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securing our energy

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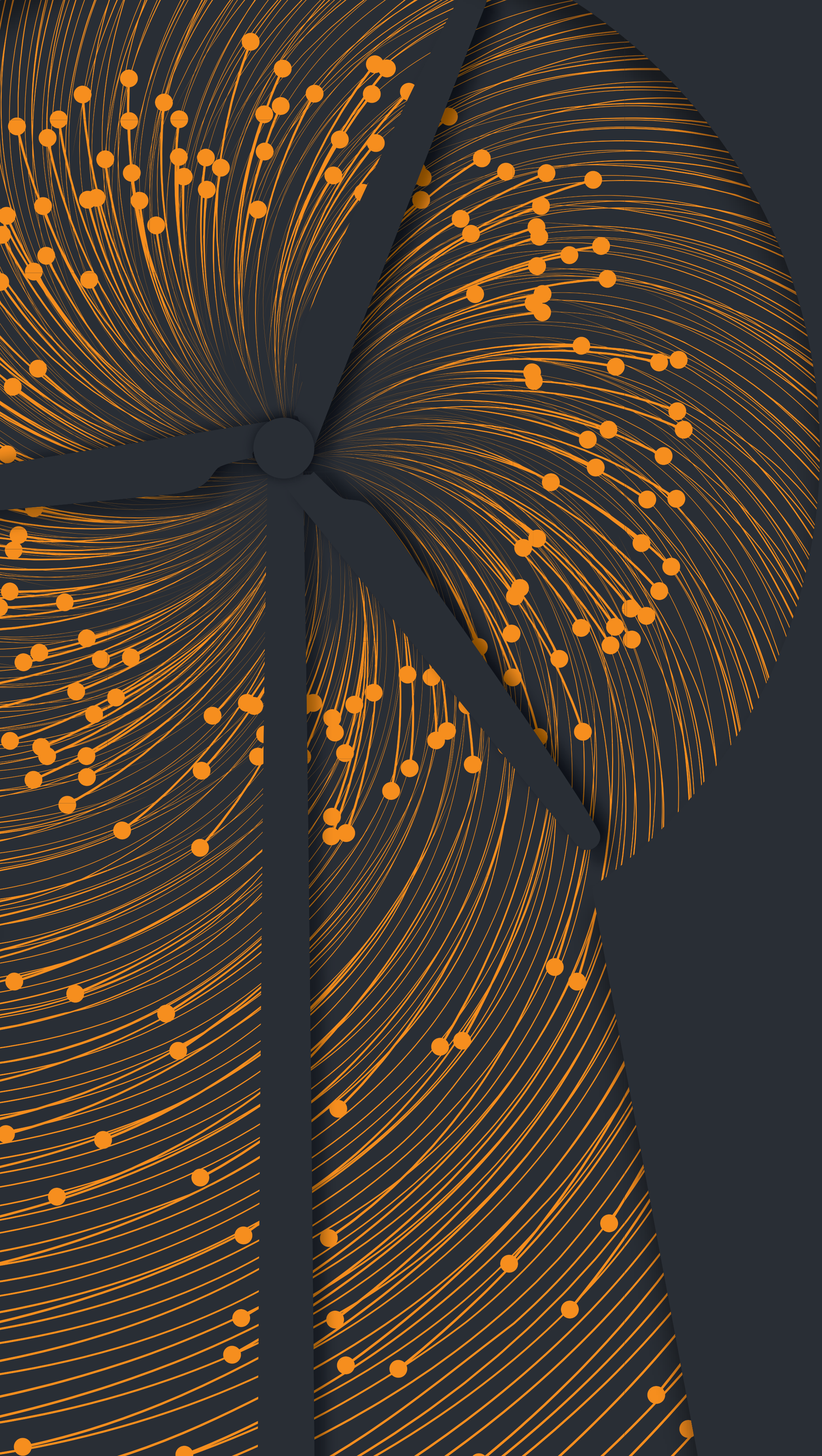

Dr Christian Downie

The global energy challenge

Together these essays offer hope that we can secure clean, reliable and affordable energy for all in the coming decades. But it will not be easy.

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On 15 November 2014, leaders from around the world began arriving at Brisbane airport. The occasion was the G20 Leaders' Summit. While it may not have received much coverage from the global press corps gathered in the Queensland heat, there was one significant new item on the agenda – reform of the international energy architecture. The reason was simple: the international system designed to govern energy was failing to respond to the global energy challenge. Concerns were mounting about the capacity of the global energy system to ensure energy security, facilitate access to energy and achieve the clean energy transition required to avert the worst impacts of climate change.

Many of the international organisations established in decades past were not equipped to meet these challenges. The International Energy Agency (IEA) was a case in point. The IEA was established in 1974 by the world's largest oil consumers, including the United States, Europe and Japan, to secure global oil supplies. A year earlier some members of the Organization of Petroleum Exporting Countries (OPEC) had instituted an oil embargo, which resulted in oil shortages and skyrocketing prices. In the United States, for example, fuel rationing was introduced as many gas stations ran dry and people queued for hours to fill their cars. The IEA was designed to ameliorate such shocks by providing stable oil supplies in times of crisis.

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For an international organisation that is said to represent energy consuming nations, the IEA does not include as full members four of the top 10 energy consuming nations, with 40 per cent of the world's population – China, India, Brazil and Russia.

While the energy security challenge has changed over the years, the IEA has not. It was established at a time when the United States was largely dependent on foreign oil, but it is now the largest producer of oil in the world. At the time, China was a net oil exporter while it is now the largest consumer of energy in the world. And climate change was a theory, rather than the reality it is today. For an international organisation that is said to represent energy consuming nations, the IEA does not include as full members four of the top 10 energy consuming nations, with 40 per cent of the world's population – China, India, Brazil and Russia.

This reality led G20 leaders in 2014 to agree that the IEA and the plethora of other actors that comprised the international energy architecture were out of date and needed to be reformed. The G20 principles on energy collaboration agreed to in Brisbane did not solve the problems associated with energy security, energy access and climate change, but they were an important marker indicating that world leaders acknowledged the scale of the global energy challenge.

Unfortunately, in the years that followed progress has been slow, and governments around the world have struggled to tackle the challenges posed by the transformations taking place in global energy markets. Nowhere is this more important than in our region, where we are witnessing a seismic shift in the energy landscape. As the world's population increases to nine billion people by 2040, primary energy demand is expected to be almost 30 per cent higher than it is today. Asia is at the centre of the story. In fact, India, China and Southeast Asia are expected to drive the growth in energy demand in coming decades, with developing economies in Asia responsible for around two-thirds of this growth.

Against such a backdrop, this volume of essays on energy is timely. Drawing on the wealth of expertise in the ANU College of Asia and the Pacific, and more broadly across the University, these essays pull back the curtain on the nature of the global energy challenge and, critically, also offer insights on how to meet that challenge.

A young boy stands under a electricity pylon in rural Tanzania.
(Photo credit: UK Department for International Development, CC BY 2.0).

Dr Christian Downie

A sunset over a windfarm surrounded by electricity pylons and solar panels

First, for many nations energy security – having a reliable, adequate and affordable supply of energy – remains a key challenge. This is a theme that runs through the essays by Elizabeth Buchanan and Natalie Sambhi, who highlight how for Russia and Indonesia, energy security is a crucial element of foreign policy and defence considerations, particularly in Indonesia where the military has historically played a large role in society. Australia is not immune from the energy security challenge. For example, Australia has the lowest strategic petroleum reserve of any IEA member, prompting ongoing concerns about the adequacy of oil stocks in the event of a disruption to global oil supplies. This topic goes to the heart of the Australian Government's current liquid fuel security review.

While energy security is often discussed in terms of geopolitics, as Hugh Saddler and Matthew Dornan highlight in their essays, the design of domestic electricity markets is just as important. Here in Australia, regulators are continuing to grapple with ensuring a reliable electricity market, which is capable of responding to major disruptions and managing multiple sources of generation. These challenges can be especially acute in small Pacific islands, which by virtue of their geography have very isolated electricity networks that require carefully designed regulatory structures.

As renewable-rich nations, such as Australia, turn to wind and solar, and electrify their transport systems, they will reduce reliance on imported fuels, thereby limiting exposure to supply disruptions in global energy markets.

A second challenge is energy access. An estimated 1.1 billion people worldwide still do not have access to electricity. While this is an improvement on the 1.7 billion who were without electricity in the year 2000, poverty reduction and improvements in health, for example, cannot be realised without universal energy access. As Edwina Fingleton-Smith argues in her essay, any discussion of energy security and energy access must put people at the centre. This is especially the case for poor and marginalised communities that are too often sidelined from policy discourses focused on energy supply and access, and not on the activities people use energy for, such as cooking and lighting.

Third, climate change is arguably the greatest global energy challenge of all. It is the source of more than two-thirds of global greenhouse gas emissions, so transforming the energy sector will be crucial to efforts to address climate change. Yet just over 80 per cent of the world's primary energy supply continues to rely on fossil fuels, and this has hardly changed in 40 years. However, Andrew Blakers and Matthew Stocks show why the remarkable rise of solar photovoltaics (PV) and wind energy could soon change this. They point out that solar PV and wind are growing fast enough to displace global coal, oil and gas consumption before 2050, reducing global greenhouse gas emissions by 80 per cent.

Of course energy security, energy access and climate change are not separate challenges – they are interrelated. For example, attempts to ensure energy security by increasing coal consumption, will in turn undermine efforts to achieve a clean energy transition. The good news, as Ken Baldwin highlights in his essay, is that clean energy is set to enhance energy security. As renewable-rich nations, such as Australia, turn to wind and solar, and electrify their transport systems, they will reduce reliance on imported fuels, thereby limiting exposure to supply disruptions in global energy markets. Over time, the pursuit of indigenous renewable energy supplies by more and more nations will work not only to address climate change, but also to reduce geopolitical instability associated with energy.

Together these essays offer hope that we can secure clean, reliable and affordable energy for all in the coming decades. But it will not be easy. As the G20 agreement in 2014 demonstrated, while political recognition among global leaders is there, what is missing is the political will to act quickly. The more swiftly we respond, the more likely we are to meet the energy challenges described in this volume.

Dr Christian Downie

Professor Kenneth Baldwin

Will the clean energy revolution enhance energy security?

The diminished importance of fossil fuel supply chains will gradually enhance national security for those nations currently subject to economic and geopolitical threats to their energy sources.

Professor Ken Baldwin is Director of the Energy Change Institute at ANU, and Deputy Director of the Research School of Physics and Engineering. Since 2011 he has been a member of the Project Steering Committee for the Australian Energy Technology Assessment (AETA) produced by the former Bureau of Resources and Energy Economics (BREE). He is a Board member of the South East Region of Renewable Energy Excellence (SERREE, from 2014). In 2015 he was appointed to the Socio-Economic Modelling Advisory Committee of the South Australian Nuclear Fuel Cycle Royal Commission. Ken chairs the Energy Cluster of the Australia-Indonesia Centre (from 2015). He is an inaugural ANU Public Policy Fellow, and winner of the 2004 Australian Government Eureka Prize for Promoting Understanding of Science, for his role in initiating and championing 'Science meets Parliament'. In 2007, he was awarded the W.H. Beattie Steele Medal, the highest honour of the Australian Optical Society. In 2010 he was awarded the Barry Inglis Medal by the National Measurement Institute for excellence in precision measurement. Ken is a Fellow of the American Physical Society, the Institute of Physics (United Kingdom), the Optical Society of America and the Australian Institute of Physics.

Over the next few decades the world's energy systems will undergo a seismic revolution, with a transformation on a massive scale as renewable energy takes over from fossil fuels. This will be driven not only by the urgent imperative to address climate change, but also by the overwhelming economics of renewable energy.

This article examines the implications of the energy revolution for national security. The analysis is in three parts: the implications for the security of supply chains; the shift from a centralised energy generating system to a disseminated network of myriad energy sources; and the implications for cyber security.

The first and most marked change in the energy security balance will be the shift away from traditional fuel supply lines, and the disappearance of dependence on foreign energy sources for many nations. The ability to exploit indigenous renewable energy (including solar photovoltaics, wind, concentrated solar thermal, geothermal, wave and tidal generation) will mean nations rely less and less on imported fossil fuels such as coal, oil and gas. The same is true of indigenous unconventional natural gas being unlocked by technological advances such as hydraulic fracturing (fracking). Further, those nations that have embraced nuclear power to address climate change can stockpile many years of high-energy-density uranium to improve supply chain security, compared with a continuous reliance on imported fossil fuels.

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For some renewable energy rich nations, such as Australia, the cutting of the energy umbilical cord will be almost complete, particularly as we increasingly electrify our transport systems through electric vehicles, hydrogen fuel cells and biofuels.

For some renewable energy rich nations, such as Australia, the cutting of the energy umbilical cord will be almost complete, particularly as we increasingly electrify our transport systems through electric vehicles, hydrogen fuel cells and biofuels – all potentially powered by energy sourced domestically.

Some parts of the transport sector – shipping and aviation – will be very difficult to decarbonise. Aviation will require the development of synthetic 'drop-in' fuels or low-carbon biofuel replacements, while shipping may move in the direction of small modular nuclear reactors (with minimal refuelling requirements). Even in these cases, however, there will be a diminishing reliance on imported fuels. This will mean many nations will not only become increasingly fuel-independent for their electricity supply, but will also significantly decrease their dependence on energy supply chains for their transport systems.

The diminished importance of fossil fuel supply chains will gradually enhance national security for those nations currently subject to economic and geopolitical threats to their energy sources. Supply chain interdiction will no longer be an option for nations wishing to control the sovereignty of other countries, and there will be fewer resource wars – as no country is likely go to war over another country's wind and solar.

This process will be accelerated by international agreements to limit damaging climate change, which will eventually see a premium placed on carbon-based imports, and consequently on the proportion of embedded carbon-based energy. A further driver will be continuing reductions in the cost of renewables, that, according to the August 2018 *Photovoltaics Report* by the Fraunhofer Institute for Solar Energy, have seen the price of solar panels fall by a factor of more than 100 in the last 37 years. This convergence of overwhelming economics, the climate change imperative and national security enhancement will further drive the revolution in our energy systems.

Nevertheless, once the energy transformation has taken place, we will face different risks and opportunities presented by the new energy paradigm. We will have moved from a centralised generation system to a more complex network of disseminated renewable generation. Generator location will be driven largely by the geography of the best renewable resources. This will be complemented by disseminated storage (such as off-river pumped hydro and batteries), linked together by an augmented electricity transmission system, which will more closely resemble the Internet than a traditional network backbone.

In the same way that multiple redundancy and complex interconnectivity was designed into the Internet to enhance security of communication, this new Internet-of-Energy might also provide enhanced robustness by removing reliance on a few centralised generators and transmission lines.

Being able to re-route energy through a more strongly interconnected system, tap into a diversity of complementary energy sources distributed over a wide geographic region, and store energy for use in times of future need, could contribute to the flexibility and redundancy needed to ensure a more secure energy system – both for the reliability of domestic supply, and the ability to withstand attack from outside.

However, this also increases the vulnerability of the Internet-of-Energy due to the vastly increased number of access points open to cyber attack. For example, demand response (that is, load reduction to match supply) will be a major component of any future energy system, particularly to attenuate loads at peak times – the equivalent to having an alternative (negative) generation source.

Demand response may be implemented on an industrial scale, or could apply to millions of demand loads all the way down to the household level. This includes the ability to control individual household appliances through the Internet-of-Things – a prospect that will make the entire system vulnerable to attack at the weakest point in the demand response system.

Together with the increased points of attack through the disseminated energy generators themselves, and the more complex transmission and distribution networks, this will require a whole-of-system approach to cyber security in order to prevent one small component in the network taking down the entire system. This is not just a potential threat. It is already a reality, as shown by events such as the 2012 cyber attack on the oil company, Saudi Aramco, as described by Christopher Bronk and Eneken Tikk-Ringass in *The Cyber Attack on Saudi Aramco*, and the taking down of the Ukrainian electricity network in 2015, which is detailed in the *Wired* article, *Inside the cunning, unprecedented hack of Ukraine's power grid*.

Professor Kenneth Baldwin

Woman poses with a sun at the #Time2Choose Sydney rally where people gathered to demand action to protect land, water and cultural heritage from the effects of coal mining and coal seam gas. (Photo credit: Kate Ausburn, CC BY 2.0).

It could be argued that even if the renewable energy revolution does not eventuate, a centralised fossil-fuel based system would also be vulnerable to cyber attack, particularly given that widespread demand response will inevitably become part of any electricity system. There would be even greater vulnerability in such a centralised system if a single or multiple power station(s) could be selectively taken out, which could have catastrophic effects on the stability of the entire network. By comparison, the effect on system stability of removing multiple, small, disseminated renewable generators could potentially be more readily mitigated by delivering ancillary services to maintain voltage and frequency control, such as might be provided by widespread, disseminated off-river pumped hydro and/or batteries.

Irrespective of this hypothetical comparison, the renewable technology train is speeding down the tracks and, at this moment, appears unstoppable. To ensure our energy systems in the coming years continue to deliver system reliability, the threat of cyber security needs to be addressed.

Potentially this may be made easier by the redundancy and diverse connectivity in a highly-disseminated, renewable energy network.

But no matter how the energy transformation develops, two other issues will need to be addressed.

The first is the increased vulnerability of energy systems to extreme climatic events, the frequency of which is expected to increase with global warming. This may be ameliorated to some extent by the robustness of a decentralised energy system, but we will still need measures to provide re-routing of network capacity, and ancillary services for voltage and frequency stability in a disseminated system.

The second issue is the decarbonisation of our energy systems, which must occur by mid-century to avoid the worst consequences of climate change. This may just be a stop-gap in our energy transformation until the advent of fusion power – the harnessing of the nuclear energy that powers the sun.

A march through St. Paul, Minnesota to protest using tar sands oil in favour of clean water and clean energy sources (photo credit: Fibonacci Blue, CC BY 2.0).

> If we are sufficiently aware of the massive energy transformation that will take place, and act in a timely manner to address the parallel threat of cyber security, then we may find ourselves living in a safer world in decades to come, increasingly free from disputes over energy supply and energy access.

Already the International Thermonuclear Experimental Reactor (ITER) in Cardarache, France, which is funded by the major energy superpowers, is anticipated to demonstrate break-even around 2030. The engineering and physical scaling laws indicate that simply increasing the size of the reactor is all that is needed to achieve break-even: the ITER project is expected to well-exceed the threshold required. If ITER is successful, the next project (DEMO, or DEMOnstration Power Station) will produce a demonstration commercial version of a fusion reactor that can run continuously. After 2050, large energy companies may supply fusion reactors to nations that have the technical capability to build and maintain them.

This will bring with it a new set of security issues, as the world potentially reverts once more to a centralised energy generating system, given that fusion reactors will be comparable to, or bigger than, the largest current thermal power stations. Further security issues may arise because of the technological complexity of fusion power, which may mean a division between haves and have-nots in a future fusion world. We might therefore have to revisit this essay in a couple of decades' time.

Finally, the unstoppable renewable energy train may eventually run right over the train-wreck graveyard of Australian climate and energy policy from the last decade. The rest of the world has watched with, at best, bemusement as destabilisation by the Greens saw the demise of Labor's Emissions Trading Scheme, the Abbott Government axed the carbon pricing mechanism, and political infighting within the Coalition scuppered the first the Emissions Intensity Scheme, dumped the Clean Energy Target and buried its planned replacement, the National Energy Guarantee. Now it may all become irrelevant until a future government decides to get on board the renewable energy train.

In the interim, it appears the increased capability of indigenous energy supply will enhance global geopolitical stability, and network reliability will benefit from multiple redundancy and better connectivity in a disseminated Internet-of-Energy system. If we are sufficiently aware of the massive energy transformation that will take place, and act in a timely manner to address the parallel threat of cyber security, then we may find ourselves living in a safer world in decades to come, increasingly free from disputes over energy supply and energy access.

Professor Andrew Blakers and Dr Matthew Stocks

Solar photovoltaics and wind energy: the climate change solution

Most of Australia's greenhouse gas emissions are due to the use of fossil fuels, which is typical for industrialised countries. Land clearing and agricultural emissions constitute most of the rest.

Andrew Blakers is Professor of Engineering at ANU. He was a Humboldt Fellow and has held Australian Research Council QEII and Senior Research Fellowships. He is a Fellow of the Academy of Technological Sciences and Engineering, the Institute of Energy and the Institute of Physics. He is a Public Policy Fellow at ANU. He has published approximately 300 papers and patents. His research interests are in the areas of silicon photovoltaic solar cells and solar energy systems. He has extensive experience with basic and applied research and was a leader of the team that developed PERC silicon solar cell technology, which currently has approximately 30 per cent of the worldwide solar market and cumulative module sales of around $30 billion (mid-2018). He also has interest in sustainable energy policy and is engaged in detailed analysis of energy systems with high (50–100 per cent) penetration by wind and photovoltaics with support from pumped hydro energy storage (for which he won the 2018 Eureka Prize for Environmental Research).

Dr Matthew Stocks is a Research Fellow in the Research School of Engineering. He has more than 25 years' research and development experience in renewable energy technologies, including 10 years commercialising solar cell technologies. His current research efforts focus on integrating high amounts of renewable energy in Australia's electricity network, including the importance of the electric vehicles in this transition. He was part of the RE100 team which won the 2018 Eureka Prize for Environmental Science.

Solar photovoltaics (PV) and wind energy are growing fast enough to eliminate global coal, oil and gas consumption before 2050, resulting in global greenhouse gas emission reductions of 85 per cent—with the time frame depending mostly on politics.

The exponential rise and rise of PV and wind offers the only realistic chance of avoiding dangerous climate change (for more information about PV, see *The Conversation's Explainer: what is photovolataic solar energy*). Indeed, it is difficult to see any timely solution to climate change that does not involve PV and wind doing most of the heavy lifting. No other solution comes even close.

Most of Australia's greenhouse gas emissions are due to the use of fossil fuels (Figure 1), which is typical for industrialised countries. Land clearing and agricultural emissions constitute most of the rest. However, PV (with assistance from wind and other renewables) is on track to eliminate these emissions within 20 years.

In particular, silicon PV is doing for energy, and greenhouse gas emission reductions, what the silicon chip did for computing and electronics.

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Figure 1: Breakdown of Australia's greenhouse gas emissions by sector. According to the Department of the Environment, most Australian greenhouse gas emissions arise from coal, oil and gas use.

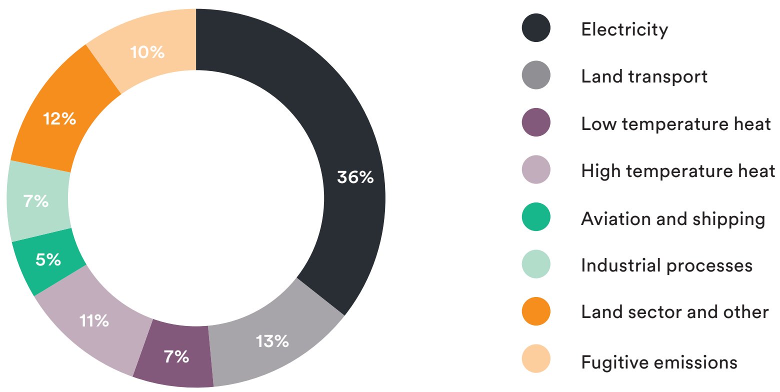
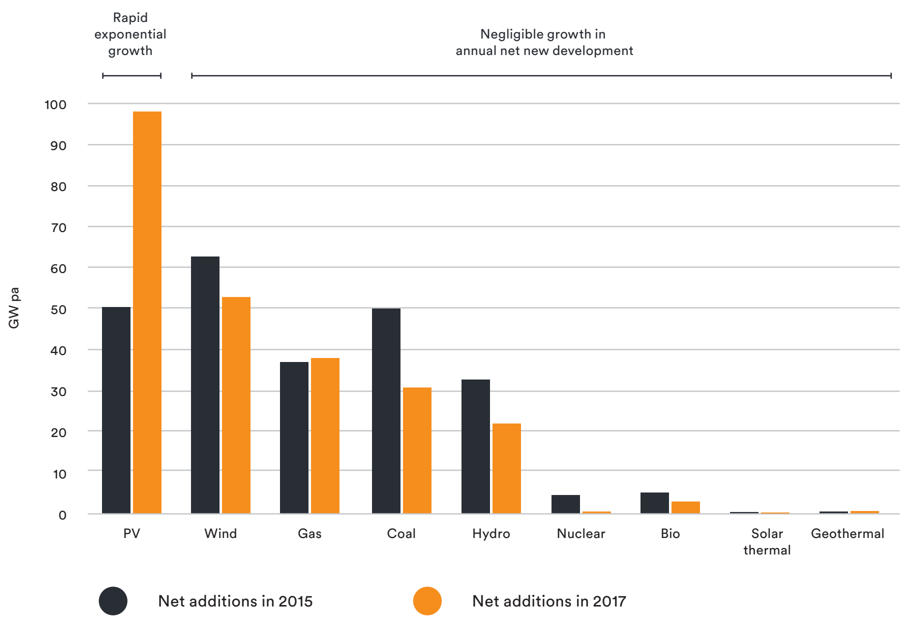


Figure 2: Net new global generation capacity added in 2015 and 2017. PV is growing rapidly while the other generation technologies have negligible growth in annual net new deployment.



Unfortunately, attempts to capture and store large quantities of CO_2 emissions from burning fossil fuels have come to naught due to technical difficulties and high cost. Thus, coal, oil and gas use must be eliminated to curtail global warming.

A replacement is needed that, ideally, meets all the following criteria:

- very large and preferable ubiquitous resource base
- small greenhouse gas emissions and other environmental impacts
- unlimited raw materials
- minimal security concerns in respect of warfare, terrorism and accidents
- low cost right now, allowing low economic impact from discarding fossil fuels
- currently in mass production, allowing immediate scale-up.

Solar PV meets all these criteria, while wind energy meets many.

Together, PV, wind and other renewables can eliminate coal, oil and gas use and thereby reduce greenhouse gas emissions by 85 per cent. Renewables already dominate capacity markets (Figure 2) since both wind and solar overtook coal and gas in 2015.

PV and wind depend only on energy from the sun, which will be available for billions of years. Complete replacement of all fossil fuels requires solar and wind collectors covering much less than one per cent of the world's land surface area. A large proportion of collectors are installed on rooftops and in remote and arid regions, minimising competition with food production and ecosystems.

The solar resource is ubiquitous – we are unlikely ever to go to war over access to sunlight or wind. Most of the world's population lives at low latitudes (less than 35 degrees), which has good solar availability that varies little with the seasons (unlike at high latitudes).

Complementing this, wind energy is also widely available, particularly at higher latitudes. Very wide distribution of PV and wind collectors over most regions of the world means that everyone has local energy generation, and this helps to minimise disruptions from natural disasters, war and terrorism. In addition, PV and wind have minimal environmental impact and water requirement. PV uses raw materials that are effectively in unlimited supply – silicon, oxygen, hydrogen, carbon, aluminium, glass and steel – plus small amounts of other materials.

Wind energy is an important complement to PV because it often produces at different times and places, allowing a smoother combined energy output. In terms of annual electricity production, wind remains ahead of PV, but PV is growing much more rapidly. As the wind energy resource is much smaller than the solar resource, PV will dominate in the end.

Other low emissions energy technologies can realistically play only minor supporting roles. The solar thermal industry is hundreds of times smaller than the fast-growing PV industry (due to higher cost), meaning an extravagant growth rate sustained over many decades would be required to catch up.

The resource base for hydro, geothermal, wave and tidal is significant only in some regions. Energy from biomass suffers from very low efficiency of sunlight capture, and unresolvable conflict with food and ecosystems for land, water, fertilisers and pesticides. Nuclear is too expensive, and planning and construction rates are far too slow, to catch up with PV and wind.

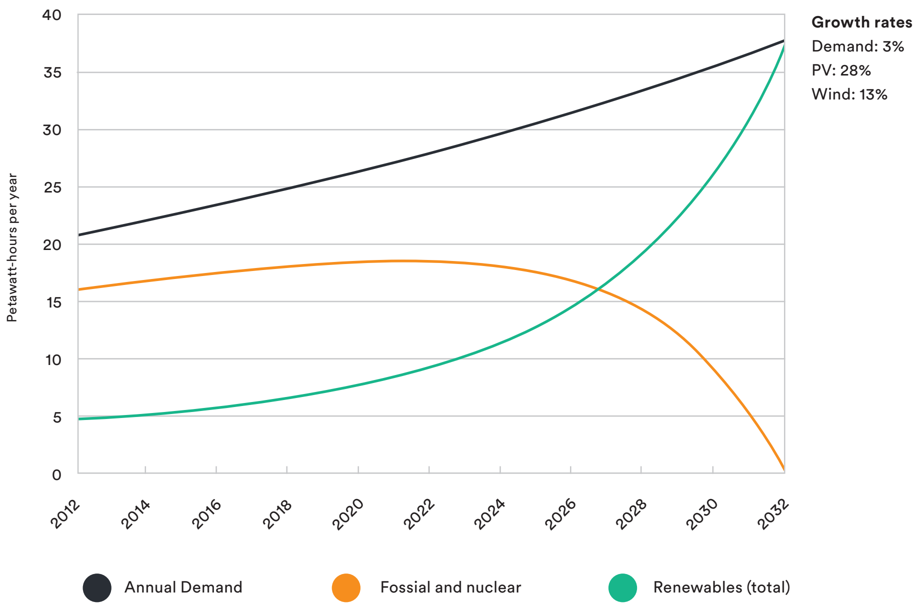
Stabilising an electricity grid with high levels of variable PV and wind is straightforward (as explained in the *ScienceDirect* article *100% renewable electricity in Australia*) and comprises storage and strong interconnection with high voltage cables over large areas to smooth out the effect of local weather. By far the leading storage technologies are pumped hydro and batteries, with a combined market share of 97 per cent, according to the DOE Global Energy Storage Database's global project installations over time.

For more information see *The Conversation's Want energy storage? Here are 22,000 sites for pumped hydro across Australia* and *Explainer: What can Tesla's giant South Australian battery achieve?*. The cost of PV and wind have been declining rapidly for many decades and is now in the range $55–$70 per megawatt hour in Australia. This is below the cost of electricity from new-build coal and gas units. There are many reports of PV electricity being produced from large-scale plants for $30–$50 per megawatt hour (for example, the *Review Economy* article, *Energy market tipping point is coming, and fast*).

PV and wind have been growing exponentially for decades. In 2017, PV and wind comprised 60 per cent of net electricity generation capacity additions worldwide, with coal, gas, nuclear, hydro and other renewable capacity comprising the rest (Figure 2). Importantly, the combined global installed generation capacity of PV and wind has now reached half that of coal and will pass coal in the mid-2020s on current growth trends. It seems likely that global coal generation capacity will peak in 2019 and decline thereafter.

In Australia, PV and wind comprise effectively all new generation capacity. About 10–11 gigawatts of PV and wind is expected by the Federal Government's Clean Energy Authority to be installed in 2018 and 2019, compared with peak demand of 36 gigawatts in the national electricity market. This installation rate is sufficient for Australia to reach 50 per cent renewable electricity by 2024 and 100 per cent in the early 2030s – meeting Australia's Paris emissions target entirely by emission reductions within the electricity system (as explored further in the paper, *Australia's renewable energy industry is delivering rapid and deep emission cuts*).

Figure 3: Current growth rates in electricity generation extrapolated until 2032, when renewables reach 100 per cent.



The amount of electricity required to completely displace fossil fuels is about three times current electricity consumption.

The cost of meeting Australia's Paris target is zero because of the low and declining cost of PV and wind (for more information, see *The Conversation's What's the net cost of using renewables to hit Australia's climate target? Nothing*). Globally, the share of annual generation by PV and wind is no longer invisible – together they are producing about eight per cent of the world's electricity and they are growing much faster than competitors. The worldwide growth rate of new PV and wind capacity over the past five years is 28 per cent and 13 per cent per year respectively. The net new installation rate of all other generation technologies is static, falling or miniscule.

It is interesting to note that PV and wind growth rates are sufficient to reach 100 per cent renewable electricity worldwide in 2032 (Figure 3), and 100 per cent renewable energy in the 2040s.

Deep cuts (85 per cent reduction) in greenhouse gas emissions require fossil fuels to be pushed out of all sectors of the economy (not just electricity). The path to achieve this is by electrification of all energy services. Straightforward and cost-effective initial steps are to:

- reach 100 per cent renewable electricity (pushing out coal)
- convert most land transport to electric vehicles (pushing out oil)
- use renewable electricity for water and air heating (pushing out gas).

These trends are already well established and would yield a 56 per cent reduction in current greenhouse gas emissions (Figure 1) at zero net cost.

The best available prices for PV already match the current wholesale price of gas in Australia ($10–15 per gigajoule after losses according to the Department of the Environment and Energy's Gas Price Trends Report 2017), The outlook for the oil and gas industries is poor as PV prices continue to fall.

High temperature heat, industrial processes, aviation and shipping fuel, and fugitive emissions can be displaced by renewable electricity and electrically produced synthetic fuels, plastics and other hydrocarbons. There may be a modest additional cost depending on the future price trajectory of PV and wind.

Taken together, the amount of electricity required to completely displace fossil fuels is about three times current electricity consumption. In other words, worldwide electricity production must triple.

Remarkably, current annual global growth rates of PV (with support from other renewables) are enough to eliminate coal, oil and gas use in the 2040s (Figure 3 shows the first 14 years).

Continued rapid growth of PV and wind (with support from other renewables) will minimise dangerous climate change with minimal economic disruption. Many policy instruments are available to hasten their deployment.

Government policy should recognise PV and wind as the by far the cheapest route to deliver the necessary solution to global warming in a short time frame.

Dr Elizabeth Buchanan

Fuelling Asia: Russia recalibrates its foreign energy strategy

On the doorstep of vast reserves, the Asia Pacific will account for the majority of growth in terms of future energy demand. For Moscow, this is a welcome reorientation of economic growth and energy demand.

Dr Elizabeth Buchanan is the Project Lead for the EU Commission Jean Monnet Energy Policy Workshop research initiative at the Centre for European Studies at ANU. Her areas of expertise are Russian foreign energy strategy, critical infrastructure security and polar geopolitics. Elizabeth completed her PhD on Russian Arctic strategy under Vladimir Putin in 2017 and holds an Honours degree in Russian-Ukrainian natural gas relations. In 2017 Dr Buchanan was the Maritime Fellow at NATO's Defense College where she examined the GIUK gap threat and sea cable security. Elizabeth has published widely on Russian energy strategy and Arctic affairs with *Foreign Affairs*, The Lowy Institute, The Australian Institute for International Affairs and *The Moscow Times*. In 2015, Elizabeth was a Visiting Scholar with The Brookings Institution's Foreign Policy unit. She has experience in the private oil sector, is an assistant Course Convenor on the ANU Strategic and Defence Studies Centre teaching staff and is a 2018 Australian Institute of International Affairs Early Career Research awardee.

Russia holds the world's largest known reserves of natural gas. Much of these reserves are located in Russia's Far East, out of reach for the existing European market given the sheer distance. Enter Asia. On the doorstep of vast reserves, the Asia Pacific will account for the majority of growth in terms of future energy demand. For Moscow, this is a welcome reorientation of economic growth and energy demand. Russia's energy sphere accounts for more than a quarter of its gross domestic product (GDP), almost two-thirds of the Russian export market and roughly 30 per cent of the Kremlin budget. Gone are the days of Putin's pipeline politics towards Russian vassals abroad and Yeltsin's resolve to siphon gas supply from unruly former Soviet states. Despite this historical 'energy weapon' sentiment that Russia attracts, the reality is that Russian foreign energy strategy is shifting to become increasingly interdependent.

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Ambitiously, Moscow is planning for the Far East to account for 40 per cent of Russia's oil and gas exports. Russian liquefied natural gas exports to Asia are expected to rise from six per cent to 30 per cent by 2035.

Future proofing foreign energy strategy

Moscow's recent re-evaluation of its foreign energy strategy illustrates this shift. However, global preoccupation with Russian action on the Crimean Peninsula since 2014 means many missed the Kremlin's redraft of its foreign energy strategy. Still in draft form, the Energy Strategy of Russia for the period up to 2035 (ES-2035) is geared at transitioning Russia away from resource-dependency and toward resource-innovation. This is an attempt by the Kremlin to future proof Russia's energy sector and reshape its development plans for the next 17 years. The strategy earmarks Eastern Siberia and the Far East as paramount to Russia's energy policy in the future. Ambitiously, Moscow is planning for the Far East to account for 40 per cent of Russia's oil and gas exports. Russian liquefied natural gas (LNG) exports to Asia are expected to rise from six per cent to 30 per cent by 2035. For Prime Minister Medvedev, Russia's ability to increase its presence in the Asia-Pacific market while executing existing commitments to Europe is of central importance to the new foreign energy strategy. And it is this balance that Moscow needs to work on.

Included in the redrafted ES-2035 are responses to external pressures – associated with Western sanctions stemming from a plethora of assertive activities by Russia since 2014. These pressures include increasingly difficult methods of securing credit to fund new energy projects in the Far East as well as the Western technology to explore new energy fields in the region.

A broader pressure is the shifting international energy sector with developing nations set to overtake developed nations in terms of resource demand. Not only is the global pole of power moving to the East, the future of global energy demand is also to be found in the Asia Pacific. Further, new energy sources are emerging, particularly in the renewables sector, and export competition is leaving some energy chains in a supply glut. As a key global energy power, Russia's future prosperity relies largely on how it mitigates this range of external pressures.

It's geography, stupid

Russia is looking East for the answers. As Matthew Sussex's 2015 Lowy Institute Analysis points out, Russia is not doing so by choice. This is a crucial fact that rejects much of the Western rhetoric surrounding Putin's pivot to the East. First, the concept of Russia not already belonging in Asia strips Moscow of its centuries old Eurasian identity. Second, to argue Russia's pivot East is a reflexive strategic choice to counter the United States' pivot to Asia conveniently writes off numerous historical attempts by Stalin, Gorbachev and even Yeltsin to revive Russia's Far East. Under Putin, we have seen a clear reorientation of Russia's foreign energy strategy to rectify Moscow's marginal share of the Asian energy market. This is increasingly evident in the use of the Northern Sea Route (NSR) to link Russian Arctic LNG to the North East Asian markets in particular, despite a closer Western market to the High North field.

Vladimir Putin participating in a plenary session with John Fraher, OPEC Secretary General Mohammed Sanusi Barkindo, Director-General of the International Renewable Energy Agency Adnan Z. Amin and Secretary General of the Gas Exporting Countries Forum Seyed Mohammed Hossein Adeli. (Photo credit: Official Internet Resources of the President of Russia, CC BY 4.0).

In any case, the notion of Russia seeking a complete pivot to Asia is entirely misguided. European energy imports from Russia have increased and new energy projects are underway. Examples are the Nord Stream-2 and TurkStream pipelines. When considering the ongoing commercial dealings undertaken in Europe, it is evident that Russia is unable to completely pivot away from the West. What is occurring is a fundamental *rebalance* of Russian foreign energy strategy – facilitating Moscow to act as a Eurasian power fuelling both the East and West. Russia's energy interest in the Asia Pacific is an unsurprising development, no more than the 'revenge' of geography. A resource rich state borders the region set to account for the majority of global energy demand – what follows is more or less a marriage of convenience shaped into a strategic relationship.

A common misperception of Sino-Russian energy relations is that there is an emerging partnership to thwart United States power in the region.

Beyond centuries of mistrust and competition, Russia and China are still far from strategic bedfellows. This is illustrated in the energy pillar of their relationship, where straightforward commercial discussions are protracted and increasingly complex. Negotiations of the natural gas pipeline, Power of Siberia, stalled for decades before a 30-year partnership was struck in 2014. Slated for completion in 2019, the route appears ahead of schedule and there are now discussions to construct a brother pipeline to increase Russian export capacity to China. On face value, the commercial partnership is a win-win for all involved. Yet in reality, Beijing was able to beat down the natural gas price and dictate the orientation of the pipeline – it meets the Chinese border in the Far East and not in the West, as Moscow had envisioned. A western route would have allowed Moscow access to further markets in Central Asia, further diversifying its customer base.

A balancing act

For a nation with energy superpower ambitions, it is perplexing that Russia's energy sphere only accounts for one quarter of total state investment. However, it becomes apparent that Moscow has found a solution – albeit a short-term one. Beijing has agreed to fund a variety of oil, natural gas and coal projects in Russia's Far East. Despite the Russian Far East accounting for 40 per cent of Russian territory, the region has remained no more than an afterthought. This is down to a range of factors, including slow development of the economy after what Putin described as the "greatest geopolitical tragedy of the 20th Century" in his 2005 State of the Nation Address – the collapse of the Soviet Union less than 30 years ago. The lack of modern technology and investment to improve the sector or branch out into renewables is also a roadblock to Russian strategy. Low growth in terms of global demand for Russian hydrocarbons and the increasingly competitive international energy market have also curtailed Russian progress.

Seizing on Russia's domestic structural issues, China is diversifying its energy import potential by also focusing on Russia's Far East region. The Russian Far East population is only about seven million, yet shares a border with roughly 70 million people in China's North East. The Far East is a resource-rich region with plenty of space for population growth, something no doubt Beijing has an interest in.

Despite centuries of border disputes in the region, of late all has been relatively quiet on this front. Nonetheless, Russia's Far East is certainly a potential flashpoint of conflict. Here, Russia is attempting to mitigate overreliance on the Chinese export market by diversifying its energy customer base within the Asia Pacific. Japan and South Korea are set to receive LNG from Russia's Yamal and Sakhalin regions via the NSR.

Discussions are ongoing with North and South Korea to extend Russia's Far East pipeline network to include a trans-Korea route. Further, Russia's efforts to insert itself into the South East Asian energy chain are highlighted by various energy projects in Vietnam. Moscow's new fuel corridors have the potential to place Russia at the helm of Asia's energy architecture. The priority for Russia is to control, as much as possible, Beijing's influence over its resource potential. This is a central challenge for the Kremlin given the sheer access to capital Beijing affords. Yet, we have witnessed attempts to limit Chinese influence in Russian Arctic energy projects. Avoiding overreliance on Chinese capital for new projects, Moscow has invited India and Japan to join various joint ventures.

The Russian Far East population is only about seven million, yet shares a border with roughly 70 million people in China's North East. The Far East is a resource-rich region with plenty of space for population growth, something no doubt Beijing has an interest in.

Vladimir Putin presenting at a plenary session at the first Russian Energy Week Energy Efficiency and Energy Development International Forum. (Photo credit: Official Internet Resources of the President of Russia, CC BY 4.0).

Implications for Australia

There are clear corresponding implications for the Australian energy export market. The most pressing: we are set on a potential collision course with Russia when it comes to fuelling the Asia Pacific. The Australian Government should watch Russia's NSR development closely, as a key component of the ES-2035 is the creation of a new global energy corridor for Asia. This has substantial implications for Australia. The Asia Pacific currently relies on the Malacca Strait corridor to receive goods, and the majority of our energy needs. This corridor is congested, poorly secured and has long lead times – all of which factor into increasing transportation costs. These costs are carried over to the consumer. Russia's NSR, which can currently operate 3–4 months of the year for Asia (year-round for Europe), offers a viable alternative to fuel the Asian market in terms of LNG. Thanks to climate change, in the coming years the NSR will be passable year-round. Of course, there is also the question of how competitive North American and Australian LNG can actually be for the Asian market, compared with pipeline gas from Russia's Far East.

The reorientation of global energy corridors provided by the NSR will ultimately make Australia an extremely expensive import and export market. Not only does this mean higher fuel prices for Australians, it will put our transit-heavy economy under stress. Our fuel insecurity, currently at about 20 days' supply despite our International Energy Agency obligation to hold 90 days, will be further exposed. The Kremlin fired a warning shot when it stated its resolve for energy to serve to ensure Russia's security in full. Recent history has indicated how serious the Kremlin takes matters of security.

On the horizon, it is evident that Australia's energy interests in Asia places us in direct competition with Russia. It is crucial to develop a robust energy strategy to meet the looming challenge Australia's energy exports will face in the region. Just as critical is planning for Russia's potential to secure its interests by weaponising energy in the Asia Pacific. Here, the East has much to learn from the Western experience of entering into energy partnerships with Russia.

Dr Matthew Dornan

Small island states and the challenge of 'best practice' regulatory reform

History shows that regulatory models advocated internationally will often not be appropriate in small island states. What is clear is that there is no one regulatory structure best suited to enabling small island states achieve their power sector ambitions: a range of different reforms and initiatives appropriate to different contexts is needed.

Dr Matthew Dornan is Deputy Director of the Development Policy Centre in the ANU Crawford School of Public Policy. His research focuses on economic development in the Pacific Islands and Papua New Guinea, and includes work on infrastructure access and regulation, foreign aid and climate finance, and regional integration. Matthew has a particular interest in energy regulation and access in small island states. He leads the Energy for Development cluster of the ANU Energy Change Institute.

Small island states have led the world in establishing ambitious renewable energy targets over the last decade. This has made for a dynamic electricity sector in small island economies, with considerable investment in new generation capacity. Achieving renewable energy targets has been one objective on which reform of the power sector has been advocated in recent years. These reforms draw on what is considered international 'best practice' and follow on from an earlier and quite different set of reforms that aimed at liberalising the sector.

Globally, reform of the electricity sector has achieved mixed success since the first wave of reform in the 1980s. The introduction of competition and private sector involvement, in what was traditionally a sector dominated by the state, was once advocated on efficiency and performance grounds, and in light of the poor performance and reach of state-owned utilities. A second more recent wave of reform has instead focused on regulatory oversight. Its primary objective has been to encourage new investment through appropriate pricing in the sector. 'Best practice' in this second wave of reform has been framed around independent price regulation – both in the case of retail and feed-in tariffs.

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There has been ongoing debate regarding the appropriateness of such reforms in small island states. The two defining features of small island states are size and the absence of land borders with neighbouring states. Both have important ramifications for the electricity sector. Almost all electricity networks in small island states are isolated networks, meaning they are not connected to other networks, including those of other countries. Energy security, an important consideration for all electricity networks, is far more challenging for isolated networks. Such networks must be self-sufficient in the production of electricity – they do not import electricity from neighbouring networks, such as occurs in other small states (for example, Luxembourg). This means backup generation (or storage) is required, which increases the economic cost of supply. The lack of a connection with other networks also makes it more complicated and costly to integrate renewable energy technologies that produce electricity intermittently.

The small scale of networks in small island states presents other economic challenges. Limited demand for electricity constrains the ability of power utilities to achieve economies of scale in generation. Unit costs are higher as a result. Although this situation has changed considerably in the last decade due to technological advances that have lowered the cost of renewable energy technologies (especially solar power), the absence of economies of scale is still important in explaining why electricity supply costs are higher in small island states than in larger countries.

The power sectors of most small island states developed as vertically integrated monopolies, as occurred across most of the world. In a majority of small island states, the state either controlled or had a share in this monopoly – in many cases after purchasing private companies that had initially developed small networks. State control or investment in the monopoly utility was often used as a means to achieve government objectives without the need for regulatory oversight.

The monopoly model worked reasonably well in small island states with effective governments and limited corruption, especially where governments had a stake in ownership. It worked less well where these conditions were not met. Many power utilities in the Pacific, for example, were obliged by political leaders to price electricity below its full cost. As outlined in a previous paper from 2014 entitled, *Access to electricity in Small Island Developing States of the Pacific: Issues and challenges*, this placed power utilities under financial pressure and they were unable to adequately maintain generation equipment and networks.

By design, the monopoly model of regulation did not attract investment from other parties. This has acted as a barrier to expanding access. Approximately 70 per cent of households in the Pacific Islands remain without access to electricity.

The small scale of networks in small island states presents other economic challenges. Limited demand for electricity constrains the ability of power utilities to achieve economies of scale in generation.

Domestic meets public with a washing line set up around power meters and an electricity pole in Port-Villa, Vanuatu (Photo credit: Michael Coghlan, CC BY-SA 2.0).

The monopoly model has also acted as a barrier to renewable energy investment. This has taken on importance in recent years in the context of climate change discussions, with small island states establishing renewable energy targets that are among the most ambitious in the world.

It is in this context that a second wave of reform has been underway in many countries.

The first wave of reform aimed at liberalising the electricity sector had limited impact in small island states – more limited than in other developing countries. Size is clearly important in determining whether liberalisation is appropriate. No country with less than 1,000 megawatts of installed capacity had established a wholesale market that features competition.

The second wave of reform has had greater impact on the electricity sector of small island states.

It has involved establishing appropriate pricing structures at arm's-length from government, aimed at facilitating the entry of independent power producers (the monopsony model). Efforts to expand renewable energy supply – often with reference to a response to climate change – have been used to justify many of these reforms.

This second wave of power reform is less problematic for small island states than the first. Economy of scale constraints to competition are less relevant in the monopsony model, central to which is a dominant power utility. However, the monopsony model is not without challenges. To function well, such a model requires independent regulation to ensure that an adequate feed-in tariff is paid to independent power producers, that electricity prices charged to consumers reflect costs, and to provide a means of preventing the abuse of market power by the dominant utility (especially important where the utility is no longer controlled by government).

Independent regulation has fixed costs, which potentially overwhelm the benefits of reform for the smallest networks. This is an issue of particular importance in microstates, or the smallest of the small island states (for example, Nauru and Tuvalu, each with populations of 10,000).

A related challenge is finding the human resources necessary for regulation. Effective regulation requires staff with particular skillsets – lawyers, accountants, economists – and necessary expertise. Such skills and experience are in short supply in most small island states.

Effective independent regulation in small island states also faces challenges unrelated to resources. Regulatory capture, where an independent regulatory agency is too heavily influenced by the regulated entity, is a risk in any country.

But it is especially likely in a small state where expertise in the sector is limited to a small number of people. In this context, personal relationships between experts are of increased importance, making confrontation between the regulator and regulated entity unlikely, no matter how warranted.

There are several possible approaches to addressing challenges associated with independent regulation in small island states.

The first is regional regulation, or pooling resources for regulation, such as might occur with a regional regulatory agency. This approach has the potential to make regulation more economically feasible for small states, and addresses the challenge of establishing a truly independent regulatory body in small states. However, experience suggests that establishing such an agency is challenging.

Power meters are surrounded by lush vegetation in Luganville, Vanuatu. (Photo credit: Michael Coghlan, CC BY-SA 2.0).

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A related challenge is finding the human resources necessary for regulation. Effective regulation requires staff with particular skillsets – lawyers, accountants, economists – and necessary expertise.

The best example of an organisation responsible for regulating the electricity sector across multiple small island states is the Eastern Caribbean Regulatory Authority (ECERA), which has taken years to develop and has had a mixed record. A common problem has been the perceived lack of legitimacy of these organisations. The public attention electricity prices receive makes this deeply problematic. A related approach involving use of regulatory capacity in larger neighbouring metropolitan states is subject to the same issue.

A second approach has involved establishing a regulatory body responsible for regulation across multiple sectors. This model has clear advantages in terms of reducing the cost of regulation. It is increasingly used in the Pacific Islands. In the case of electricity supply, multi-sector regulators have been given the power to regulate prices in Fiji (2002), Papua New Guinea (2002), Vanuatu (2007), and Samoa (2009). Multi-sector regulators also control electricity prices in a number of Caribbean states, including Jamaica and in Trinidad and Tobago.

There are a range of such models. A multi-sector regulator could be large, as in the case of the Australian Competition and Consumer Commission, which incorporates the Australian Energy Regulator. But it could also be small, drawing on external expertise as required. In an extreme form, a multi-sector regulator could operate only as a secretariat for external commissioners, a model which would have the added value of reducing the risk of regulatory capture.

Such an approach might seem suited to small island states, but it too is not without flaws. External expertise is costly, and establishing sound contracts requires another set of specialised skills. Neither alternative comprehensively addresses the challenges of independent regulation for microstates.

There are other options. In some states, the traditional monopoly model has worked reasonably well, minimising the need for specialist regulatory expertise. Indeed, the push for independent regulation in small island states recently has come about due to a desire to attract private sector investment. Such investment may not be needed in small island states where the power utility is in a sound financial position or where foreign aid provides necessary funds. Where private sector investment is needed, there are also alternatives to independent regulation, such as regulation by contract. However, for such options to work, a strong judicial system and confidence in government are needed.

History shows that regulatory models advocated internationally will often not be appropriate in small island states. What is clear is that there is no one regulatory structure best suited to enabling small island states achieve their power sector ambitions: a range of different reforms and initiatives appropriate to different contexts is needed.

Edwina Fingleton-Smith

The three E's of energy security – equitable, effective and efficient

The way we use energy as individuals, as families, as households, is intimate. It reflects our deepest desires for how we want to live – our priorities, our values, our dreams.

Edwina Fingleton-Smith is a Postdoctoral Fellow at the ANU Fenner School of Environment and Society. She is a qualitative researcher whose work focuses on creating a more detailed understanding of how energy access can most effectively improve people's lives. Edwina is driven by a passion for sustainable development and the big questions that arise from the relationship between energy and development: Who benefits from access to modern energy and how do they benefit? What can we do to maximise the benefit of access to energy access? What does the future of energy access in developing countries look like? Prior to starting her PhD at Fenner, Edwina completed a Masters of Environmental Law and Sustainable Development at SOAS (University of London) and a Bachelor of Development Studies at ANU.

The Three Gorges Dam in China, the largest power station in the world, has a generation capacity of 22,500 megawatts. A breastfeeding mother, gently illuminating a room in the middle of the night so as not to disturb her baby, uses but a handful of watts.

The why of energy security is very different to the how of energy security.

The way we use energy as individuals, as families, as households, is intimate. It reflects our deepest desires for how we want to live – our priorities, our values, our dreams. We cook for loved ones, transfer money to the other side of the world to support family, and chill champagne to celebrate great successes. We also turn up the heating (often just when guests are visiting) to hide the shame of poverty, slam down phones in anger, and create a global mountain of e-waste in our desire to keep up with the Joneses.

Energy security starts with human security, and is as much about individuals and communities as it is about technology and economics.

A focus on how individuals benefit from energy is also useful because it inevitably commits us to thinking about who actually is benefiting from energy, and who is not.

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Globally more than one billion people still do not have access to electricity.

To make sure that energy is in fact delivering security, energy projects need to address three issues. Firstly, they need to recognise the legitimate needs of people in places the grid has not, or will never likely go to, and provide a meaningful alternative. Secondly, they need to be certain that the form of energy provided is appropriate and useful for the people who will be using it. And thirdly, the energy service needs to be provided in a broader environment that facilitates productivity and thus can enable tangible changes in people's lives.

Equitable access

Energy security that only focuses on grid-based security is energy security for the relatively rich. It relegates and excludes the poor, marginalised and rural groups most in need of better energy access.

Globally more than one billion people still do not have access to electricity. And in many cases the easiest fixes have been implemented and the remaining populations without access are the poorest and most geographically remote people of the developing world. The cost of accessing electricity for these groups is generally prohibitive, and the remote locations of many only increases this cost.

Research continuously shows that poor households spend a far greater proportion of their incomes on significantly lower quality energy. According to a paper by Evan Mills and Arne Jacobson in *Energy Efficiency*, households not connected to the grid spend $40 billion per year on lighting, yet receive only 0.1 per cent of the lighting service consumed globally.

While the benefits of grid-based electricity solutions are undeniable, we must not leave behind those people who it is too inconvenient logistically or economically to extend the grid to.

Historically, renewable energy offered inferior results for remote communities but that is no longer the case. Today renewable energy offers cost effective scalable solutions from micro grids and household systems right down to a single solar powered light. However, policy makers must prioritise access to these technologies as enthusiastically as they do expansions and upgrades of centralised grid systems.

Effective use

The extreme lack of energy access globally has rightly increased focus on expanding the supply of energy to poor people around the world. Yet frequently this devolves into success being defined simply as an increase in energy supplied when it should be measured by burdens reduced, incomes increased, and lives improved. A focus on the technology rather than the people obscures the actual needs that energy access might meet. When we talk about energy security in terms of renewable versus non-renewable, centralised versus decentralised, we talk about solutions when we should be talking about problems. We should be talking about cooking and washing and mobility and agricultural spoilage and physical insecurity. And then we should ask ourselves what are the most appropriate solutions to those problems, and is our technology of choice the best solution?

Traditional forms of energy have always been a means to a specific end. Three-stone fires for cooking, coal irons for ironing, kerosene lamps for lighting, smoke for prolonging the life of food. But modern forms of energy, electricity especially, are often sold as being not the means, but the end.

To have electricity access is to have increased your development, to have climbed up another rung towards the much vaunted goal of civilisation. However, energy is only as useful as the service it supplies.

When it comes to energy access, improved cook stoves – simple technologies designed to increase the efficiencies of, and reduce smoke from, traditional cooking methods – lack the glamour and technical appeal of more complex technologies. Yet the health impacts from smoke inhalation are so insidious that in 2016 the World Health Organization stated that "household air pollution is the single most important environmental health risk factor worldwide". This leads to 4.3 million people, mainly women and children under five, dying each year. That is more than the number of people who die each year from malaria and HIV/AIDS combined. This is the definition of energy insecurity.

A revolution in energy security would not be providing electric lights to everyone; it would simply be enabling 2.7 billion people to use improved cook stoves.

Efficient outcomes

Genuine energy security should focus on human needs. In the context of poor people around the world, this focus must be on how we can use energy to maximise development outcomes. If limited aid budgets are directed towards energy for productive activities, and away from other infrastructure or services that could improve people's socio-economic wellbeing, then it is important that energy access can and does meet its intended outcomes.

Modern energy is a fundamental building block in the process of obtaining the increased wellbeing that we call development. Energy access brings with it the possibility of a raft of different benefits – reducing drudgery, improving security, facilitating gender equality and enhancing access to information, just to name a few. Yet it is an oddly difficult relationship to monitor. Energy access can support increased income generation, but only in conjunction with other factors.

Elizabeth Mukwimba displays her new solar lighting and electricity in her home as provided through a scheme backed by UK Aid (Photo credit: Russell Watkins/UK Department of International Development, CC by 2.0).

Edwina Fingleton-Smith

It is unarguably tied with development, but whether demand for energy is a product of development, or access to it is a driver of development, remains unsubstantiated. Indeed, the energy–development relationship broadly is characterised by the lack of a rigorous evidence base.

Arguably though, the greatest potential of modern energy is its ability to enhance productivity. Almost all development interventions that seek to improve energy access do so with the intention of directly or indirectly increasing growth or incomes.

Most modern energy access programs focused on productivity will, in some manner, attempt to assist individuals to use newly acquired energy to increase their income, such as training them in small business skills or facilitating financing services. But these individual services offer limited prospects for transformational change and there are few systematic approaches that use energy as part of a broader development process. Instead the necessity of energy access to development almost becomes reframed as the non-necessity of all other development interventions.

Productive uses of energy are not automatic functions of energy access. They are a result of a much larger collection of skills, knowledge, infrastructure, capital, input availability and policy environment. For energy access to have any chance of meaningfully changing people's lives, it must be within an environment that is already supporting and facilitating individuals and businesses to succeed. The utility that can be created from an energy supply is low if it doesn't occur in a systematic environment that facilitates economic development.

The additional components that need to co-exist in order to turn energy access into economic development are often termed 'complementary services' and include both hard and soft infrastructure and various forms of knowledge and skills.

Providing these complementary services might take the form of focusing on delivering energy access programs in areas where significant sectoral development activities are already planned, such as agricultural development programs.

Employees of a solar savings cooperative in Bariadi, Tanzania. These cooperatives allow many people access to solar technology where they may have not previously been able to afford it. (photo credit: Russell Watkins/UK Department of International Development (CC by 2.0).

Energy is nothing without the humans who use it – it enhances all of our capabilities and our potential, for better and for worse. But its critical importance to every aspect of modern society can overshadow the very people who use it.

This means places where it is obvious how energy can be used productively to add value to goods and services produced and traded in the area, and places with more systematic approaches to removing barriers to development, such as actively facilitating access to markets, vocational training, government support for additional infrastructure like roads, and tariff reduction on additional capital.

There are examples of energy policy being directed in a more industry specific way to maximise economic gains. Vietnam's attempts to electrify were heavily based on the understanding that rice production was the major agricultural activity. They channeled resources into bringing modern agricultural processes to the main rice growing areas, controversially even de-prioritising household lighting initially in favour of irrigation and small businesses. The unquestionable development success Vietnam has had in the last few decades suggests that more targeted policies can overcome the question marks around how to best utilise energy to maximise development outcomes.

Conclusion

Energy is nothing without the humans who use it – it enhances all of our capabilities and our potential, for better and for worse. But its critical importance to every aspect of modern society can overshadow the very people who use it. For energy to truly generate security, it must be equitably accessible to all users, effectively address the problems of those users, and be provided within an environment that supports development. For all its size and grandeur, the Three Gorges Dam, without the tired mother quietly settling her baby, is irrelevant. We are energy, and energy is us.

Honorary Associate Professor Hugh Saddler

System security in the National Electricity Market

System security in a large electricity supply system goes beyond the obvious need to protect the system from deliberate damage. It is also about the system's capability to remain functional under all but the most catastrophic circumstances.

Dr Hugh Saddler is an Honorary Associate Professor at ANU Crawford School of Public Policy and an independent consultant, specialising in energy and environmental policy and economics, with a particular focus on climate change policy. He first worked professionally on these issues in the United Kingdom, during the 1970s and did his first work on climate change policy in 1988. Over the intervening years he has worked as both an academic and a consultant. He is a regular media commentator on energy and climate change policy and is the author of the monthly *National Energy Emissions Audit Report* on trends in Australian energy supply, consumption and greenhouse gas emissions. Over the past few years his work has had a strong focus on the operation of the Australian electricity supply system and on factors affecting demand for electricity.

System security in a large electricity supply system goes beyond the obvious need to protect the system from deliberate damage. It is also about the system's capability to remain functional under all but the most catastrophic circumstances. In the event of a catastrophic event, causing complete collapse, a secure system must also be able to restart promptly without incurring further damage.

When examining system security in Australia's National Electricity Market (NEM), it is important to understand that the term NEM has two distinct, but related, meanings. Firstly, it refers to the rules and institutions through which electricity is traded in wholesale volumes across most of the country (excluding Western Australia and the Northern Territory that are not part of the NEM). Secondly, the NEM refers to the connected system of around 40,000 kilometres of transmission lines, transformers, circuit breakers and other equipment transporting electricity from power to consumers. The combination of this equipment transporting electrical energy and the generators supplying the energy constitutes an electricity supply (or power) system. The system was largely built by the various state electricity commissions, before the establishment of the NEM as a wholesale electricity market in the late 1990s. Some of this legacy has been replaced and some upgraded by the successor transmission service provider businesses in each state (of which three are now privately owned and two remain government owned).

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The term security also has two meanings in this context. The more general meaning refers to protection against deliberate damage, which is crucial given society's dependence on electricity supply. Security measures to protect the electricity system from such deliberate damage are, rightly, not a matter for general public debate. Security, in this sense, is not considered further in this essay.

A more technical and precise definition of power system security, as discussed in this essay, is provided by the Australian Energy Market Operator (AEMO):

> *"Power system security arises when the power system is operating within defined technical limits, and is likely to return within those technical limits after a disruptive event occurs, such as the disconnection of a major power system element (such as a power station or major powerline)."*

When applied to an electricity supply system, the meaning of *security* is quite distinct from the meaning of *reliability*, which AEMO defines as:

> *"The ability of the power system to supply adequate power to satisfy consumer demand, allowing for credible generation and transmission network contingencies."*

While a power system cannot be reliable if it is not secure, it can be secure but not reliable if the volume of available generation is insufficient to meet demand for electricity at all times. The requirements for system security are defined by the laws of physics. Ensuring those requirements are met is primarily a task for electrical power engineers. Ensuring the system is reliable, on the other hand, requires the NEM, as a market, to deliver the necessary volume and mix of generation capacity. In other words, security is mainly concerned with the operation of the NEM as an electricity supply system, whereas reliability is mainly concerned with the operation of the NEM as a wholesale electricity market.

The recent AEMO publication, *Power system requirements*, itemises the separate security services essential to the operation of an electricity supply system, including frequency management, voltage management, and system restart services. They can be summarised as follows:

- frequency management: inertia, primary frequency control, secondary frequency control
- voltage management: fast response voltage control, slow response voltage control, system strength
- system restart services.

The key point is that all the services are requirements for the system as a whole, rather than requirements for, or properties of, individual generators.

In the NEM, and most other electricity supply systems around the world, these services are provided by synchronous generators – large rotating electromagnetic machines, driven by the energy contained in high pressure steam (coal fired power stations), hot combustion gases (gas turbine power stations), or falling water (hydro power stations). Synchronous generation is the only technology able to provide all of these services.

Another characteristic common to steam, gas turbine and hydro power stations is that the primary energy required to drive the generators comes from stored sources such as coal stockpiles, compressed gas in pipelines, or water in reservoirs. Consequently, generator output can be varied either up or down as directed, a characteristic referred to as dispatchability. It is straightforward to ensure system reliability in a system supplied by dispatchable generators, provided enough generation capacity is available.

The share of electricity consumption in the NEM supplied by synchronous generators has fallen from 100 per cent in 2002 to 88 per cent today. The remaining 12 per cent is supplied by a mix of wind and solar photovoltaic generation.

Until now the main driver for the growth of wind and solar generation has been the financial subsidies provided through the Large-scale Renewable Energy Target and Small-scale Renewable Energy Scheme policies.

Neither of these technologies uses synchronous generation (and hence are called asynchronous) and neither uses stored primary energy. In the South Australia region of the NEM the change has been much more dramatic: falling from 100 per cent synchronous generation within the state in 2002 to 52 per cent in 2017–18. The South Australia region of the NEM is connected to Victoria, and then the rest of the NEM, through a single high voltage synchronous transmission line.

Until now the main driver for the growth of wind and solar generation has been the financial subsidies provided through the Large-scale Renewable Energy Target (LRET) and Small-scale Renewable Energy Scheme (SRES) policies. These twin policies (originally combined in a single scheme) have their origin in Australia's first package of policy measures designed to moderate growth in greenhouse gas emissions. This package of measures was announced by then Prime Minister John Howard in November 1997, on the eve of the Kyoto Climate Conference.

Around five years ago, AEMO – as the organisation with responsibility "to maintain and improve power system security" – recognised the need to look more closely at the operational challenges presented by the growing share of wind and solar generation in the NEM, as well as many other changes in electricity supply systems. That work has now expanded into a more comprehensive Future Power System Security Program. The aim is to identify how best to maintain system security in a system that is being transformed, from one dominated by large thermal power stations, to one that includes a multitude of power generation resources and technologies of various sizes.

AEMO's *Power system requirements* report makes it clear that a number of technologies, other than synchronous generation, are also able to provide the services necessary for security and reliability services. For example, non-synchronous generators, such as wind and solar photovoltaic, are able to provide frequency and voltage control, as are batteries, while machines called synchronous condensers are able to provide both inertia and system strength.

AEMO and the Australian Energy Markets Commission (AEMC), the body responsible for maintaining and updating the National Electricity Rules, are working together to enable the introduction of the new system security technologies identified by AEMO. The AEMC's System Security Market Frameworks Review began shortly before the black system event in South Australia, on 26 September 2016. However, that event demonstrated the urgency and importance of this work.

The event was set off by a series of tornadoes that demolished towers on three of the four transmission lines linking the south and east of the state to the north and west, and through which most of the state's windfarms were connected.

Solar panels in the desert.

At the time there was no challenge to reliability – the operating generators, including both synchronous gas turbine generators and asynchronous windfarms were more than sufficient to meet demand. However, immediately prior to the event, the system was not in a secure condition, and the system operators were unaware of this lack of security. For consumers, however, the result of its collapse was like a complete failure of reliability in the everyday sense of that word.

Detailed technical reports have since concluded that a series of errors of omission were to blame. Some of these errors were made during the morning before the event. Others arose from the failure of responsible parties to fully inform themselves, over preceding months or years, of key settings in the software controlling many of the windfarms in the state (settings which could have been changed, had they been known). The collapse did not occur because there was too much wind generation, as so many opponents of wind generation claim, and none of the wind generators failed.

All were operating well immediately before the tornadoes and all returned to service once the transmission system was repaired.

The first substantive outcome of the System Security Market Frameworks Review, in September 2017, was changing the National Electricity Rule to make Transmission Network Service Providers responsible for maintaining minimum levels of inertia and system strength in their part of the network. In response, ElectraNet, the Transmission Network Service Provider for South Australia, is planning to install at least three synchronous condensers in its region of the NEM grid.

This is the first of many system options to enhance system security – as the mix of electricity generation technologies changes across the NEM – set out in AEMO's Integrated System Plan, published in July 2018. This plan recognises that many of the technology changes now occurring are not driven by subsidy policies, but by rapid improvements in technology that mean wind and solar generation are now the lowest cost sources of new electricity generation.

Although Australia lags behind several countries in our share of wind and solar generation as a whole, we lead the world in the uptake of household-scale solar photovoltaic generation.

The August 2018 meeting of the COAG Energy Council was expected to decide on the now defunct National Energy Guarantee. Instead, a more important decision was actually made: to ask the Energy Security Board to advise by December 2018 on how the high priority projects identified in the Integrated System Plan can be implemented and delivered as soon as practicable.

For more than a century, as the electricity supply systems grew in Australia and many other countries, the technical challenges of ensuring system security and reliability were seen as the responsibility of the engineers planning, building and operating the systems. The public and politicians took no interest except during the very occasional event of a supply disruption affecting large numbers of consumers. Now, however, numerous politicians, political commentators and members of the public are expressing opinions on how we should achieve and maintain electricity supply system reliability and security, even without understanding the important distinction between the two. Very few demonstrate any awareness of the large amount of work on these issues already taking place across the electricity supply industry in Australia.

It is difficult to believe that so many people are really fascinated by the technical issues of power system security. A more plausible explanation is that they believe concern about security to be a rationale for their real motives, which are to oppose the growth in renewable generation and the introduction of further policies to reduce greenhouse emissions. Fortunately, the responsible agencies are getting on with the job, and they are not alone. In most countries around the world electricity supply systems are undergoing similar changes. Australian industry personnel share experience and insights with their colleagues in other countries.

This interest is reciprocated. Although Australia lags behind several countries in our share of wind and solar generation as a whole, we lead the world in the uptake of household-scale solar photovoltaic generation, which presents particular challenges to the management and operation of the local distribution part of the electricity supply industry. Almost more than any other country, Australia also has high quality resources of wind and solar energy and, almost irrespective of politics, could see the continuation, or even acceleration, of the electricity supply industry transformation now occurring.

Natalie Sambhi

Guardian, consumer or middleman? The role of the military in Indonesia's energy security

As Indonesia continues to grow in population size, economic and military strength and thus strategic importance, energy security will play a more prominent role.

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The Indonesian military plays a critical role in securing the country's energy supplies and infrastructure. However, energy security policies also impact the military, given its need for a constant supply of fuel and electricity, particularly in light of increasing reliance on networked electronic systems and the planned acquisition of more modernised air and naval platforms. Despite the imperatives to support energy efficiency and emission reduction, the Indonesian military's involvement in activities such as private security for energy exploration make it far from a neutral party in policy development. Why does the Indonesian military have such a role in energy security? And, what are the implications of its multiple conflicting interests in Indonesia's energy security policies?

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Background

The story of Indonesia's energy security is mixed. Indonesia is a significant oil producing nation in the Indo-Pacific region producing some 890 thousand barrels per day, 35 per cent of regional production. It also produces 38 per cent of the region's natural gas, according to the International Energy Agency's 2014 statistics. Nevertheless, by 2004, due to a lack of investment in domestic production and processing capacity, it became a net crude oil importer. Highly vulnerable to the effects of anthropogenic climate change, Indonesia is attuned to the need to reduce carbon emissions. However, it is also one of the world's largest exporters of coal (mainly to China), which is the dirtiest of the three main fossil fuels. With a population of more than 250 million spread across a vast archipelago, as well as a growing middle class with commensurately growing demand for energy, Indonesia will also use coal to provide full access to electricity. This has been a priority for President Joko Widodo (Jokowi), although realising this goal has been more difficult, with only 3.8 per cent of his 35,000 megawatt electricity procurement program realised.

The guardian

Within that snapshot of energy security challenges, the Indonesian military's role is to protect critical infrastructure and ensure the security of shipping and aviation from hijacking, piracy and smuggling (Presidential Decree No. 63 of 2004 on securing Vital National Objects states that the National Police have a primary role in providing security assistance, the military are able to assist upon request from police). The army is engaged in securing land infrastructure such as power plants, railways and coal mines, while the navy and air force secure sea lines of communication and ports. Piracy and maritime terrorism are particular concerns for the Indonesian navy, with hijackings of crude oil tankers through the Straits of Malacca, which fluctuates with the price of oil and kidnappings of Indonesian crews aboard coal ships near the Philippines. Compared with other Southeast Asian states, Indonesia is far more affected by both attempted and actual maritime-borne attacks. According to the International Maritime Bureau, in 2017 Indonesia suffered the most attacks with 43 incidents, while the Philippines experienced 22 and Malaysia experienced seven.

Military Police base with what appears to be their own power plant in Batuampar, Indonesia (photo credit: Vetatur Fumare (CC BY-SA 2.0).

The ability of the armed forces to provide protection for energy companies operating in Indonesia can have an immediate impact on local communities.

Natalie Sambhi

The ability of the armed forces to provide protection for energy companies operating in Indonesia can have an immediate impact on local communities. In early August, a group of soldiers accompanying a survey team from electricity company PLN were ambushed by an armed group in Paniai regency, Papua. The company had reportedly promised to provide 99 per cent of villages in Papua with power by 2019, but withdrew its teams following the ambush.

The onshore role of the military, however, provides an added justification for a continued domestic role that extends beyond mere security provision. During the New Order era (1966–1998), the military's involvement in internal affairs, including socio-political, economic and cultural spheres, was the norm. During the *Reformasi* era (post-Suharto from 1998), the military's role was largely redefined to security-related functions although, in recent years, the military is moving beyond that mandate.

In mid-2017, the Indonesian military signed a memorandum of understanding (MoU) with the Energy and Mineral Resources Ministry to cooperate on security precautions for natural resource exploration activities in the country. As part of the deal, the military agreed to secure all vital objects and exploration and exploitation activities conducted by the Ministry. However, then military commander General Gatot Nurmantyo also noted that the military would monitor the implementation of the government's one-fuel-price policy across Indonesia, especially in remote areas.

This deal raises questions about scope of the military's role. As the MoU case illustrates, the Indonesian military's role can often exceed the mandate appropriate for armed forces involvement, particularly in energy security. Monitoring of the government's fuel-price policy is more appropriate for a civilian body, whether that is a branch within the Energy and Mineral Resources Ministry or even the police. The military's ability to operate in remote areas of the archipelago, however, could serve as a pragmatic justification to monitor the fuel price. It is exemplary of the kinds of complex arrangements that the Indonesian military has within several sectors outside traditional security roles.

The military has also a vested interest in defining the parameters of energy security and conflict discourse. Indonesia's 2015 Defence White Paper identified oil and gas as 'contested strategic resources' due to decreasing energy supplies and inefficient use globally. It cautioned that an energy crisis could become the trigger for conflict in future. Former commander, General Gatot Nurmantyo took this a step further during his tenure. In 2016, he declared that Indonesia's resource wealth and geographic vulnerability would make it the site of 'proxy wars' due to diminishing energy supplies and increasing demand globally. The year before, Gatot's predecessor, General Moeldoko, now serving as President Jokowi's Cabinet Secretary, foreshadowed that energy shortages could impact on national disintegration.

Solar panels in Bali, Indonesia (photo credit: Selamat Made CC BY 2.0).

This kind of discourse has three potential effects. First, it further justifies the military's involvement in energy security in ways that encourage further capability modernisation to address vulnerabilities across the archipelago, which is needed to manage a range of other security threats. Second, an increased role in energy security could see the military's role extend further into civilian management of policies. Third, presidential candidates in the 2019 campaign will have to adopt a similar stance as the military, in case denying Indonesia's vulnerability to resource wars could make them appear weak.

The consumer of energy

Operational energy is defined by the United States Department of Defense as the energy "required for training, moving, and sustaining military forces and weapons platforms for military operations". This includes energy used in "tactical power systems, generators and weapons platforms". As Indonesia implements its Minimum Essential Force military modernisation plan and the military grows in size, there will be greater demand for energy supply. Defence publication *Jane's 360* reported in April this year that the Indonesian navy planned to have 274 vessels and 137 aircraft, with an increased number of submarines and fighter jets, by 2024. As the Indonesian military also grows more complex with the adoption of more networked and electronic systems, the armed forces will rely on access to continuous power and cooling.

At present, technological and energy supply issues are a constraint for the military. With the Indonesian government's increasing interest in building or purchasing unmanned systems, a key focus will be developing the technology to power unmanned aerial vehicles for long-endurance missions. Another example is the navy's ability to participate in multinational exercises such as Rim of the Pacific (RIMPAC), which can be constrained by the range of its vessels. The navy's frigate, KRI Raden Eddy Martadinata, was able to join RIMPAC 2018 due to replenishment of fuel from the United States navy. Whether or not Indonesia is able to develop its own refuelling capability, fuel shortages will also be a problem. For example, in November 2014, only 27 per cent of the required amount of fuel was reportedly allotted to the navy.

Regional militaries have already begun to develop strategies to address energy security. The United States Department of Defense released its first Operational Energy Strategy in 2011 in order to, in the words of then General James Mattis, "unleash" the military "from the tether of fuel". The document has since been updated in 2016. Both documents emphasise the criticality of energy requirements in the force development process, and prioritise identifying operational energy vulnerabilities to maximise warfighting capability. Similarly, the Singapore Armed Forces' Directorate of Research and Development published a report in 2009 outlining how the military can reduce dependence on fuel, increase the efficiency of battery systems and encourage the use of renewable sources for uninterrupted energy supply.

The Indonesian military could be at the cutting edge of different kinds of renewable energy and blended forms of fuel such as biodiesel, with government policy pushing the latter this year to help cut carbon emissions and reduce oil imports. It would make sense for a country wanting to boost its local defence industry to develop a concurrent program of more efficient energy consumption.

The middleman

The military's business practices, which have drifted into the energy realm, are related to the issue of budgetary constraints. Since the 1950s and through the New Order era, the Indonesian military has developed practice of raising its own revenue by managing companies such as Pertamina (an Indonesian oil and natural gas corporation). Although relinquishing its businesses was a key part of post-1998 reform, the practice has not been eliminated entirely. The more a military raises its own revenue, the harder it is to have civilian oversight of those funds.

A grey area in the military's involvement in energy security is the provision of troops as guards for mines. As is the case for energy exploration, this falls technically within the mandate of protecting energy-related operations and assets. That said, unlike the MoU discussed earlier, the arrangement for security provision is often made between the military and the private company operating the mine. The practice is well known when the military protects other designated assets of 'strategic industry' such as the Freeport-McMoRan Grasberg mine in Papua, where the military is alleged to have been involved in human rights abuses.

Outside of Grasberg, the military has also been involved in security provision and payments in coal mining. PT Arutmin, a company that managed a coal mine in South Kalimantan, engaged the local army cooperative to help address illegal mining in its areas. With soldiers acting as intermediaries between unlicensed miners and PT Arutmin, the cooperative received a share in profits of the coal sales, according to a 2006 Human Rights Watch report. Not only was the army in South Kalimantan engaged in independent revenue raising, but it was also reported to have used coercion to demand bribes from miners.

There are several problems with this kind of activity. First, in some cases, the military is using its force against Indonesian citizens and there is potential for human rights abuses. Second, incentivised by revenue raising, the military has an interest in the continued operation of coal facilities, despite the impact on carbon emissions. This causes a conflict between the military's fundamental mandate of securing the welfare of the Indonesian state and the military's own self preservation. Third, the revenue raising disincentivises accountability to civilian authorities.

Conclusion

As Indonesia continues to grow in population size, economic and military strength and thus strategic importance, energy security will play a more prominent role. The military inevitably plays a role in the physical security of the archipelago's energy supply and infrastructure but its non-security roles can undermine Indonesia's broader energy security policies and transparency of its armed forces.

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