

Powering Onwards:

*Australia's Opportunity to Reinvigorate
Manufacturing through Renewable Energy*

By Dan Nahum

Economist

The Centre for Future Work at the Australia Institute

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Level 1, Endeavour House, 1 Franklin St
Canberra ACT 2601
Tel: (02) 6130 0530
Email: mail@tai.org.au
Website: www.tai.org.au

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About the Author

Dan Nahum is Economist at the Centre for Future Work, with a research focus on industrial transformation, labour markets in low-carbon economies, and inequity and inequality in Australia and globally. He holds a Master of Political Economy from the University of Sydney and a Bachelor of Science (Psychology) with Honours from Macquarie University.

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Summary

Australia enjoys a large landmass with an abundance of renewable energy resources and a low population relative to that landmass. We are the only developed nation to have access to such a large quantity of solar and wind power; we could generate many of our energy needs renewably by using just a very small proportion of our landmass. This means that we enjoy a considerable competitive advantage in the production of renewable energy.

Not only are we able to power an expanded manufacturing sector using renewables, but it is cheaper to do so than to continue down the path of an energy grid that favours and subsidises coal and gas. These economic advantages in turn can expedite a broader economic rebalancing, away from extraction towards production, in which value-added manufactures increasingly supplant the export of raw materials in our economic mix. This will be good for Australia's economy—and for the world's emissions.

Australian manufacturers would save significantly—in the order of one-quarter or more—on their electricity costs by switching their supply entirely to renewables. That would mean greater international competitiveness and more high-quality Australian manufacturing jobs.

Manufacturers spent **A\$5.4 billion on electricity** in 2017–18. If we assume that manufacturing uses an energy mix representative of the broader Australian electrical system, then 60 per cent of that power was sourced from coal, and another 19 per cent from gas. In the short- to medium-term the existing fossil fleet will need to be retired: both because units reach the end of their useful life, and because Australia needs to accelerate its emissions reduction (and fossil fuel power generation, especially coal, is 'low hanging fruit' in that effort). If Australia's current coal- and gas-fired electricity was replaced with renewables (even allowing for six hours of pumped hydro storage), rather than more fossil fuel generation, the Australian manufacturing sector could save **\$1.6 billion per year**, or **23% of bill under the current energy mix**.

Moreover, over time those savings would get even larger – because the cost of renewable energy production is falling rapidly and steadily. By 2050, such a transition would save manufacturers **\$2.2 billion per year** (in constant dollar terms), or 33% of their energy bills.

Many manufacturers operating in Australia are already taking advantage of the opportunities offered by renewable energy, notwithstanding the dearth of

Commonwealth government support. They are developing their own dedicated renewable energy supplies, contracting for renewable power through power purchase agreements, and developing value-added products and technologies to further leverage the coming boom in renewable power. However, more consistent and supportive policy measures by government would accelerate those positive developments, and allow manufacturers to make the most of Australia's unique endowment of renewable energy.

In addition to reducing energy costs for all sorts of manufacturing, a renewables-focused strategy for revitalising Australian manufacturing would also feature ambitious plans to promote the domestic production of manufactured goods with a direct connection to the coming renewable energy revolution. These could include:

- Sustainable transportation vehicles, including electric vehicles (EVs) and rolling stock for public transit applications.
- Manufacturing lithium batteries and related products, leveraging our existing endowment of that mineral.
- Green hydrogen, produced with renewable power.

There is abundant evidence of the success of active policy approaches to promote the linkages between renewable energy and manufacturing in other countries. Indeed, across the OECD, most other industrial countries are outperforming Australia on both reducing emissions and supporting domestic manufacturing. There is no positive statistical relationship between manufacturing in OECD countries (as a proportion of GDP or exports) and carbon emissions. In fact, there is a weak negative correlation between manufacturing success and carbon pollution: in general, countries which emit *less* tend to manufacture *more*. Australia is currently in the worst of both worlds: it is an extremely high emitter per capita, with a hollowed-out manufacturing sector. This is particularly alarming and unnecessary in light of Australia's spectacular advantage in renewable energy resources.

There is clear evidence of the popularity of a renewable-powered manufacturing policy agenda with the Australian public. This support will have become even stronger due to heightened awareness of the vulnerability of global supply chains for essential manufactures, exposed by the COVID-19 pandemic.

Australia can attain both global manufacturing success and timely reductions in our GHG emissions. But to do so will require an active and consistent policy commitment by government. Australia is especially well positioned to make policy choices in favour of a rejuvenation of manufacturing industry based on renewable energy.

Introduction

Prime Minister Scott Morrison, former Resources Minister Matt Canavan and other influential voices have expressed the view that coal is an essential and irreplaceable input to our manufacturing sector.

The Prime Minister, Scott Morrison, said in Question Time on 11 February 2020:

... [I]f you're putting all your eggs in one basket on intermittent renewals, you cannot support jobs in heavy industry.

He continued:

Our Government believes in jobs ... Right across the country we believe in jobs and we believe in ensuring that manufacturing continues to be able to get access to the reliable power it needs to ensure that they can support jobs and livelihoods into the future ... We are technology agnostics when it comes to ensuring we have reliable power generation in this country. We want to ensure the electricity prices come down, not go up. We want to ensure the lights stay on, not go off. We want to ensure that industries, whether they be in North Queensland or anywhere else, that provide the livelihoods for Australians continue to be maintained and we will assess the options which support those jobs.

Note the juxtaposition between the firm statement that renewables are out of the question and the government simultaneously claiming to be technology agnostic.

Former Minister Canavan (2017) said:

We have grown rich as a nation on our abundant cheap energy sources in our country, including our coal ... [C]heap energy in this country means we can have dear wages in those industries.

Since we have cheap energy, we can have industries like an aluminium sector, which provides thousands of jobs for Australians who just want to have a good job to provide for their families ... There is no other way around it ... If you do not support a coal industry—if you do not support coal-fired power—we will not make aluminium in this country.

For the government's position to be tenable, renewables would have to be:

- expensive, relative to coal

- not available in sufficient quantities at the right times and locations
- less reliable than fossil fuel generation
- not suitable for certain industrial purposes, including steel and aluminium production and other heavy industrial uses.

As this paper will demonstrate, none of the above statements are true. Continuing reliance on coal-fired energy is only one of many possible options, and one with many costs—economic, social and environmental—which we continue to experience, as the 2019–20 bushfire season has dramatically demonstrated. Mr Canavan is wrong: a nation’s industrial, energy and financial policies are matters over which it, especially its national government, exert control. They are not somehow set in stone. As eminent economist Ross Garnaut (2019), Reserve Bank Governor Dr Philip Lowe (Wright, 2020) and even Morrison and Canavan’s former boss, ex-Prime Minister Malcolm Turnbull (2020), have all noted, Australia also enjoys an abundance of *renewable* energy resources to be tapped.

Meanwhile, the big banks and other financial investors are divesting from coal quickly (Verrender, 2020). Lord (2019, p. 15) states: ‘Australia’s natural advantages mean an industrial renaissance powered by renewables is a realistic option, even if it requires a large increase in electricity generation’.

Australia’s renewable resources include:

- an abundance of sun and wind, with the cost of renewable energy plunging faster than even the most optimistic industry estimates predicted
- a large landmass upon which to install solar and wind power
- many identified potential sites for hydro and pumped hydro power
- untapped geothermal resources.

In addition, Australia has the other critical inputs to build a cutting-edge, competitive renewable energy sector:

- capital resources, both public and private, to fund the transformation of our energy sector
- a skilled, educated workforce
- world-class research and development capabilities.

Australia also has a population that is supportive—by very significant majorities—of both the importance of the manufacturing industry for Australia’s future prosperity, and of making a more assertive transition to renewable energy. This indicates that this is a politically appealing dual objective for policy makers.

In short, Australia is particularly well positioned to make policy choices in favour of a rejuvenation of manufacturing industry based on renewable energy.

The government’s own figures indicate that more than half the energy in the electricity grid will come from renewable sources by 2030 (Department of the Environment and Energy, 2019). In other words, notwithstanding the Prime Minister’s and former Minister Canavan’s contentions, the government has in practical terms conceded that most Australian manufacturing will in fact be powered by renewables within a relatively short period of time.

This paper compiles evidence to demonstrate that Australia can achieve the continuation and resurgence of a vibrant, competitive manufacturing sector based on the even faster development of renewable power. To do this, the paper:

- reviews the strategic importance of, and opportunities presented by, manufacturing
- discusses Australia’s competitive advantage in renewable energy
- shows that, based on the government’s own figures, renewables are already cheaper than coal—and quickly getting cheaper
- debunks claims about the unreliability of renewables relative to more traditional energy sources
- identifies examples where renewable power is already in use, or could be put to use, in manufacturing and industrial processes, and instances where we can use our natural and manufactured inputs to add further value to these renewables
- examines international evidence showing that there is no connection between reliance on fossil fuels and success in global manufacturing trade
- presents a range of recommendations for government action to capitalise on the opportunity of renewable energy for revitalising Australian manufacturing.

An enlightened industrial and energy policy, informed by successes both overseas and at home, could allow Australia to identify and rediscover opportunities in an advanced and expanded manufacturing industry powered by renewable energy. It is past time

for Australia to stop trying to dig our way to the future; instead, we need to act on what both the economics and the environment are telling us.

Why Manufacturing Matters

The Australian manufacturing sector has experienced a difficult decade, but there are promising green shoots—which can be nurtured if we deliberately pursue proactive, ambitious policies relating to the sector. Unfortunately, there has been a sort of fatalism, and even a celebration of that fatalism in some quarters, regarding the Australian manufacturing industry: a sense that manufacturing is somehow unviable or even unimportant in Australia. This contrasts sharply with other industrial countries, where innovative and high-value manufacturing has remained resilient, thanks in large part to the hands-on involvement of governments. The COVID-19 pandemic, and subsequent chaos into which global trade has been thrown, demonstrates starkly the risks of being reliant on other countries for our everyday manufactures. One particularly acute example is that of personal protective and medical equipment.

Notwithstanding Australian policy makers' unusual and destructive pessimism, manufacturing in Australia continues to be a high-productivity industry sector that directly employs almost a million Australians (ABS, 2019a).

As Stanford (2016a) notes:

- Australians are buying more manufactured goods over time, not less; and manufacturing output is growing around the world, not shrinking.
- Manufacturing is not an 'old' industry. It is the most innovation-intensive sector in the whole economy—and no country can be an innovation leader without the ability to apply innovation in manufacturing.
- Manufactured goods account for over two-thirds of world merchandise trade. A country that cannot successfully export manufactures will be shut out of most trade.
- Many countries around the world (including high-wage industrial countries) are expanding manufacturing output, creating new manufacturing jobs and boosting manufactured exports. Australia's experience is not at all representative of the experience of other industrialised countries. Even small remote countries (like Korea, Ireland, New Zealand and Israel) are increasing their manufacturing output and preserving and creating manufacturing jobs. Such countries demonstrate that we cannot blame geographic isolation for the problem.

The worldwide consumption of manufactures is increasing, and as parts of the developing world come to enjoy lifestyles more closely resembling those of the developed world, that trend is set to continue. An important policy question for Australia is whether we capitalise on that demand and pivot to take advantage of our bountiful renewable energy endowment in the process of doing so. Manufacturing anchors other jobs upstream and downstream throughout the economy—including demand for raw resources, but also technical support, maintenance services and a myriad of other supplies and inputs that are purchased by manufacturing facilities.

If Australia does not join the trend of countries developing their value-added industries such as manufacturing, we can anticipate that our relative standard of living will decline.

Garnaut (2019) points out that Australia’s abundance of renewable energy resources favours value-adding processes on Australian soil, rather than exporting both unimproved materials and the energy resources with which to process them. This indicates that leveraging domestic renewable energy to underpin a manufacturing resurgence makes social and economic sense. This theme will be developed further in subsequent sections of this paper.

Australia's Competitive Advantage in Renewable Energy

As the disastrous 2019–20 bushfire season has made abundantly clear, climate realities mean that the world must transition to renewable energy. This will have a far greater ecological, social and economic cost if we try to delay and deny that transition, rather than if we are proactive.

Australia is also a signatory to the emissions targets of the Paris Agreement of 2016, having nominated an emissions target of 26–28% below 2005 levels by 2030, with the expectation that during 2020 signatories will come back with more ambitious targets. However, for the time being Australia has one of the most carbon-intensive economies in the world. For each unit of Gross Domestic Product (GDP) generated, the amount of emissions generated is especially large compared to other nations (March, 2019). In addition, on a per capita basis, Australia emits more carbon dioxide (CO₂) equivalent than any other major industrial country (Organisation for Economic Cooperation and Development (OECD), 2019).

On the one hand, this means that there are more opportunities for us to decarbonise our economy. On the other, it means that we have further to go than most other nations (Stock, 2018).

But there is reason to be optimistic. As Professor Ross Garnaut argues in *Superpower: Australia's low-carbon opportunity* (2019, pp. 8-9): 'Per person, Australia has natural resources for renewable energy superior to any other developed country and far superior to our important economic partners in northeast Asia'. We have the capacity to generate far more renewable energy than could ever be needed: the Australian Energy Market Operator (AEMO) states that in the area covered by the National Energy Market, the potential for renewable generation is about 500 times greater than current electricity demand (AEMO, 2013). A 300% renewable energy target—that is, supplying our own energy needs three times over—would take up only 0.15% of the Australian landmass (AEMO, 2013). There has been a leap forward in the quantity of renewable power available to the Australian energy supply, driven by plummeting prices for solar, wind and storage.

In the longer term, Australia's abundant geothermal resources should also be considered as an under-exploited, highly consistent renewable energy source for metals production, and for our grid more generally. At present, there is no commercial

production of geothermal power in Australia; however, significant resources have been identified across the continent, most especially in South Australia (Geoscience Australia, 2019).

The technology to convert geothermal resources into electricity is not complex, and it has existed for over a century. For example, the majority of Iceland's primary energy is drawn from geothermal sources (Askja Energy, 2017) and, despite Iceland's tiny geography and population, it has become the world's 11th largest aluminium producer, with total production just behind that of the United States (US) (United States Geological Survey, 2020). Future Australian metal production operations could be co-located with our geothermal resources to reduce transmission losses.

Therefore, in a world that is shifting—hopefully, quickly enough—towards low-carbon production, any sector that is electricity-hungry enjoys a corresponding competitive advantage in Australia. Garnaut (2019, p. 110) points out that 'fossil energy can be imported at relatively low cost by countries with poor resources, but renewable energy cannot'.

A number of large-scale, ubiquitous manufacturing sectors are indeed energy-hungry—for example, energy is the largest cost in minerals processing. Far from hampering Australian manufacturing, therefore, the abundance and low cost of renewables will open up expanding opportunities for manufacturing, both in the domestic market (allowing all Australian manufactures to compete more favourably with imports, given lower energy costs) and in the export market.

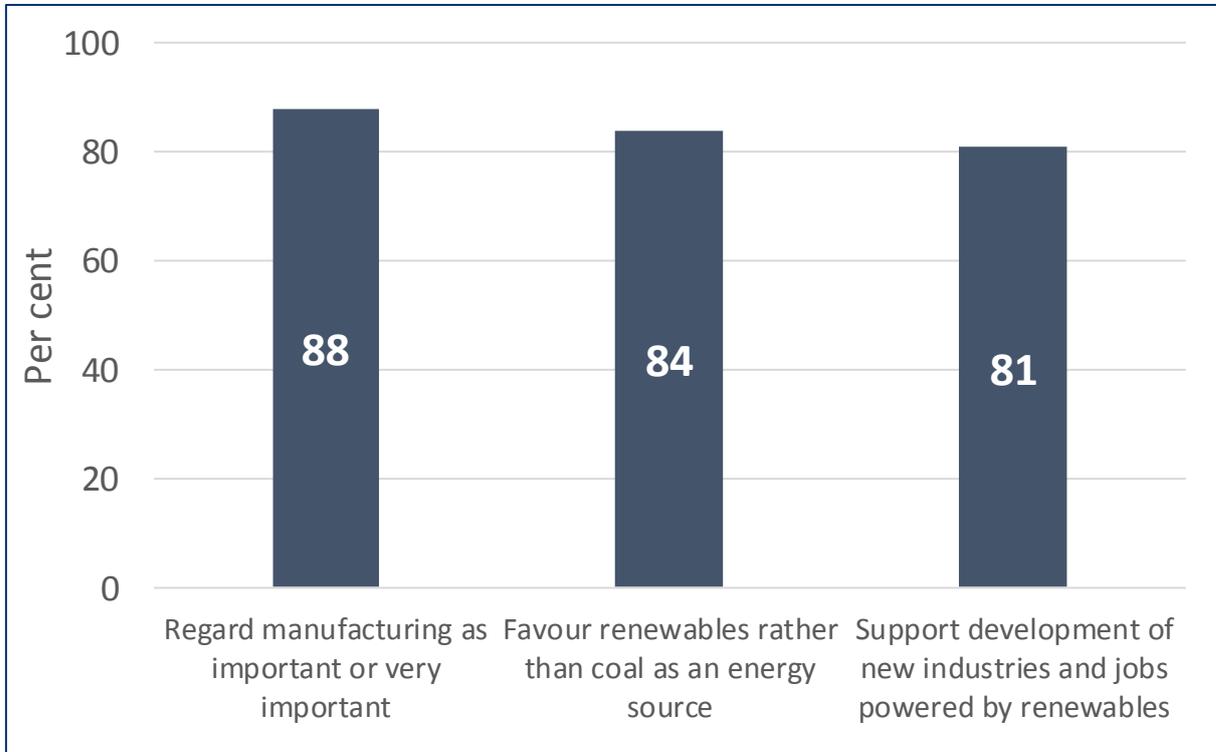
A pivot to renewably powered manufacturing would be popular. Essential Research polling (2020) reports that 81% of polling participants support the accelerated development of new industries and jobs powered by renewable energy. Furthermore, 71% support a zero-carbon pollution target to be set for 2050. According to previous research by the Centre for Future Work, a total of 88% of respondents rated manufacturing as 'very important' (53%) or 'important' (35%) to the economy. Similarly, 79% of respondents agreed that the health of the manufacturing sector should be a 'national priority' (Stanford, 2016a).

Meanwhile, Lowy Institute (2019) polling reports:

Most Australians do not support the use of coal over renewables for the nation's energy security. Almost all Australians remain in favour of renewables, rather than coal, as an energy source. In 2018, 84% (up three points since 2017) said 'the government should focus on renewables, even if this means we may need to invest more in infrastructure to make the system more reliable'.

These results can reasonably be expected to have been buttressed by the catastrophic 2019–20 bushfire season.

Figure 1. Australian Polling Support for Manufacturing and Renewable Energy.



Source: Centre for Future Work, Lowy Institute, Essential Polling.

Considering the unavoidable arithmetical overlap between voters holding positive positions on manufacturing and renewables, one is compelled to conclude that most Australians simultaneously view a healthy manufacturing industry and a cleaner energy future as important dual objectives for governments. This majority voting bloc is therefore looking for a persuasive policy narrative involving a renewables-based manufacturing industry.

The Reserve Bank of Australia’s figures show that there is no expectation that domestic coal demand will significantly increase (Cunningham et al., 2019). Logically, then, *if* Australian manufacturing is dependent on coal, and yet official figures show that domestic coal use is going to tail off, we are implicitly conceding that manufacturing is going to tail off as well. Fortunately, the government is wrong about the intrinsic ties between coal and manufacturing—and it is therefore reasonable to take a much more upbeat view of possible futures for manufacturing in Australia.

The Potential Savings of Renewable Power for Manufacturers

WHAT IS COAL'S PURPOSE IN MANUFACTURING PROCESSES?

Broadly speaking, coal has two purposes in manufacturing.

Thermal coal is used to supply energy and heat to industrial processes. It is true that manufacturing can be energy-intensive, although not in all cases; but it is far from accurate to suggest that the only way of supplying this heat and energy is through the burning of coal.

Coking (or metallurgical) coal is a higher grade of coal, with fewer impurities, used in the production of industrial metals at high temperatures using blast furnaces—especially steel, but also lead, copper and other industrial metals. Importantly, this is a chemical process, not an energy input.

A significant majority of Australia's coal exports are metallurgical (not thermal) coal, and, as we will see, there are pilots examining the possibility of replacing this chemical input in metal production in the short to medium term.

COST SAVINGS OF RENEWABLE POWER

The existing fleet of aging fossil generators needs replacing on engineering and maintenance grounds. AEMO expects that 60% will need to be retired by 2040, with a consistent, ongoing stream of closures expected in the interim (Anthony & Coram, 2019; AEMO, 2020). In addition, climate imperatives require us to phase-out fossil fuels faster than simply waiting for existing plants to wear out.

However, the Commonwealth government is still favouring further construction of coal and gas-fired capacity. It has pressured for the Liddell coal-fired power station to be kept open and upgraded for continued operation – regardless of climate imperatives, and even the preferences of the plant's owner. It is funding a feasibility study into building a new coal-fired power station in Collinsville, Queensland, prompting the former Resources Minister to ask: 'Why should we send all our fantastic coal overseas

for other countries to create jobs with?’ (Canavan, 2020). The current Energy Minister also promotes future gas developments, even speaking of a ‘gas-fired recovery’ from the coronavirus downturn (Foley, 2020). This continued support for coal and gas-fired generation is very difficult to understand from an economic perspective, as renewable energy is already preferable on cost grounds, as well as for environmental reasons.

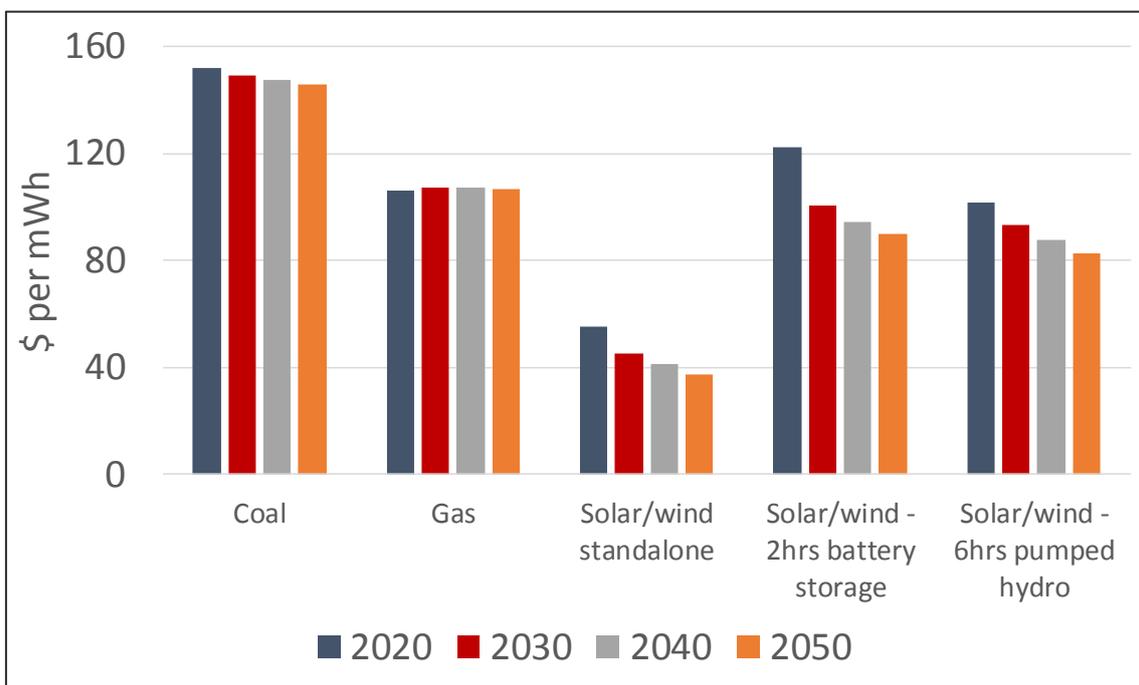
Indeed, recent analysis shows that strong investment in solar and wind, including from manufacturers installing their own renewables and storage, is driving down wholesale and retail electricity prices. Retail prices are projected to fall by 7.1% across Australia from 2019 to 2022 (Australian Energy Market Commission, 2019). This is not because of Australia’s abundance of coal. Rather, this trend is being driven by new solar capacity. Solar expansion has been most rapid in South-East Queensland, which correspondingly is enjoying the greatest wholesale and retail energy savings compared to other regions (with prices set to fall by an estimated 20% over the same period).

The government’s own figures, produced by the Commonwealth Scientific and Industrial Research Organisation (CSIRO), state that the cheapest sources of newly installed power are now wind and solar (Graham et al., 2018). Bloomberg New Energy Finance analysis concurs (Parkinson, 2019). Australia’s coal-fired power plants are scheduled to be decommissioned by their operators in coming years – and if anything, we need to accelerate the timetable for those closures (since coal-fired electricity is one of Australia’s largest sources of GHG emissions). Why would any operator, focused either on profits or social licence, want to open a new one? And why would government try to support the development of energy sources that are both more polluting and more expensive?

The potential savings from a faster transition to renewable power for the Australian manufacturing sector are enormous. This section will provide a broad estimate of the potential scale of those savings, and their value in stimulating a revitalisation of domestic industry. Of course, it is complex to simulate all the factors affecting costs and prices of different energy sources, and hence of the savings to be made from a shift to renewables in the manufacturing sector. Coal and gas facilities face both capital costs (amortised over those plants’ operational lifespans) and marginal costs (fuel, maintenance), which are all passed on to the consumer (depending on regulatory practices and market conditions). Installing renewables incurs significant capital costs (but which are falling faster than most analysts’ expectations); the marginal costs of running renewables, once installed, are negligible. By way of analogy, readers who have considered the economics of installing rooftop solar panels on their homes will recognise the capital- versus marginal-cost trade-off being considered here.

A measure that considers the cost of installation as well as marginal (running) costs exists: the levelised cost of electricity (LCOE). The LCOE can be understood as the comprehensive cost of different generation options, averaged and discounted over the full life-cycles of those facilities. CSIRO's *GenCost* report (Graham et al., 2018) shows that **renewable sources (wind and solar) cost only about one-third to one-quarter of the LCOE of coal generation facilities** (see Figure 2). This comparison includes a small risk premium on fossil fuel use (to reflect the fundamental uncertainty facing fossil fuel projects), but does not include a carbon price (which would shift the comparison even further in favour of renewables).

Figure 2. Comparative Electricity Generation Costs.



Source: Author's calculations from Graham et al., 2018.

Notes:

1. Energy costs for different sources reflect the averages of high and low estimates in the CSIRO data. Coal costs assume the introduction of high-efficiency 'supercritical' units, hence the modest fall in costs without a carbon price over time.
2. Coal and gas costs without carbon prices assume a 5% risk premium, but no carbon price.

One operational and economic issue facing renewable energy developments is the challenge of storage, given the inherent variability of supply from wind and solar projects. Even including the costs of six hours of storage, which is more storage than

most analysts believe is necessary, the levelised cost of new renewables is still only one-half to two-thirds that of coal.¹

Moreover, the cost of renewable energy is also already less than the cost of newly-installed gas, which has been described erroneously as a ‘transition fuel’. With the cost advantage and reliability of renewables becoming clearer every year, it therefore makes no economic or environmental sense to invest in new gas power.

If Australia’s existing coal and gas-fired generation fleet is replaced by renewable energy it will bring substantial savings for manufacturers – especially compared to the replacement of those facilities with new coal and gas generation. That would mean greater international competitiveness and more high-quality Australian manufacturing jobs.

SCALE OF ENERGY COST SAVINGS FOR MANUFACTURING

The magnitude of potential savings that renewable energy could bring to manufacturers can be estimated based on the LCOE estimates above and existing manufacturing electricity consumption. **Manufacturing consumed 52,461 gigawatt hours (GWh) of electricity** from the grid in 2017-18 (ABS, 2019b). Assuming that this power was generated from a fuel mix similar to the wider electricity supply, this implies that 60% (or 31,424 GWh) came from coal, around 10,000 GWh from gas-fired generators, and 6,400 GWh from solar and wind (BP, 2019)². Other forms of generation make up the remainder.

We can compare that cost breakdown to a counterfactual scenario in which all gas and coal grid energy being used by the manufacturing sector is replaced with wind and solar (including storage). Applying CSIRO’s 2020 LCOE to Australia’s energy mix in 2018 (BP, 2019), we can estimate the potential savings of moving to a fully renewable mix.

¹ This assumes pumped hydro as the storage mechanism. Other storage technologies may be somewhat more or less expensive, but the order of magnitude of the cost advantage of renewables is nonetheless robust.

² BP’s figures on energy mix do not distinguish between black and brown coal; however, CSIRO’s LCOE estimates do. Approximating Geoscience Australia estimates, the analysis assumes that 20% of Australia’s coal-fired electricity supply is brown coal. As the costs associated with brown coal generation are higher, this has been factored into a weighted average cost of producing energy from coal. Solar and wind have been combined into an unweighted average (since their costs do not substantially differ).

Table 1 supposes that the current coal and gas-fired grid electricity supply consumed by manufacturing can be replaced by either new coal and gas capacity, or by renewables with six-hour storage, based on the LCOE estimates in Figure 2. If the system shifts fully to renewable energy sources, the manufacturing sector would save **\$1.6 billion** in annual electricity costs compared to a scenario in which coal and gas power continues to fill its current share of total power supply (including the ultimate replacement of existing fossil fuel facilities).

This is a conservative figure, since our estimated LCOE for renewables assumes that *all* renewables are fitted with 6 hours of pumped hydroelectricity storage. If Diesendorf and Elliston (2018) are correct that storage is not required for a stable, renewable grid (see the following section for further details on this issue) then annual electricity cost savings for manufacturing more than double, to **\$3.5 billion per year**.

Another cautious feature of our cost comparison is that it simulates cost savings based on present-day LCOEs. It does not presuppose the effects of a potential carbon price, nor the mandating of costly lower-emissions technology for coal or gas plants (such as carbon capture and storage). In those cases, the energy cost savings from renewables become even more impressive. Additionally, the analysis assumes that total electricity demand from the manufacturing sector does not grow; if power usage grows (in part thanks to ambitious electrification strategies in some industries), then the potential savings are still greater.

In other words, the analysis is deliberately safe and simple: it models the energy cost savings for the Australian manufacturing industry on the basis of current cost comparisons only, with coal and gas power ramped down and wind and solar (backed by ample storage) in their place.

Table 1
Energy Cost Savings from Renewable Energy

| | <i>Units</i> | Coal | Gas | Renewables (solar and wind) | Other | Total |
|--|--------------|-------------|------------|--|--------------|--------------|
| Current manufacturing grid electricity demand | | | | | | |
| Expenditure | \$m | | | | | 5,378 |
| Consumption | GWh | | | | | 52,461 |
| Technology share of grid generation | % | 60% | 19% | 12% | 9% | 100% |
| Current consumption by technology | GWh /year | 31,424 | 10,073 | 6,400 | 4,564 | 52,461 |
| Replacement | | | | | | |
| LCOE of new build | \$/MWh | 151.9 | 106.0 | 101.9 | NA | NA |
| Coal and gas capacity replaced as per current mix of generation | | | | | | |
| Annual electricity cost | \$m | 4,773 | 1,068 | 652 | 468 | 6,961 |
| Generation replaced with firmed renewables (Six hours pumped hydroelectric storage) | | | | | | |
| Mix | % | - | - | 91% | 9% | 100% |
| Consumption | GWh/year | - | - | 47,897 | 4,564 | 52,461 |
| Annual cost | \$m | - | - | 4,881 | 468 | 5,349 |
| Difference between renewable and coal-gas scenarios | \$m | | | | | 1,613 |
| Saving expressed as proportion of coal-and-gas scenario | % | | | | | 23% |

Source: Author's calculations from ABS (2019b), unpublished data from Graham et al., 2018, and BP (2019).

Note: Energy costs for different sources reflect the averages of high and low estimates in the CSIRO data.

The estimates in Table 1 are of course a simplification of Australia’s very complex electricity system. Transmission, distribution and retailing systems also interact with generation and market structure, and political considerations loom large over all of these issues. The relationship between generation cost and the prices actually paid by power users is also not always direct: depending on regulatory factors, market demand, pricing strategies of private power producers, and other factors. However, comparing life-cycle cost estimates for competing sources of power certainly confirms the implications for manufacturers of the declining cost of renewable energy – and the size of the opportunities they would capture if Australia moves quickly with this energy transition.

| Table 2 | | | | |
|---|-------------|-------------|-------------|-------------|
| Future Cost Savings Comparing Renewables With A Business-As-Usual Energy Mix | | | | |
| | 2020 | 2030 | 2040 | 2050 |
| Annual dollar savings (millions, 2017–18 dollars) | 1613 | 1912 | 2078 | 2216 |
| Savings (%) | 23 | 28 | 31 | 33 |

Source: Author’s calculations from ABS (2019b), based on data from Graham et al., 2018, and BP (2019).

Notes:

1. This analysis compares the reinstallation of a present-day energy mix with a mix where coal and gas generation are replaced by renewables.
2. The analysis assumes that electricity use by manufacturing remains constant; if electricity use increases, potential savings will correspondingly grow.
3. Coal and gas costs assume a 5% risk premium (but no carbon price). Potential savings increase if a carbon price is introduced.
4. All renewables are assumed to be firmed with six hours of pumped hydroelectricity storage. Savings increase if we assume that some renewables do not require storage.

Projecting this analysis into future years, we can see that the savings from renewable energy development will get even larger in years to come. Renewable energy projects are becoming steadily less expensive to construct and operate, thanks to economies of scale in production and installation, new technologies, and whole new applications

(such as offshore wind power). So the potential savings of a faster and more complete transition to renewables will grow over time. As before, this projection does not include the potential impacts of a carbon price or of mandated low-emissions technologies on the future costs of coal or gas power. Annual cost savings to manufacturers from switching from coal- and gas-fired power to renewable power expand to **\$2.2 billion per year** by 2050 (in constant dollar terms): one-third cheaper than a business-as-usual energy mix (Table 2).

Our findings of substantial potential energy cost savings from an accelerated transition to renewable sources are consistent with an extensive economic literature, including work generated by the CSIRO and Commonwealth Treasury, showing that a shift to renewables is increasingly beneficial on both economic and environmental grounds. While the results of individual models vary, depending on their methods and assumptions, many other models also find that ambitious transitions to renewable power will reduce power costs. For example, new modelling by Gray et al. (2020) finds substantial cost advantages for renewable energy relative to coal-fired facilities – even existing ones. And Swann and Merzian (2019) survey several economy-wide models of electricity transitions in Australia that also conclude that the expanding share of renewable energy will reduce electricity prices.

Moreover, these potential savings are being borne out by manufacturing firms' real-life investment decisions, as more and more of them develop renewable power supplies for their own operations (including both dedicated on-site renewable generation facilities, and contracted renewable energy through power purchase agreements, or PPAs). Reports confirm that **businesses (including manufacturers) are already locking in electricity savings of up to 50 per cent** by entering into renewable PPAs (Catt, 2018). If anything, therefore, the savings estimated above (equivalent to 23% of current manufacturing power bills, rising to 33% by 2050) are conservative.

In conclusion, we now inhabit a country where hard-headed economic analysis supports low-emission outcomes in manufacturing—and in other parts of the economy, too. Several specific case studies of the application of renewable power in manufacturing decisions are provided in the section below, entitled 'Technologies for Powering Sustainable Manufacturing'.

Importantly, while private firms and investors can make—and many clearly are making—prudent decisions to reduce future electricity costs and contribute to the inevitable decarbonisation of the economy, even the biggest private sector entities have far less access to finance capital than governments do; far less ability to mobilise labour; and, most crucially, far less policy control.

In other words, the transformation of Australia’s energy future is both promising and inevitable—on both environmental and economic grounds. But that transformation would be considerably accelerated, allowing firms to enjoy considerably larger energy savings, with more consistent and proactive involvement of governments: including via firm policy guidelines for renewables investments, fiscal incentives for renewables (and disincentives for fossil fuels), and co-investments or public ownership of generation and transmission assets.

ENERGY EFFICIENCY: ‘THE FIRST FUEL’

Another important source of potential energy cost saving for manufacturers is what the International Energy Agency (IEA) calls ‘the first fuel’: energy efficiency (IEA, 2019). In fact, the IEA proposes that efficiency should be considered a ‘resource’ in its own right, and that it should be the first resource to be considered in the hierarchy of transitioning to a post-carbon energy future (followed by renewables and then green hydrogen).

The benefits of energy efficiency are both environmental and commercial. Efficiency improvements reduce overall electricity demand, especially peak demand, which, in turn increases grid reliability and reduces wholesale prices. Unfortunately, the IEA reports that improvements in energy efficiency are slowing down. IEA (2019) data indicate that 2018 showed the lowest rate of improvement in energy efficiency since the start of the decade, after weakening each year since 2015.

Nonetheless, there has been some important progress in the Australian context and some other major energy markets. The Australia Institute, the Public Interest Advocacy Centre and the Total Environment Centre have successfully proposed a draft rule to the Australian Energy Market Commission (AEMC) that consumers be able to produce ‘negawatts’ with demand response measures, through which they sell aggregated wholesale reductions in their energy usage at peak demand times (Cass, 2019). Using less power at peak times is equivalent to increasing capacity available in the grid, without the need to build the additional energy infrastructure to support that capacity.

Governments could require major commercial users of electricity are required to undertake audits to consider options for reducing their energy usage. This is good for grid reliability and for the consumers themselves, and it expedites the transition to renewables (by reducing peak energy demand and therefore the capital costs associated with that transition).

Renewable Energy is Suitable for Manufacturing

Some commentators argue that renewables are intrinsically unable to supply ‘baseload power’, and that a consistent, flat source of energy is necessary for reliable and secure energy supply—not only for manufacturing and other heavy industry, but also across the grid more generally.

This represents a misunderstanding of the nature of demand in the energy market. As a developed, industrial economy, Australia experiences highly variable demand across the day. Peak demand typically occurs as people return home from work and turn on appliances. Peak rates occur at the same time. A flat quantity of generation, using sources such as fossil fuel–powered turbines (or even nuclear plants³), which take hours or days to ramp up, is precisely the wrong tool for the job. Demand across the network—with manufacturers making up only one portion of that overall demand—is highly variable. Therefore, for electricity supply to meet such a demand, it must be responsive to changes in demand.

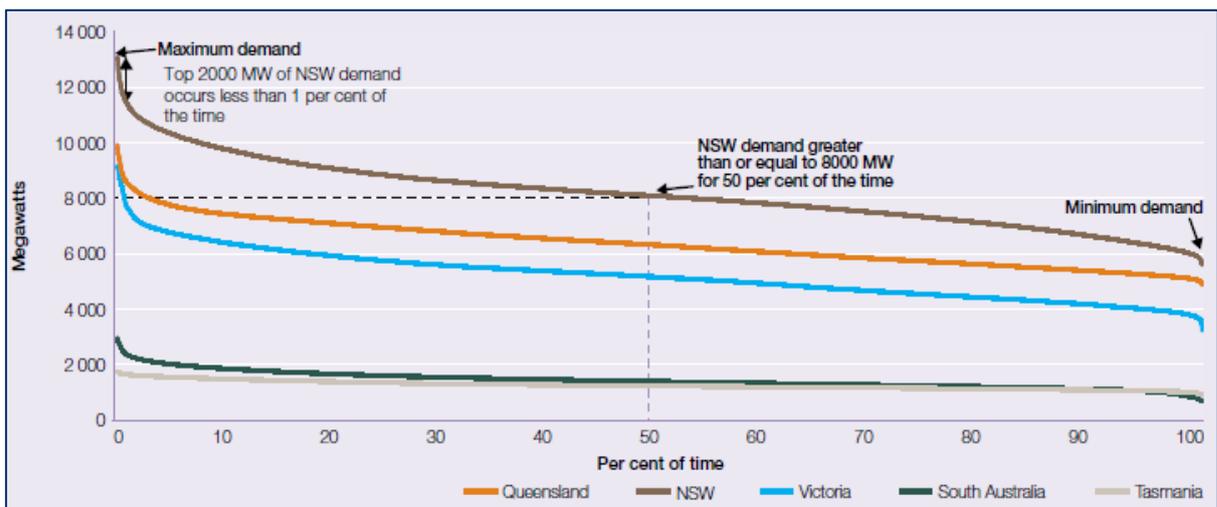
Definitionally, the term ‘baseload’ is often misused: it describes *demand* at its lowest point, rather than supply. To put it another way: the baseload is the permanent minimum amount of energy that consumers require producers to put into the grid at all times. The term’s use in the context of energy *supply* therefore refers to the difficulty of ramping big coal plants up and down (and, for countries that use them, nuclear plants).

Examination of load duration curves for Australia shows the difference between energy demand at its highest points and capacity utilisation across time (see Figure 5). These curves demonstrate that it is uneconomic to use power sources (like coal) that cannot be ramped up and down quickly to supply the grid. Suppliers simply will not be selling enough power, or charging a high enough price, for enough of the time, to be able to build new plants that do not have the ability to quickly ramp up and down. This analysis is borne out by the investment behaviour of Australia’s energy companies, none of which have any plans to build new coal plants.

³ New nuclear is in any case economically uncompetitive (Graham et al., 2018) and will take so long to install, even in the most optimistic scenario, that consideration of it can be set aside, given the urgency imposed by climate change.

What the contemporary electricity network requires is *dispatchable* power—power that can be ramped up and down in response to sudden and substantial changes in energy demand. Highly dispatchable stored power most often comes in two forms: batteries and pumped hydro (which, in terms of its effect on the grid, can be considered ‘virtual batteries’). Geothermal and gas power sources can also be configured to be dispatchable.

Figure 5. Load Duration Curves for the National Electricity Market, 2017–18.



Note: Demand is ordered from maximum on the left to minimum on the right. Each point on the curve represents the percentage of time that demand exceeded that level during 2017–18.

Source: Reproduced from Australian Energy Regulator (2018).

Furthermore, most intermittency in the Australian energy network comes from transmission problems rather than from generation failures. For example, the state-wide blackout of South Australia on 28 September 2016 was caused by damage to transmission lines (AEMO, 2017). However, Australia’s aging coal generation fleet is not becoming any more reliable, either, especially as the climate heats up: indeed, brown coal plants are the National Energy Market’s least reliable generators, with just two brown coal plants in Victoria responsible for almost a third of breakdowns across the National Energy Market through 2018 and 2019 (Plastow, 2020; Quicke & Browne, 2020).

As any engineer knows, a resilient system is one with redundancies built in. Therefore, a distributed grid—in which firms and households generate power across a large geographic footprint—is superior to a centralised one. This is reflected in AEMO’s stated priorities (AEMO, 2019), and in the growing number of firms which are co-locating their own power generation with their operations. AEMO and analysts are

of the view that the top priorities for Australia's energy supply are storage and transmission—that is, the priorities are to make energy available where it is needed, when it is needed.

Diesendorf and Elliston (2018) advance a more ambitious position based on international experience, arguing that even in a grid in which the vast majority of electrical energy is supplied by variable renewables (wind and solar), we would not require substantial quantities of storage to achieve reliability. They note that reliability is, properly considered, a property of the whole grid, not of individual generation sources. Electrons are interchangeable, so some individual intermittent renewable sources can be offline while others are producing, as long as the supply of energy for any given consumer at any given time is sufficient to meet demand.

Their conclusion is that the principal barriers to a renewable electricity supply—not just for manufacturers, but for the economy as a whole—are neither technological nor economic, but instead are primarily political, institutional and cultural.

Technologies for Powering Sustainable Manufacturing

The following case studies identify and describe several impressive projects and possibilities where renewables are fulfilling, or could plausibly fulfil, an expanded role in powering manufacturing. The common denominator is manufacturing processes that use, or could use, renewable energy as an input—and in an advanced industrial society, that is essentially all manufacturing. Indeed, the government’s own projections indicate that 51% of energy in the grid will be renewable by 2030 (Department of the Environment and Energy, 2019). Even on a simple proportional basis, therefore, most manufacturing will be powered by renewables by the end of this decade. That figure could rise further and faster, with accelerated investments in own-source generation by manufacturers, and a more ambitious and consistent commitment to renewable energy in government policy.

A number of the proposals outlined below are ‘low-hanging fruit’: instances where renewable, dispatchable power could simply supplant fossil fuels, or where it already has supplanted them. Others are more ambitious and require setting out a medium-term industry policy—one that would orient Australia’s industrial output around the transition towards renewably manufactured, value-added products. At the firm level, forward-thinking manufacturers might tend to make decisions in the context of sustainable and holistic business horizons (‘beyond business as usual’), rather than aiming for short-term and narrow growth (see Gibson et al., 2019).

Renewable Power Purchase Agreements

Several Australian firms are indicating, through their economic behaviour, that the economics of renewable investment are very attractive. Power purchase agreements (PPAs) represent contractual arrangements between a generator and a consumer, typically to allow new generation investment to be undertaken by confirming long-run sales of the resulting power. These commercial decisions bear out the analysis in the preceding section, ‘The Potential Savings of Renewable Power for Manufacturers’: namely, that renewable energy sources offer superior cost savings as well as environmental performance.

For example, Bluescope Steel has signed a large seven-year PPA with ESCO Pacific’s 500,000 panel Finley Solar Farm, located west of Albury, NSW, to provide energy for its

Port Kembla steelworks (Parkinson, 2018). These facilities are not co-located, nor do they need to be; rather, the PPA matches incremental power inputs to the grid with an equivalent demand elsewhere on the grid. However, an important factor in the tender selection process was the Finley site's direct connection to an existing substation (Jacobs, 2018), reducing costs for upgrading and operation of transmission facilities. This emphasises the critical importance of a top-quality, flexible transmission infrastructure to the continuing roll-out of renewable power projects. This PPA will supply approximately 20 per cent of Bluescope's energy requirements.

In another sub-sector of manufacturing, Carlton & United Breweries (CUB) have signed a 12-year PPA with German firm BayWa r.e. to buy 74,000 MWh per year, generated by the newly-built Karadoc solar farm in Mildura (Gifford, 2018). The purchase is a key part of CUB's plan to source 100% of its electricity from renewables (CUB, 2018). Less than half of the output of Karadoc will provide more than 90 per cent of CUB's business needs; the remainder will be sold by BayWa r.e. into the grid (Vorrath, 2018).

These are just two examples of iconic Australian manufacturing operations which are circumventing fossil power in response to commercial imperatives. Energetics (2020) has tracked 35 other PPAs, some involving other Australian manufacturing firms, supporting a total of 4600 MWh of new renewables capacity in the last 4 years. PPAs are reported to typically reduce power costs for final purchasers by 50% (Catt, 2018). This trend confirms that manufacturers are energetically embracing the potential of renewable energy to both reduce their energy costs, and reduce their environmental footprints.

Renewable Energy in Conventional Steel Production

Raw iron ore is Australia's largest export. By definition, this means that we are missing enormous opportunities to add value to our own mineral products. Instead, in many instances we are paying a value-added 'penalty': we pay extra for companies and workers overseas to produce steel, a critical and utterly ubiquitous commodity, from Australian iron ore.

Nonetheless, we do produce significant quantities of steel in Australia—almost \$3 billion dollars' worth in 2017–18 (ABS, 2019c). The largest single cost input into metals production is energy. Metals are energy-intensive, and metal manufacturing accounts for some 9% of global emissions—more than that contributed by car usage globally. These emissions are dominated by steel production (Lord, 2019).

Steel is an irreplaceable input into many other forms of manufacturing, construction and engineering. By making the production of steel less emissions-intensive, there is therefore a knock-on effect on the emissions intensity of those other processes.

Like the production of green hydrogen, such a scenario is not ‘science fiction’. In 2011, Tony Abbott, then Opposition Leader, famously said that Whyalla would be ‘wiped off the map’ if the Gillard Government’s carbon price was implemented. Yet in 2017, the Whyalla Steelworks was bought by British industrialist Sanjeev Gupta’s Liberty House Group. The company is now installing 280 MW of solar energy capacity—780,000 solar panels over an area 550 times the size of Adelaide Oval, enough to power almost 100,000 homes (Puddy, 2018; Zen Energy, 2018). In this instance, Liberty House Group is addressing the issue of uncompetitive energy prices by simply installing its own supply (which will also serve to stabilise energy prices across the grid). Meanwhile, Rio Tinto has announced that it will be powering iron ore mining operations at the Koodaideri mine in the Pilbara with its own 100,000-panel, 34 MW solar farm, to lower costs and cut emissions (Parkinson, 2020).

These companies are changing their practices despite the absence of consistent federal climate and energy policy. Australia seems to have gone out of its way to be unattractive for companies that envisage a thriving place in a low-carbon future.

The Next Step: Hydrogen Steel Making

German industrial giant Siemens has recently demonstrated the use of hydrogen in steel manufacturing to replace the use of coking coal. The timeframes are short-term: a Siemens hydrogen steel plant is expected to be operational at the end of 2020, and Siemens is building a wind-powered electrolysis plant to provide hydrogen, to be used initially for the partial coking of steel (Power Engineering, 2019).⁴

Similarly, ThyssenKrupp has successfully demonstrated running a blast furnace on hydrogen, partially replacing coking coal and crossing an important bridge towards reaching zero-emissions steel production. As Dr Klaus Keysberg, member of the Executive Board of ThyssenKrupp, put it (ThyssenKrupp, 2019):

⁴ Simultaneously, Siemens has confirmed its involvement with the Adani Carmichael coal mine project (Wiggins, 2020). The incongruity between Siemens’s research and development in decarbonised steel and its pivotal role in this environmentally disastrous coal mine is explicable in terms of the direction of industrial public policy in the respective countries in which the company’s operations are located: Germany supports high-technology energy transition, while Australia subsidises new coal mines. Similarly, ThyssenKrupp’s trial (outlined in the next paragraph) is being supported by the government of North Rhine-Westphalia. In other words, strategic industrial public policy settings matter, and firms respond to them.

Steel production will play an important part in reaching our climate targets because the potential for reducing emissions is huge. That's why we're working flat out to drive the transition to hydrogen technology.

In addition, Swedish-Finnish company SSAB plans to be the first to market fossil-free steel, beginning in 2026, accelerating its earlier plan to accomplish this by 2035. This transformation will ultimately lead to a reduction of Finland's total greenhouse gas emissions by 7%, and of Sweden's emissions by up to 10% (Mazengarb, 2020). Both countries have ambitious carbon neutrality goals: Finland aims to attain carbon neutrality by 2035 and Sweden by 2045.

Given Australia's unmatched natural endowment of renewable resources and iron ore, it is difficult to argue that producing 'green steel' is uneconomic for Australia, if it uses energy inputs from renewables and chemical inputs in which hydrogen—itsself produced cleanly using solar, wind and water—replaces coal. If Germany, with a much more limited renewable endowment, can achieve this, Australia must be able to do so, too.

Since iron ore is Australia's biggest export commodity, it is not difficult to imagine, in the medium term, a scenario in which a greater proportion of our iron ore could be domestically refined into green steel using renewable power and hydrogen, and then used as an input to value-added manufactures right here in Australia.

Alternatively, this green steel could be exported at value-added prices that included a premium for its clean production. This would appeal to emissions-conscious markets such as Japan or South Korea. Australian manufacturing would save such nations from needing to import both Australian iron ore *and* hydrogen—a product that is not simple to transport—to undertake green steel production themselves. In this way, Australian manufacturing could assist other countries to meet both their emissions targets and their demand for steel.

Aluminium Smelting

Aluminium is often somewhat humorously referred to as 'congealed electricity': a large, consistent supply of electrical current is required to smelt aluminium from alumina. Interruptions to the power supply are highly damaging to both plant and equipment.

However, in contrast to the claims of former Resources Minister Matt Canavan (2017; Maiden, 2019) and others (for example, Kelly, 2019), aluminium refining is not necessarily reliant on coal. Canavan claimed (2017):

Apparently we can still export the coal to other countries, like Japan and China. They can make the aluminium for us, and we can import it back here for our planes and for our cars. We can still enjoy the resource but not have the jobs. We will not have the jobs if we do that.

In contrast to Canavan's simplistic claims about the industry policies of other countries, Wood (2014) notes that Australian aluminium manufacturing is especially and unusually dirty and inefficient:

With the exception of Bell Bay in Tasmania, which uses hydro power, Australia's smelters produce 15–20 tonnes of carbon dioxide per tonne of aluminium because their electricity comes from fossil fuels, mainly coal. This is two to three times the global average.

Wood and others (for example, Holmes à Court, 2019) suggest that the market liberalisation of the Australian energy sector, which has resulted in increased prices (see Denniss, 2018), compounded by the failure to proactively invest in renewables, is primarily to blame for the inefficiency and dirtiness of the Australian aluminium sector.

Regarding the crucial question about how reliable the electricity supply to aluminium smelters is, we need to ask whether coal actually *is* reliable. In fact, the Victorian brown coal power stations Loy Yang A and Yallourn W (which help supply the Alcoa aluminium smelter at Portland) are the two most outage-prone plants in the entire National Energy Market, accounting for almost a third of all breakdowns in the network between them. The brown coal Liddell generator in NSW is also notoriously unreliable, and the newest coal plant in Australia, Kogan Creek Power Station in Queensland, which was commissioned in 2007, is the most breakdown-prone individual unit of all (Quicke & Browne, 2020).

This unhappy situation is unnecessary. Coal-fired electricity is expensive, unreliable and polluting: far from being essential to aluminium smelting, it has been a disastrous source of power. Moreover, aluminium does not require coal for coking, as is presently the case for steel manufacturing; and with a sufficient, reliable supply of renewable electricity, aluminium smelting can occur with functionally zero emissions. This may imply the need for large-scale storage, including batteries and pumped hydro, along with reliable connectivity to the overall grid.

There is another dimension of synergy between aluminium smelting and renewable energy. Technological improvements to aluminium smelters can allow them to accept a more flexible temperature range in their smelting pots, and hence they can instantly accept substantial variations in purchased electrical current. Aluminium smelters could thus become very important sources of demand response in electricity demand,

thereby delivering greater energy efficiency in the smelting process itself, as well as greater stability across the grid.

In essence, smelters themselves would act as enormous batteries. These improvements already exist—indeed, they were pioneered in New Zealand—and have been installed at Trimet’s smelter in Essen, Germany (Djukanovic, 2019; Noble, 2014). Because of this technology, aluminium smelting in Australia could serve as a stabilising complement to the expansion of renewable electricity generation (Holmes à Court, 2019).

Manufacturers who use renewable energy to produce aluminium are able to charge a premium, since top-tier manufacturers are demanding sustainably sourced inputs throughout their supply chains. Numerous major Original Equipment Manufacturers (OEMs), including companies like Toyota, Apple and Volkswagen, have pledged to use low-emissions aluminium, but supply is thus far restricted (Lord, 2019). Many countries will experience physical barriers (for example, sunlight, landmass) in bringing the requisite renewable energy supply to bear, but Australia faces no such restrictions. Considering the beneficial on-effects to the broader economy, including regional economies, of aluminium manufacturing, governments should play a fiscal role in supporting the provision of renewable electricity to Australia’s smelters—as, in the past, they have subsidised non-renewable electricity.

A timely example of the possibility of using renewable energy to rebuild and modernise Australia’s aluminium industry is provided by the Portland aluminium smelter in Victoria. At present, the plant relies on electricity generated from brown coal, and hence its carbon emissions are higher than industry-wide averages. Other additional economic pressures (including corporate restructuring within Alcoa, the primary owner of the smelter) mean that the plant’s future is in question.

Various proposals have been advanced to develop sources of renewable power for the smelter (see, for example, Williams, 2019). Stanford (2016b) estimates that the closure of the Portland smelter would result in over 3600, and perhaps up to 8800, direct and indirect job losses, with an annual cost to the Australian economy of between \$800 million and \$1750 million. It would also push Australia further down the route of exporting unimproved, lower-value bauxite and alumina.

On the basis of the raw materials and renewable resources available to Australia, we can and should remain a major producer of aluminium for both the domestic and export markets. Our ability to follow through is dependent only on policy foresight and will.

Sun Metals Zinc Refinery with Integrated Solar Farm

Sun Metals provides another clear example of how energy-intensive manufacturing operations can benefit from co-investments in renewable energy. When grid electricity depends on coal as its primary energy source, it is neither cost-competitive nor reliable, imposing a burden on manufacturers that will only grow as time passes.

Sun Metals is an Australian subsidiary of Korea Zinc; it began refining zinc in 1999 close to the Port of Townsville. In 2018, the plant completed the largest integrated solar farm—in which the power plant is co-located with the industrial operation—in Australia (with 125 MW capacity), at a cost of \$200 million. The plant draws 30% of its electricity from this array, and it also exports surplus power to the grid. The company is also investigating wind power. In the words of Yun Choi, former chief executive of Sun Metals (and now chief executive of its Korean parent): ‘For Sun Metals, wind and solar generation offer the most competitive power prices’ (Ludlow, 2019).

Also in 2018, Sun Metals announced that it was planning to expand its Townsville refinery at a cost of \$300 million, adding another 820 direct and indirect jobs (Wainwright, 2018). The case of Sun Metals demonstrates not only that renewable energy is an affordable and reliable power source in heavy industrial applications, but also that Australia’s abundance of renewables is already attracting additional foreign manufacturing investment.

Food Manufacturing

Industrial food manufacturing processes rely on products and equipment, such as ovens, that use considerable quantities of natural gas. As renewable energy continues to become cheaper, it will make increasing economic sense to retrofit food processing factories, or to build new factories, with electrically powered equipment. Beyond Zero Emissions (2018) has estimated that by electrifying the manufacturing process, a prepared meal can be manufactured with half the energy input of a gas-fired production process. This electricity can in turn be supplied renewably.

The food manufacturing industry⁵ is an especially large and relatively stable employer in Australia (215,200 people as of November 2019; ABS 2019a). It is also a major electricity consumer: the Australian Bureau of Statistics (ABS, 2019b) reports that electricity expenditure by the entire food manufacturing subdivision was \$1.1 billion in 2017–18 (about one-fifth of all manufacturing electricity demand). The potential

⁵ Note the distinction between food manufacturing and primary agriculture, which is beyond the scope of this paper.

savings to this sector from the shift to renewable power generation, in addition to the switch from natural gas to electricity, would be substantial.

As a country with a large landmass and a low population density, Australia produces large quantities of food, and it is a net exporter. In fact, the food manufacturing sector bucks the overall trend of Australia's growing reliance on imported manufactures. In 2018–19, processed food and beverage product exports showed an increase of 10.8% over the previous financial year, and returned a trade surplus of almost \$12 billion (ABS, 2020; note that this does not include exports of fresh produce and meat).

The use of renewable electricity in food manufacturing therefore represents an opportunity to add value to our internationally respected agricultural products. In using renewable electricity, the industry would become more competitive, opening the possibility for even more employment opportunities.

A Substantially Expanded Hydrogen Industry, Based on Electrolysis

Hydrogen is a special case, as it is both a potential energy input into other manufacturing processes and a manufactured product in its own right (since it does not exist in usable form in nature). Current Australian hydrogen production, largely a by-product of the petrochemicals industry, is heavily polluting and highly reliant on natural gas energy. A proactive transition of this industry to renewable energy inputs would be less costly – ecologically and ultimately financially – than preserving the current energy mix. Additionally, due to hydrogen's increasing use as a fuel (for example, for transport and heating), new and expanding markets for this product are emerging.

Rather than orienting Australia's emerging hydrogen energy industry around export markets, Australia should consider ways of linking hydrogen production, including industrial and manufacturing processes, to the domestic use of hydrogen (Kaitsu et al., 2019). Otherwise, we will repeat the same errors that have consigned Australia to its current, underdeveloped role in the global economy, wherein we supply raw materials to other countries, which are then processed and manufactured into value-added products that we re-import at a premium price. With hydrogen, we could link the development of domestic capacity to domestic use, using that hydrogen to add value through other production processes.

This approach would reduce the international transportation costs associated with both the export of hydrogen and the resulting re-import of manufactures. Australian-manufactured hydrogen could support metal refining in contexts where the direct use

of renewables isn't immediately or always possible, and other processes, such as supplying fuel cells for hydrogen-powered vehicles. The parallel and balanced development of both the supply and demand side of the domestic hydrogen industry puts policy and investment levers wholly within Australian purview.

Some proposals for Australian hydrogen production have been geared towards producing hydrogen from hydrocarbons—fossil fuels—and sequestering the resulting emissions using carbon capture and storage (CCS; Commonwealth of Australia, 2019a). In Australia, CCS technology has already received around \$1.3 billion in public funding, but there is no meaningful track record of success to show for that investment (Browne & Swann, 2017). One interpretation is that CCS-linked hydrogen projects are simply another avenue to prop up the fossil fuels industry rather than an earnest effort to transform Australia's emissions profile. Hydrogen certainly has clear potential to make a big contribution to Australia's future industry, but only if it is linked from the beginning to the shift toward renewable energy.

Producing hydrogen through the electrolysis of water, powered by renewable energy and resulting in outputs of hydrogen fuel and oxygen, is a much more promising policy to pursue (Kaitsu et al., 2019). Costs for electrolyzers are decreasing quickly: Glenk and Reichelstein (2019) report that renewable hydrogen may become cost-competitive with large-scale fossil hydrogen supply within a decade. A 30% investment tax credit for electrolyzers could see renewable hydrogen reaching a competitive price four and a half years earlier than this.

Renewable production of hydrogen is not a far-fetched proposition. On 15 April 2020, the Australian Renewable Energy Agency announced a \$70 million fund for two or more large-scale renewable energy hydrogen electrolyzers (ARENA, 2020). The Hydrogen Park South Australia (HyP SA) facility is already under construction at the Tonsley Innovation District in South Australia: it will house a 1.25 MW electrolyser—the first Australian demonstration project of its scale and size. Small quantities of renewable hydrogen will be produced and blended into the local gas distribution network from mid-2020 (Spence, 2019). South Australia's world-leading wind and solar resources can be used to make additional hydrogen during times of surplus energy production—since at many times there is an oversupply of renewable power in this jurisdiction.

There are a number of other electrolyzers also under development in South Australia, including two much larger than HyP SA. Hydrogen Utility (H2U) is developing a 30 MW water electrolysis facility near Port Lincoln using wind and solar power to generate up to 18,000 tonnes of green ammonia (a compound of hydrogen) annually to supply local agriculture and industrial sectors. Neoen Australia is investigating the construction of a

50 MW hydrogen super hub, which would produce about 25,000 kg of hydrogen per day at its proposed Crystal Brook Energy Park (Spence, 2019).

Federal and state governments should commit to ongoing, equity ownership or co-investment in electrolysers—including research and development—and the renewable energy sources with which to power them. Australia certainly has the capacity to build a genuinely renewable hydrogen industry, but again the question is whether we have the policy determination to make it happen. An industrial policy pathway to support domestic green hydrogen production and use would make a huge contribution to the broader energy and industrial transformation of our economy.

Wind: Onshore and Offshore

Norwegian energy giant Equinor has plans to supply up to one-third of the electricity in the United Kingdom (UK) via the enormous new Dogger Bank offshore wind development in the North Sea. Initially planned with a capacity of 3.6 GW, it has the potential to expand by a factor of six. The initial development will include 300 turbines at a total capital cost of \$10 billion (USD; Lee, 2020).

Even setting aside the installation of Dogger Bank, the UK's energy mix is already focused on renewables to a remarkable extent, accounting for one-third of its *current* supply (BP, 2019). The rapid growth of offshore wind energy could therefore facilitate a dramatic expansion of renewable energy for the UK.

As with solar, Australia has incomparable natural advantages in wind energy, both onshore and offshore. We have a huge landmass and a lengthy coastline. Meanwhile, the cost of wind power generation has plunged more quickly than even highly optimistic analysts expected (Garnaut, 2019, p. 47).⁶ Sadly, Australia has yet to establish a regulatory framework for offshore wind power, and the future potential of this immense resource is not even being considered by energy planners.

Equinor is investing in wind in the UK not because the company is staffed by climate activists but because it recognises the economic and profit potential of the technology. Ironically, Equinor is the same company (majority-owned by the Norwegian Government) that considered drilling for oil in the Great Australian Bight – only abandoning the project in the face of strong popular opposition. Equinor and other companies (like Siemens, which is investing in green steel making even as it participates in the development of the Adani Carmichael coal mine project) are

⁶ For a discussion of the cost-competitiveness of wind power, see an earlier section in this paper, 'The Potential Savings of Renewable Power for Manufacturers'.

investing in renewables because there are enormous and durable commercial opportunities to be gained from doing so—if the right policy settings are in place.

Gemini Nevada Solar Array

Even in the US, where President Trump has expressed scepticism about renewable energy, companies and governments alike are expediting investments in renewables.

The planned Gemini solar array (Roth, 2020) in the Nevada desert joins other very large arrays across the south-west US, where solar power is, as in Australia, the cheapest source of new energy generation. The array is designed to produce 690 MW at full capacity, and it will include the world's largest battery (531 MW; Roselund & Sylvia, 2019). That capacity is over five times the size of the now-famous Tesla/Neoen battery at the Hornsdale wind farm in South Australia (100 MW, in the process of being upgraded to 150 MW). The Gemini project demonstrates that targeted renewable and storage investments now have the capacity to cheaply and reliably supply even the largest of industrial uses.

If applied to heavy manufacturing, what could be done with the quantity of energy represented by a project like Gemini? Major industrial power users also rely on power from integrated grids, from which additional renewable electricity can be accessed. Hence it is not essential for an individual renewable investment, such as the Gemini project, to single-handedly supply a large industrial process.

Nevertheless, it is telling that the potential capacity of these large renewable projects is now on par with the peak demands of even large industrial facilities, like primary metal manufacturing plants. This also opens the possibility for on-site investments tying renewable power directly to major industrial facilities. An investment like the Gemini project (supplemented with storage and back-up capacities) could meet the power demands of large steel or aluminium manufacturing facilities.⁷

Although solar arrays of the size of the Gemini project have yet to be built in Australia, this example demonstrates that we can move quickly and economically towards an energy mix with a much greater emphasis on renewables. That renewable energy can provide a competitive, reliable and sustainable energy base for even the heaviest manufacturing customers.

⁷ For example, the Portland aluminium smelter is Victoria's biggest single energy customer, with peak requirements at around 600 MW (Leitch, 2017).

Tesla Giga Nevada

Tesla's Giga Nevada battery and electric vehicle (EV) factory provides an example of a visionary project whereby, in a circular fashion, renewable energy is used to facilitate the further expansion and use of renewable energy. Tesla considers its mission to be to 'advance the world's transition to sustainable energy' (O'Kane, 2018).

The factory, near Reno, uses its own solar arrays to power the production of lithium-ion home battery packs and subassemblies for Tesla's electric cars. By co-locating most production processes, the so-called Gigafactory expects to capture economies of scale and savings from vertical integration. This will allow Tesla to reduce costs on battery production (which is the most expensive component in its EVs). It will do so in the hope that EVs will soon be cost-competitive with internal combustion vehicles, even without government subsidies and before considering the lower energy costs of operating EVs. The Gigafactory also mitigates Tesla's reliance on the supply of batteries from its external supply chain.

It is easy to see how the same principles of vertical integration and co-location could apply in the renewables-rich Australian context. We have both the renewable energy resources and the extractive industries already in place to benefit from large-scale vertically integrated sites.

When completed, the Gigafactory will employ an estimated 6000 people. A number of further Gigafactories are planned globally. Australia, with its abundance of lithium and solar resources, could be part of that story—but again, only if we have the policy courage to do so.

Opportunities to Add Value to Renewable Energy

The potential of renewable energy sources to spur a revitalisation of Australian manufacturing is not limited to the use of renewable energy as a cost-effective and reliable input to manufacturing. The development of renewable energy products and systems could be a major stimulus for the expansion of advanced manufacturing in Australia—since those products and systems imply enormous demand for manufactured inputs.

This section identifies opportunities for Australia to manufacture the products that will be required by an expanding renewable energy industry, both domestically and globally—in many cases leveraging our significant endowments of minerals and other natural resources. The connection between growing renewable energy investments and our own manufacturing output is doubly important, because manufacturing is itself an engine of sustainable growth. To transform to a low-carbon economy, both domestically and globally, we need to put in place a new energy infrastructure, which implies major demand for manufactured products (Gibson et al., 2019).

Lithium and Batteries

Over the past few years there has been a dramatic expansion in the use of lithium-ion batteries for a large variety of uses, at a variety of scales. Lithium-ion batteries are rechargeable; they carry a lot of energy for their size and weight; and they are easily aggregated.

In 2017, the global market for lithium-ion batteries was US\$30 billion; by 2025 it is projected to grow to over US\$100 billion, with over half of that to be in automotive usage. Other drivers of demand include consumer electronics, home energy storage and utilities. An example of utility use is the Tesla/Neoen battery in South Australia mentioned earlier (Harmsen, 2019). The combination of intermittent renewable energy sources such as solar and wind with lithium-ion battery storage makes for a powerful source of dispatchable energy.

Australia enjoys some of the richest accessible deposits of high-quality lithium in the world, largely in Western Australia. We are already the world's largest global producer of the unrefined material, with \$1.4 billion in exports in 2018–19 (Department of Industry, Innovation and Science, 2019). Unfortunately, however, as we have done

with other minerals, we are leaving the refining and manufacturing to our trading partners. We are allowing them to capture the value-added benefits of moving the product up the value chain, leaving us dependent on their exported useable manufactures. The opportunity cost is very significant: manufactured lithium batteries sell for 135 times as much as raw lithium per unit of potential energy (Manufacturers' Monthly, 2019).

It beggars belief that we could not improve on this imbalance with domestic manufacturing; and it certainly makes no economic sense for us not to be capturing that value-add in our own domestic manufacturing processes by employing our own workforce and thereby enjoying all of the associated upstream and downstream economic and social benefits, in a rapidly and inexorably expanding industry sector.

Electric and Hydrogen Vehicle Manufacturing: A New Model

Decarbonising the transport sector will play a significant role in meeting the Paris Agreement commitment of achieving net-zero emission by 2050, in order to limit global warming to 1.5°C. The marginal cost per kilometre of running an EV is presently about a fifth that of running a petrol car (Electric Vehicle Council, 2020). Meanwhile, the capital costs—the initial outlay—are expected to plunge as EV market penetration continues to increase, due to both economies of scale and increased competition between manufacturers. Globally, EV sales grew to more than 2 million units in 2018, an increase of 63% year-on-year (Hertzke et al., 2019). We already know from international examples (such as Germany, Sweden and Japan) that high-wage countries can successfully manufacture and export cars—even without the cost advantages that could be accessed through Australia's renewable energy resources.

Notwithstanding the devastating dissolution of the Australian car manufacturing industry and the concomitant damage to regional economies and communities (see Stanford, 2016c), there are promising signs for EV manufacturing in Australia. For example:

- Avass produces a range of electric buses, trucks and personal transport vehicles in Victoria (see avass.com.au).
- The bus bodymaker Volgren has begun to produce electric buses in Victoria (Schmidt, 2019).

- ACE EV will begin commercial production of electric utes and vans in Adelaide from next year, aiming to build 15,000 vehicles per year by 2025, with 80% of those vehicles oriented towards the export market (Evins et al., 2019).

If Australia was to integrate domestic lithium-ion battery and hydrogen fuel cell industries with a revived domestic car manufacturing industry, we would position ourselves to add substantial value all the way up the value chain: starting from the extraction of raw materials right through to domestic vehicle sales and a reinvigorated export industry in vehicles and parts.

Crucially, we can and should use renewable power in the process of manufacturing EVs. The sustainable goals of a resurgent car manufacturing industry focused on EVs would be at odds with the use of fossil fuel power.

By reimagining, reinventing and tangibly supporting Australian vehicle manufacturing, and combining such manufacturing with domestic lithium-ion and hydrogen industries based on renewable energy, Australia's energy security would be improved and the emissions of our transport sector would substantially decrease. By moving expeditiously, we could capture the benefits of serving both export and domestic markets ahead of some of the world's existing manufacturers.

Furthermore, on the demand side, the government could use its own purchasing power to stimulate the demand for Australian-made EVs. For example, in line with its zero-emissions target, the ACT Government is investing in a fleet of hydrogen-powered cars and electric buses. The Victorian Government has also linked its purchases of electric buses to growing manufacturing within that state by EV producers.

Active procurement strategies are always a powerful lever for stimulating domestic investment and employment in strategic sectors (see Stanford, 2018 for a review of examples). Governments ought to consider the full economic and social consequences of their spending decisions. It is surely preferable for Australian governments to support Australian jobs and communities by buying Australian-made vehicles.

Mass Transit and Rolling Stock

Active government procurement policy could also stimulate and reinvigorate other sectors of Australian manufacturing with a connection to renewable energy use. A good example is the major infrastructure investments that are being made in rail and other public transit equipment. The ongoing expansion of sustainable public transit will play a vital role in the decarbonisation of Australia's transportation sector. It will also

improve the efficiency and quality of life of our communities (especially in major cities).

We should carefully consider the full range of benefits of manufacturing rolling stock domestically, including the development and maintenance of our ability to engineer heavy, complex, innovation-intensive manufactures.⁸ Collectively, Australian purchases of railway equipment over the coming decades will be as economically important as our purchase of submarines⁹—a major expense that has elicited abundant attention and intervention by government to support domestic inputs and jobs. We should be at least as ambitious to optimise the industrial benefits from our equally important (but more peaceful!) purchases of transit equipment.

In 2018, Sydney to Melbourne was the second-busiest air route in the world (Adams, 2018). Taking internal combustion motors off the road and reducing air traffic by using high-speed intercity rail powered by an increasingly renewable grid would make a substantial contribution to decreased emissions. It could also make a substantial contribution to a resurgence of domestic manufacturing.

Wind Turbine and Solar Panel Manufacturing

The demand for wind power in Australia will increase dramatically in coming years, even in the absence of a meaningful renewable energy policy at the federal level. Australia should therefore maximise the domestic industrial spin-offs from our coming major investments in wind energy—for example, by linking fiscal and policy support for new wind power to purchases of Australian-made wind power equipment.

Danish wind energy giant Vestas has set up turbine manufacturing operations at the former Ford automotive factory in Geelong, Victoria (Vorrath, 2019); and wind turbine maker Keppel Prince Engineering is based in Portland, Victoria, building tower sections for large windmills. Both operations are highly scalable, and they employ not only production workers but also technical services staff.

An Australian solar panel manufacturing industry would also benefit greatly from proactive efforts to link coming solar power investments to Australian manufacturing. That would enhance the spin-off economic benefits from those solar investments. Using Australian materials to manufacture solar panels in Australia would also minimise transport costs. Australia's only solar panel manufacturer at present, Tindo Solar, is already expanding in response to an uptick in demand for locally-produced

⁸ Stanford (2016d) discusses the potential economic benefits of manufacturing rolling stock domestically.

⁹ See Deloitte Access Economics, 2013.

panels, bucking the downward economic trend caused by COVID-19 (AuManufacturing, 2020). With appropriate support and planning, there is no reason that much more of the coming expansion of Australian demand for solar power equipment could be translated into Australian manufacturing opportunities – rather than relying so heavily on imported solar power equipment as is presently the case.

Rare Earths Processing

Rare earth metals are a group of elements with unique metallurgical, magnetic and other properties that are critical to the production of many complex manufactures. Renewable energy products which use rare earths include magnetic components in wind turbines, many electronics (common in renewable energy systems), and even the storage and transportation of hydrogen (as alloys made with rare earths have superior electrochemical and thermodynamic properties for containing it). Geoscience Australia describes the rare earth elements as strategically important; at present, China accounts for almost all the world's rare earths production (Geoscience Australia, 2013).

As the federal government's own *Critical Minerals Strategy* (Commonwealth of Australia, 2019b) notes, Australia has the potential to become a powerhouse in the extraction and refinement of rare earth metals. While estimates of our rare earth deposits rank us sixth in the world (Geoscience Australia, 2018), rare earths are an under-explored and under-exploited dimension of our natural endowment.

In the realm of international security, the defence apparatus in the US and elsewhere also relies heavily on rare earths and their manufactures. Given the increasing tensions between China, our biggest trading partner, and the US, our most influential military ally, there exists a commercial and strategic opening—one which has been identified by the US defence establishment—for Australia to break China's near-monopoly over most parts of the rare earths supply chain (Bowen, 2019). As Uren (2019) points out, with this much at stake in a strategic sense, the case for government support for the rare earths industry is strengthened.

To expand the domestic manufacture of renewable technologies such as wind turbines and hydrogen infrastructure, we will need to ensure access to rare earth metals such as neodymium. While Australia enjoys rich deposits of these minerals, we have allowed China, in particular, to corner their extraction and refinement. We can undo this near-monopoly – quite possibly using renewable electricity sources, and thereby engendering a virtuous cycle of using renewables to expand the supply of renewables. The path dependency for manufactures associated with these minerals is one that we can and should fully control.

Sun Cable

Australia enjoys a superabundance of renewable energy, especially in comparison with major trading partners to our north, and this offers us a competitive advantage in the production and distribution of energy. Investors Mike Cannon-Brookes and Andrew Forrest have proposed a novel venture to take advantage of Australia's competitive advantage in renewable energy. They are proposing a 3750-kilometre underwater cable to supply one-fifth of Singapore's energy needs, powered by an enormous solar array near Tennant Creek in the Northern Territory (Edis, 2020).

The associated battery would be 150 times the size of the battery at Hornsdale, South Australia. The total estimated capital cost of the project is \$20 billion. There are no particular technological barriers associated with this project's scale: rather, it is simply a matter of aggregating and scaling up technologies already in use.

Innovative Australian manufacturing and construction technology would be essential to complete the enormous array in a cost-competitive manner. In particular, the array would be loaded out and 'unfurled' using forklifts in a concertina-type pattern, rather than being fitted to individual frames in the field (as occurs in conventional installations). This configuration has been developed by Australian company 5B, in conjunction with former car-parts supplier IXL (Edis, 2020).

Singapore is desperate to import Australian solar energy, as, due to its equatorial, rainy climate, solar arrays are far less feasible in Singapore than in dry and sunny Tennant Creek. Solar power imports from Australia would be cheaper than the Liquid Natural Gas (LNG) with which Singapore presently generates most of its electricity. Indeed, Cannon-Brookes has noted that it is possible that Singaporean customers would then get cheaper electricity via Sun Cable than Australian customers currently do. If this infuriates Australian consumers and governments, it might spur them to accelerate their own, similar arrays (Mazengarb & Parkinson, 2019).

The implications of this project (and other potential projects like it) for Australian manufacturing are significant. First, the project confirms again the unmatched potential to tap Australia's renewable energy capacity with large, industrial-scale generation projects. The obvious conclusion to draw from this is that if we can develop these resources to benefit far-off Singapore, then surely we should use them to meet our own energy needs (for example, by powering a manufacturing renaissance) in a cost-competitive, reliable and sustainable manner.

Second, the Sun Cable project implies massive new demand for manufactured inputs, associated with the solar array, the cable, supporting transmission facilities, and related machinery and equipment. Further planning and development of the project

should make maximising the domestic manufacturing spin-offs for all these capital goods a high-priority condition for the project's approval. With adequate notice, planning and fiscal arrangements, hundreds of Australian manufacturers could supply most of the project's varied manufactured inputs—thus demonstrating, once again, the virtuous circle which can link Australian renewable energy and Australian manufacturing.

International Evidence: Renewable Energy and Manufacturing Success

International experience decisively refutes the Commonwealth Government's argument that Australian manufacturing is fundamentally and intrinsically reliant on continued consumption of coal and other fossil fuels. To the contrary, there are clear and inspiring examples of other countries which have placed a much greater emphasis on renewables in their energy mix, yet which have enjoyed success in manufacturing production and exports far superior to Australia's.

This happy combination of renewable energy development and manufacturing success reflects a more forward-thinking policy orientation in both dimensions. These countries have recognised the strategic importance of maintaining a strong domestic advanced manufacturing sector. In addition, they have embraced the inevitability, but also the opportunity, of renewable energy development. Australia should seek to emulate this approach on both fronts, instead of continuing to pretend that fossil fuels are the only way to power industry.

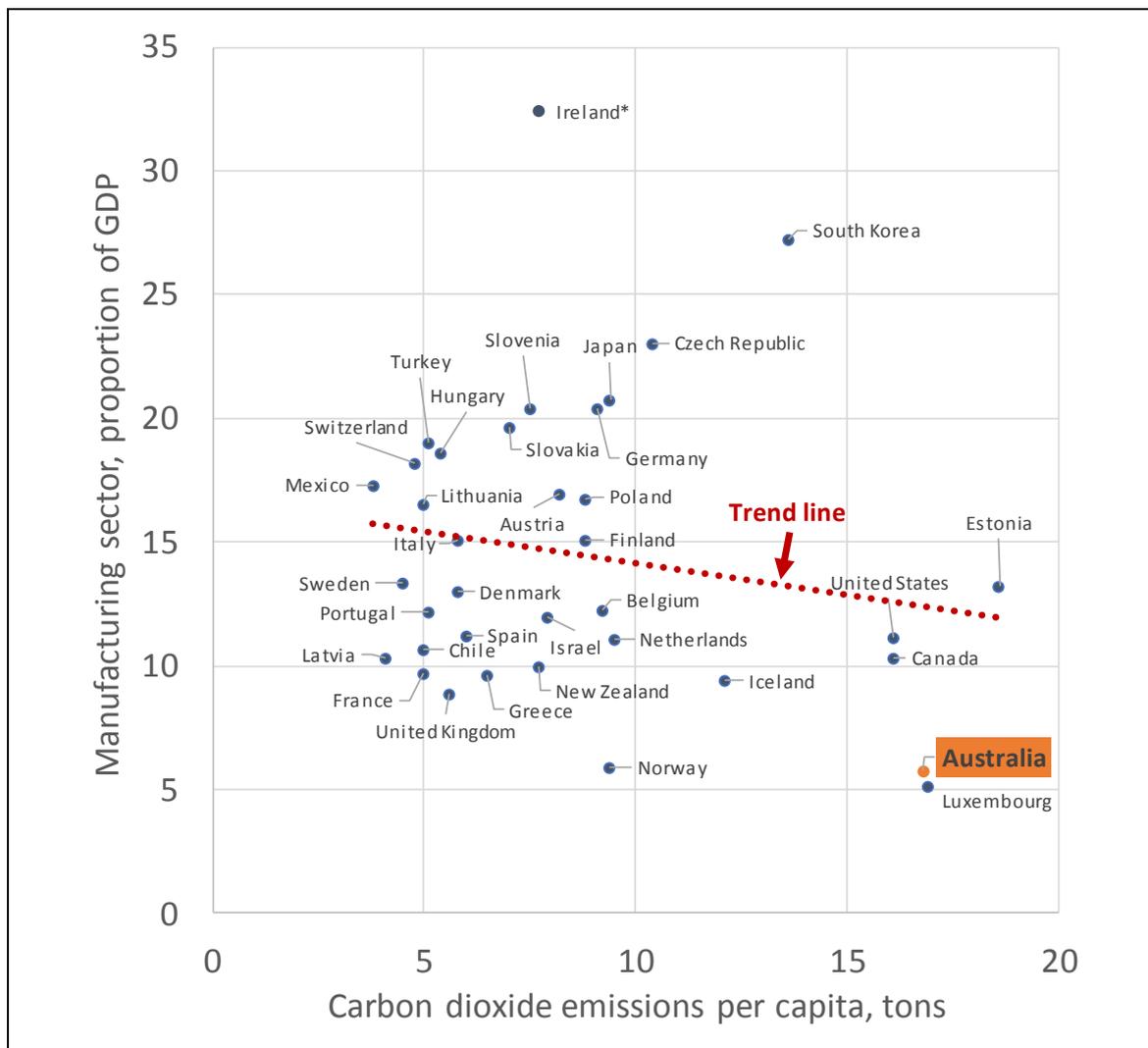
Notwithstanding Japan's poor natural resource endowment and reliance on imports of Australian fossil fuels, that country still manufactures far more than Australia, while emitting far less carbon (on a per capita basis). Meanwhile, notably, Germany deliberately and rapidly phased out its coal mining industry, and is doing the same with coal-fired electricity, while mitigating impacts on affected workers. Yet Germany continues to rank as perhaps the world's most successful advanced manufacturer, including in heavy manufactures.

Germany's ongoing industrial success, alongside its ambitious energy transformation away from coal and towards renewables, is described in detail by Sheldon et al. (2018). Germany still generates a proportion of its electricity from coal, but this is a far smaller proportion than Australia—and thermal coal use will be eliminated entirely in coming years. Yet Germany does not enjoy the abundance of renewable resources that Australia does. A similar story can be told of virtually every European nation.

Meanwhile, South Korea is another manufacturing powerhouse, again producing vast quantities of high-tech manufactures for world markets while emitting far less carbon per capita than Australia.

As illustrated in Figure 3, which shows the relationship between manufacturing intensity and CO₂-equivalent emissions, most other industrial countries are outperforming Australia on both reducing emissions and supporting domestic manufacturing. Across the OECD, only tiny tax haven Luxembourg has more emissions and less manufacturing than Australia, on a proportional basis. The claim that continued fossil fuel consumption is essential to the future of manufacturing is decisively refuted by this international evidence.

Figure 3. Manufacturing Success and Carbon Intensity, OECD Nations, 2018.



Source: 'Manufacturing, value added (% of GDP)' and 'CO₂ emissions (metric tons per capita)', World Bank (2019a, 2019b). Note: In a small number of cases, the latest manufacturing sector (vertical axis) data are from 2017, 2016 and in the case of Canada, 2015. CO₂ emissions exclude land use. * Irish GDP data must be interpreted with caution (due to issues of international tax shifting); however, removal of Ireland does not affect the general correlation.

There is no positive statistical relationship between the relative strength of manufacturing in OECD countries and their carbon emissions. In fact, there is a weak negative correlation between manufacturing success and carbon pollution: in general, countries which emit less tend to manufacture more.¹⁰ Australia is in the worst of both worlds: it is an extremely high emitter per capita, with a hollowed-out manufacturing sector.

In other words, our voracious consumption of fossil fuels has not helped us add value or complexity to our merchandise, nor has it moved our goods production up the value chain. If anything, Australia's continued over-reliance on the production, consumption and export of fossil fuels has probably contributed to the extreme deindustrialisation of the national economy since the turn of the century.¹¹

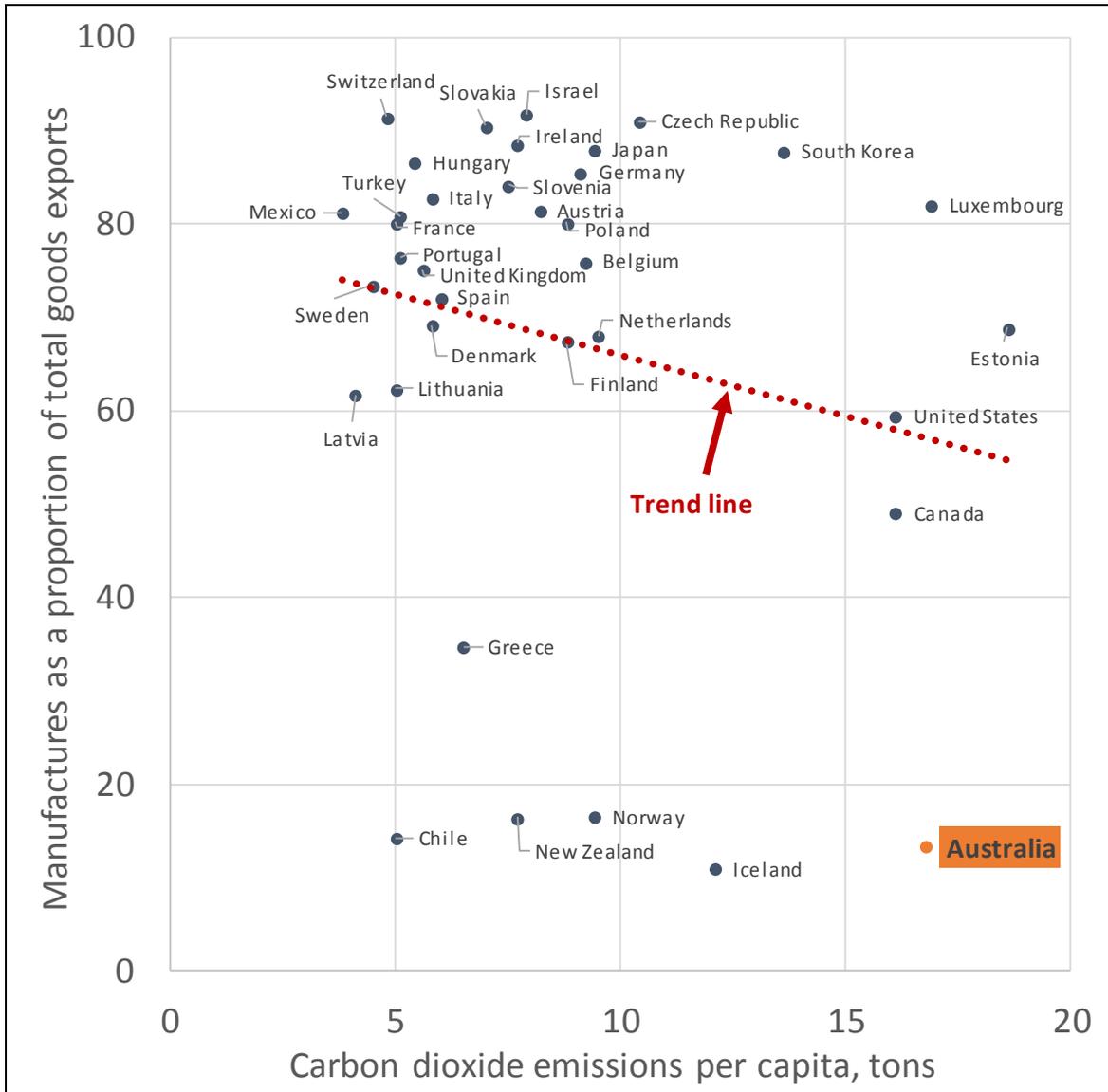
Figure 4 illustrates the relationship between carbon emissions and manufacturing exports, further supporting the position that Australia could expand manufacturing while also expanding the use of renewable energy. There is virtually no OECD nation doing worse on manufactured exports than Australia: we export fewer manufactured goods (as a share of total merchandise exports) than every OECD country except Iceland.

Yet Australian carbon emissions per capita are among the highest in the OECD. Only Luxembourg and Estonia emit more carbon per capita than Australia, but their manufactured exports are far more important to their international trade than are ours. Conversely, a handful of countries experience very weak manufacturing exports (similar to Australia's), but they have carbon footprints that are considerably smaller than ours. Meanwhile, the large majority of OECD nations have successfully maintained more manufactured exports while emitting far less per capita.

¹⁰ That negative relationship is not statistically significant, with a correlation coefficient of -0.18.

¹¹ One channel through which fossil fuel reliance has undermined domestic manufacturing is through exchange rate effects. When global commodity prices were very high, and large amounts of foreign capital flowed into Australia for fossil fuel projects (such as coal mines, LNG plants and petroleum projects), Australia's exchange rate became vastly overvalued—reaching a peak of US\$1.10, some 75% higher than its purchasing power parity level. This effectively priced Australian-made manufactures out of world markets and clearly contributed to the closure of many Australian manufacturing operations, including motor vehicle assembly. See Stanford (2016a, 2017) for more discussion of the impacts of resource-driven appreciation on Australian manufacturing. With the Australian dollar falling back to levels more consistent with purchasing power comparisons, this cost distortion has largely dissipated, and Australian manufacturing facilities are once again very cost-competitive with their peers in other industrial countries.

Figure 4. Manufacturing Share of Exports by Carbon Intensity, OECD Nations, 2018.



Source: ‘Manufacturing, value added (% of merchandise exports)’ and ‘CO2 emissions (metric tons per capita)’, World Bank (2019b, 2019c).

Examining the trendline, we see that two remarkable facts present themselves.¹² First, broadly speaking, countries that export more manufactures emit less carbon. Second, Australia performs far worse than even that trend would suggest: even given our unique over-reliance on fossil fuels (and resulting carbon pollution), we still export far less manufactured goods than we ‘should’. This dramatically demonstrates the failure of Australian policy making, in energy and climate policy as well as in industrial policy.

¹² The statistical relationship is not significant, with a correlation coefficient of -0.21.

This strongly suggests that successive governments have been asleep at the wheel, failing to connect our industrial development to our energy and trade policies. The need to quickly reduce our reliance on fossil fuels as a source of both domestic energy generation and export income is a policy imperative that we have faced for decades.

The matter becomes even more vexed when we consider again the wealth of renewable resources that Australia enjoys. Australia's competitive advantage in the production of renewable energy—a product that will undoubtedly be one of the most valuable commodities in the future global economy—should be leveraged as an engine for revitalising manufacturing, diversifying our trade and decarbonising our economy.

Policy Recommendations

We have reviewed the positive potential of Australia’s renewable energy endowment to power a revitalised and prosperous domestic manufacturing industry. The technology, reliability and cost advantages of renewable energy are undeniable. Equally undeniable is the evidence that other countries are doing much better than Australia on both fronts, supporting successful domestic advanced manufacturing while reducing reliance on fossil fuel use more rapidly and enthusiastically.

Australia faces an extraordinary opportunity to embrace and develop our unmatched renewable energy endowment to power high-value industrial and technological development. Doing so would make Australia a sustainable manufacturing superpower. This opportunity will be squandered, however, unless Australia quickly establishes a consistent, stable and comprehensive policy framework to guide decisions in both the energy and the industrial realms of our economy.

Simply leaving these decisions to ‘the market’ will never allow our economy to capture the full economic and social benefits of sustainable manufacturing, just as private market forces have failed, in the past, to achieve the well-rounded industrial development we need. The confusion and inconsistency of recent Australian energy policy—marked by repeated, whiplash-inducing changes in direction, and dominated by fleeting political calculations—has made matters worse, inhibiting and discouraging private companies that would otherwise be moving forward on purely profit-maximising grounds. Even Reserve Bank Governor Dr Philip Lowe has stated that policy uncertainty is affecting renewables investment, notwithstanding the enormous opportunities in the sector (Wright, 2020).

Below are summarised several of the most important policy principles that would confirm and accelerate the energy transformation of Australian manufacturing, thereby helping our industry to make the most of the renewable energy opportunity before it.

1. Australia desperately needs clarity and stability in energy policy, to affirm to all stakeholders that our commitment to emissions reduction is meaningful, permanent and consistent with international targets. Even the business sector has made clear its desire for the federal government to institute a firm Paris-consistent policy mechanism, so that businesses can make informed investment decisions that will not subsequently be undermined by unexpected changes in policy and politics.

2. In this context, the introduction of carbon pricing in some configuration would help to immediately rebalance Australia's industrial incentive structure in favour of cleaner manufacturing. Economy-wide, this could be revenue-neutral (with revenues recycled into other fiscal measures or projects), while reshaping our overall industrial profile and changing the way firms do business. A carbon price would incentivise manufacturers to seek efficiencies in their energy usage, and it would also reinforce incentives to develop sustainable sources of energy to power their own operations (and to supply their surplus energy to the grid).
3. Governments at the federal, state and local levels can and must play an active role, partnering with both renewable energy firms and manufacturers working to develop Australia's sustainable manufacturing potential. These efforts should include:
 - a. fiscal and investment strategies to accelerate renewable energy initiatives linked to domestic manufacturing opportunities; these could include fiscal support for the production and use of renewable energy (eg. through the Clean Energy Finance Corporation and the Australian Renewable Energy Agency), direct equity investments and co-investments in new manufacturing projects, and favourable tax treatment of sustainable manufacturing investments (such as investment tax credits)
 - b. provision of public goods to assist these firms to facilitate training for workers in transitioning industries (noting that the future prosperity of regional Australia will be very much tied up in the success of these workers and businesses)
 - c. leveraging of government procurement to favour domestic manufacturers who are actively engaged with the renewable energy transition.
4. Sector-specific industrial policy strategies must be developed in key identified manufacturing sectors that can benefit from inputs of renewable energy, and/or that can supply manufactured inputs to renewable energy developments. Potential sub-sectors which could benefit from such strategies include:
 - a. primary metal production (including 'green' steel and aluminium production)

- b. lithium-ion battery production
 - c. EV manufacturing
 - d. manufacturing public transit equipment
 - e. producing wind and solar generation equipment.
5. A key factor in the successful roll-out of renewable energy in Australia will be upgrading and strengthening transmission and exchange facilities, which have been badly damaged by years of short-sighted profit-seeking and regulatory failures in Australia's largely privatised electricity system. Federal and state regulators must move urgently to facilitate improvements in transmission capabilities and interconnectivity with spatially decentralised renewable power projects. This will require greater accountability and long-range planning from private utilities, and/or expanded public ownership.
 6. The expansion of renewable power supplies, and their connections to manufacturing, must be undertaken with full commitment to high-quality standards, the use of fully qualified labour, fair employment practices, and the consultation and involvement of Traditional Owners. The renewable energy industry must uphold the highest social and labour standards, as well as environmental standards. This commitment will be especially important if we are to convince Australian workers that renewable energy (including its application in innovative value-adding manufacturing) can be a site of high quality, stable jobs as the economy decarbonises.
 7. A national, independent statutory authority should be established to design plans for economically and socially rewarding labour market transitions into the high-value industries that will play a leading role in the low-carbon economy of the future. This authority should design these plans in conjunction with affected businesses, workers, unions, educational institutions (such as TAFEs) and other stakeholders. Its tasks would include managing adjustments and transitions for workers in affected fossil fuel industries (including coal-fired electricity generation and thermal coal mining), as well as mobilising and training the workers who are required in a growing, sustainable manufacturing sector.
 8. Given that institutional investors are acutely aware that Australia's energy arrangements are in flux (see, for example, Anthony & Coram, 2019), they should consider the medium- and especially long-term payoff of weighting their energy investment mix towards renewables in line with CSIRO's cost estimates.

This could be expected to have positive effects for renewables investments and usage throughout the value chain (for example, economies of scale and large-scale supply agreements signed between producers of electricity and retailers/consumers).

- a. This stance would be especially advantageous in an investment environment where the clients of institutional investors are more actively interested than ever in how their savings are invested.
 - b. Large investors should also exert pressure on governments to adopt consistent and ambitious energy and climate policy settings.
9. Hydrogen is likely to be a major output from, and input into, manufacturing processes in years to come—both in Australia and internationally. We are at a crucial juncture in terms of getting the industry settings right. Proposals to develop a hydrocarbon-based hydrogen industry (even using unproven CCS technologies) would not advance the goals of either decarbonisation or revitalised domestic manufacturing—and Australians would be stuck with huge sunk costs that would make it even harder to reorient hydrogen production in the future. Instead, Australia should expect policy clarity and targeted government co-investments in a green hydrogen strategy, with priority placed on maximising the potential manufacturing spin-offs through both greater use of hydrogen in domestic manufacturing processes and maximisation of the domestic manufacturing content in hydrogen projects.

Conclusion

Contrary to the simplistic claims of Prime Minister Scott Morrison, former Resources Minister Matt Canavan and others, the relationship between manufacturing and fossil fuels is not at all essential or permanent, even for heavy industry. We know this from both international experience—with manufacturing representing a much larger share of GDP and exports in countries that have achieved a more sustainable energy mix than in countries that have not—and from the ambitious innovation and investment plans of prominent investors and industrialists in Australia.

The COVID-19 pandemic has reinforced the importance of manufacturing self-sufficiency and shorter, less complex, supply chains. In rebuilding our economy in an inevitably changed post-pandemic configuration, Australia is especially fortunate to have access to abundant renewable energy sources. Once the immediate danger of coronavirus has passed, we will still be in a world that needs to undertake a climate-related industrial transition. With the right policy settings in place, our renewable resources will serve us well in fostering economic reconstruction after the pandemic.

Australia's superabundance of renewable energy resources makes supplying renewable electricity both cost-competitive and reliable. Renewable electricity can be substituted for fossil fuels in almost all industrial contexts—and research and development presently underway will quickly close the remaining gaps (such as replacing coking coal in steel making with non-carbon processes).

It is just as well for our many manufacturing firms—and the almost one million workers who are employed across the industry—that there are so many opportunities to support and expand the industry using renewables. Indeed, the Commonwealth Government's own analysis shows that domestic coal-fired electricity is powering down, and that renewable power sources will increasingly dominate our energy supply—notwithstanding the government's awkward and inconsistent tendency to deny that this is happening. Moreover, the gloomy commercial outlook for the coal industry creates additional impetus for the development and availability of new, high-quality jobs in industries that are more sustainable (both commercially and ecologically).

With important investments being made in renewable energy by the private sector (including major manufacturers) almost daily, one gets the impression that the government is downplaying, obscuring or even undermining the extent to which our manufacturing industry is already integrating renewables (or planning to). The

manufacturing industry is embarking on the inevitable and beneficial transformation of its energy infrastructure, notwithstanding the policy confusion and dearth of support coming from our government. The government's failed attempt to shut down its own profitable 'green bank' (the CEFC), and its unwillingness to expand the CEFC into new areas (such as demand response initiatives or green hydrogen production), are demonstrative of a lack of ambition and vision. Meanwhile, new coal projects continue to receive favourable government attention—even as they find it harder to access private finance.

That Australia would not have already seized the positive potential of its renewable energy wealth to foster an industrial renaissance reflects a general lack of courage, imagination and proactivity on the part of policy makers, and this has caused a series of lost opportunities. However, it is not too late to overcome these failures and grasp the enormous potential of sustainable manufacturing: Australia has the natural resources and investment wealth to pivot to renewables and simultaneously reinforce the strategically important and socially beneficial manufacturing sector.

Australia's past mismanagement of our natural endowment of raw materials has resulted in an over-reliance on pure extraction and export. Some refer ironically to Australia as the 'lucky country,' given this abundant but badly managed resource endowment. We should set a better industrial, economic and environmental direction for our country. It is well past time that we, as a nation, made our own luck.

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