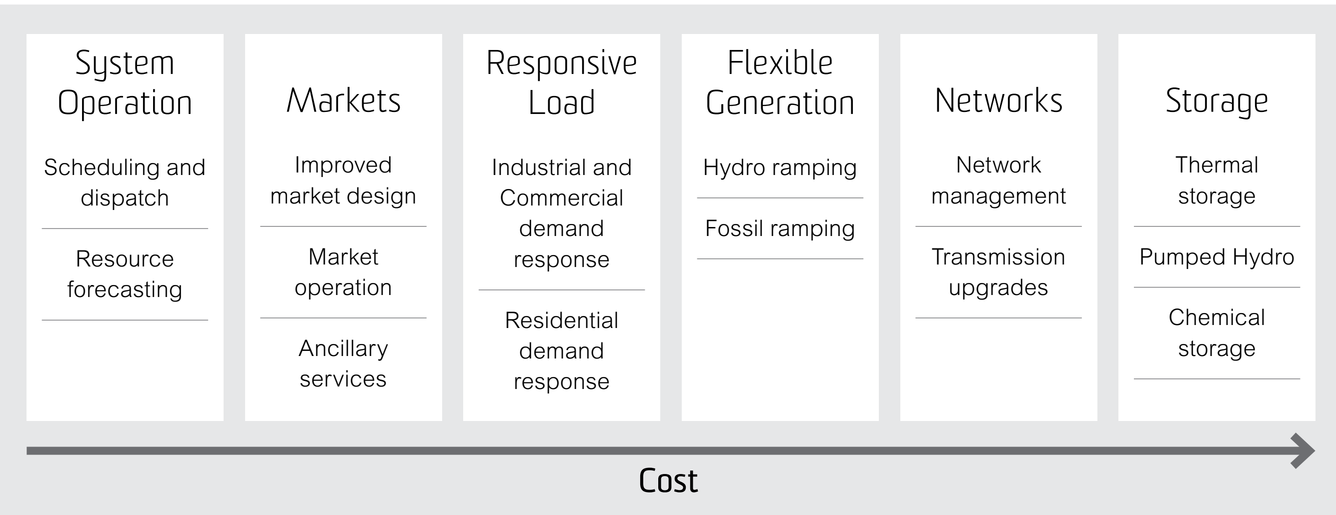


Figure 10: Market flexibility options on the supply and demand side, and their relative economics[40]



37 Curtailment refers to the deliberate restriction in generation output levels.
38 Supplied by Dylan McConnell, 2017, University of Melbourne Climate and Energy College, October 3, 2017
39 Rocky Mountain Institute, The Economics of Demand Flexibility, 2015.
40 Based on NREL, Flexibility in the 21st Century Power Systems, 2014.
41 Demand loads which can respond to tight market supply conditions which correlate with extreme volatile wholesale pricing.
42 https://www.aemo.com.au/Media-Centre/ARENA-and-AEMO-join-forces-to-pilot-demand-response-to-manage-extreme-peaks-this-summer

The future is both more global and local

The rapid rate of solar PV uptake globally shows the extraordinary rate at which technology can be adopted across the world, particularly if it is scalable, adaptable and targeted at consumer markets. A future with high levels of renewable and distributed energy seems likely to replace the role of existing global fossil fuel supply chains, with global technology supply, along with a return to local energy production.

The development of battery storage demonstrates that markets for technology are global, but at the same time their application is being driven by local needs and circumstances. Residential solar PV dominates the amount of total solar PV deployed to date in Australia. This makes it an attractive market for residential energy storage as prices come down and technology options increase for customer demand aggregation and control.

Australia's extensive grid and widely dispersed population may also support the development of storage technologies that are best suited to substation siting for local network constraint management or for peak period energy supply.

Similarly, electric vehicle production is being driven by global demand. Nonetheless, adoption appears likely to be drawn, initially by incentives, to areas where electrification exists, renewable penetration is high and transport fuel is a significant import. Localised travel preferences and distances involved will influence how local implementation occurs.

The emergence of localised technology deployment is also supported by new social models of change. These models reflect a simultaneous awareness of business interests, local societal needs and global challenges to drive social change. Examples in the energy sector include the various models of community owned renewable energy projects[43], as well as disparate groups of business and corporates working together to provide waste streams that can be used in local bioenergy projects.[44] The political power of large consumer groups are also responding to changes in solar feed-in tariffs.[45]

These groups often represent community efforts to transition to sustainable energy systems faster than their governments appear willing to, while also focussing on local jobs, keeping money spent on energy within the local economy and increasing energy security[46]. This social trend extends across both industrialised and developing economies. It is reinforced by the increasing availability of cost effective, modular renewable energy technologies.

Snowtown II Wind Farm, South Australia. Credit: CATCON, Civil & Allied Technical Construction Pty Ltd

43 https://www.greentechmedia.com/research/report/us-community-solar-outlook-2017.
44 For example, bioenergy initiatives in Western Sydney and Cowra.
45 For example, Solar Citizens.
46 For example, Zero Emissions Byron

Energy Sector Transitions

What transitions are needed?

To secure a sustainable energy future, a range of transitions are required. Some are already underway in different parts of the world, and the timing of the transitions will vary depending on local circumstances and policy settings. Some changes span a discrete timeframe, others are ongoing. Where there remains debate about the transition, more research may be required to build understanding and consensus – these transitions may not otherwise be universally embraced over the coming decade.

The transitions can be separated into those related to:

- Fuel change transitions: displacement of fuels
- Technology driven transitions: changes in energy technology, including increased efficiency
- Transitions in market design and institutions: in part to facilitate the other transitions.

There are, of course, overlaps between these transitions. Further, the ease with which they can be accomplished varies by country and region due to existing investments, energy resource bases, socio-economic cross subsidies, political preferences and societal expectations. Hence the transitions need to be well planned.

What can we agree upon?

There is broad based agreement in the energy sector on some of the features of an energy transition to meet the climate challenge. These agreed areas provide a basis for low risk government action and include:

- A carbon price, so that carbon emissions are factored into investment and asset decisions
- A range of clean energy technologies, with renewables playing a key role
- Market mechanisms and technologies to manage the new challenges of high penetration variable renewables
- More engaged and informed energy users
- Integrated planning across energy, water and other services, but also across broader societal objectives of liveable, affordable and healthy living environments, with a key role for government
- A significant role for energy efficiency
- Significantly reduced reliance on coal and oil
- Sustainable urban planning and transport to prevent long-term lock-in to inefficient energy use.

Where there is still some debate

There are several issues where there is still some disagreement and hence where further technology research and policy discussions are needed to clarify costs and benefits. These include:

- The future role for nuclear and carbon capture and storage, which have both struggled to achieve necessary cost reductions or widespread deployment over the past two decades
- The role of gas in the energy transition
- The role of hydrogen as another energy vector
- The extent of the challenges posed by the integration of variable renewables
- The extent to which changes in energy market designs are needed
- The outlook for future cost reductions for different renewable energy technologies.

Implications for Australia

Some of the key changes necessary in Australia under each type of transition are summarised below and illustrated in Figure 11.

Fuel change transitions

A range of fuel transitions is needed in Australia over the next decade to meet the 2-degree temperature increase target agreed in Paris, and, hopefully, increase the chances of limiting temperature increases to 1.5 degrees:

- Replacing high emission fossil fuels with lower emission options
  - Gas displaces coal for electricity
- Replacing fossil fuels
  - Renewables replace fossil fuels for heat and electricity
  - Biofuels, hydrogen and electricity replace fossil fuels in the transport sector and as an industrial gas replacement
  - Synthetic hydrocarbons and electricity replace fossil fuels for transport

Natural gas has been viewed as a transition fuel to facilitate the shift from coal and oil to renewables. However, this anticipated transition has been superseded by the rapid price decreases in renewable energy technologies and may not play as large a role as previously anticipated.

Brown coal has one of the highest emission intensities of all fuels currently used, so its phase out can have large and immediate impacts on greenhouse gas emissions. Over time, black coal and gas will also need to be displaced. Australia has one of the highest levels of electricity emissions intensity in the world, so these transitions will need to be a priority, or serious efforts in carbon capture and storage will be necessary[47].

47 See for instance: https://gogreenr12.org/foreign/victorias-plans-hydrogen-exports-japan-way-making-brown-coal-look-green/

For Australia, the nuclear option is currently not cost effective relative to other low emission solutions. Its potential role in other countries is a function of the availability of local generation options and technological innovation, while broader opportunities for the industry are influenced by the extent to which those countries participate in the nuclear fuel cycle. To gain a social licence to operate in Australia would also require resolution of the safety and security of nuclear fuel cycles and power plants.

Technology driven transitions

A rapidly increasing range of technology options is developing and many are already being deployed in Australia. Uptake will initially be site dependent and some transitions may not eventuate as others take hold. Continuing research and development is needed in almost all areas to assist with technology development and improve the deployment outlook.

- Electrification of the energy sector
  - Electricity replaces hydrocarbons for transport
  - Electricity replaces gas for industrial processes
- Storage
  - Energy storage provides more flexibility in balancing supply and demand
  - Storage can be via thermal, mechanical or electrical[48] means
- Digitisation and connectivity of the energy sector
  - Distributed generation replaces large portions of centralised generation
  - Load management used to balance energy generation and demand
  - Smart cities, buildings, devices, intelligent meters
  - Connectivity of appliances, internet of things
- Efficiency increases to reduce demand and peaks
  - Appliance efficiency increases
  - Building efficiency increases
  - Transport efficiency increases
  - Industrial process efficiency increases.

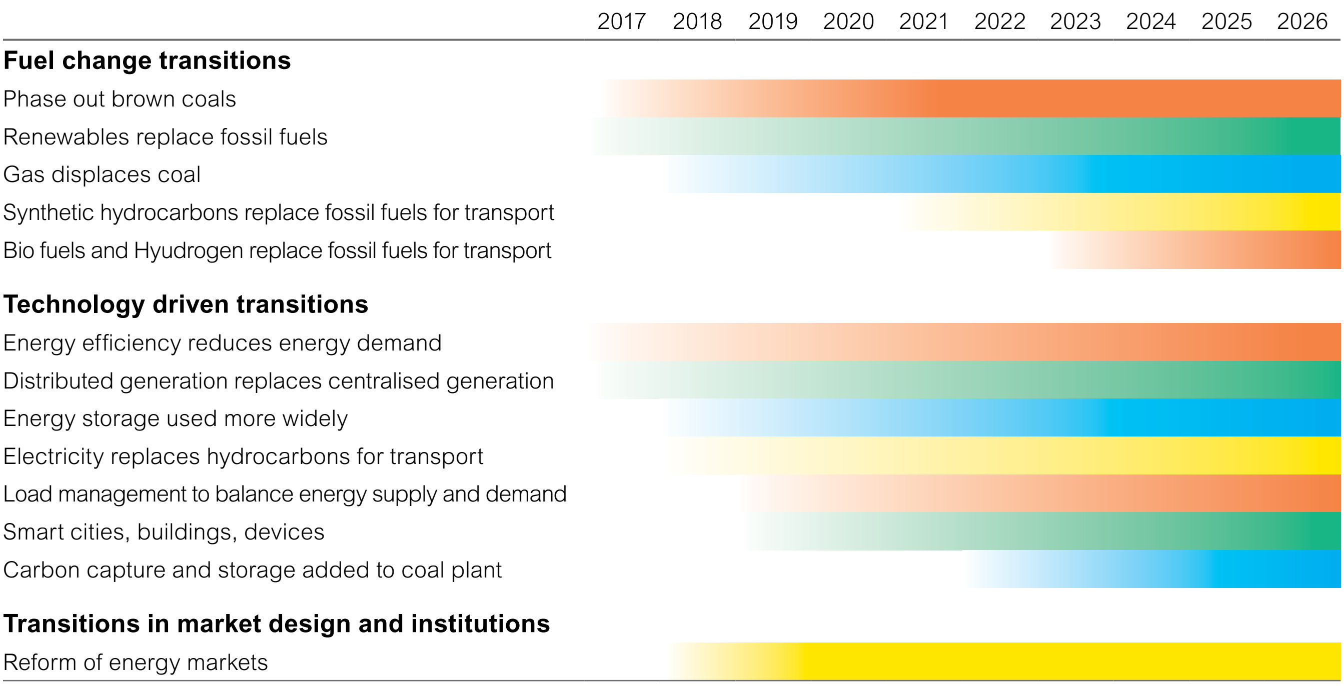
Transitions in market design and institutional structures

The complexity of the energy sector is increasing rapidly. New energy sources, loads and control systems are being added to or replacing the more standardised, centrally managed systems of the past. New sources of supply possess different cost structures to past supply sources. Markets are moving to greater levels of price elasticity.

The shift in ownership of central generators by private companies and governments, to more distributed forms of energy ownership by end consumers, raises a number of issues relating to fundamental energy market design and regulation:

- It puts into question the regulation of parts of the energy supply chain currently defined as "non-contestable", as consumers increasingly compete with energy networks and generation supply. Under this changed setting, revenue and business models for networks in particular need to be adjusted so that new entrants can compete for service delivery and incumbent network utilities can benefit

Figure 11: Possible Australian energy sector transitions over the coming decade



48 Some examples of storage mediums for each of these are thermal - molten salt and chillers, mechanical storage - pumped hydro, compressed air and flywheel, and electrical - batteries

Barcladine solar farm. Credit: CATCON, Civil & Allied Technical Construction Pty Ltd

from distributed energy and be incentivised to support deployment.

- The efficiency and transparency of current energy pricing regimes must be improved to provide incentives for end users to participate in the market.
- Retail electricity markets must be re-designed to accommodate emerging energy service oriented market participants.

Accountability is dispersed across a range of market institutions as well as Local, State and Federal governments. These entities will need to work collaboratively to manage the energy transition and develop new knowledge and internal capabilities. Clear, long-term strategies are needed to provide investment certainty and minimise transition costs. Transparent, open-source energy modelling can assist with internal capability development, as well as to facilitate analysis and discussion of strategies and options amongst a broader base of stakeholders.

Ownership of energy assets could shift from being vested in a few players to a larger number, and these may also be dispersed across diverse sectors. Institutions that regulate for competition will increasingly need to recognise a greater convergence of industries in the energy market space.

If governments reinvest in energy infrastructure, competitive neutrality between private and public-sector energy supply entities, as well as supply choices, will become more prominent issues than they have been. The implementation of appropriate guarantees and regulatory oversight of these new arrangements, such as generation investment in South Australia, will be critical to success.

Global opportunities

Each country starts from an established energy supply system and market. Change involves disruption of extensive supply chains, vested interests and communities. Strong drivers are needed. There are also, however, extensive global opportunities in developing and using the new energy technologies, some of which can be tapped by Australia.

Developing economy transitions

Providing adequate energy services to the developing world is a key aspect of the global energy transition. Achieving this in a way that doesn't exacerbate greenhouse gas emission levels is crucial. Significant opportunities exist for developing countries to leapfrog the fossil fuel era and move directly to the use of renewable energy, distributed energy and efficient, electrified energy appliances and systems. These promise faster energy access, without the local pollution and intrenched international indebtedness associated with fossil fuel based energy systems.

For countries totally reliant on imported fossil fuels – such as the Pacific Islands, and parts of Asia and Africa – increased self-reliance via use of local renewable energy sources can free up money for other uses. With many of these countries reliant on aid budgets, a change in emphasis from paying variable annual fuel bills to stable financing of capital equipment and maintenance could facilitate a transition to increased self-reliance in the long-term.

Another opportunity arises from the scale of new energy technologies and systems. Modular, smaller scale, electronically controlled systems are much easier to deploy for individual users or small communities. This provides the opportunity to supply energy in areas which, until now, had little chance of accessing conventional energy services without significant investment in road, rail or electricity transmission infrastructure.

For countries with manufacturing capacity, large opportunities are being created for the manufacture of new technologies associated with increased electrification, renewable energy and energy storage, along with hardware and software associated with electronic energy management and control systems. South East Asia, India and China, in particular, have seized this opportunity and now lead the world in many aspects of production and deployment.

Geo-political and investment transitions

The transitions described above will dramatically change the global balance of geopolitical power. For the past century, this power has been centred around the Middle Eastern oil suppliers and by those countries, including Australia, with coal and gas resources.

This balance is already shifting to suppliers of new technologies: solar, wind, storage, electronic controllers and now electric vehicles. With deployment and manufacture in volume, there is opportunity for technology cost reduction, as shown in Figure 12. It shows that, at early stages of technology development, costs increase, but after commercialisation costs decrease due to learning and other factors.

Renewable energy technologies are at different points of the curve but a significant number have moved into the deployment phase over the past decade.

While the transition to smaller scale electricity systems has empowered consumers and communities, thus shifting power at a local level, the transition to electric vehicles will have a more dramatic shift at the global level.[50] They are expected to be cheaper to own than internal combustion engine vehicles from 2025 and to account for more than half of new cars sold by 2040.[51]

Modes of ownership will also likely change, with shared vehicles and central charge points proposed. This, in turn, will dramatically reduce the number of vehicles sold each year[52], again with major economic and industrial impacts.

With energy markets dominant in the world economy, energy transitions are already impacting investment decisions and returns. Over the past two years, global investments in renewables have exceeded those in fossil fuels[53] with significant drops in PV and wind costs now driving uptake, even where policy settings are sub-optimal.

In the past, energy planning concerns have centred around the limited supplies of fossil fuels and the price rises likely to result as demand outstripped supply. The current reality is that demand for fossil fuels is likely to drop dramatically over the coming decades. Prices will remain low and investments may well be stranded. For instance, China, which has been the dominant coal market for the past decade, dropped its coal investments by 25% in 2016[54].

As investment focus shifts, market power will move to countries manufacturing and deploying the new energy technologies and their related components. As previously mentioned, China, and more recently India, have focused strongly on supporting new industries supplying renewable energy, storage and control technologies, taking over from the early market leaders Japan, Germany and the US.

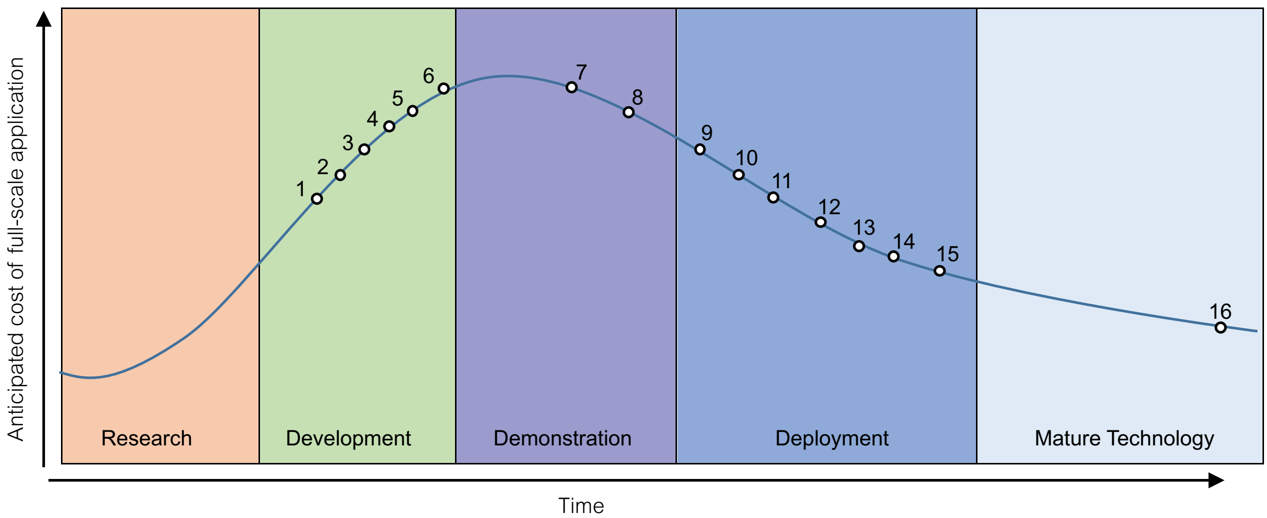
Market power will also rest with countries, including Australia, which have reserves or refining facilities for metals and other components used in the new products. The latter includes copper, lithium, indium, a range of rare earth elements, as well as graphite, silicon and replacements for expensive noble metals such as platinum and silver, currently used in some PV manufacture.

Nevertheless, new energy markets and technologies are only just past the early adopter phase of uptake. There will be significant developments over the coming decades, as well as many new technologies and products.

Since new technologies have long lead times to market diffusion, country level innovation strategies which are sustained and focussed at various points of the technology development curve are important. Australian institutions which fund renewable energy[55], focus on different stages of the innovation chain but work to complement each other's remit.

New economic opportunities exist for dispersed global production and supply chains for a variety of energy and end-use technologies, and many

Figure 12: Capital expenditure learning curve for renewable technologies[49]



1: Tidal and river turbines
2: Solar PV concentrating
3: Wave
4: Solar PV nano-structured
5: Biomass gasification
6: Solar dish-stirling
7: Solar thermal central receiver
8: Geothermal
9: Offshore wind
10: Solar thermal parabolic trough
11: Solar PV thin film
12: Co-fired biomass
13: Solar PV silicon
14: Direct-fired biomass
15: Onshore wind
16: Hydro

49 Based on an earlier version from ABARE and Geoscience Australia, Australian Energy Resource Assessment, Chapter 2 Australia's Energy Resources and Market, March 2010.
50 https://cleantechnica.com/2017/09/17/electric-cars-obvious-not-obvious-impacts/
51 https://www.technologyreview.com/s/608231/by-2040-more-than-half-of-all-new-cars-could-be-electric/
52 http://www.thedrive.com/news/9982/self-driving-evs-will-mean-200-million-fewer-cars-in-u-s-by-2030-study-claims
53 IEA World Energy Outlook 2017
54 Ibid
55 Australian Research Council (early stage research), ARENA (later stage research & development), State based agencies (demonstration) and the CEFC (deployment)

countries are interested. Australia retains a competitive advantage in some aspects of PV development and control systems, capabilities in information and communication technologies. It also has mineral reserves which can service some of the demand for new elements and materials.

Markets for these technologies will likely replace fossil fuel markets over the next two decades. Countries with natural endowment in renewable energy resources such as Australia could also find ways of exporting that advantage if the cost-effective production and transportation of that energy can be realised.

What is needed to ensure a social licence?

Environmental sustainability

With rapid rates of investment needed to support the energy transition, principles of environmental sustainability must be maintained to ensure community support for projects continues. Governments must develop best practice statutory processes for planning and development which balance the need for more investment and legitimise community concerns.

These assessments factor in land use, water use, impacts on heritage, flora and fauna and native title. They also involve consultation with environment protection agencies and other relevant resource protection agencies, landholders and the community in general.

In emerging economies where coal fired investment will still occur, albeit at diminishing rates, the siting of facilities has important local impacts. This is illustrated by mortality and illness rates in local populations near existing coal regions across the world, including in Australia.[56]

Renewable energy technologies must also meet environmental standards and community expectations. For PV, clean manufacturing is essential, while siting, especially for large power plants, must also meet environmental and community standards. Bioenergy options have many environmental challenges centred around land use for food versus fuel, removal of biomass from land, leaving denuded soils and landscapes, biodiversity and other local concerns.

All renewable energy projects must be developed carefully, otherwise the benefits of renewables in the climate change transition will be eroded and the social licence revoked.

Societal acceptance

Recent community action on climate change has been linked to a resurgence of interest in dispersed, locally based energy solutions which maintain money within the local community and generate local benefits whilst also meeting greenhouse gas reduction aims. This is now increasingly affordable and cost-effective as the prices of wind, solar, storage and energy management technologies reduce.

Local industries and jobs

Planning by governments at local and national level for structural changes to industry and employment would assist communities in the energy transition. These measures must address the distributional implications of national energy transitions, especially for low income households and regions economically reliant on fossil fuel industries.

Overall, it is estimated there will be six million additional jobs in the global energy sector by 2050. New jobs in renewables could fully offset job losses in the fossil fuel industry, with more jobs being created by energy efficiency activities.[57] The latter, as well as those associated with distributed energy deployment, have a significant local employment component, even if manufacturing remains global.

Policy support is needed to capture at least some of these jobs in the areas where fossil fuel jobs are displaced. This already happens, to an extent, where old coal mines are closing. Case in point: the Latrobe Valley.[58]

New manufacturing opportunities are also developing to meet the rapidly increasing global supply chains. As noted earlier, these are already changing the geopolitical balances, leaving many countries competing for the new jobs and industries on offer.

Economic growth

Governments can also position economies to grow during the transition. Global GDP is expected to increase by 0.8% above business as usual by 2050 if increased economic growth is driven by the investment stimulus and use of carbon pricing proceeds to lower taxes.[59] However, carbon pricing is still under debate around the world, so that this opportunity is currently limited.

Nevertheless, the new development, industries and employment being created around renewable energy, as well as the increased access to affordable energy which is being extended to previously excluded communities, is providing local economic stimulus and new local enterprises. While many regions of China are benefitting from large PV manufacturing infrastructure, small communities in Afric, Asia and the Pacific are using PV to facilitate mobile telecommunications, internet and banking services previously unavailable.[60]

Corporate attitudes

Actions being taken increasingly by businesses in partnership with cities, local and state governments suggest there is a strong support base for energy transition as an essential structural change with widespread economic and social dimensions. In some cases, the basis for these actions goes beyond financial and reputation benefits of transitioning to zero carbon. Such attitudes and their influence, more broadly, could underpin major reforms and policy actions.

Local self-reliance

Countries and communities purchasing larger proportions of their energy from local sources increases economic opportunities, self-sufficiency and increasingly also energy reliability. Increased reliance on imported energy has left many developing nations vulnerable to international energy and finance market price changes and supply delivery.

56 Doctors for the Environment Australia, Health of residents in Port Augusta, 2012.
57 OECD/IEA and IRENA, Perspectives for the Energy Transition, 2017.
58 http://lva.vic.gov.au/
59 OECD/IEA and IRENA, Perspectives for the Energy Transition, 2017.
60 See for instance: http://www.bbc.com/news/business-30805419

Electric vehicle and residential PV system. Credit: ITP

In countries with central generation facilities, distribution and transmission infrastructure has been vulnerable to severe weather events or system failures. They are now seeking to generate more energy locally. Because of the link between climate change and increased severity of weather events, they are also turning to renewable energy sources.

The city of New York, for instance, is planning local mini-grids.[61] Pacific Islands are replacing diesel generators with wind and solar[62], and regions of Australia are looking to ensure supply in the event of central system failure.[63] As the costs of renewables and distributed energy components continue to fall, this trend is likely to continue, even if central generation and transmission infrastructure is maintained for supply in normal conditions.

Cross sector impacts and risks

Increased knowledge about the ways unmitigated climate change will manifest or impact on other important areas will influence societal acceptance for action.

For human health, the World Health Organisation estimates direct costs from climate change at between US$ 2 to 4 billion per year by 2030, with approximately 250,000 additional deaths per year after 2030.[64] An improved understanding by policy makers and the general community of increased local level health care costs – from impacts of pollution, heat waves, storms, bushfires, river flooding and water-borne infectious disease – could create stronger urgency for policy action.

In the financial sector, there are indications that institutions are increasingly thinking about climate change as a risk to economic resilience and financial stability.[65] The global insurance industry and their regulators are increasingly attempting to quantify climate change risks and to incorporate them into financial models, risk outlooks and investments.[66] To manage quantified, uninsured losses, insurers will need to use investments to fund increased resilience to climate change. Greater policy and public awareness of financial risks could drive urgency for the energy transition.

THE GLOBAL INSURANCE INDUSTRY AND THEIR REGULATORS ARE INCREASINGLY ATTEMPTING TO QUANTIFY CLIMATE CHANGE RISKS AND TO INCORPORATE THEM INTO FINANCIAL MODELS, RISK OUTLOOKS AND INVESTMENTS

61 NY City Mayor's Office of Recovery and Resiliency, 2016, Enhancing Resiliency of New York City's Energy Systems, https://www.iea.org/media/workshops/2016/6thnexusforum/KeWei.pdf.
62 See for instance: IRENA, 2013, Pacific Lighthouses Renewable Energy Roadmapping for Islands, https://www.irena.org/DocumentDownloads/Publications/Pacific-Lighthouse-Roadmapping.pdf.
63 Reneweconomy, 2014, http://reneweconomy.com.au/s-a-network-operator-to-trial-micro-grids-for-regional-towns-65654/
64 World Health Organisation, Fact sheet – Climate change and health, 2017 http://www.who.int/mediacentre/factsheets/fs266/en/ (Date accessed 20 July 2017).
65 See for instance: http://www.mckinsey.com/business-functions/sustainability-and-resource-productivity/our-insights/how-companies-can-adapt-to-climate-change
66 The Insurance Council of Australia has developed its own Climate Change Policy: http://www.insurancecouncil.com.au/issue-submissions/issues/climate-change

Recommended Actions

What do we need to do?

A common thread in the energy sector transitions is the need to reduce the risks of, and address the barriers to the massive mobilisation of new global investment needed for the transition to 2050.

Figure 13 shows that meeting the 2 degree target requires investing an additional US$29 trillion between 2015 and 2050, with the greatest investment needed in energy efficiency and renewables. Total investment cost is minimised by avoided fossil fuel investments in the upstream sector and in fossil fuel and nuclear power generation.

Large-scale clean energy deployment has driven down technology costs rapidly. For instance, solar PV module costs have fallen by about a quarter for each doubling of capacity produced, as shown in Figure 14. It shows historical prices for two common types of PV, crystalline silicon (c-Si) and thin-film amorphous silicon or cadmium telluride (CdTe).

Simultaneously, greater levels of project development experience have improved confidence levels for financing clean energy as an asset class, thus lowering the financing costs.

How does Australia do it?

There are a number of key actions Australia can undertake to meet the climate change challenge. These need a broad cross-section of stakeholders to be engaged, as outlined in Figure 15.

Figure 13: Additional investments needed to meet 2 degree target, 2015-2050 (US dollars)[67]

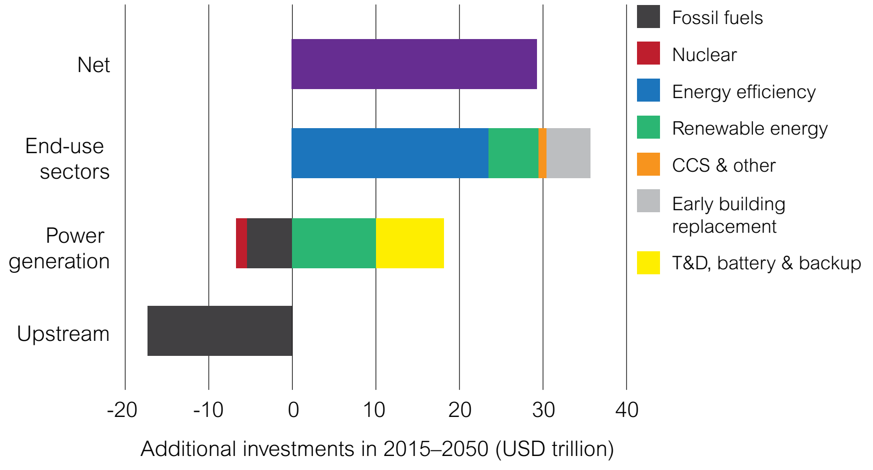
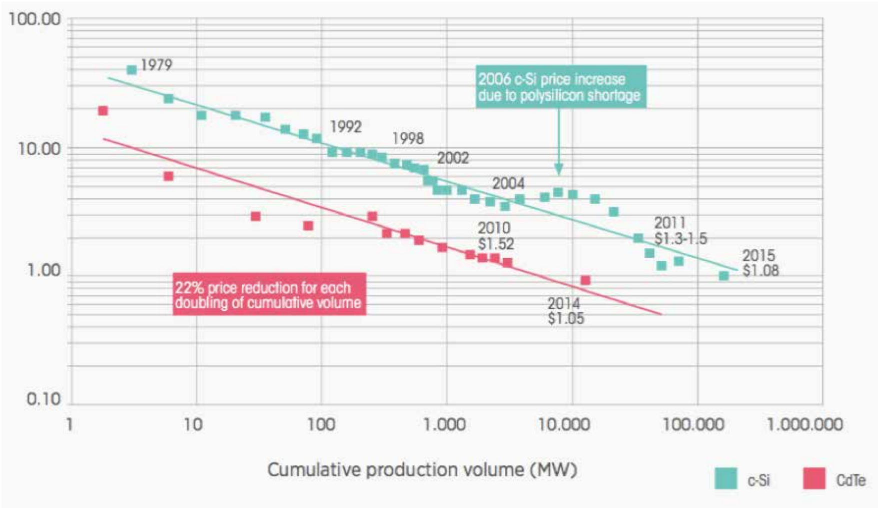


Figure 14: Photovoltaics Learning Curve, showing the decrease in costs as the market has increased over the past 4 decades.[68]



67 From Chapter 3 of Perspectives for the energy transition – investment needs for a low-carbon energy system ©IRENA 2017.
68 EPIA and Photovoltaic Technology Platform, 2010 and Liebreich, 2011 cited in IRENA, 2012, Renewable Energy Technologies: Cost Analysis Series, Volume 1: Power Sector Issue 4/5.

Figure 15: Key Australian climate change priorities, actions and stakeholders

Key priorities and actions	Stakeholders and roles
1. The new energy system must be affordable to all, secure and environmentally sustainable. Australia's market oriented economy provides the basis for domestic approaches that can be least cost. There is opportunity to build on energy reforms to date to transition to a diverse, distributed and flexible energy system. New energy market structures and regulatory approaches must ensure that Australia can continue to gain maximum benefit from current and future technology changes. Institutional structures should be technologically agnostic to provide flexibility in utilising the most appropriate new technologies as they are developed and mature. Otherwise there is risk of perverse outcomes, including investments in networks or generation which will not be required by the time they are commissioned or another cycle of technology lock-in.	Governments, policymakers, market institutions and a broad base of market participants – including consumers and the community – must be engaged in the design and careful implementation of any new energy market structures and regulatory approaches
2. Australia must use its resources and institutional arrangements to reduce its own emissions and to assist others to do the same. There is much scope for two-way transfer of knowledge on energy market design and new technology integration with jurisdictions having similarly liberalised markets, such as the UK and some markets in the US. Many of the lessons learned can be applied across all energy market types.	Governments must fund arrangements to facilitate two-way transfers, and industry and researchers across various countries can undertake knowledge and technology exchanges.
3. Independent and enduring governance arrangements must be in place to ensure the success of the energy transition. Energy policy proposals are complex. These are circumstances where policy makers and institutions are susceptible to policy capture by vested interests, and hence policy decisions which are not in the best interests of the public, the nation or the planet.	Governments must establish independent and enduring governance arrangements that are robust to political pressures.
4. The national electricity market design must change to accommodate distributed and renewable energy technologies and changes in end-use behaviour. The current market, designed in the 1990's, is a casualty of technology and regulatory lock-in. It now constitutes an impediment to innovation and the implementation of new and more appropriate solutions.	A broad base of market participants, including consumers and the community must inform industry and regulators of distributed energy and end-use changes. They must also be engaged by governments, policymakers and market institutions on market design.
5. To address uncertainty regarding the impacts of climate change, there must be disciplined analysis and no-regrets action, not delay. Under uncertainty, knowledge has high value. This supports the need for greater investment in applied climate science.	Governments must support action on climate change generally, and specifically support investment in climate science research. Researchers must undertake new research in climate science and engage with policy makers on the findings.
6. There must be coherence between domestic policy and global agreements. National targets that are inconsistent with global commitments, or commitments to targets in the absence of substantive actions, damage long-term integrity of local economies. Domestic policy must guide targets and trajectories and increased R&D and innovation.	Governments must ensure coherence between domestic policy and global commitments.
7. To be sustained, the global transition must be consistent with prosperity and equity. The solution requires participation of developing countries from an early stage, but equity requires developed countries to play a major part as well.	Governments and policy makers must guide country-level initiatives and interact with other nations on prosperity and equity outcomes.

Credit: iStockphoto

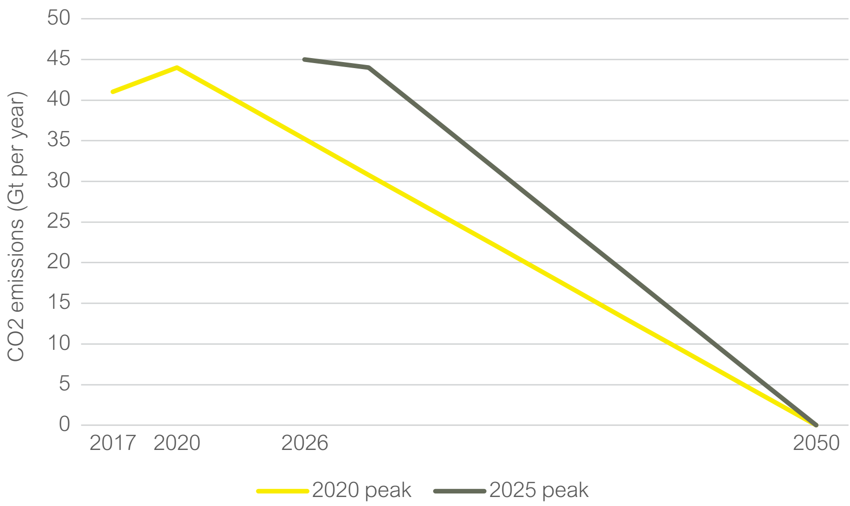
When do we need to do it?

The longer Australia delays taking serious action, the harder and costlier the transition will be. This was well enunciated a decade ago by the Stern report[69]. Still, it has not yet been taken on board by many decision makers.

World emissions have stabilised over the past two years but must begin falling as soon as possible. The steepness of the required fall with each year of delay is clearly illustrated in Figure 16.

Peaking annual CO_2 emissions in three years and the possible trajectory to reach net zero emissions is shown by the yellow line. If the peak is delayed, say for around another 10 years, as shown by the grey line, the trajectory for the economy to adapt to net zero emissions must be much more rapid.

Figure 16: The transition to a low carbon economy will need to be much faster if action on greenhouse gas reduction is delayed[70]



69 Stern, N, 2006, The Economics of Climate Change, Government of the UK.
70 Based on figure published in Figueres, C., Schellnhuber, H.J., Whiteman, G., Rockström, J., Hobley, A., & Rahmstorf, S., Three Years to Safeguard our Climate, Nature – comment, Vol.546, pp593-595, 29 June 2017.

Notes

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