EXECUTIVE SUMMARY

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The *New* Energy Trade

Harnessing Australian renewables for global development

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The Superpower Institute

About Reuben Finighan

Reuben Finighan holds a PhD in Political Economy from the London School of Economics and a Masters of Public Policy from the Harvard Kennedy School, as a Fulbright, Frank Knox, John Monash, and Leverhulme scholar. He has co-authored papers with Harvard Professor Robert Putnam, Ross Garnaut AC, and Lord Nicholas Stern, and previously worked at the University of Melbourne in applied economics and as Chief Economist for the Universal Commons.

Reuben is currently Research Lead, Economic Pathways at The Superpower Institute.

About The Superpower Institute

Founded in 2023 by economist Ross Garnaut and public policy expert Rod Sims, The Superpower Institute is a not-for-profit organisation dedicated to helping Australia seize the extraordinary economic opportunities of the post-carbon world.

The Institute's focus is on developing the policy settings, market incentives and practical knowledge necessary for Australia to become a major exporter of renewable energy and green industrial products. By leveraging the nation's comparative advantage, the Institute aims to elevate Australia's economic and climate ambition and secure its place as a leader in a decarbonised global economy.

This report was authored, edited and designed on the Traditional Lands of the Wurundjeri People of the Kulin Nation. We pay our respects to their Elders past, present and emerging and acknowledge their enduring connection to the land, waters and community.

As Australia advances toward a new era of clean energy trade, we recognise the vital importance of ensuring that First Nations communities benefit equitably from these opportunities. Their stewardship and deep knowledge of this land remain invaluable as we work toward a sustainable, just and inclusive energy future.

The Superpower Institute
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Foreword

Australia has an opportunity to turn its exceptionally rich resources for producing renewable energy and sustainably harvested biomass into immense quantities of zero-carbon products that replace goods made with large carbon emissions. Utilising that opportunity makes it possible for the densely populated, highly industrialised countries of the world to achieve net zero emissions without suffering large reductions in their standards of living. And it makes it possible for Australia to return to full employment with rising living standards for most of its people after an unprecedented decade of stagnation.

These opportunities were sketched in *Superpower: Australia's Low-Carbon Opportunity* five years ago and *The Superpower Transformation: Building Australia's Zero-Carbon Economy* in 2022. This paper by Reuben Finighan at The Superpower Institute turns that sketch into a portrait.

International trade in fossil carbon has made modern economic development supporting high standards of living possible in Northeast Asia and Europe despite their own coal, oil, and gas resources being able to support only a small proportion of their requirements for energy and carbon industrial inputs. Reliable supply from Australia has played an important part in that trade, especially for Northeast Asia.

Finighan's work shows that Australia's role will be even more important in the world of net zero carbon emissions that we must build quickly if we are to avoid human-induced climate change causing catastrophic disruption of living standards and political order all over the world.

Finighan examines in detail the quantities of renewable energy and biomass that will be required to achieve net zero emissions in Japan, Korea, China, Europe and India. Japan and Korea are the extreme cases of economies able to supply economically only a small proportion of their energy and carbon-related industrial inputs in a zero-emissions world. China and Europe now and India as its modern economic development proceeds will have proportionately smaller but absolutely immense requirements. Together these economies account for over half of global greenhouse gas emissions. Australia is one of several countries which can produce economically much more than their own requirements of goods with net zero emissions. It is distinguished as the country with by far the largest capacity to export to the densely populated, highly developed countries of the northern hemisphere.

Success for Australia requires continuing analysis of the Superpower opportunity, continuing development of policies to allow the emergence of large, new industries, and continuing structural change. That is only possible if governments, businesses and communities are well-informed. The Superpower Institute looks forward to contributing to continuing development of the knowledge building process that has been advanced by Finighan's important contribution.

Ross Garnaut
The Superpower Institute

In most major economies, there will not be enough cheap clean energy available to meet demand by mid-century.

This is Australia's opportunity to contribute to global climate mitigation, and to benefit from large scale exports.

Introduction

This paper is about the crucial—and widely neglected —role of international trade in achieving least-cost mitigation. Cheap clean energy is crucial to achieving the world's decarbonisation ambitions and sustaining global growth in living standards. But in most major economies, cheap clean energy is either already scarce, or will become so before mid-century.

Future clean electricity demand is underestimated by most analysts. The availability of cheap clean electricity is overestimated. In a few fortunate countries, exceptional renewable resources are effectively unlimited; the supply curve is low and flat. Differences in cheap energy availability will drive mutually beneficial trade.

This is the argument of Garnaut (2015; 2019), who posits that Australia can act as a renewable energy "superpower" that exports energy-intensive products at large scale.

This argument is tested in a much more detailed analysis in this paper, the first edition of an ongoing Superpower Institute study of international trade in clean energy. It examines the clean energy supply challenges faced by five major economies—China, India, Japan, Korea, and Germany—and the potential for Australia to assist by exporting cheap clean energy.

The new energy trade will differ markedly from the fossil fuel trade. Exporting clean energy as hydrogen or ammonia is extremely costly. Clean energy will be exported as energy embedded in energy-intensive products, including iron/steel, aluminium, silicon and polysilicon, ammonia and urea, and green fuels for shipping, aviation, and heavy-duty road freight.

The argument depends on establishing the magnitude of future clean electricity demand, driven by electrification and economic growth, against the availability of cheap zero-carbon energy. It depends on establishing the much lower costs of solar and wind against nuclear power, bioenergy, and carbon capture and storage.

This analysis finds that even with acceleration, the five countries examined are on track for large shortfalls in clean electricity supply, equal to between 37 and 66 percent of future demand by around mid-century (or 2060 for China and 2070 for India). Their options for closing the gap themselves are internationally uncompetitive.

Australia's "superpower" exports can, on average, close a majority of these countries' supply-demand gaps. They can do so at a price cheaper than any alternative. Like the contemporary trade in fossil fuels, this would lower energy prices in all countries compared to autarky.

All major analysts anticipate that renewable energy will dominate grids in most countries. Among the alternatives, nuclear is expensive and will play a minor role even in countries where heavy subsidies render it competitive, such as China. Even if China triples its recent nuclear build rates, nuclear may contribute only 7 percent electricity supply in 2060. Table ES.1 summarises the supply outlook in the five focal countries.

Australia's potential contribution to global mitigation via these exports is large, equal to between 6.7 and 9.6 percent of 2021 emissions. The emissions replaced will be those that are most expensive to remove, and least likely to be removed, in the importing countries. The required renewables would occupy around 0.6 percent of Australia's land mass, or 1.1 percent including the space between wind turbines.

The total potential revenue from Australian superpower exports is $693 billion at today's levels of industrial output, or $987 billion at forecast 2060 levels of output. Iron accounts for half of the contemporary potential, and around a third of that in 2060. The total is 6 to 8 times larger than needed to replace typical revenues from Australian fossil fuel exports, which will decline to mid-century.

Realising the Australian superpower trade requires correcting market failures, using market forces instead of picking winners, preserving open international trade, maintaining low interest rates through careful management of fiscal and monetary policy, timely approvals processes, and securing policy certainty via bipartisan recognition of the opportunity.

Table ES.1 - When deployed at scale, clean energy technology costs across the five countries will be high

	India	China	Korea	Japan	Germany
Renewables	**Cheap today, uncompetitive at scale** as better resources are exhausted. Highly seasonal, large integration costs. Indian situation worse than Chinese.		Among the **most expensive in the world today**. Costs rise further as resources are exhausted. Offshore wind dependent, doubles costs.		**Expensive today.** Very poor solar. Moderate wind limited, quickly exhausted.
Nuclear	**Expensive**, costs rising over time.	**Uncompetitive** when on a level playing field; relies on large taxpayer subsidies.		**Expensive,** costs sharply rising.	**Banned.**
CCS*	Major projects depend on enhanced oil recovery for viability; this is not net-zero and will be phased out. Potentially competitive for retrofit on stranded assets; opportunity applies to limited number of convenient sites. New-build CCS plants are uncompetitive and have a lower expected “learning rate” than competitors. Long-run potential is therefore low. However, important for non-electrifiable industries.				
Bioenergy	**High cost** outside of niches, rising marginal cost with scale. Carbon feedstock needs will push far up supply curve.		**Negligible resources**, biomass needed as a carbon feedstock. None left for bioenergy.		

* Carbon capture and storage.

01.
Context: The new energy trade

Fossil Fuel Trade

Global development rests on the international energy trade. Today, as much as 60 percent of fossil fuel energy is traded internationally, half of that directly in the form of coal, gas, and oil, and half indirectly as the fossil fuel energy embedded in traded goods and services. Without this trade, sustained growth in global living standards would have been impossible; most countries have only enough resources to burn brightly for a moment, before depletion would return them to poverty.[1]

Clean Energy Trade

The clean energy trade is no less significant for achieving international goals in the twenty-first century. It will underpin rapid and least-cost climate mitigation and further improvements in global living standards.

This clean energy trade will, however, differ qualitatively from the fossil trade before it. The significance of this trade, and its novel properties, have been largely neglected in the international discussion.

This paper examines the dynamics of the clean energy trade, its benefits for China, India, Japan, Korea, Germany, and more briefly Europe and Southeast Asia, and the role of Australia as one of what Garnaut (2019) calls the "superpower" countries.

The clean energy trade will be driven by the interaction of three realities:

1. **The high cost of transporting clean energy**

   The high cost of transporting clean energy as a fuel means that it will mainly be traded as embedded in goods and services. Fossil fuels are cheap to transport, but shipping clean energy as hydrogen, ammonia, or other intermediaries involves very large losses. This will cause a shift away from trading energy directly and towards trading embedded energy. The new energy trade will be primarily a trade in energy-intensive goods.

2. **Uneven distribution of low-cost renewable resources**

   Some countries have large comparative advantages in clean energy production. Renewable energy has become by far the cheapest

[1] Great Britain, for example, reached peak coal in 1913. It purchased a majority stake in the Anglo-Persian Oil Company the next year, which later became known as BP (Kuiken, 2014).

source of clean electricity, and its costs continue to decline. Like fossil fuels, the costs of renewable energy differ across the globe. The cheapest energy will be found in countries with solar and wind resources that are more intense, less seasonal, and that exhibit greater complementarities, especially where those countries have abundant land relative to population and economic size.

3. **Demand growth and resource limits**

   Comparative advantage cannot be adequately understood without accounting for the effects of growth in clean electricity demand. Many countries appear to have renewable resources of at least moderate quality. However, growth in electricity demand—driven by continued economic development and the electrification of economic activity—will be sufficient to exhaust most countries' cheaper renewable resources. Marginal costs rise thereafter. In "superpower" countries such as Australia, world-class resources are effectively unlimited and the supply curve is relatively flat.

The embedded clean energy trade, like today's fossil fuel trade, will make the world's cheapest clean energy available to all economies.

The superpower trade in energy-intensive goods

The "superpower" trade is defined as the trade in energy-intensive products including iron/steel, aluminium, silicon and polysilicon, ammonia and urea, methanol, and green fuels for heavy-duty road freight, shipping, and aviation.

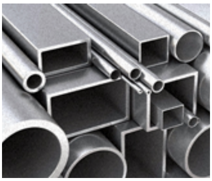
The case for the trade was first made at a high level by Ross Garnaut (2015; 2019; 2022), who identified the potential for Australia as a renewable energy superpower. This paper tests and extends Garnaut's arguments with a detailed analysis of future energy supply and demand in five potential importing countries: China, India, Japan, Korea, and Germany.

"The embedded clean energy trade, like today's fossil fuel trade, will make the world's cheapest clean energy available to all economies."

The Superpower Industries

Iron / Steel

Iron and steel-making is energy-intensive and largely reliant on metallurgical coal. Australia is the world's top supplier of iron ore, with a 40 percent share in global exports, and it feeds the mills of China, Japan, and Korea. New technologies allow zero carbon iron/steel to be produced using clean electricity, but electricity demand will be immense – around double all the electricity used in the European Union.



Aluminium

Aluminium production is three times as energy-intensive as steelmaking, although volumes are much smaller. Australia is the world's largest aluminium ore exporter, with around a 30 percent global share. China, the world's largest producer, mainly makes aluminium using coal-powered electricity. Shifting to clean electricity could drastically cut emissions.

Silicon & Polysilicon

Silicon and polysilicon are essential for solar panels and all kinds of electronics. The former is twice as energy-intensive as steelmaking, while the latter is 20 to 50 times as intensive. China overwhelmingly dominates global production, and powers its factories with coal-based electricity. Demand is rapidly growing due to increased production of solar panels and superconductors

Green Fuels for Shipping, Aviation, and Road Freight

Shipping, aviation, and road freight together consume about 30 percent of global oil. Decarbonisation may occur via batteries for a large share of road freight, a small part of shipping, and a tiny fraction of aviation – but the rest will require green fuels. Production of green fuels is extremely energy-intensive and volumes are very large; it will increase demand for clean electricity more than even steelmaking.

Ammonia & Urea

Ammonia is the essential foundation of nitrogenous fertilisers such as urea, and has rich potential as a green fuel, especially for long-term energy storage. Production is twice as energy-intensive as steelmaking, and mainly occurs via natural gas but with large coal-based production in China. It can be produced using clean electricity instead, via hydrogen electrolysis.

Methanol

Methanol serves mainly as a chemical feedstock for industrial products, notably plastic, although is also a useful fuel. In China, the top producer, methanol is primarily derived from coal, while natural gas is the main source elsewhere. Green methanol, derived from green hydrogen and sustainable carbon sources, offers a lower emission alternative.

02. Methodology: Estimating demand and cheap supply

The paper builds the argument up through a series of transparent analytic steps.

Building a 2021 electrification model

The first step is to build a 2021 electrification model: a model of how much electricity demand would rise, if the five focal countries were maximally electrified today. Today, only 29 percent of fossil fuels globally are used to produce electricity. The remaining 71 percent will be decarbonised through a variety of means, but electrification will dominate. Electrification can be avoided with carbon capture and storage (CCS), direct use of biomass, or via trade. These are accounted for in later steps.

The electrification model involves a detailed analysis of the various uses of coal, gas, and oil, the feasibility of electrifying those uses, and the anticipated efficiency of electrification—that is, how many megawatt hours are required to replace each gigajoule of fossil fuels used in a given application.

The energy-intensive superpower industries are large contributors to final electricity demand. The model includes a more detailed examination of these industries' potential electricity demand, both globally and across the five key countries.

The analysis also covers superpower industry needs for carbon as a feedstock. Today carbon is sourced from fossil fuels, but in the future it will mainly come from sustainable biomass. This is important for two reasons: First, because using biomass for feedstock purposes means there is less available for energy purposes. Second, comparative advantage in carbon farming will be another driver of the superpower trade—although this is only dealt with briefly and will be explored in future work.

Projecting electrification demand to net-zero

The second step is to extend the electrification model to around mid-century, to the point at which the five key countries reach net-zero. This is 2045 for Germany, 2050 for Japan and Korea, 2060 for China, and 2070 for India. To project forward, we must account for two opposite influences on future demand: the rise in GDP with further development, and the fall in the energy-intensity of GDP. The latter is driven by efficiency gains and, especially in China, reduced output of some energy-intensive products. The result is a model of electricity demand at the time of reaching net-zero, in a world with maximally electrified economies.

Identifying substitutes and supply options

The third step is to account for the main technologies that:

- act as substitutes for electrification, so reduce modelled electricity demand, or
- supply electricity, so satisfy electricity demand.

These are potential competitors for the superpower trade in the five countries. The extent of the trade depends on whether these are cheaper or more expensive than importing embedded renewable energy from Australia.

Technology Feasibility in Key Countries

Nuclear power - Nuclear power is one of the most expensive means of clean electricity generation. Unlike other technologies, it has become much more costly over time, not only in the West but also in countries including India. This puzzle is briefly investigated. The apparent exceptions to the trend, Korea and China, are five-year-plan economies with heavy government control and subsidisation of the electricity sector; prices cannot be directly compared.

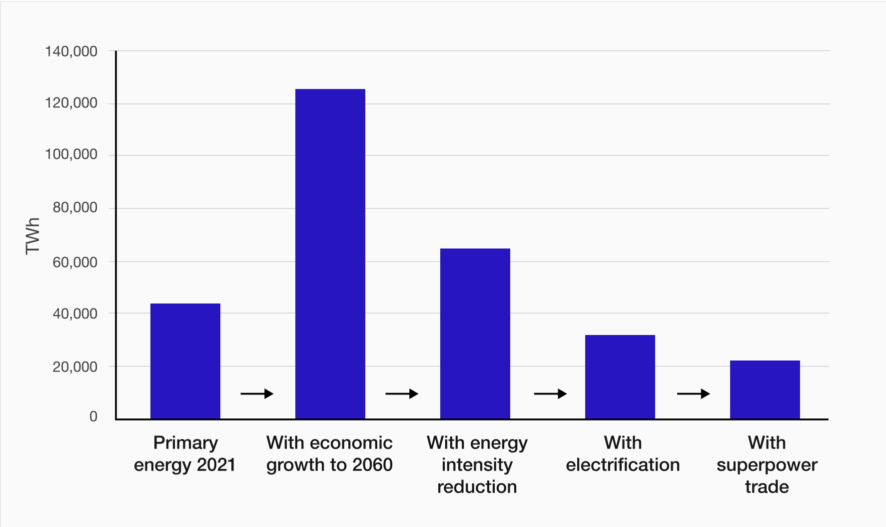


Figure ES.1 - Detail on China: Separating the effects of economic growth, energy intensity reduction, electrification, and the superpower trade on energy demand

Nuclear install rates are accordingly low in all countries. Although China is installing nuclear several times faster than any other country, it is on track to achieve a nuclear generation share of only 3-4 percent by 2060. It would need to accelerate 10-fold just to reach a 20 percent share; this would likely strain supply chains and raise costs. Despite its low reported costs of nuclear, China is planning a renewables-dominated grid: it installed 1.3 GW of nuclear, versus around 290 GW of wind and solar, in 2023.

Carbon capture and storage (CCS) - Carbon capture and storage (CCS) helps to avoid electrification, by capturing emissions from the direct combustion of fossil fuels (e.g. from steel blast furnaces). It can also help to satisfy electricity demand, by capturing emissions from fossil fuel power plants. If attached to biomass-based power stations, it can contribute electricity with negative emissions.

Carbon capture is also expensive in all countries. Today's large CCS projects are made viable by using captured CO2 for enhanced oil extraction. This is not compatible with net zero and will be phased out over time. There may be opportunities for competitive CCS where CO2-emitting assets, such as coal power stations or blast furnaces, would otherwise be stranded, and where they are located close to geological structures that are highly suited to this purpose. This opportunity may be significant in the 2030s in China, and into the 2040s in India, but will diminish over time. Low "learning rates" suggest that new-build CCS power plants or blast furnaces will not be cheaper than renewables-based superpower imports.

Bioenergy - Bioenergy may also contribute to avoiding electrification (e.g. via direct combustion of biomass in industry) or satisfying electricity demand via biomass power plants. Importantly, biomass plays a special role as a source of sustainable carbon feedstock for industry. The paper estimates that the superpower industries alone will require around 1 billion tonnes of carbon, and so around 2.2 billion tonnes of dry biomass, by 2060. This demand will press the world deep into its biomass supply curve.

Biomass supply curves suggests that bioenergy will be costly at scale. Future supply is more constrained than suggested by major analysts such as the IEA (2021). Only a small share of crop residues is available for withdrawal from fields. Oil crops are far too unproductive and compete with food production; an area equal or greater than the entire world's croplands would be required to satisfy carbon demand via oil crops. Whole-plant bioenergy crops are the most promising alternative. They can be grown on land that is marginal for agriculture and of relatively low value for pastoral activities. Suitable marginal and low-value land is limited.

Satisfying carbon feedstock needs will be challenging, but is possible. After feedstock needs have been satisfied, the marginal cost of bioenergy will be high.

Wind and solar - Wind and solar supply curves are examined for the five countries. At the expected scale of electricity demand, marginal costs are expected to be uncompetitive.

Japan and Korea have poor and highly seasonal resources and little available land; they already have among the most expensive wind and solar in the world. This disadvantage will grow. Germany's solar resources are very poor, and its moderate-quality wind resources are limited and enough to satisfy only a fraction of expected electricity demand. The same applies to the large majority of European countries. Good quality solar is available in Europe's far south, and wind in the far north, but the high costs of transmission means that countries will mostly use poorer local resources.

India has moderate quality solar made seasonal by the monsoon cycle. Wind resources available at scale are very poor and even more seasonal. At middling renewables penetrations, India's marginal electricity prices will be uncompetitive.

China's solar and wind resources are concentrated in the Gobi Desert and its surrounds in the north of the country, far from the populated south, east, and centre. Northern solar is of moderate quality and highly seasonal, being at the opposite latitude to Tasmania. Northern wind resources of moderate to good quality are large, but China's electricity demand will be high enough to exhaust them. The costs of transmitting electricity from the north will be high, and will encourage extensive use of renewables in the densely populated provinces. Resources there are very poor.

Solar and wind power generation in northern China

03.
Results: Countries' decarbonisation pathways and the contribution of the superpower trade

For the five focal countries, we compare (A) future electricity demand at maximal electrification with (B) future electricity supply, and avoided electricity demand, using the above technologies and (C) the potential contribution of the superpower trade.

Future supply is estimated by build-rate in two scenarios:

1. A base scenario, using observed rates of clean energy deployment, which indicates each country's current decarbonisation pathway.
2. An "accelerated" case, based on government deployment targets, and other specialist projections of clean energy deployment.

As an example, Figure ES.2 presents the Chinese supply-demand gap in 2060, in the "accelerated" scenario. This assumes a threefold acceleration of China's recent nuclear install rate, CCS deployment at the top end of IEA projections, and IEA-based levels of bioenergy deployment that would require high carbon prices. China's record level of renewables deployment in 2024 is sustained to 2060, and the potential for further increase is explored; China's demand is large enough to exhaust its cheap renewable resources.

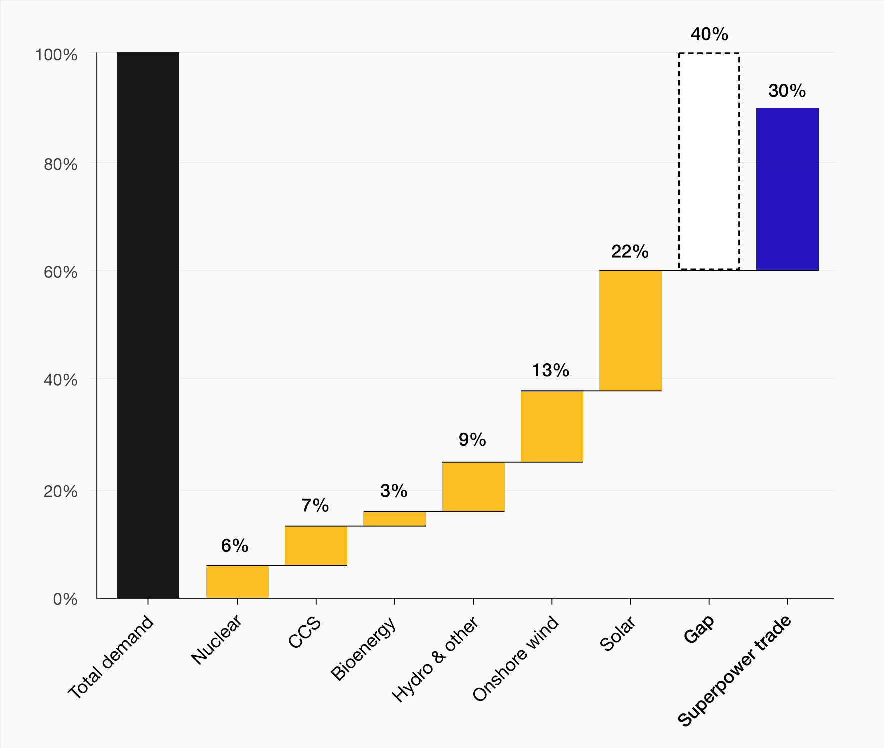


Figure ES.2 - The superpower trade can bridge three quarters of China's projected zero carbon demand energy gap

Despite acceleration, the gap is large at 40 percent of 2060 demand. If China imports the materials of the superpower trade, electricity demand declines by around 30 percent and most of the supply-demand gap is eliminated.

Figures ES.3 and ES.4 present supply-demand gaps and the potential superpower trade contribution for the five countries.

The gaps are large: from 37 to 62 percent of demand is not covered by anticipated rates of deployment. The superpower trade can close around three-quarters of the gap in China and Germany, a little above and below half of the gap in Korea and Japan respectively, and just over a third in India.

Economically, prospects for the superpower trade depend on the marginal cost of importing embedded energy versus the marginal cost of domestic clean energy supply. Figures ES.3 and ES.4 show demand in the "accelerated" case, which already entails the extensive use of high-cost energy technologies. These cannot compete against superpower imports.

Closing the rest of the gap will entail higher costs still—the countries must turn to lower-quality renewable resources, nuclear power, fossil fuel generation with CCS, or ammonia imports. China has the best prospect for restraining costs, with the richest renewables endowment among the five countries and significant advantages in supply chains. However, deeper reliance on its northern solar and wind resources will greatly increase transmission costs and will exhaust its cheap wind resources. High resource seasonality will also raise costs at higher penetrations.

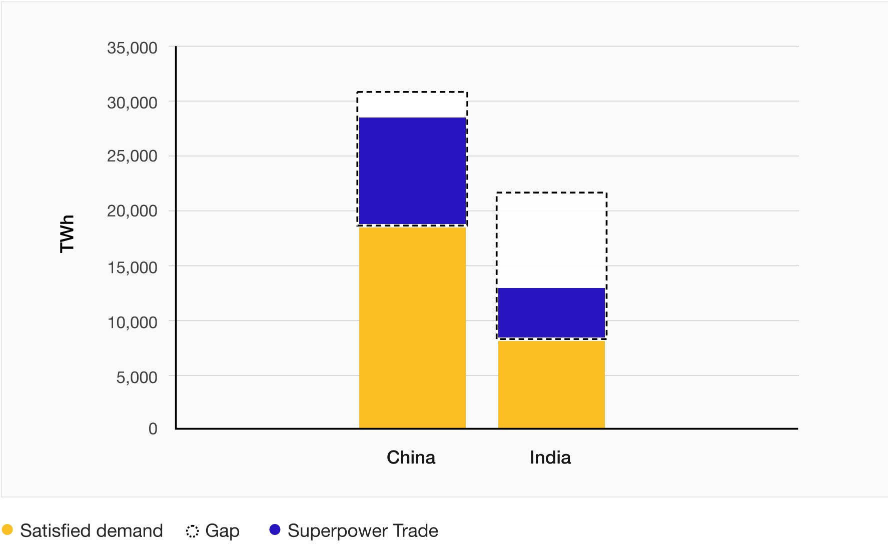


Figure ES.3 - Bridging the supply-demand gap: The superpower trade in China and India

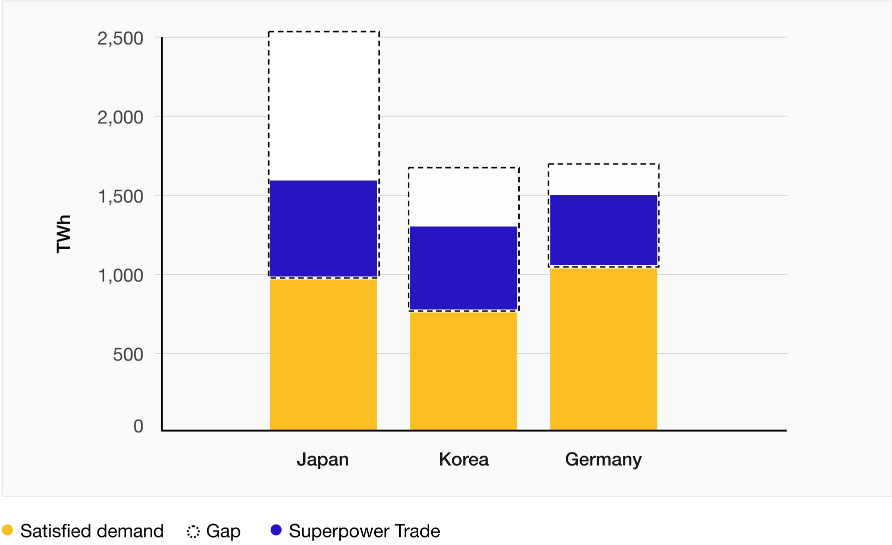


Figure ES.4 - Bridging the supply-demand gap: The superpower trade in Japan, Korea, and Germany

“The superpower trade can close around three-quarters of the gap in China and Germany, a little above and below half of the gap in Korea and Japan respectively, and just over a third in India.”

04.
Australia's Opportunity and Challenge

Scale of electricity demand is crucial for modelling the marginal quality of available renewable resources. At the relevant scales, Australia's renewable resources are greatly superior to those available in the five countries analysed here (Table ES.2).

Note that increasing the capacity factor increases profitability more than linearly, because costs remain fixed. At high penetrations, reducing seasonality has the same effect.

Table ES.2 - Especially at scale, Australia's wind and solar resources are greatly superior to those of China, India, Japan, Korea, and Germany

	Solar capacity factor	Seasonality	Wind capacity factor	Seasonality
Australia	**26%**	Low to moderate	**30-35%** onshore at multi-TW	Low to moderate
China	**17%**	Moderate to high	**<25%** in north at multi-TW, **<20%** elsewhere	High to very high
India	**18%**	High	**<14%** onshore at multi-TW	Very high to extreme
Japan	**13%**	Low	**<20%** onshore at multi-GW	Moderate to high
Korea	**14%**	Low to moderate	**<20%** onshore at multi-GW	High to very high
Germany	**11%**	Very high	**<20%** onshore at multi-GW	Moderate to high

The case for the superpower trade is exceptionally strong for Japan, Korea, and Germany, from today into the early 2030s. The case for China is less compelling in the short run, but will commence early and is absolutely very large. For India, the trade may begin in the 2030s and accelerate into the 2040s.

Australia's potential share of the superpower trade is estimated. At maximum, Australia exports all its current share in iron ore (40 percent) and bauxite/alumina (30 percent) as iron/steel and aluminium. Australia's potential share in most other industries is set to 25 percent. This is ambitious, but reasonable if Australia were to position itself as the favoured investment and trade partner, given its comparative advantages, established trade relationships with the East Asian demand centre, and importer country preferences for supply chain security. Notably it is less than Australia's global share in the two major metal ores.

The exception is for the less intensively traded road freight fuel sector, which is set to 15 percent.

Results are mainly driven by iron/steel, and only shift modestly if other industry shares are reduced.

Based on the scale of these industries, Australia's potential contribution to climate mitigation is estimated as 6.7 percent of 2021 global emissions. Allowing for growth to 2060, especially in silicon, ammonia, and green aviation fuels, the mitigation contribution in 2060 reaches a maximum equivalent to 9.6 percent of 2021 emissions.[2]

"Allowing for growth to 2060, especially in silicon, ammonia, and green aviation fuels, the mitigation contribution in 2060 reaches a maximum equivalent to 9.6 percent of 2021 emissions."

[2] This cannot be estimated as a share of 2050 emissions without a model of 2050 emissions and changes in industry shares over time. Because emissions will decline to 2050, but the superpower industries are "hard to abate" sectors, their share will likely increase. The true share will likely exceed 9.1 percent.

Table ES.3 - The Australian superpower trade can contribute significantly to global climate mitigation

	Australia's potential market share	Today's mitigation contribution†	Global industry growth to 2060	Mid-century mitigation contribution†
Iron / steel	40%	4.0%	10%	4.4%
Aluminium	30%	0.7%	30.40%	0.9%
Silicon & polysilicon	25%	0.2%	100% (Si), 300%(PSi)	0.5%
Ammonia & urea	25%	0.5%	300%	1.5%
Methanol (industrial)	25%	0.2%	30%	0.3%
Shipping	25%	0.4%*	0%	0.4%*
Aviation	25%	0.6%	100%	1.1%
Road freight	15%	0.1%*	180%	0.4%*
Total		**6.7%**		**9.6%**

* Excluding the share covered by batteries, including only that covered by green fuels.
† Today's mitigation contribution is calculated on 2021 global superpower industry output. The mid-century mitigation contribution is calculated on forecast 2060 superpower industry output, with mitigation contribution measured against the 2021 baseline.

Total potential superpower export revenues add up to $693 billion on contemporary levels of production, or $987 billion on forecast 2060 levels (Table ES.4). Iron accounts for half of contemporary potential, and nearly 40 percent of that in 2060.

Australia's fossil fuel exports are expected to decline sharply into mid-century. Potential trade revenues from superpower industries are together 6 to 8 times larger than typical combined coal and LNG export revenues. Even at much more pessimistic estimates of Australia's potential share in these markets, total revenue still exceeds that of fossil fuels.

Table ES.4 -Australia's potential superpower industry revenue, excluding green premia

	Export Revenue, contemporary market size	Export revenue, 2060 market size
Iron / steel	$386 billion	$386 billion*
Aluminium	$67 billion	$89 billion
Silicon & polysilicon	$11 billion	$36 billion
Ammonia & urea	$29 billion	$90 billion
Methanol (industrial)	$15 billion	$29 billion
Shipping	$43 billion	$43 billion†
Aviation	$90 billion	$158 billion
Road freight	$54 billion	$156 billion
Total	**$693 billion**	**$987 billion**

* Entry of competitors offsets iron/steel industry growth, such that it is assumed that Australia maintains today's absolute volume of iron ore production.
† Shipping growth is curtailed by the decline in the fossil fuel trade, which comprises roughly 40 percent of shipping today.

The full Australian superpower trade would require around 9,000 TWh of power, which may be supplied with around 3.4 TW of wind and solar. Based on real-world land use patterns, this deployment would directly use around 0.6 percent of Australian land, or 1.1 percent if including the space between wind turbines that may still be used for other purposes.

It would also require sourcing a little over 210 million tonnes of sustainable carbon, which is feasible across the mallee country of southern Australia, the savannas north of Capricorn, and the mulga country in the mid-latitudes of eastern Australia.

"Potential trade revenues from superpower industries are together 6 to 8 times larger than typical combined coal and LNG export revenues."

Requirements for Australia to grasp the opportunity:

1. Australia must address three market failures: the non-pricing of CO_2, the innovation spillovers that disadvantage early movers, and common infrastructure spillovers that prevent efficient investment in transport, wires, and pipes.

2. After addressing market failures, Australia must allow market forces to select the most cost-effective investments.

3. Australia must maintain open international trade, so that it utilises the world's lowest-cost sources of power generation and industrial inputs and is trusted as a reliable source of other countries' requirements for zero-carbon goods.

4. Superpower industries are capital-intensive and will require that Australia has competitive interest rates.
   This depends on careful management of debt and inflation, and warns against US IRA-style stimulus. Attracting foreign investment will be important, including as an enabler of technology transfer.

5. Australia must streamline project approvals. Green project investors report larger hurdles and slower processes than in competing countries.

6. Investors require policy certainty. This depends on bipartisan support for major economic reforms, without which there is no reliable economic environment for investors.

The more that Australia succeeds in resolving these issues, the greater the share of the superpower trade it will capture, and the greater its contribution to cheap and rapid global climate mitigation.

“The more that Australia succeeds in resolving these issues, the greater the share of the superpower trade it will capture.”

Glossary of Terms

Biomass

Organic materials, most importantly from crop residues and dedicated energy crops, used as carbon feedstock for industry or combusted to produce energy.

Bioenergy

Renewable energy produced from organic materials (e.g. crop residues, dedicated energy crops).

Carbon Capture and Storage (CCS)

Technology for capturing carbon dioxide emissions, mainly from fossil fuels combusted in power plants or industrial processes, and storing them underground to prevent release into the atmosphere.

Carbon Feedstock

Carbon sourced from biomass, captured fossil fuel emissions, direct air capture, or other processes, used in industrial processes - such as making plastics, chemicals, or fuels - rather than for energy production.

Comparative Advantage

A country with comparative advantage can produce a good or service relatively more cheaply than others (most precisely, at lower opportunity cost), such that specialising in and exporting that product generates gains for all. Australia has a comparative advantage in renewable energy production.

Direct Air Capture

A technology for extracting carbon dioxide directly from the atmosphere for storage, to reduce atmospheric CO_2 concentrations, or for utilisation as a carbon feedstock.

Electrification

The process of replacing fossil fuels with electricity in various sectors (e.g., transportation, heating) to reduce emissions, often in combination with clean energy sources.

Embedded Energy

The energy used in producing a product or service. Trading energy-intensive goods is an indirect trade in energy; importing embedded energy allows countries to reduce their domestic energy demand.

Energy-Intensive Goods

Products requiring large amounts of energy to produce, including steel, aluminum, and ammonia, and so with significant embedded energy. In the fossil economy they have large CO_2 emissions and are important targets for clean production.

Market Failure

When markets fail to allocate resources efficiently, due to incomplete property rights, misaligned incentives, and/or asymmetries in information. The non-pricing of harmful CO_2 emissions is a classic example.

Primary Energy

Energy in natural resources before conversion or transformation, including coal, oil, natural gas, biomass, wind, and solar energy sources.

Superpower Trade

The trade in clean energy embedded in energy-intensive goods, that relies on export countries' comparative advantage in clean energy production.

This executive summary of *The New Energy Trade: Harnessing Australian renewables for global development* provides an overview of the challenges and opportunities in positioning Australia as a leader in the new energy trade.

We invite you to read the full report for an in-depth look at these critical issues and the transformative potential for Australia and the world.

Read the full report

https://www.superpowerinstitute.com.au/work/the-new-energy-trade

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