AUSTRALIA AS AN ENERGY SUPERPOWER IN A LOW-CARBON WORLD

Ross Garnaut

Professorial Research Fellow in Economics,
The University of Melbourne
President of SIMEC ZEN Energy
Chairman of the Energy Transition Hub
Australian-German Climate and Energy College

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1. The Great Energy Transformation

Modern economic development over the past quarter of a millennium has transformed for the better the lives of most people. It has lifted about a third of humanity to standards of comfort, knowledge, health and longevity unknown to the elites of earlier times. It has placed another half of the people on earth on paths towards enjoying the living standards of the developed countries comfortably within this century, so long as development is not blocked by a breakdown in political or ecological order. The remaining sixth of humanity aspires to be on one of those paths and there will be no stable resting place for global society until they have achieved that goal.

Modern economic development was built on intensive use of fossil fuels. Solar energy had been converted by photosynthesis and natural storage processes into coal, oil and gas amongst other carbon compounds over hundreds of millions of years. It was then drawn down at a rate many tens of thousands of times faster than it was ever deposited, to drive the machines of the newly industrial world and meet the expanding demands of the households enriched by economic growth. Coal dominated the mix of fossil fuels at first, and was joined by oil early and natural gas late in the twentieth century. The availability of this concentrated energy was important to the burst of incomes growth that revealed the tendency for human fertility to fall when living standards became higher and more secure. The decline in fertility, in turn, allowed us to climb out of the Malthusian trap that had blocked large and sustained increases in standards of living for ordinary people from the beginnings of human civilisation.

So take a bow coal, oil and gas, and all of the people who worked in producing and distributing them from the beginnings of the industrial age until the recent past. Humanity's ascent from poverty and ignorance would not have happened without your work.

Economists and other social scientists of the early industrial economy worried that the finite nature of fossil energy reserves would eventually bring modern economic development to an end. One of the founders of neo-classical economics, sometime Australian William Stanley Jevons, wrote about Britain's choice, between a glorious several decades of high prosperity and power while coal reserves were depleted without restraint, and a longer period of modest prosperity (Jevons, 1865). Weber's brilliant exposition of the social and ideological origins of capitalism saw the efforts of the people driving modern economic development continuing until "the last ton of fossilised coal is burnt". (Weber, 1905).

The Australian economist Colin Clark—global pioneer of national income accounting and development economics—had his initial training in chemistry and considerable knowledge of biological systems. This gave him confidence that humanity would find a successor to fossil fuels in meeting the needs of economic development on a sustainable basis. Three quarters of a century ago he noted that we can calculate the likely amount of undiscovered fossil fuel from the carbon that was once in the atmosphere. "However", he said, "we must not set out to burn them up too fast, even if we do find them, at any rate not faster than the carbon dioxide can be converted by photosynthesis..."

Clark assures us that keeping the use of fossil fuels within the limits of what can be absorbed by photosynthesis need not be the end of economic growth. He tells us that there is an abundance of solar energy falling on the earth, if we know how to tap it. The best method at present, he said, is the proven process of photosynthesis in plants. He commented that the eucalypt is the most productive known agent for conversion of solar into sustainably useable energy. Algae had the potential to do better. “The silicon battery and other recent discoveries”, he said, “may do better still one day”. (Clark, 1940, pp488-9).

Transition to other forms of energy was always going to be necessary at some time. Without concern for climate change, or other external environmental costs of fossil energy combustion, there would have been an extended period of rising fossil fuel prices, leading to investments in alternative technologies and a gradual phasing out of coal, oil and gas.

Over the last several decades, educated opinion has learned that maintaining modern economic development while avoiding catastrophically disruptive climate change requires fundamental adjustment in the way we produce and use energy. We must bring forward in time what was always an inevitable transition from fossil fuels to other forms of energy. The scientific arithmetic tells us that to avoid severe disruption, the world must move to zero net emissions of carbon dioxide and other greenhouse gases in the second half of this century. Doing this at minimum cost for the world as a whole requires the developed countries to achieve zero net emissions in electricity generation by mid-century. That means no combustion of coal or oil or gas for electricity in the absence of full and permanent sequestration of emissions. Just as the

stone age did not end because we ran out of stones, or the bronze age because we ran out of copper and tin, the fossil energy age will not end because we run out of coal.

This is a hard message, especially for the owners and employees of the most fossil energy-dependent companies in the most fossil energy-dependent economies. These are companies accustomed to exerting immense influence over policy. It is no surprise that establishing policy frameworks to support the transition has met great resistance from vested interests, with heavy investment in misinformation and attempts to distort the political process in open democracies.

The energy transition has been most strongly contested politically in the United States and Australia, with our distinctive political and media cultures.

Despite the rancour, it is much clearer today than it was when I concluded my official advisory work seven years ago that the direction of change towards a low carbon world energy economy is well established (Garnaut, 2008; 2011). It is not yet clear that the transition will occur at a pace that avoids seriously disruptive climate change.

My objective today is to illuminate some of the implications for Australia of the inexorable if dangerously slow global transition from coal, oil and gas to forms of energy with low carbon dioxide emissions.

When all of the Governments of Australia—Commonwealth, State and Territory--gave me the advisory task 11 years ago, I described climate change policy as a diabolical policy problem with a saving grace.

Four characteristics of the problem make it diabolical. The central policy problem and solution is familiar, but politically difficult to apply rigorously in practice: for the operation of markets to generate good outcomes for society, external costs that some people's decisions impose on others must be compensated by a tax equal to those external costs, or regulation blocking the activities that impose costs on others. The most committed supporters of free market exchange from John Stuart Mill and Pigou to Hayek and Friedman recognised the necessity of such interventions to secure the public interest when there are environmental externalities.

Not to tax an activity that imposes costs on others is to subsidise the harmful activity. That is why the International Monetary Fund refers to the absence of taxes or other restrictions on carbon emissions as a subsidy to the fossil fuel industries. A carbon tax at an appropriate level does not subsidise low carbon activities; the absence of carbon restrictions subsidises the use of fossil fuels.

The three other characteristics of the policy problem that make it diabolical are uncertainty about the magnitude and timing of the effects of greenhouse gases on climate; the need for effective action by all substantial countries; and the fact that the costs of dealing with the problem are incurred early, and the benefits of effective action received late. But for all the difficulty, the international community and its major national components have groped their ways towards understanding the implications of uncertainty in the climate

change context; adopted a workable approach to international cooperation that I call "concerted unilateral mitigation”; begun to think analytically about how to value benefits in the long term future against current costs; and are increasingly aware of the challenge to the public interest posed by the influence of private interests.

The saving grace to which I referred in 2008 is that there is more community interest in this issue, in Australia and many other countries, than in any other economic policy issue of modern times. If governments seek to avoid dealing with climate change because it is too hard, or to placate vested interests, they are dragged back to the issue by many concerned members of the community. The world’s religious leaders and Professors of Ethics have helped us feel or think our way through the issues (Francis, 2015; Broome, 2010).

At the conference of the United Nations Framework Convention on Climate Change in Paris in 2015, nearly all of the countries of the world committed themselves to contributing to a global effort to limit human-induced warming to less than 2 degrees, and as close as possible to 1.5 degrees. Two countries were not signatories at the beginning. The Nicaraguan government thought the action proposed too weak. It signed up later, in October 2017. Syria had other things on its mind in December 2015, but signed the agreement in November last year.

The Paris agreement embodies a process of unilateral commitments by all countries, accompanied by periodic joint review of progress against announced goals. The first round of commitments fell well short of what would be required to hold temperature increases to less than 2 degrees, let alone 1.5

degrees. The reviews, commencing in 2018, are intended to support successive tightening of commitments, to bring global emissions reduction in line with mitigation goals.

The Paris Agreement was challenged when the Trump administration in the United States announced in June 2017 that it would withdraw from the UNFCCC and therefore from the Paris Agreement. Reversal of recent progress on decarbonising the US economy would be a major blow to the global mitigation effort—directly, and potentially through effects on the behaviour of others. There are questions about the significance and permanence of the Trump announcement. Withdrawal requires a process of considerable length, and there are signs within the Administration of ambivalent commitment to following through. There is considerable momentum in emissions reductions within United States business, driven by technological change and cost reduction and innovation in new forms of energy, relating both to gas (replacing coal) and renewable energy. A number of US states and cities have strengthened measures to reduce emissions since the election of President Trump; and the courts so far have blocked the most important of the Trump Administration's steps to wind back Obama era regulation of emissions. Total US emissions in 2017 fell to the lowest in 25 years.

The reality of climate change and the global interest in mitigation are placing pressure on the new US policy. Storms and wildfires in the US attributed to some extent to human-induced climate change, are reported to have imposed costs of $306 billion in 2017 (Acosta, 2017) The cost of withdrawal from the global mitigation effort to US global leadership more generally is becoming part of the US foreign policy discussion.

Climate change figured prominently in candidate Trump's statements during the election campaign, and in early statements by President Trump, so that the absence of any reference to it in the State of the Union address in January 2018 is a dog that did not bark. Is withdrawal from the Paris Agreement still a major objective of the Trump Presidency?

Time will tell whether the conditions that created the Trump Presidency will sustain governments with similar objectives through future Congressional and Presidential elections.

Since Paris, there has been considerable strength in the global energy transition beyond the US. China is the biggest story, since it accounted for the majority of the increase in global emissions through the first twelve years of this century. At the end of this period, China contributed around half of global coal combustion, and was by far the world's largest emitter of greenhouse gases. As I noted in my 2008 Report (Garnaut, 2008), continuation of early twenty first century trajectories for Chinese coal use and carbon emissions would have put a 2 degrees objective beyond reach, whatever happened in the rest of the world. China's new model of economic growth, articulated with increasing clarity and emphasis in official statements since 2012, places great emphasis on reducing China's output of greenhouse gases. China committed to absolute limits on greenhouse gas emissions in the context of the Paris Agreement for the first time: its emissions would reach a peak no later than 2030, and if possible earlier. It now seems that Chinese coal combustion and even total greenhouse gas emissions may already have passed their all-time

peaks—a decade and a half in advance of the Paris commitments (Garnaut, Johnston and Song 2017).

2. Australia in the Fossil Fuel Economy: the Injured Energy Superpower

Australia has been a significant force in global energy supply since rapid economic growth in Japan in the 1960s and elsewhere in east Asia in the following decades moved the centre of gravity of global industry closer to this region. Australia is the world's largest exporter of coal and uranium and probably soon and for a while the largest exporter of liquefied natural gas. Energy exports contributed significantly to Australia's standard of living, rising strongly in the decade of the China resources boom 2003-11.

Australia was for a while the largest and is still a major exporter of aluminium—the most electricity-intensive manufactured product that is important in international trade. Australia's metallic mineral and fossil energy resources gave it comparative advantage in much metals production through the twentieth into the early twenty first century. Exceptionally low natural gas prices in eastern Australia after the development of the Bass Strait field in the late 1960s supported highly competitive manufacturing industry based on low-cost natural gas.

The coal, oil and gas industries will remain large and important in Australia for several decades, but since the peak of the China resources boom in 2012 detract from Australian incomes growth.

We have lost the advantage in energy-intensive industry we once drew from our rich natural endowment of fossil energy. That followed the internationalisation of domestic coal and gas markets and the associated lift in domestic wholesale electricity prices; inevitable economic consequences of as well as policy errors in the macro-economy through the resources boom, resulting in huge appreciation of the real exchange rate; mistakes in regulation of a complex industry; errors of historic dimension in private investment decisions; large reductions in the costs of renewable relative to fossil energy; and discord and policy instability over the transition to a low carbon economy.

The good news is that with sound policy and an innovative private business sector, Australia can recover its advantages, based this time on exceptional natural endowments of renewable energy. Unlike the old advantages in the fossil energy economy, the recovered strengths will be sustainable.

In the sporting city of Adelaide, here alongside the Adelaide Oval, think of a young champion, whose stellar early career has been broken by injury. A West Australian thinks of Dennis Lillee pushed out of the game with an injured back after only eleven Tests. Then applying the best technology and extraordinary self-discipline to make the most of prodigious natural talent. Returning to contribute brilliantly to five times as many Test victories after the apparently career-ending injury.

External pressures and our own mistakes have temporarily crippled Australian energy. Make the right choices now, and the future will be better than the past.

Let's look more closely at how we lost our advantage. We will then turn to how we can restore, extend and sustain comparative advantage in energy-intensive industry, through utilisation of Australia's exceptional renewable energy natural resources.

Energy costs everywhere have internationally tradeable and non-tradeable components. Both the tradeable and the non-tradeable components of Australian energy costs have increased exceptionally both absolutely and relative to the rest of the world through the twenty first century so far.

Energy raw materials are the most important tradeable component of energy costs. The cost advantage that abundant domestic energy resources give to users in their host country is greater in forms of energy with high international transport costs. Prices in the energy-rich country are lower still if exports are restrained.

Queensland and New South Wales in earlier times reserved high quality coal resources for the use of the state electricity commissions. Victorian lignite was by its nature not exportable. Western Australia reserved part of gas production for domestic use, and there was no gas export capacity or opportunity in eastern Australia. Coal and gas were available domestically in four mainland states at extremely low prices by international standards.

South Australia lacked the fossil energy wealth of the other mainland states, but had access to low gas prices through interstate pipelines. The absence of high quality coal resources meant that South Australia always faced higher wholesale electricity prices than other states.

The internationalisation of eastern Australian domestic coal and gas prices over the past two decades removed most of the Australian cost advantage from rich coal and gas resources. Coal prices for electricity in Queensland and NSW rose towards international levels with the corporatisation and privatisation of generation in the late 1990s and 2000s. Eastern Australian gas became tradeable as the export facilities in Gladstone were commissioned from 2016. Gas has moved from being readily available in eastern Australia at extremely low prices by international standards, to temporarily having prices above export parity because of overinvestment of historic dimension in gas export capacity.

Within the domestic wholesale electricity market, prices are set in each trading period by the source of power that has highest marginal cost. Gas generation sets the price of power whenever gas is needed to meet demand. The three hundred percent and larger increases in eastern Australian gas prices since exports from Gladstone commenced have therefore had immense leverage over wholesale electricity prices.

The leverage of gas over electricity prices has been greater because of the closure of a number of coal-based generators over recent years. This has been caused by the rising costs of ageing generators and the increased penetration of renewable generation bidding into the market at prices that reflect negligible marginal costs of generation.

For Australia, renewables are currently non-tradeable. If superior natural resources make it much cheaper to produce wind or solar power in Australia

than in Germany or Korea, the full difference can be experienced as lower domestic wholesale prices. There has been recent discussion of a high voltage transmission line from the rich solar resources in northwest Australia to Java. This may be part of the future; but if it is, the costs of submarine international transport of electricity will be high. The cost of solar energy to Australian users will remain well below those to Indonesians.

Australia has richer renewable energy resources per person than any other developed country. Some developing countries in Latin America, Africa and West Asia have comparable renewable energy resource endowments to Australia. The costs of renewable energy generation and storage are overwhelmingly capital costs. This gives developed countries, with lower supply prices of investment, advantages over developing countries. These considerations together create an opportunity for renewable energy to be produced more cheaply in Australia than in other countries.

It follows from the economics of international transport that Australia's advantages in low domestic power prices from abundant energy resources are greater in a world in which renewable energy plays a major role, than in a world in which freely tradeable coal and gas play a dominant role in energy supply.

There are several non-tradeable components of electricity costs. One is the domestic component of the cost of turning energy natural resources into electricity—the labour and other domestic inputs in construction of generators. Another is the cost of transmitting and distributing electricity from generators to users. A third is the retail business component of selling power

to final users. All of the non-tradeable costs have risen much more than in Australia than in other developed countries so far through the twenty first century.

Non-tradeable costs vary with the real exchange rate (the general cost level in Australia compared with other countries when both are expressed in the same currency), the relative technical efficiency of Australian production in the energy sector (which is affected by the quality of the regulatory environment), and the extent of competition in provision of services to energy users. The transmission and distribution networks are natural monopolies, so costs to users depend on the quality of regulation rather than the extent of competition.

The appreciation of the real exchange rate during the resources boom was excessive, with the fiscal and monetary authority allowing most of the temporary increase in incomes from high terms of trade and investment to feed directly into expenditure (Garnaut, 2013). The appreciation was partially reversed with the nominal depreciation of the Australian dollar from 2013, but much of the general increase in Australian relative to international costs remains.

Micro-economic sources of the extraordinary inflation of Australian energy costs have been the subject of recent inquiries by the Productivity Commission, the Australian Consumer and Competition Commission, a special review of electricity prices commissioned by the Victorian Government, and a series of reviews initiated by the Council of Australian Governments and the regulatory agencies reporting to the Council (see Garnaut, 2017a, 2017b for a

summary). The reviews have drawn attention to a number of sources of increases in the non-tradeable energy costs. Flaws in regulation of the electricity and gas network monopolies have led to wasteful overinvestment, passed through with high guaranteed rates of return to electricity and gas users. The overinvestment has been large enough to show up in massive declines in total factor productivity in the utilities sector. There are problems of oligopoly in parts of the retail and wholesale markets for both electricity and gas.

Uncertainty about climate change policies has raised the supply price of investment to all non-tradeable components of costs in the energy sector.

What can be done to remove or reduce the increase in tradeable and non-tradeable components of Australian domestic energy costs?

First, let us look at the tradeable component of costs. Recent legislative change gives the Commonwealth Government the regulatory power to restrict exports of gas. This provides a mechanism for reducing domestic prices to export parity or lower. Statements of policy make it clear that export parity is the goal for the time being. This would reduce Australian relative costs, but leave them well above the relativities that preceded Gladstone LNG exports.

Sooner with more active use of new Commonwealth export powers, or later, gas prices will fall to near export parity—moderately lower than in the Asian countries to which we export. This will reduce wholesale electricity prices.

The second opportunity to reduce wholesale power prices is to expand domestic generation of power that is bid into the market with low marginal costs. Renewable energy has negligibly low marginal cost of generation. Renewable generation has expanded rapidly with the Renewable Energy Target transferring revenue from intra-marginal thermal power generators to producers of renewable electricity. The Clean Energy Target recommended by the Finkel Review, and the Emissions Intensity Scheme recommended by the ESB in its advice to the Commonwealth Minister, would have similar effects.

Retaining more relatively low-cost coal generation capacity for longer would also assist in holding down wholesale prices, since coal sets the price whenever there is insufficient renewable energy to clear the market, and no need for gas generation. This is easier said than done with the high maintenance costs of ageing plants, and expectations of falling costs of and the possibility of future rising policy preference for renewables discouraging investment.

Second, how can we reduce the non-tradeable component of Australian relative to international costs?

There has been a substantial but partial correction of the real exchange rate since early 2013. Excessive real appreciation has been partially reversed through nominal exchange rate depreciation and attrition of relative living standards (Garnaut, 2013). The necessary correction in relative costs is happening, but with bumps along the way, and slowly.

Much of the increase in non-tradeable costs has followed mistakes in regulation which have encouraged and allowed wasteful overinvestment in the

poles and wires that connect generation to power users. High rates of return on what have been perceived as low risk investments have compounded the costs to users. The ACCC has noted that the correction of the network cost problem may require the writing down of unnecessary components of the Regulated Asset Base. This will be contentious, as Governments, consumers and owners of network assets contest the allocation of losses from the write-downs. To be permanently effective in reducing costs to Australian power users, the write-downs in asset values would need to be accompanied by rigorous restriction of future investment to the minimum levels consistent with providing appropriate services. The rigour would need to extend to re-investment of depreciation allowances.

Recent official reviews and reports have also drawn attention to the blow-out in retail margins since current regulatory arrangements were established in their current forms around 2006. Oligopoly in the retail market has been associated with margins that are extraordinarily high by Australian historical as well as international standards. The cost implications of oligopoly is the subject of a current ACCC review. Remedies will need to include the avoidance of regulatory innovation that restricts competition, systematic removal of barriers to entry by new retailers and promotion of the expansion of smaller market participants.

3. Linking Emissions Reductions and Security and Reliability at Reasonable Prices: the National Energy Guarantee (NEG)

The series of electricity supply problems in late 2016 and early 2017 in SA, Victoria and NSW led to high political focus on energy security and reliability. The Council of Australian Government Energy Ministers established the Finkel Review to make policy recommendations on these issues (Garnaut 2017c).

The Finkel Review discussed requirements for Security (avoidance of systemic failure) and Reliability (matching supply and demand period by period). Finkel recommended the establishment of an Energy Security Board (ESB), to coordinate the main rule-making, regulatory and market operation agencies. In the first days after its establishment, the ESB advised the Commonwealth Government to establish a National Energy Guarantee (NEG), which would place on retailers and large users of power the obligation to achieve an average level of emissions intensity of energy supply that was consistent with Australia's commitments on climate change to the international community, and also to obtain power from sources that together guaranteed Security and Reliability. The advice was incomplete in many ways, and has triggered a wide-ranging discussion of instruments for securing emissions reduction, Security and Reliability at reasonable cost.

Here I suggest some design characteristics that would be important to ensuring that any NEG that were adopted would contribute positively to reducing emissions to an appropriate level, enhancing Security and Reliability and minimising costs of power to users within these constraints.

The current electricity wholesale market, with a transparent and continuous spot price in each region of the National Energy Market (NEM), and with forward contracts settled by reference to that spot price, is centrally important

to the current electricity supply system. The wholesale electricity market is one part of the system that is generally working well, and care should be taken not to damage it in the process of repairing other weaknesses.

I comment separately on the Emissions Reduction and Security and Reliability components of the NEG proposal.

EMISSIONS REDUCTION

The foundational documents from the ESB describing the NEG (ESB2017a, ESB2017b) suggest that the obligation to achieve specified average levels of emissions intensity would be placed on the retailer or user of power. This follows the current Renewable Energy Target. I see no problem with this in principle, so long as the relationship between retailers and suppliers is an open, transparent and competitive one, so as to avoid strengthening the current oligopolistic position of three large retailers.

Should the emissions reduction standards apply uniformly across the Commonwealth or separately region by region? The wholesale market is regionally based, with regions corresponding geographically to States. A uniform standard would place an onerous burden on a retailer or large user operating mainly in a State which currently has high emissions intensity, unless there were an open, transparent and competitive market for emissions intensity variations from the standard across State borders. Since most States and Territories have their own emissions targets, the setting of targets could be left to each State or Territory.

If the setting of targets were left to the individual States, the Commonwealth would need to intervene only if the sum of the States' targets led to average emissions intensity that exceeded the emissions intensity commitment—in which case the Commonwealth could require an across the board downward adjustment in emissions intensity targets.

The ESB's original description of the NEG (ESB, 2017a) proposed regulatory surveillance of contracts rather than of purchase of tradeable certifications of emissions intensity to determine compliance with a standard for emissions intensity. There is a practical difficulty in this proposal, and a possible contradiction of the requirements for efficient operation of the wholesale market. Not all power supply is contracted forward. There is an active spot market, which is used by generators, retailers and users to balance loads—and by some users to meet their total requirements. This spot market sets the prices for settlement of contracts, and so is an integral part of the contract system.

The ESB advice to COAG (ESB 2017b) suggested that the proportion of a retailer's or a user's load that was not contracted to a specified generator with defined emissions intensity would be judged to have the average emissions intensity of the uncontracted pool. It would not be a simple matter to calculate the emissions intensity of the uncontracted pool—and to judge in advance how it was changing over time, as a retailer or user would be required to do. But there is a more basic and severe question to be answered. Placing an emissions intensity obligation on top of the energy trade as it operates at present would encourage the withdrawal from the spot market of supplies with below average emissions intensity. This would raise the emissions intensity of the remaining pool. In turn, a new set of generators, now newly

with lower emissions intensity than the average of the pool, would have an incentive to contract outside the pool. The end point of this dynamic process would be to leave in the pool only supplies from the most emissions-intensive generator—with total volumes too small to support the efficient operation of the wholesale market.

SECURITY AND RELIABILITY

The challenge is to meet all of several Energy Security and Energy Reliability requirements at all times at the lowest possible cost.

Energy Security requires some specified minimum of synchronous generation, to maintain frequency at levels consistent with continuous operation of the grid. The power engineering modelling by the Melbourne Energy Institute, upon which the Finkel Review relied, noted that challenges to Security arose when the proportion of synchronous power fell below some calculable proportion. There would be no problem until the proportion of synchronous generation fell somewhere below one quarter of generation in a particular region. The proportion of intermittent solar and wind generation could rise to three quarters without challenging Security.

It follows that provision of synchronous generation at present is sometimes an issue in South Australia, but not yet in other States. In South Australia, the combination of substantial gas generation capacity, new batteries and the reserve diesel generation (later gas) installed by the State amply covers the requirement, so long as there are incentives to bring the private generators into use when required.

The Melbourne Energy Institute report for the Finkel Review noted that the proportion of synchronous power generation required for Security would fall over time with technological change, which allows larger roles for introduction or removal of power into an AC system from DC transmission, batteries and various sources of what has been called digital inertia.

The other requirements for Security include Frequency Control Ancillary Services (FCAS) of many durations—the full range of current services purchased by the Australian Energy Market operator (AEMO), plus faster response systems necessary to avoid systemic insecurity in contemporary circumstances. The markets established by AEMO for purchase of FCAS are appropriate, so far as they go. The requirement that the causers of instability should pay for the services is appropriate and should be continued and if possible extended to the costs of other grid stability services. It is important quickly to fill the gaps in the markets for faster response FCAS markets.

We do not have an effective market for black start services for rapid recovery after systemic failure. Established arrangements have failed in recent episodes of system stress.

Energy Reliability has become more challenging with changes on both the supply and demand side of the electricity market. Demand has become much more variable and peaks more extreme, as households have come to represent higher and heavy industry lower proportions of loads. The peaks have been accentuated by the increased frequency and intensity of hot days that has been a feature of the early stages of human-induced climate change, and the

increased use of air conditioning. Supply has become much more variable with the increase in intermittent wind and solar energy output.

At the time of my initial Climate Change Review (Garnaut, 2008), it had been anticipated that gas generation would play a larger role in balancing highly variable supply and demand. The increase in domestic gas prices has challenged that expectation.

Reliability requires the market operator to have access to means of reducing demand or increasing supply of power quickly in response to unexpected variation in generation (the failure of a thermal generator in hot conditions, cloud going over a solar generator, the wind suddenly changing speed) or demand (unexpected heat leading to a surge in demand for the services of air conditioners) or transmission (the failure of a transmission line in a storm or extreme heat event, or technical fault in a transmission line or interconnector). The Operator has to be able to call on reductions in demand or increases in generation that would not otherwise occur.

The Operator needs to be able to call upon immediate responses to emergency (failure of a thermal generator in heat, or technical failure of an interconnector). It also has to be able to call upon responses to changes in demand or supply that can be anticipated for some time in advance (increased demand for power on some future day that is expected to experience extreme heat). The market Operator therefore needs to be ready to purchase balancing opportunities with varying response times.

The various means of balancing short-term demand for and supply of power are substitutes for each other: greater interconnection allowing balancing between regions; demand management; maintenance of fast response surplus generation capacity; pumped hydro and battery storage. The Reliability requirements are met most economically with a competitive market for each response time. The system would be more reliable if there were effective day-ahead markets, as well as long term capacity markets, each meeting requirements defined by the Australian Energy Market Operator's analysis of future supply and demand.

If an attempt were made to use surveillance of contracts for policing compliance with Security and Reliability obligations, issues would arise that were similar to those arising out of linking Emissions Intensity requirements to contracts in the wholesale electricity market.

The requirements for Security and Reliability are determined in a regional market, so that, in the nature of things, the requirements would need to be differentiated across the States. However, some recognition would need to be given for the way in which Security and Reliability services provided in one State affect outcomes in others.

Private incentives would correspond more directly with the public interest in Security, Reliability and low energy costs, if the causers of insecurity and unreliability were required to meet the cost, as they are within contemporary FCAS markets. This would happen automatically if each power retailer or user were required to purchase its attributed share of Security and Reliability services on a competitive market. Where the limited size or other

characteristics of a regional market prevent effective competition in provision of some Security or Reliability service, it may be necessary for AEMO to secure the service by contract from particular suppliers, and to recoup the cost of the purchase through charges allocated proportionately among causers of the need for the services—as in current FCAS markets.

4. Australia as a Superpower in the Low-carbon World Economy

Australian opportunities in the energy sector will be different and at least as rich in a low-carbon world as they once were in the fossil energy economy.

The old fossil fuel industries no longer provide opportunities for incomes growth. Export markets for coal are unlikely to support remunerative prices without continuing closure of substantial established capacity somewhere in the world. Some of that withdrawal will be in Australia. If new mines are established, more old ones will be closed. After a few decades, the surviving coal exports are likely to supply only processes and industries and locations endowed with favourable carbon sequestration opportunities.

Gas exports will fare better for a while than coal. Gas combustion generates substantially less greenhouse gas per unit of energy, and it is therefore favoured as a transitional fuel. And costs of geological sequestration are likely to be lower per unit of energy.

Geological carbon capture and storage uses a large amount of energy so will be economically viable only where primary energy costs are low. It needs favourable and tested sites near major sources of emissions. Despite the future

prospects for Australian exports of coal and gas being closely related to sequestration, little effort has been invested so far by coal and gas producers to developing these technologies.

Most emissions-intensive manufacturing processes can only find paths to low or zero emissions through intensive use of zero emissions electricity. This applies to use of hydrogen for reduction of iron ore; or production of nitrogen fertilisers that avoids traditional reliance on petroleum or coal. The combination of rich resources for renewable energy and abundant raw materials create exceptional opportunities for processing industries in Australia.

The low-carbon global economy will vastly expand opportunities for Australian mining to supply inputs to processes and products that are used in low-emissions energy. Demand for uranium oxide (nuclear power, at least in India and China), lithium and other rare earths (batteries), high grade silicon (photovoltaic panels), carbon fibre (energy-efficient vehicles) and special metals (wind and hydro-electric turbines) will all expand prodigiously in the low-carbon economy. These all use minerals in which Australia is well endowed. The processing of all of these materials for final application uses electricity intensively. The combination of internationally competitive domestic mineral reserves and low-cost electricity would make Australia the natural supplier of manufactured inputs.

Amongst the world's developed countries, Australia has by far the greatest per capita potential for low-cost production of energy from most of the promising

renewable sources: solar, wind, deep geothermal, biomass, wave and tidal. While endowed less abundantly than many countries with hydro-electric capacity, it has two developed sources, in Tasmania and the Snowy Mountains, that are considerable by world standards and which are able to contribute a great deal in the balancing of intermittent renewable generation. Recent research has identified vast new opportunities for pumped hydro storage using salt water and off-river fresh water. Australia has excellent geo-sequestration potential in several locations, including adjacent to the low cost, high volume lignite generation in the Latrobe Valley of Victoria. At least amongst the developed countries, Australia has the greatest potential for biological sequestration of carbon wastes. It has the richest opportunities for production of biomass as a base for biofuels. At least amongst the developed countries, it is the most richly endowed in minerals that will be used in much greater quantities in the low-carbon economy. Complementing its advantages in mining uranium and potentially in enriching it, Australia has perhaps the world's safest geology for safely storing nuclear wastes from power generation.

Australia happens to be disproportionately strong in the applied physical and biological sciences and engineering that are important to turning opportunity in low-carbon energy into competitive advantage.

5. Utilising Opportunities in the Low-Carbon Economy

Whether these inherent strengths are converted into success in the low-carbon world economy depends on our being able to transform what in the recent past has been a dysfunctional policy-making and institutional framework.

In the best of circumstances, it will be many years before a new and stable system of incentives for low emissions energy, efficient support for Security and Reliability, reforms of network regulation and transformation of competition in retail sales supports the supply of electricity at prices that reflect Australia's inherent strengths. We can start to take advantage of new opportunity without waiting for completion of a long process of institutional and policy reform, by removing barriers making sure that barriers from the path of businesses that seek to establish their own systems linking generation with industrial demand.

As I worked my way into my first review of climate change policy 11 years ago, I saw Australia's participation in a strong global effort to reduce risks of dangerous climate change being in Australia's interests despite some cost to Australian economic growth in the early decades. The costs of the low-emissions technologies have fallen much more rapidly than once seemed possible, and we have learned more about Australian opportunities in the low carbon world. I now see the costs and benefits of purposeful transition within a rational policy framework being more closely balanced from the beginning,

with benefits growing rapidly and costs declining as we use the new opportunities in the low carbon world economy.

This holds for the whole of Australia. It holds most strongly for our host State today, South Australia. This State did not do as well as any of its mainland sisters when the creator handed out the world's best fossil fuel resources. South Australia leads them all in combinations of the zero emissions energy that will build the low carbon economy of the future.

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