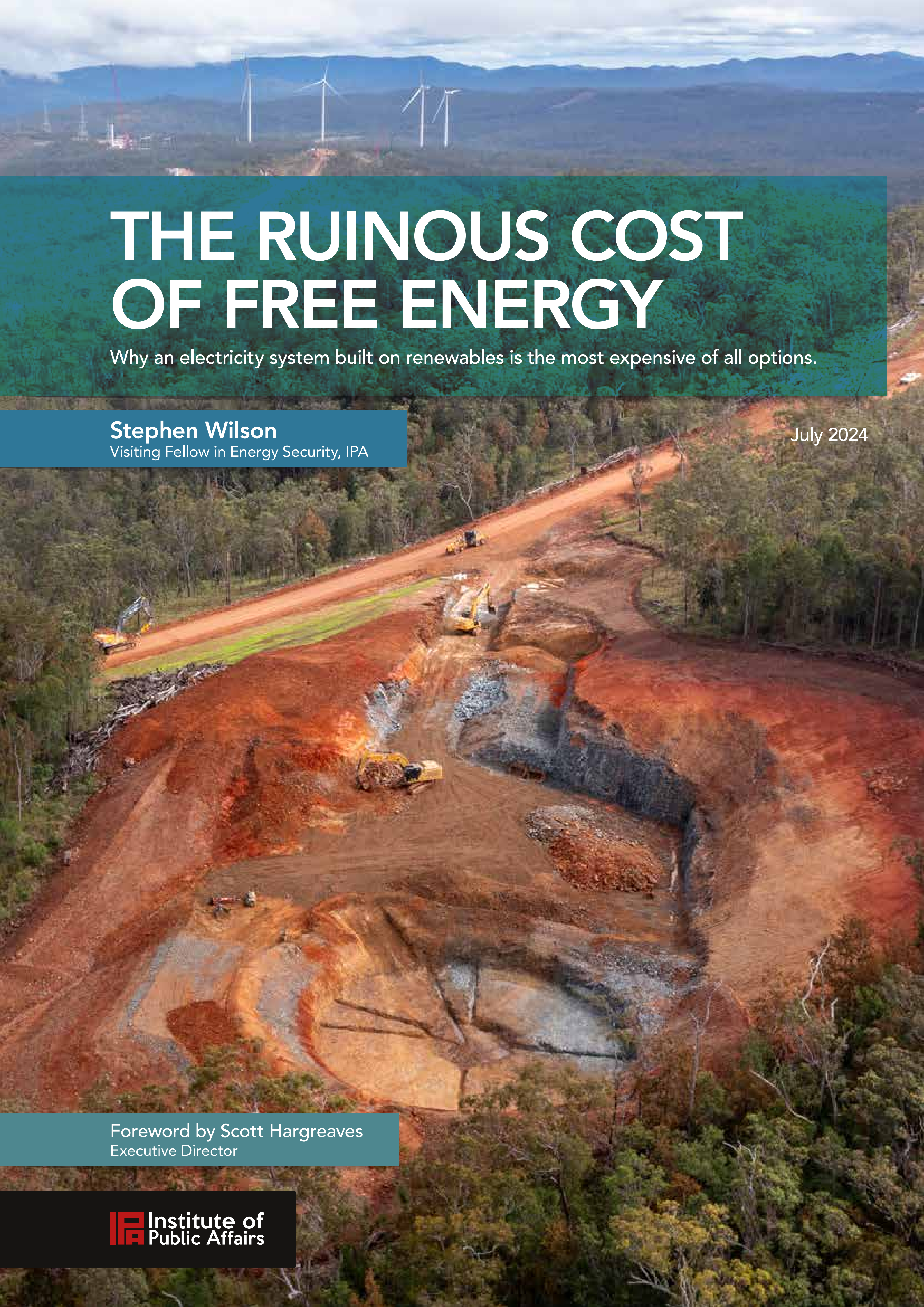

THE RUINOUS COST OF FREE ENERGY

Why an electricity system built on renewables is the most expensive of all options.

Stephen Wilson
Visiting Fellow in Energy Security, IPA

July 2024

Foreword by Scott Hargreaves
Executive Director

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Hypothesis:

"The latest GenCost report reiterates what we already know – renewable energy is the cheapest form of energy in Australia now and in 2030, even when accounting for storage and transmission costs."[1]
—The Hon Chris Bowen MP, 2023

Antithesis:

"Energy is not the same as electricity. Left undisturbed and unused, energy in its raw form does little for us. Water flowing in a river or falling in rain; coal, gas, oil, uranium buried in the ground; sun and wind from the sky – there is no cost but also no electricity. The cost comes with conversion of energy into electricity and making it available to all consumers at precisely the instant it is needed. This service includes the instantaneous transmission and distribution of electricity from the point of generation to the point of consumption at the required quality (voltage and frequency).
Energy policy should be aimed at making the conversion of energy into electricity, and making it available to all consumers everywhere, at the lowest possible cost. Unfortunately, this imperative has been deliberately ignored in recent years."
— Adjunct Professor Stephen Wilson, April 2024

If we have a system of improvement that is directed at improving the parts, taken separately, you can be absolutely sure that the performance of the whole (system) will not be improved.
—Professor Russ Ackoff, 1994

There ain't no such thing as a free lunch.[2]
—Robert Heinlein, 1964

THE RUINOUS COST OF FREE ENERGY:
Why a system built on renewables is the most expensive of all options.

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Photo credit: Steven Nowakowski.
This is the clearing for one wind turbine foundation at the Kaban Wind Farm in north Queensland. Each foundation requires the clearing of access roads up to 60m wide to enable wide and heavy loads into the often remote and rugged locations whereby a wind resource can be harnessed. This wind farm consists of 28 such foundations with each foundation requiring 650 cubic metres of reinforced concrete that will last 40 years. There are over 3,500 turbines planned for the rugged high elevation ranges of Queensland.
See also (You Tube video)
Proposed renewable energy projects across Queensland
www.bit.ly/windandsolarqld

EXECUTIVE SUMMARY

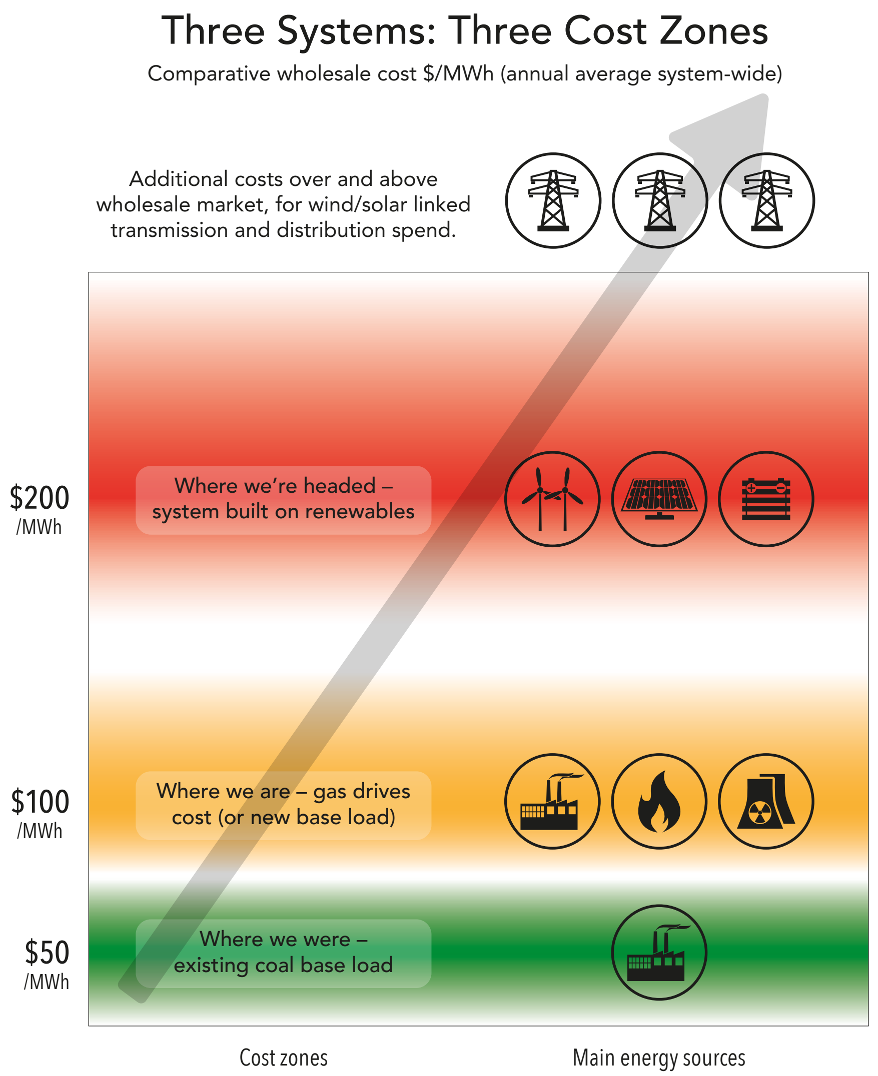
- Australia previously benefited from some of the lowest consumer electricity prices in the industrialised world, but it now has some of the highest.†
- This paper shows that an electricity supply system built on a foundation of baseload generation – that which provides power 24/7 to the grid to meet base energy needs – results in the lowest Total System Cost.
- This invalidates claims that renewable energy is the cheapest form of energy. That may be true in particular locations at particular points in time, but at the system level a system built on renewable energy would be the most expensive – by far – of available options.
- Customers pay for what they use, but far more of what we pay is required to cover the costs of the physical infrastructure, from generation to our meter, than for generating the electricity itself. To expose the full costs of providing electricity, we need to focus on Total System Cost.
- For example, when a consumer installs rooftop solar panel they draw less electricity from the system, and daytime load on the system is reduced. The excess is exported into the distribution network further reducing load on the system, which forces large-scale generators to reduce output. But the large-scale generators, transmission and distribution networks, retailers and environmental costs still exist. Less energy drawn from the main system does not mean less fixed cost: in this case it means more fixed costs overall.
- The main power system that Australians inherited – engineered in the 20th century on a foundation of low-cost mine-mouth **coal** – can provide bulk electricity at a wholesale cost level in round numbers of about **$50** per megawatt-hour (MWh) or in other words **5c** per kilowatt-hour (kWh).
- When a flexible, fast-response open cycle **gas** turbine meets the last megawatt of demand it sets the spot price for all generators operating at that moment across the entire market. Such units are increasingly called upon to balance not only the relatively predictable and smoothly changing variability of aggregate customer demand, but at the same time the far steeper and more volatile fluctuations in wind and solar power output. Also in round numbers, if the price of an extra unit of gas for the marginal

† Bongers et al, May 2024, Australian Retail Energy Prices in an International Context, MRC, www.menziesrc.org

generator is about $10 per gigajoule (GJ), then the wholesale electricity price at that moment will be about **$100**/MWh, which is **10c**/kWh. Each $1/GJ change in the gas price will change the corresponding electricity number by $10/MWh (1c/kWh).

- Continuing with round numbers, if the system is to be operated only on wind, solar and hydro power, with energy shuffled in and out of large and small storage assets and devices, the generation cost averaged across the energy for the total interconnected system will approach **$200**/MWh (**20c**/kWh) or more. The additional costs in the transmission and distribution systems will be far higher than for the historical coal-based and the current increasingly gas-price exposed system.
- In other words, the further the system moves away from the inherited generation system in the coal-based '$50 cost zone' through the gas-based '$100 cost zone' and towards the wind- and solar-based '$200 cost zone,' the more the actual outcomes for final consumers are likely to escalate to even higher price levels. The underlying economic problem remains even if cost of living price relief shifts costs from electricity bills to the tax-and-welfare system.
- This paper is summarised in the following short statements:
    - The system with the lowest Total System Cost is the one we have.
    - The levelised cost of energy (LCOE) of any generation type does not reflect Total System Cost.
    - There is a modest role for renewable technology before it increases Total System Cost.
- Contrary to popular belief, coal-fired power plants do not have a predetermined life. They can be refurbished periodically and remain in service for an indefinite period. The benchmark for comparing costs is not a hypothetical fleet of new coal plants: it is the fleet of already existing coal plants.
- **Thus the lowest cost system is the one we have, and the next lowest cost system is one built on new baseload power plants, whether they be coal or nuclear.**
- Official plans assume, encourage, or require the elimination of coal-fired generation, not on cost, but on emissions grounds.
- Notionally wind and solar provide "free energy" because there is no fuel cost. LCOE acknowledges the up-front investment required to generate electricity from the wind or the sun, and 'levelises' that cost across the output from the turbines or the panels over their life. However, LCOE (which is used by AEMO – relying in turn upon the CSIRO's GenCost model – to develop the ISP) is a simplified calculation applied at the generation level that is not able to provide insight into the Total System Cost with various types of generation technology needed to serve customer demand at all times..

- These conclusion are summarised in Figure 5, below, which appears in the body of the report on page 20.



- Beyond the $200/MWh wholesale cost zone indicated in the Figure above, there is the additional cost of the poles and wires required to deliver the electricity as the system hypothetically transitions to one built on renewables.
- Storage via batteries and pumped hydro is often raised as a means of shifting excess wind and solar generation to periods of high demand, but each has significant limitations with respect to duration and cost.

- **The total system cost of a renewables-based system (>80% share) may be two or three times as expensive as one premised on baseload (whether current or with new build nuclear), and a 'renewables only' system is likely to be five or six times as expensive. All such costs must ultimately be recouped from the consumers, if not the taxpayer.**
- It is true that it takes time to plan, prepare, finance, and build nuclear power plants. Avoiding increasingly high cost electricity while also pursuing environmental goals would require prudent management for a number of years of the existing system, including the existing coal plants and gas plants, while replacement baseload assets capable of playing the same role without incurring far higher costs are planned, prepared, financed and deployed.

FOREWORD

The more simple the proposition, the more complex it is to explain.

In my experience those who actually understand the energy system will wholeheartedly agree that attempts to force a dramatic increase in the proportion of electricity that comes from renewable energy can only reduce energy security and increase cost. And that households and consumers will bear the direct costs ('no free lunch'), with further indirect costs incurred across the economy in terms of reduced consumption, investment, and jobs.

But it is also my experience that when we advance that argument to the 'interested middle' — those without the experience of working across the energy system — what is obvious to insiders becomes complex rather than simple, and correspondingly difficult to explain. This is no fault of the audience; it is usually because:

- They are looking at only one part of the system (e.g. their rooftop solar system has reduced their bills, therefore if everybody had such systems all bills would be reduced);[3] and/or
- They judge outcomes based on current prices in distorted markets, unaware of subsidies and regulations which hide the true costs (again, rooftop solar is an excellent example);[4] and/or
- They are prey to deliberate cherry-picking of outcomes in just one part of the system by interested parties, such as the prices in wholesale electricity markets which for extended periods will be reduced by renewables bidding their energy output at a very low price or even below zero to earn certificate revenue (while effects on the wider system are ignored).

The genesis of the current paper goes right to the reboot of the IPA's research program in mid-2022. We had been planning for the establishment of a Centre for Energy Security, and embarked on a series of interim research projects, which resulted in publications on the Integrated System Plan (ISP), the implications of baseload power station closures (*Liddell: The Line in the Sand*), energy security (*Energy Security IS National Security*) and others. In materials circulated to stakeholders and potential stakeholders we outlined our plan for a research centre within the IPA which would provide:

- Honest and thorough appraisals of the energy system, technologies, global trends, options, and the true costs and benefits of proposed policy interventions between now and 2100, in a world in which energy security will remain universally valued by nation states; and

- Realistic scenarios for action which reflect the value consumers and industry place on the reliability and competitiveness of our domestic energy supply, and global markets' desire for secure energy supplies.

My examination of the costs of the Federal Government's 2022 energy plan had shown — at least to my satisfaction — that there was no way the goals could be achieved (if at all), at less than prohibitive cost. [5]

Further, I was heartened by the excellent work done by activist analysts (to coin a phrase) who had critiqued the methodology and assumptions used by AEMO and CSIRO in system planning and cost estimation.[6] Amongst other victories they had exposed difficulties with the calculations of levelised cost of energy.

Some of these criticisms were not even particularly technical in nature: it was that the planners had not included all costs of the transition (e.g. new transmission), or they had compared new build baseload rather than acknowledging we already have a system in place (which is of course the lowest cost of all possible options, for reasons outlined in this paper).

It was at this time I commenced work – in conjunction with my IPA colleague, Dr Kevin You – on what became an IPA Working Paper, released in ahead of this report, *Issues With the Levelised Cost of Electricity: Why a Simple Metric Cannot Determine Our Energy Future*.[7] This elaborated on what happens when you select the wrong tool (LCOE) for the job (scenario planning and thinking at the whole system level).

But I found that when sharing these critiques of the promised costs of the energy transition, audience members would ask what *my* numbers were. While in one sense it is entirely reasonable to ask such questions, I resisted that formulation of it, and the degree of precision sought, because I believed:

- First of all, we needed to elevate the importance of energy security (and so this was the first paper commissioned from Adjunct Professor Stephen Wilson)[i]; and/or
- Seeking ever more precise figures from 'improved' modelling traps us in the paradigms of the central planners, and the central planning conceit, leading to interminable arguments that are impossible to win[8]; and/or
- The costs of the energy transition envisaged by government are so great, that calculating whether the increase above the baseline is, say, 264% or 378% or 329%, is both pointless and claims a degree of precision that would not bear scrutiny, while adding nothing to the decision-making process.

I found this even with LCOE. The whole point of LCOE is that it is a useful 'quick rule-of-thumb' tool for market participants to estimate the marginal cost of new generation. But some market observers were critiquing CSIRO estimates of LCOE for various fuel sources and then seeking simply to substitute their own 'better' estimates, based on reports from engineering firms or financial analysts. Thus the

i See also Appendix Two for a definition of Energy Security interminable debates about which form of electricity generation is 'cheapest', which in the abstract is a pointless question. The most important question is: what mix of generation in the system is able to achieve our goals for cost, energy security, and environmental considerations. Financial analysts and engineering contractors are correctly interested in the cost of actually building a new plant, but they do not necessarily have any better grasp of the system as a whole.[9]

And so, in discussions with Stephen Wilson we decided to start at the level of first principles: that before we joined the serried ranks attempting to cost out alternative scenarios, we had to establish the means by which we (or some third party) should undertake that costing.

The cost to consumers and taxpayers is what matters, and that must necessarily be a function of the total system costs.

Conveying this is no small matter. Systems thinking does not come naturally to humans. This should be a simple observation, but the reasons are undoubtedly complex and there are various reasons proffered. The neuroscientist, Dr Ian McGilchrist, for example, locates our zest and skill for 'clarity and precision' in the left hemisphere of our brain (as we seek to 'grasp', predominately with our right hand), while our right hemisphere allows us to see context and the system as a whole.

Whether he's right or wrong in attributing the reasons for these different human tendencies to evolutionary pressures, I hope the reader can reflect on their own experience of the difference between dealing with people who will obsess over one fact or one element or one 'solution', as opposed to those prepared to engage in seeing the system as a whole, and asking the questions that flow from that.

Needless to say, Stephen Wilson is an example of the latter, and I commend the paper to you.

All you need to remember is that the lowest cost system is the one we have, and the next lowest cost system is one built on baseload, whether it be coal or nuclear.[ii] **Any departure from that towards greater reliance on intermittent renewable energy will make it more expensive and less reliable, at an increasing rate as the share approaches 100 per cent.**

Scott Hargreaves
Executive Director
Institute of Public Affairs
July, 2024.

ii Yes, you can have baseload from hydro, if you are Quebec or Norway. And yes, you can have baseload from Geothermal, if you are Iceland or New Zealand. And yes, *technically* you can have baseload from combined-cycle gas turbines, but then we in Australia would have to be encouraging rather than discouraging the development of new gas resources (we are fuel constrained). In Australia baseload means coal or nuclear.

Acknowledgements

I would also like to acknowledge the wise and data-rich contributions of electrical engineer and experienced gas industry energy professional, Ben Beattie BEng(elec) CPEng RPEQ, to the development of our thinking, and this paper, and also vital contributions and assistance from a number of academics and expert consultants who would prefer to remain nameless.

CONTENTS

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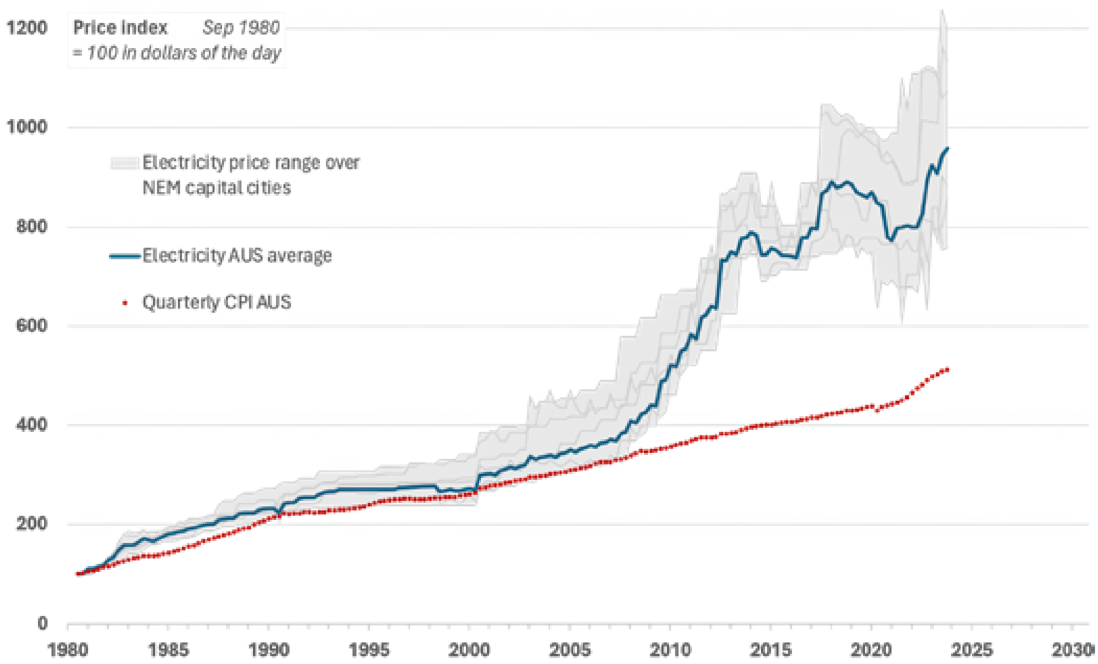
1
TOTAL SYSTEM COST

If an alternative cannot be deployed at a lower Total System Cost than the existing system, the alternative is higher costs.

The closest connection most Australians have with the power system is via the sockets and light switches in the walls of their homes and offices, in schools, hospitals, and elsewhere. We take clean and reliable power for granted, always available at the flick of a switch, when and where we need it. However, what once just involved another bill has increasingly become a quarterly financial shock for many Australian households and businesses.

Australia previously benefited from some of the lowest consumer electricity prices in the industrialised world, but it now has some of the highest. The trend since 1980 is shown in Figure 1, below.[10] Electricity consumers – both residential and business customers – experienced average price increases of about 20 per cent in 2022/23 and again in 2023/24.

Figure 1: History of consumer retail electricity prices in capital cities.

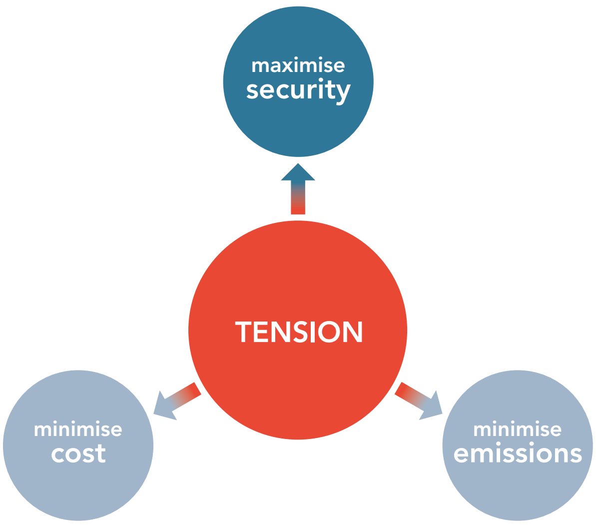


At the same time, the capacity of wind and solar power in the system increased, as did its generation output. Close to the core of the public debate now intensifying among engineers and other energy professionals is the question of whether the price increases occurred *despite or because of* the increase in renewable energy. This paper contributes to that debate.

Though the pattern of large increases appears to have paused in 2024/25, it is the author's view that further substantial increases should be expected in the future if current plans and policy settings remain unchanged. For exporting or import trade-exposed businesses, power prices, power quality, and power reliability – either as single factors or in combination – are rapidly becoming internationally uncompetitive.

The Institute of Public Affairs' recent framing paper *Energy Security IS National Security*[11] refers to the energy policy trilemma: the observation that maximising security, minimising cost, and minimising environmental impacts are the goals of every government, and that the three objectives are normally in tension and require trade-offs (see Figure 2, below). While that paper explained the importance of energy security, the focus of this paper is on costs.

Figure 2: The energy policy trilemma.



This paper is specific to the electricity sector, not the whole energy complex (which would include gas and oil, for instance). While the emphasis is on the National Electricity Market (NEM), the underlying principles discussed may be applied also to the South-West Interconnected System (SWIS) in Western Australia, and to other smaller systems.

In order to untangle the public debate about the costs of different forms of electricity generation, this paper focuses on the *delivered cost* of electricity. The delivered cost is the **Total System Cost** of supplying electricity to the consumer. Unless there is a source of subsidies (such as taxpayers) from outside the customer base of the electricity sector, then the total system costs will be reflected in aggregate customer bills.[12] This paper will show that an electricity supply system built on a foundation of baseload generation[iii], **results in the lowest total system cost.**

This is not a novel finding but has been known and understood since it was first expounded in France in 1949.[13] In the Australian context, with limited hydropower and geothermal resources, current or feasible baseload sources are limited to coal-fired power plants, natural gas combined cycle plants, and nuclear plants.

iii To take but one definition: "baseload electricity generation creates 24/7 power to the grid to meet the base energy needs…while peaking generation must follow the varying hourly electricity needs as demand rises and falls, baseload generation operates constantly to support the increment of demand that is always there no matter the time of day or day of the week.

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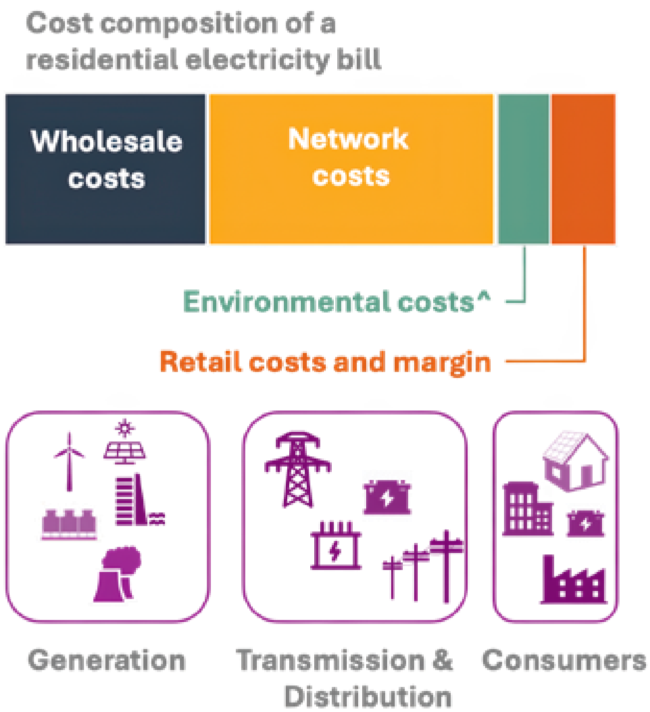
2
HOW DO WE PAY FOR THE TOTAL SYSTEM COST?

We have been conditioned for generations to think of electricity in terms of *energy*, but all consumers – from the smallest households to the largest businesses – see the total system cost reflected in their electricity bill (with the notable exception of rooftop solar owners).[14] A typical retail electricity bill is metered, calculated, and presented in terms of *consumption* (measured in kilowatt-hours or kWh), compounding the misconception. Figure 3, below, describes the various contributions to the average household bill, including wholesale costs, network costs, environmental costs[iv], and the retail costs including margin.[15]

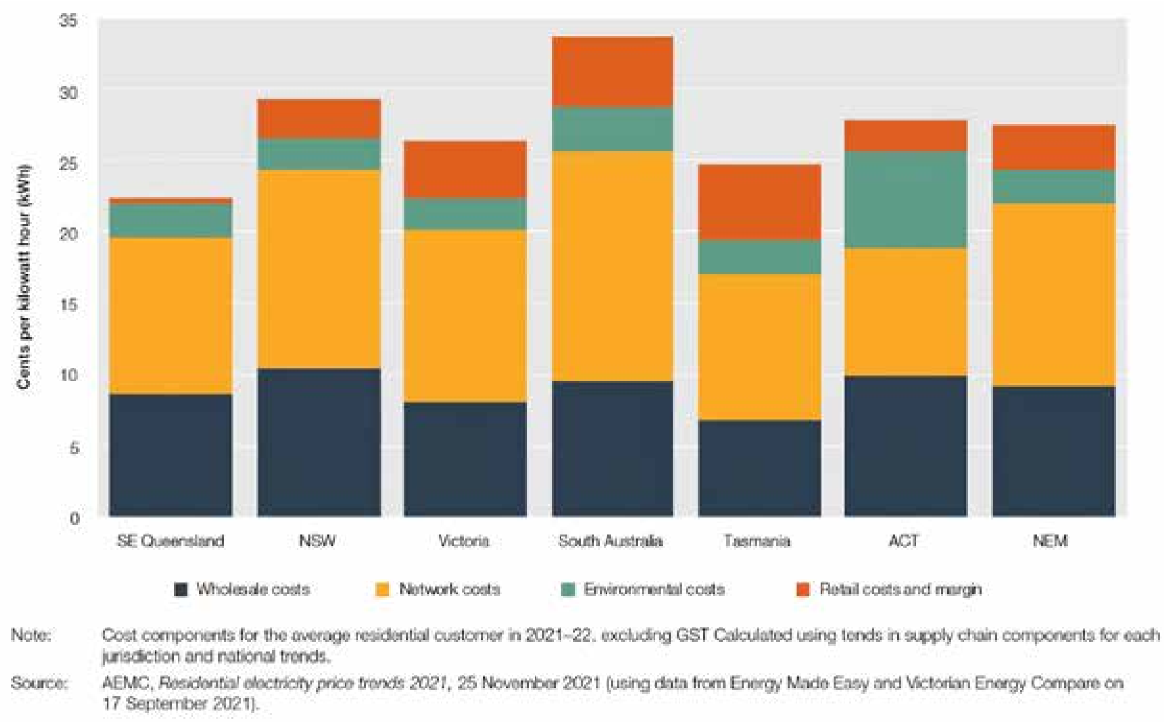
Figure 3: Cost composition of a residential electricity bill.



iv The costs of environmental schemes for promoting renewable generation, energy efficiency, and reducing carbon emissions.

Paying for what we use seems *fair*, but we must also pay for the fixed infrastructure. An analogy is the mobile phone – while we are no longer charged for minutes of usage, everybody understands that we still pay for the exchanges, towers and optical fibre routes that keep the mobile networks functioning. There are parallels in our electricity system. Far more of what we pay is required to cover the costs of the physical infrastructure, from generation to our meter, than for generating the electricity itself.

Figure 4: Cost contributions to residential electricity bills averaged across the NEM.



Source: **Australian Energy Regulator** (AER), 2022, *State of the Energy Market*. The version of this chart in the 2023 edition is less intelligible, so this 2022 version is retained for illustrative purposes.

Driving an Energy Transition from $50/MWh to $200/MWh Wholesale

In any discussion about completely replacing an entire interconnected generation system, it is important not to get lost in details and decimal places, but to retain a practical sense of the big, round numbers. The main power system that Australians inherited was engineered in the 20th century on a foundation of low-cost mine-mouth coal. That system can provide bulk electricity at a wholesale cost of about $50 per megawatt-hour (MWh) or in other words 5c per kilowatt-hour (kWh). Power from that fleet is sent out to the physical transmission system, with generation optimised across the plants on the interconnected regions, and available whenever it is needed, 24 hours a day, 365 days a year.[v]

The contemporary National Electricity Market is operated under a set of rules designed to signal the marginal cost of power. Under what was historically considered normal competitive market conditions, there is at all times a reserve of available and instantaneously dispatchable generation capacity beyond the total level of customer demand for power. Where a flexible, fast-response open cycle gas turbine is meeting the last megawatt of demand and therefore setting the price, if the gas price is about $10 per gigajoule, the wholesale spot market electricity price at that moment will be about $100/MWh, which is 10 c/kWh.[vi]

Computer models can be used to estimate the lowest cost at which generation could match hourly demand in the National Electricity Market without coal-fired or gas-fired generation, with the nuclear energy bans in place, and instead relying

v If the coal fleet is pushed far from its optimum operating conditions, costs are driven up, and revenues are driven down. At some point in that process, a plant can be rendered prematurely uncommercial and withdrawn. That has happened to a number of plants. For example, the Northern power plant in South Australia (SA), now demolished, was commissioned in 1985 and retired in 2016 about 20 years short of a normal service life. As a result, the small SA system relies to a significant extent on the ability of the far larger fleet of brown coal plants in the Latrobe Valley to increase or decrease their output to balance, stabilise and secure SA at relatively low marginal cost.

vi The technical and economic market rules are conceptually simple, but in practice they are very complex. In less than 20 years since AEMO and the AEMC were established in 2005, the version number of the National Electricity Rules is now over 200 and the document runs to almost 2,000 pages. The rules are the successor to the prior series of NEMMCo rules from 1999, adapted from the original Victorian Power Exchange rules from the mid-1990s, which were adapted from the original gross pool market design in England and Wales. Great Britain has since made at least two major changes to the basic type of electricity market design in place. The lesson is that the set of rules for competitive electricity markets are technically very complex and have proved to be unstable over time in most jurisdictions where they have been implemented. These issues are beyond the scope of the present paper, which is focused not on price formation, electricity market design, or competition policy, but rather on the essential aspects of total system cost.

entirely on wind and solar power, existing hydropower (assuming Snowy 2.0 is operating along with significant additional pumped hydro capacity), and batteries of electrochemical storage. Research that the present author has supervised suggests that the total system cost of an interconnected generation system of that type would approach $200/MWh, or 20c/kWh averaged over all annual energy. The estimate is conservative (low) for a number of reasons. It does not include cost recovery for the extensive 'Rewiring the Nation' transmission upgrades, nor any costs in the distribution systems, nor any risk premium reflecting the high market price volatility in such a system.

The current National Electricity Market, which has a very low share of wind and solar generation relative to a fully decarbonised system without coal, gas or nuclear generation, transmits wholesale prices up to the cap of $16,600/MWh (1660c/kWh) and down to the floor of negative $1000/MWh (–100c/kWh) with increasing frequency.

Fixed and Variable Costs

The bulk of the costs of converting energy into electricity are fixed. Those fixed costs are translated into customer bills to cover debt service and equity returns on the capital physical infrastructure, depreciation of that physical infrastructure, and the labour required to operate and maintain the assets that comprise the system. Further costs include company overheads and green compliance costs. Very few of the costs vary with consumption of fuel. The upstream fuel supply chains themselves are dominated by fixed capital, for gas wells, pipelines, and compressor stations, and for coal mines, mining equipment, conveyors and trains.

Electricity is priced to customers with most emphasis on the variable cents per kilowatt-hour (kWh) and less on the fixed costs. This pricing structure reinforces the misconception that generation is the primary driver of the cents per kWh rate charged by retailers.

Consumers must better understand that cents per kWh – a measure of *consumption* – does not reflect the mostly fixed cost structure of the electricity supply system. Networks, environmental and retail costs are largely fixed, at least compared to daily and seasonal time scales. Even generation costs are largely slow moving: only a small portion of the generation fleet is exposed to variable costs at daily time frames.[vii]

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vii Furthering this understanding amongst consumers – and indeed amongst decision makers – should be one of the goals of those involved in planning and administering the electricity markets of Australia. In the meantime, Brisbane based electrical engineer and host of the "The Baseload Podcast", Ben Beattie, has produced a useful series of graphics, *Cost Drivers in the NEM 2050*, which are reproduced in Appendix One.

Among the biggest impacts on total system costs are deliberate decisions by governments – such as targets and subsidies – that distort the fixed and variable components of system costs.

Regulatory policy and the way competition policy has been implemented in Australia, as well as policies on the environment and climate change, need to be considered in any discussion of the structure and level of electricity prices. However, to properly consider the price people end up paying for electricity, it is necessary to understand the cost of an electricity system, which is the focus of this paper.[16] A subsequent paper will build on this foundation to explore prices, price formation, and price regulation in greater detail. Beyond costs and prices are other considerations regarding the competitive market and future electricity sector competition policy.

To expose the full costs of providing electricity, we need to apply **systems thinking**.

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3
WHAT IS A SYSTEM?

There is perhaps no better answer than the extended quote below, transcribed from a short talk by pioneer in the field of operations research, Russ Ackoff, in 1994 (emphasis in bold and italic added throughout):

> **A system is a whole…that consists of parts, each of which can affect its behaviour or its properties.**
> You, for example, are a biological system called an organism, and you consist of parts, your heart, your lungs, your stomach, pancreas and so on, each of which can affect your behaviour or your properties.
> The second requirement is that **each part of the system, when it affects the system, is dependent for its effect on some other part**. In other words, the parts are *interdependent*.
> **No part of a system, or collection of parts of a system, has an independent effect on it**. Therefore, the way the heart affects you depends on what the lungs are doing and the brain is doing. The parts are all interconnected. And therefore, **a system is a whole that cannot be divided into independent parts**. Now that has some very, very important implications that are generally overlooked.
> First, **the essential or defining properties of any system are properties of the whole**, which none of the parts have. … **when a system is taken apart it loses its essential properties**. … **the system is not the sum of the behaviour of its parts, it's the product of their interactions**. … Now, what does that mean?
> **If we have a system of improvement that is directed at improving the parts, taken separately, you can be absolutely sure that the performance of the whole will *not* be improved**. And that can be rigorously proven.[17]

No power system can be understood properly without understanding the definition, description, and explanation above. A short note is needed here on terminology: the term **power system** is preferred over 'network', 'power network,' 'power grid', or simply 'grid'. A network refers to transformers and conductors that connect generators to loads.

The 'grid' is *formed* and sustained by the synchronous operation of the generators within an AC (alternating current) power system.[18] The ability of generators to synchronise to form a grid, and to remain synchronised at a common frequency affects the **behaviour** and properties of the system as a whole. The relevant behaviour of a power system includes frequency, phase angle and voltage **stability**.

Relevant **properties** of a power system include its **strength –** referring to the system's ability to withstand disturbances. The ability of the system operator to keep the system in a secure operating condition, and hence to be confident of meeting reliability criteria is heavily influenced by the technical characteristics of the system. Changes to a system that reduce its ability to perform as required may be offset by other changes, which will have an associated cost.

At this point it is becoming evident that there is a great deal more to the total system cost than the annualised average or 'levelised' costs of generating electricity.

In the last decade or more, the system has seen the addition of a large volume of solar panels on the rooftops of residential and commercial customers. The uptake of small-scale solar systems in customer premises, as well as the deployment of large arrays of large-scale wind turbines and solar panels has had an adverse effect on system operation.

When a consumer installs rooftop solar panel, the consumer draws less electricity from the system, and daytime load on the system is reduced. Any electricity generated by the rooftop solar and not consumed 'behind the meter' is exported into the distribution network, further reducing load on the system. This system load reduction forces large-scale generators to reduce output. But the large-scale generators, transmission and distribution networks, retailers and environmental costs still exist. **Less energy use does not mean less fixed cost**. The opposite is the case: at the total system level (including the solar panels), the fixed costs and the total system costs have increased.

Systems thinking exposes these effects. When most of the total system cost is fixed and not related to the quantity of electricity delivered, reducing the quantity delivered must reduce total system revenue. Less revenue for the same costs must result in a higher price. When consumers are billed in cents per kWh, and the kWh decreases, the consumer's bill will reduce in the short term. However, the system delivering less kWh must still recover the total system costs. Therefore, cents per kWh must increase in future periods (regulators will allow, see also Appendix 1). That is the case even before including the additional fixed costs of the solar panels, which must be recouped somehow.

Another system-level effect of rooftop solar is that electricity distribution systems in the suburbs become more complex. Suburban distribution networks are sub-systems of the total system. Additional complexity in those sub-systems increases complexity in the system as a whole. Inverters, smart meters, voltage monitoring, communications systems, home batteries, community batteries, vehicle-to-grid schemes are examples of innovative technology that is fascinating to watch being deployed. It all represents costs being added to the system that were completely unnecessary just a few years ago, without necessarily adding benefits, or sufficient benefits to justify the extra costs.

Rooftop solar policies are directed at one part of the system, without considering the effect on the whole. Therefore, if Ackoff is correct, systems theory predicts that the performance of the whole will *not* be improved. At the highest level, the performance we are interested in encompasses reliability, cost, and broad environmental impact. The emphasis of this paper is on costs. **Total System Cost** is the key. If the total system cost increases – even if there is no degradation of reliability, and no overall reduction in broad environmental impact – the performance of the whole will not have been improved.[19]

Reduced performance of the whole system, as predicted by systems theory is indeed what we see, despite reports and widespread claims that renewable energy is 'the cheapest' form of electricity generation or, more broadly, of energy. For example, the Minister for Energy & Climate Change, Chris Bowen, has said:

> The AEMO and CSIRO GenCost report has made clear the hierarchy of costs: renewables being the cheapest and nuclear being the most expensive.[20]

The Integrated System Plan (ISP) published by the Australian Energy Market Operator (AEMO) and the report containing estimates of the current and future costs of generating electricity from various technologies published by the CSIRO have unfortunately been leading energy ministers, governments, and the Australian public to dangerously wrong conclusions.

The conclusions are dangerous for Australia because they are damaging on a number of levels:

- technically, for the operation of the physical power system itself;
- economically and financially, for Australian households, businesses and society at large; and
- environmentally, via adverse impacts on rural communities and natural ecosystems.

Within the scope of Total System Costs, the structure of this paper is summarised in the following short statements:

1. The system with the lowest total cost is the one we have.
2. The levelised cost of energy of any generation type does not reflect Total System Cost.
3. There is a modest role for renewable technology before it increases Total System Cost.

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4
WHY THE LOWEST COST SYSTEM IS THE ONE WE HAVE

The system with the lowest total cost is the one we have for a number of reasons. Existing assets require operation and maintenance, not full capital investment. Periodically, additional capital may be required to refurbish and extend the life of assets. While these observations can be applied to any asset, it is appropriate to focus our attention first on the fleet of existing coal-fired power plants. That is also where much public and media attention is currently focused.

Although it is not necessarily popular to acknowledge it, the 15 coal plants with 44 individual generation units with more than 20 Gigawatts of capacity are at the heart of the existing power system in Eastern Australia. There are also three coal plants with seven units totalling 1.4 GW in the South-West Interconnected System (SWIS) in WA (see Table 1, below). In the mid-2020s, coal plants continue to provide the majority of the bulk power generated throughout the year. The coal fleet makes the largest contribution to continuously available capacity.

It is true that some of the fleet is approaching ‘engineering old age’. The oldest unit in service was commissioned in the 1970s and the youngest in the late 2000s. The future of the coal fleet would eventually become an issue regardless of the public debate on climate change. In theory, a power generation fleet largely owned and fully operated under competitive (or ‘contestable’) free market policies, laws and regulations, would evolve over time as investment capital responded to price signals. While that is what is supposed to happen in theory, it is clearly not the lived experience in Australia, when decisions about the timing of closure are increasingly driven either directly by government, or indirectly from government through the economic impact of policies that support the forced expansion of alternative sources, especially solar and wind.[21]

The Table below shows the power stations projected to close by 2035, and the year of commissioning, for the major power stations in the NEM.[22]

Table 1: Australia: Power Station Closures to 2035.

Power Station	State	Fuel	Commissioning Date	Notified Closure	Capacity (MW)
Eraring‡	NSW	Coal	1982	2025	2,880
Torrens Island B	SA	Gas	1967	2026	800
Collie	WA	Coal	1999	2027	340
Callide B	QLD	Coal	1989	2028	700
Yallourn	VIC	Coal	1975	2028	1,450
Bluewaters	WA	Coal	2009	2029*	400
Muja	WA	Coal	1981	2029	1,094
Vales Point B	NSW	Coal	1978	2029	1,300
Bayswater	NSW	Coal	1982	2033	2,600
Callide C	QLD	Coal	2001	2035	825
Gladstone	QLD	Coal	1976	2035	1,680
Kogan Creek	QLD	Coal	2007	2035	750
Loy Yang A	VIC	Coal	1984	2035	2,200
Stanwell	QLD	Coal	1993	2035	1,400
Tarong & North	QLD	Coal	1984 & 2002	2035	1,840
Total					**20,259**

It is common in analysis of any power system to assume that a coal plant has a technical service life of 50 years. This is a reasonable assumption for analysis, in the absence of other information. However, contrary to popular belief, coal-fired power plants do not have a pre-determined life. Coal-fired power plants can be refurbished periodically and remain in service for an indefinite period, recalling the Ship of Theseus or the 'grandfather's axe' of popular lore. In the case of well-maintained coal-fired power plants, the capital required for such refurbishments is typically an order of magnitude smaller than for new plants: measured in the hundreds of millions rather than billions of dollars.

‡ This table was prepared prior to the recent announcements by the NSW Government concerning the extension of the life of the Eraring Power Station.

A new plant can offer more advanced technology, higher efficiency (and hence lower fuel costs), and lower emissions. However, a new plant needs to be able to justify its full capital cost rather than a small increment of capital, as is the case for investment in the refurbishment of existing assets. The relatively small incremental benefits offered by a new high efficiency, low emissions coal-fired plant relative to an old coal-fired plant are likely insufficient to justify the large capital investment. Additionally, a HELE plant must burn higher quality fuel, typically reserved for export markets and the associated price premium.

Therefore, **in an electricity market such as Australia that has exhibited low or no-growth for a prolonged period, it is very unlikely that there would be investment in new coal plants, even before considering the question of climate change.**[23]

That situation dictates the reality that the benchmark for comparing costs is not a hypothetical fleet of new coal plants: it is the existing fleet of older coal plants. Whether the motivation for any given policy is the reduction of emissions or any other reason is beside the point. **If an alternative cannot be deployed at a lower Total System Cost than the existing system, the alternative is higher costs**.

That is the sense in which in this paper we say the lowest cost system is "the one we have", when strictly speaking we refer to the low cost base load system that we had, prior to the interventions which have already moved us into a higher cost zone. The diagram below shows the three principal cost zones, that of the "system we have" (or had), the emergent reality of one based on gas, or possibly new base load, and the future state (per official objectives) of a high cost system built on renewables.

Government policies at both the state and federal level, and official plans (such as the *Integrated System Plan* or ISP originally published in 2018 and biennially since[24]) assume, encourage, or require the elimination of coal-fired generation, not on cost grounds, but on emissions grounds. Many statements and much media reporting and other commentary suggests that coal is being removed from the system because its costs are too high, or because the cost of the favoured alternative, wind and solar power, is so low. That is misleading: at best a half-truth or a misunderstanding based on partial information and incomplete analysis.

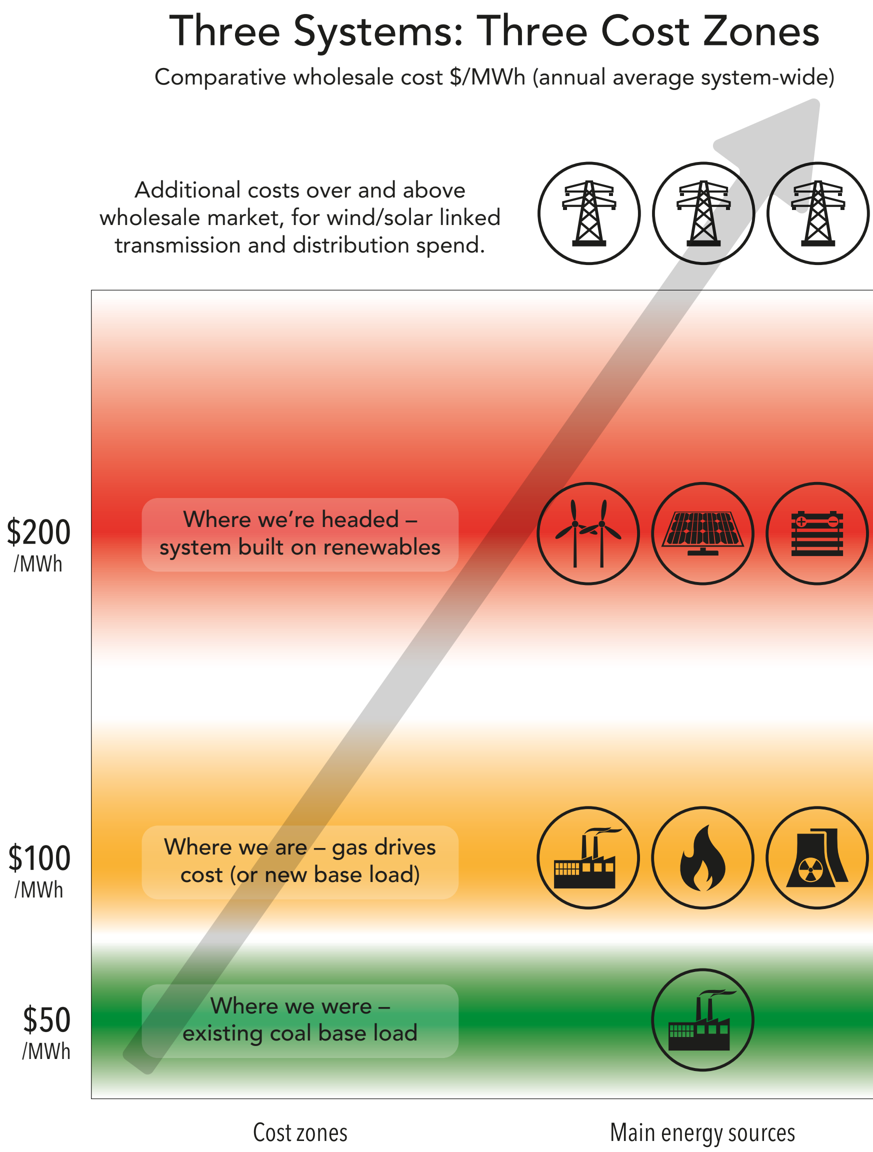
The economics of wind and solar power are typically viewed in two ways. Each represents only a part of the picture. The first perspective says that wind and solar provide "free energy", because there is no fuel cost. Once the fixed capacity exists, there is no cost to providing an extra unit of output. In economic terminology it is said that wind and solar power have zero short-run marginal cost. An example of this view is the quote from a prominent Australian renewable energy advocate, Tim Buckley:

> Cheap solar is parasitic, it destroys the competition because it has zero marginal cost.[25]

The "free energy" view does not acknowledge the up-front capital costs, and the need for investors and lenders to earn a return on that capital.

The second perspective is the Levelised Cost of Electricity (LCOE), which acknowledges the up-front investment required to generate electricity from the wind or the sun, and 'levelises' that cost across the output from the turbines or the panels over their life. The limitations of LCOE are discussed in the next section.

Figure 5: Wholesale energy market outcomes.



5
LCOE GIVES A DISTORTED VIEW OF ELECTRICITY ECONOMICS

LCOE is not recommended for selecting from mutually exclusive alternatives.

Using LCOE is convenient, because the formula is simple and can be easily calculated by anyone with access to a spreadsheet. The limitations of LCOE are widely recognised, including by the CSIRO:

> LCOE is a simple screening tool for quickly determining the relative competitiveness of electricity generation technologies. It is not a substitute for detailed project cashflow analysis or electricity system modelling which both provide more realistic representations of electricity generation project operational costs and performance.[26]

The report then goes on to note 'several issues and concerns in calculating and interpreting levelised cost of electricity', which have been acknowledged since the 2018 edition of the same report. The US National Renewable Energy Laboratory identified the shortcomings and limitations of LCOE at least as early as 1995. LCOE **is not recommended for selecting from mutually exclusive alternatives.**[27]

LCOE is a simplified calculation applied at the generation level: it is not able to provide insight into the Total System Cost with various types of generation technology.

It is well-recognised in the literature that 'with the increasing penetration of variable renewable energy (VRE), it is inappropriate to use traditional equations to calculate the LCOE for non-dispatchable VRE due to its intermittent nature.'[28]

Readers interested in learning more about the role of LCOE, and its limitations, can refer to a Working Paper published by the IPA in April 2024, *Issues With the Levelised Cost of Electricity: Why a Simple Metric Cannot Determine Our Energy Future*. As stated in the Foreword:

> The LCOE is a measure of the average net present cost of electricity production for a generating asset over its lifetime. It does not tell us

> the full cost of electricity generation. Neither does it tell us the cost of the poles and wires that deliver the electricity. Moreover, LCOE does not tell us the cost of other power supplies – mostly coal and gas – that must be there as a backup to support variable renewables when the wind doesn't blow or when the sun doesn't shine…
> The fundamental problem with the current approach to estimating the cost of energy by generation is that LCOE is a project-level metric, and one that is easy to manipulate to deliver a desired outcome. It does not scale up to reflect the complexity of Australia's electricity markets.[29]

The paper presents a fully worked example demonstrating large effects of changing a few key assumptions (and why changing these assumptions can be justified). In a progression table, we see the impact of adjusting capacity factors, discount rates, and asset life.

Table 2: The combined impact of capacity factors, interest rates and operating life on LCOE.[viii]

	Onshore wind	Solar PV	Black coal
Interest rate (r)	5.99%	5.99%	5.99%
Operating life (n)	20	25	40
Overnight capital cost ($/kw)	2,642	1,572	5,398
Fixed O&M ($/kw)	25	17	53
Capacity factor	32%	22%	89%
Fixed cost sub-total ($/MWh)	91	73	53
Efficiency	100%	100%	40%
Fuel cost ($/GJ)	0	0	7
Fuel cost ($/MWh)	0	0	17
Variable O&M ($/MWh)	0	0	4
Variable cost sub-total ($/MWh)	0	0	21
Total LCOE ($/MWh)	**91**	**73**	**74**
Base case ($/MWh)	55	47	108
Variation ($/MWh)	36	26	-34
% change	65%	54%	-31%

viii This originally appeared as Table 5, on page 11, of IPA Working Paper #1: *Issues with levelised cost of electricity.*

6
WHY IS THE OPTIMAL ROLE FOR RENEWABLE ENERGY ONLY MODEST?

Renewable energy will reduce Total System Costs only when the additional costs of renewable energy are less than any costs avoided across the system. The costs avoided by renewables (wind and solar) are limited to the reduced fuel costs in coal and gas power stations. However, the intermittent nature of renewable energy means that capacity-related costs, at best, cannot be avoided and, at worst, are increased. At low shares of renewable energy, it may be possible to avoid burning fuels with high marginal costs. As the share of renewable energy increases in a system, its value to the system decreases as it 'eats into' fuels with lower and lower marginal costs. The reality of the Australian experience shows this – over 7 GW of coal-fired power stations have closed since the Renewable Energy Target subsidy scheme commenced in the early 2000s, the vast majority since 2010. Less than 1 GW of gas-fired generators have retired in the same period.

Renewable energy can *displace* coal (and gas) generation, but it cannot by itself *replace* synchronous generation. As higher and higher shares of renewable energy are deployed in a power system, it becomes progressively more and more difficult to match generation with load. AEMO per its 2023 reliability update now identifies the weather as a key driver of reliability risk:

> Wind availability at times of high demand is a key driver of reliability risk.
> A revision to the prediction of wind generation suggests that low wind conditions coincident with high demand are more probable.[30]

The solutions used to manage this problem so far include curtailing the output from wind and solar, and paying large loads (aluminium smelters) to reduce consumption (partially or temporarily).[31] Further 'demand management' due to the unpredictable effect of weather on electricity supply is expected in coming years, with recent heatwaves seeing widespread reduction of air conditioning consumption.[32]

Storage via batteries and pumped hydro is often raised as a means of shifting excess wind and solar generation to periods of high demand, but each has significant limitations with respect to delivering the necessary duration of supply at anything like a reasonable (system) cost.

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7
WE ARE AT OR NEAR THE SATURATION LIMITS OF RENEWABLE ENERGY

The question arises: what proportion of the energy required could be drawn from renewable energy, before energy security is threatened, for the reasons outlined earlier in this paper? This is the ‘saturation limit’.

It is a well-established principle in system planning that the first approximation of the saturation limit for renewable energy is its annual capacity factor. This depends on the location, but typically ranges between about 20 per cent (solar) and 30 per cent (wind) but can be as low as 15 per cent or as high as 40 per cent (some places are sunnier or windier than others).

The precise answer depends on factors such as:

- the relationship between the patterns of generation relative to the shape of the load;
- the capital and operating costs of storage relative to wind and solar generation (taking into account the charge-discharge cycle round trip energy losses);
- the cost and performance characteristics of alternative generation technologies; and
- the configuration of the generation-transmission-distribution system as a whole.

Given the above, the working hypothesis should be that the level of renewable energy already in the system is at or near the saturation limit.

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8
HOW CAN FREE RENEWABLE ENERGY CAUSE PRICES TO INCREASE?

Our electricity consumption changes from second to second, and the generation of electricity must precisely match consumption. Even storage such as dams and batteries consume electricity (when pumping or charging) that must be balanced instantaneously with the generators. This process does not need to be costly, but policies by state and federal governments over the last two decades have made this balancing act increasingly difficult. Difficulties can be overcome, but at a cost. Higher costs translate into higher prices.

Energy is not the same as electricity. Left undisturbed and unused, energy in its raw form does little for us. Water flowing in a river or falling in rain; coal, gas, oil, uranium buried in the ground; sun and wind from the sky – there is no cost but also no electricity. The cost comes with conversion of energy into electricity and making it available to all consumers *at precisely the instant it is needed*. This service includes the instantaneous transmission and distribution of electricity from the point of generation to the point of consumption at the required quality (voltage and frequency). Energy policy should be aimed at making the conversion of energy into electricity, and making it available to all consumers everywhere, at the lowest possible cost. Unfortunately, this imperative has been deliberately ignored in recent years.

Now consider a large coal-fired power station, with its own coal mine. This generator is shielded from international fuel price fluctuations and, while expensive to build, that up-front cost is expected to be recouped over 30 years by generating as much electricity as possible, day in day out. Generating the largest possible quantity of electricity allows the power station to sell its electricity for the lowest possible price while maintaining the plant, servicing its debt, and earning a return for the owners. The model is high volume at low cost per unit output. Low unit costs allow the fixed capacity to be used more.

The opposite is true of gas-fired power stations in Australia. The up-front capital cost is relatively low, but the operating cost is closely coupled to the price of gas. A gas-fired power station's operating model is low-volume at high-cost. Higher unit costs mean they get used less. The lower fixed costs can be recovered over far fewer operating hours per year.

An intermittent generator – typically wind and solar – has no fuel costs and a low operating cost. But the intermittent and variable output places demands on the rest of the system that means the overall cost of generation increases across the system as a whole. The operating model is low volume at low cost. This problem is exacerbated because the output cannot be controlled, and similar assets tend to produce their output at the same time, when the system doesn't necessarily need or value it. The low volume and the price depression effect means the revenue must be guaranteed by another source (such as renewable energy certificates or other schemes) to subsidise the electricity output.

Rapid growth of rooftop solar has led to the current situation where the capacity of all solar panels combined is the largest single 'generator' on the system. When the sun is shining, this huge capacity reduces the market share available to all generators. This is another reason why the overall cost of the electricity system has increased. As well as creating extra costs for existing generators due to intermittency, variability and loss of market share, rooftop solar receives state-mandated feed-in-tariffs. Those financial flows are an additional cost for retailers to pass on to customers.

9
CONCLUDING OBSERVATIONS

We began by describing the energy trilemma, and noting that in a previous paper, *Energy Security IS National Security*, we established that to achieve energy security we must have a system built on baseload generation. Renewable energy cannot achieve energy security, and indeed the further pursuit of it will imperil national security.

In this paper we have examined the next part of the trilemma, cost, and established that the cheapest total system cost will be achieved by a system with a preponderance of baseload generation, not one built on intermittent renewables. It has provided a framework by which one might calculate the total system costs, and thus ultimately the costs to consumers; a framework superior to those reliant on LCOE. To do so would be a major but not impossible piece of work. Indeed, the search for granular detail should not blind us to the reality that we are dealing with not incremental costs but almost orders of magnitude. As shown in Figure 1, the cost of the current system is already double what it was fifteen years ago.

Based on the foregoing, the total system cost of a renewables-based system (>80%) may be two or three times as expensive as one premised on baseload (whether current or with new build nuclear), and a 'renewables only' system is likely to be five or six times as expensive. All such costs must ultimately be recouped from the consumers, if not the taxpayer.

A genuine appreciation of the final element of the trilemma, environmental goals, leads to a blunt conclusion that has already been made by others: there is no 'Net Zero' without nuclear energy. As remarked by Dr Fatih Birol, the head of the International Energy Agency:

> In my view the main driver for pushing nuclear to the forefront was energy security.
> If you want to reach Net Zero without having any nuclear [energy] it is impossible. It plays a crucial role.… in today's economy, if you want to compete, you need stable electricity prices.[33]

This paper is concerned principally with showing how a move away from baseload leads to higher total system costs (with costs progressively increasing from the baseline of existing generation, to new build baseload coal or nuclear, and thence to further reliance on intermittent renewables). So, while the arguments for removing nuclear prohibitions are persuasive and have been made elsewhere, they have been beyond the scope of this particular paper.

That said, I agree with the observation that wind and solar power is a cheap way to provide expensive electricity, whereas nuclear power is an expensive way to provide low-cost (but high value) electricity. The saying is not only witty, but true.

It is true that nuclear energy requires large capital investments, and that it takes time to plan, prepare, finance, and build nuclear power plants. Avoiding increasingly high cost electricity while also pursuing environmental goals would require prudent management for a number of years of the existing system, including the existing coal plants and gas plants, while replacement baseload assets capable of playing the same role without incurring far higher costs are planned, prepared, financed and deployed.

10
APPENDIX ONE

Cost drivers in the NEM 2050

Estimates of future consumer costs will always be subject to external factors that change over time. What can be done with certainty is describe the current system and establish cost drivers. Planned future scenarios can then be discussed relative to the known system.

All electricity system policy should be discussed in terms of effect on consumer prices and the system as a whole. The insistence of forcing renewables into the electricity system to chase arbitrary emissions reduction targets ignores the impacts of these policies on consumers.

A systems approach should consider the physics of the entire electricity system operation, and the market that's supposed to pay for it. The National Electricity Market (NEM) includes most of Queensland, New South Wales, Victoria, South Australia and Tasmania.

A systems approach reveals consumer bills include the costs of generation (wholesale), networks, environment and retail, adequately conveyed by the Australian Energy Regulator in its annual State of the Energy Market reports. Combined, the cost of wholesale and networks make up over 80 per cent of consumer bills.

Since there is no path for intermittent sources to reduce network, retail or environmental costs, lower consumer prices under the proposed high-renewables system can only occur if renewables lower the wholesale cost component more than increases in all other cost components combined. This is not feasible.

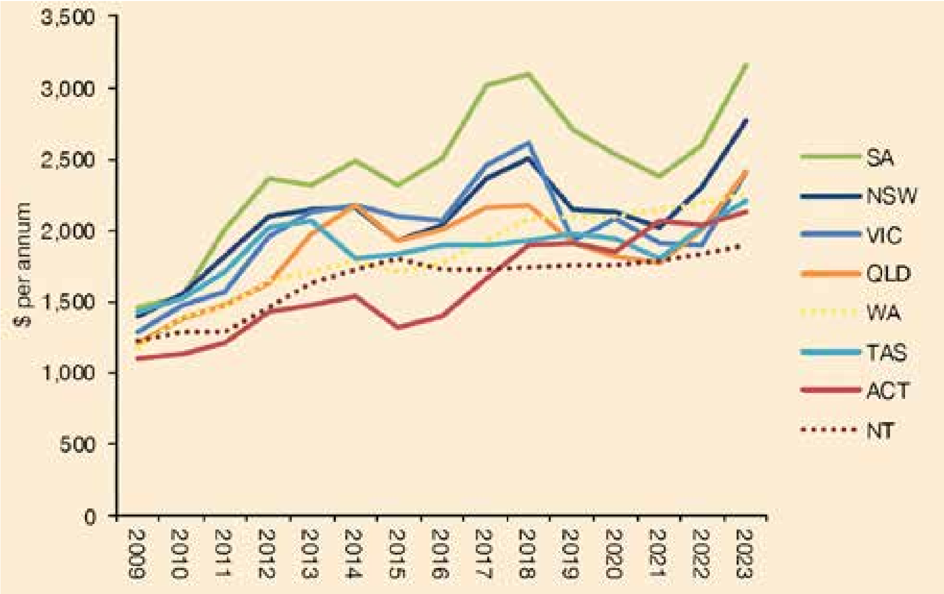
Retail prices are whole system costs

Retail prices reflect the total system costs, reinforcing the importance of systems thinking being applied to electricity policy. If the system costs more, the people pay more.

High up-front generation cost does not necessarily mean high consumer costs. $/MWh × MWh = $. A baseload generator can see high $ at a relatively low $/MWh if the MWh are high.

Analogy 1: a bicycle is cheap to buy and low emission, but nobody jumps on the Malvern Star to pick up the family from the airport.

Analogy 2: which do you prefer, a $5 pizza with $10 delivery, or a $7 pizza with $5 delivery?



Source: St Vincents de Paul Society, 2023, The NEM: Where Prices are High and Innovation is Low, (chart 1).

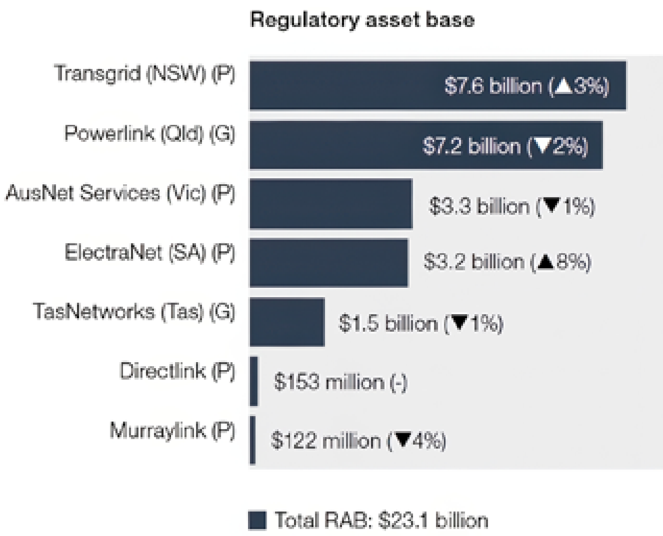
Do transmission lines reduce system cost?

Transmission costs and the regulated guaranteed profits are recouped from consumers in proportion to the value of the network. The regulatory asset base (RAB) of transmission in 2023 was $23.1 billion.

AEMO's 10,000 km of new transmission network, proposed by 2050, requires possible spending to 2030 of an additional $32 billion according to AEMO ISP estimates.

An additional $32 billion would be a 140 per cent increase by 2030. If the transmission component of your monthly bill is $100 today, it could increase to $240 by 2030.

There is no path for cost reduction in the transmission network.



Source: AER, 2023, State of the Energy Market Report.

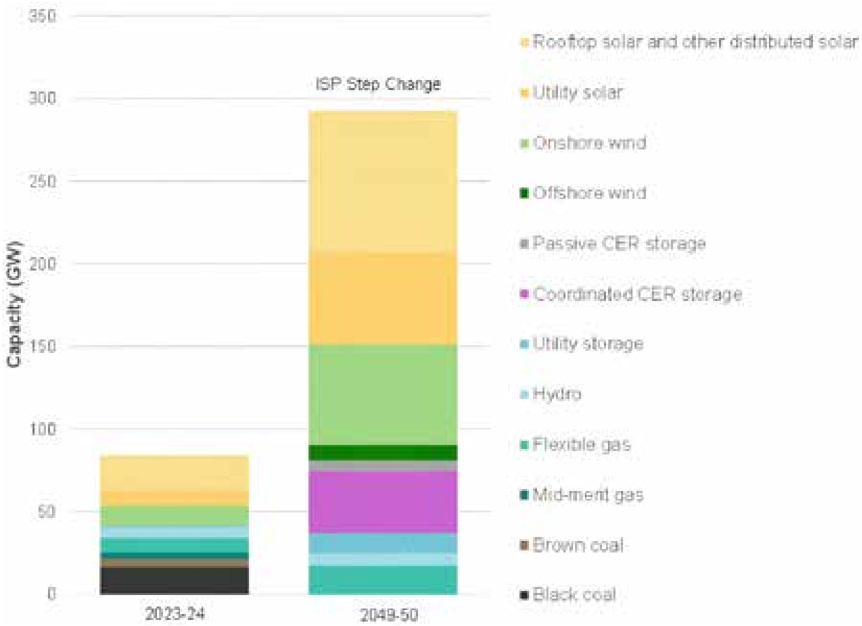
Can renewables reduce long-term wholesale prices?

Much is made of the ability of renewables to reduce wholesale prices. Closer inspection of wholesale market data indicates that intra-day wholesale prices are indeed forced very low by rooftop solar. However negative prices are still a cost (on somebody) that must be recouped (from consumers).

The argument most often raised to promote the ability of renewables to reduce wholesale prices is the merit order effect, where low-cost generation forces out high-cost generation, therefore lowering the wholesale price. However, market data indicates that high-cost generation is pushed out of the market far less than mid-merit generation. In other words, baseload generators like coal are pushed out, leaving the high-cost gas, hydro, and increasingly batteries, to set the wholesale price.

Over longer periods, e.g. quarterly, data indicates that renewables increase wholesale price volatility. This unpredictability increases costs throughout the system. A system dominated by low-volatility baseload generation offers the lowest long-term wholesale price. The evidence of this can be seen in the NEM's average wholesale prices *circa* $50/MWh prior to the introduction of renewables.

Additionally, the vast majority of renewables are contracted separately, usually above the market price. These costs must be recouped from consumers, regardless of fluctuations in wholesale price. The proposed Capacity Investment Scheme will establish a floor price for renewables, ensuring the market cannot naturally achieve lower prices.



Source: AEMO, ISP 2024 Assumptions Workbook.

The Baseload Podcast

The information in this Appendix is reproduced from fact sheets created by Ben Beattie BEng(elec) CPEng RPEQ, a Brisbane based electrical engineer, and host of The Baseload Podcast, available on all leading platforms including Apple and Spotify (https://open.spotify.com/show/6A7qfCxyRhJhEgyck9wxfE)

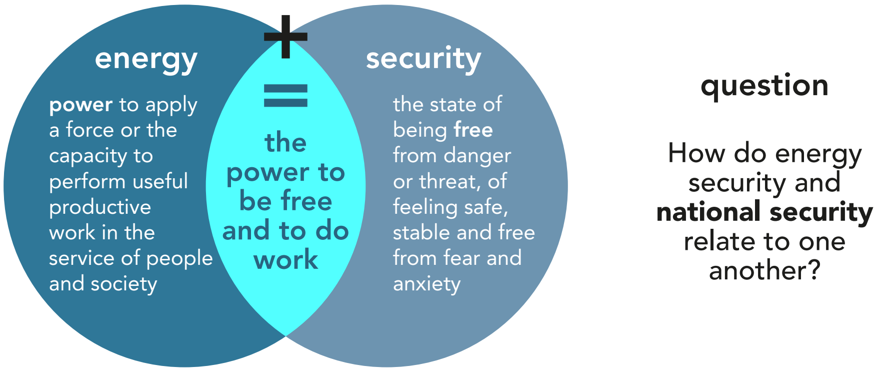
11
APPENDIX TWO

What is energy security?

Energy security may be defined by combining definitions of energy and of security as:

> **the power to be free and to do work**.

Figure 5: Defining energy security: the Canberra definition[34]



Why energy security matters

'Stop blowing up your coal plants — you're not ready to live without them yet!'

—Maria Korsnick, President and CEO of the Nuclear Energy Institute

Without energy security a nation may be rendered powerless. Without sufficient propulsive power at its disposal, an army, a navy, an air force, a space force, or a cyber force is unable to position itself as needed, or is unable to apply the concentrated force required for national defence. For this reason, direct attacks on energy supply lines and infrastructure are standard in military strategy and tactics.

In the civilian sector, the capacity to do work applies in the narrow engineering sense through the machinery and systems of agriculture, transport, communications, industry, business and financial services; and also in the broad socio-economic sense. Without adequate capacity to do work, a nation will rapidly grind to a halt, both literally and figuratively, and descend rapidly into civil unrest, and potentially into long-term civilisational collapse. Unable to defend itself, and without the capacity to do work, such a nation will then be liable to lose its freedom. Deep understanding of the mutually interdependent nature of energy security between the military and civilian realms is vital. Defence forces require secure energy supplies to be able to defend energy and national security. Australia is an island continent with abundant resources. Australia's energy security is an integral and vital part of the energy security of neighbouring nations, especially in the Indo-Pacific region.

Further reading: *Energy Security IS National Security*, IPA, November 2023, ipa.org.au.

ABOUT THE INSTITUTE OF PUBLIC AFFAIRS

The Institute of Public Affairs is an independent, non-profit public policy think tank, dedicated to preserving and strengthening the foundations of economic and political freedom. Since 1943, the IPA has been at the forefront of the political and policy debate, defining the contemporary political landscape. The IPA is funded by individual memberships, as well as individual and corporate donors.

The IPA supports the free market of ideas, the free flow of capital, a limited and efficient government, evidence-based public policy, the rule of law, and representative democracy. Throughout human history, these ideas have proven themselves to be the most dynamic, liberating and exciting. Our researchers apply these ideas to the public policy questions which matter today.

ABOUT THE AUTHORS

Stephen Wilson

Stephen Wilson is a Visiting Fellow in Energy Security at the IPA.

Stephen is an engineer and an energy economist with over 30 years' experience on projects in some 30 countries, spanning all forms of energy along the value chain.

Stephen's work has ranged from energy efficiency and demand side management, through electricity and gas transmission and distribution networks and storage, to power generation and all of the major primary energy sources. His work spans uranium and thermal coal for nuclear power generation, metallurgical coal in the iron and steel industry, as well as natural gas, oil, biofuels, and the role of wind and solar in power systems. He has supervised research on the production and export cost of green hydrogen. He has worked with a number of energy-economy-emissions models over the years.

Stephen supervised research at UQ on *Understanding the opportunities and costs of planning and operating electricity systems with high shares of variable renewable energy sources*. That work also looked at the effect on costs of repealing the bans on nuclear energy in Australia and allowing the new generation of small modular reactors with a high degree of operational flexibility.

Stephen was the principal investigator of the study and lead author of the report on *What would be required for nuclear energy plants to be operating in Australia from the 2030s* published by the University of Queensland in 2021.

Stephen's career spans roles in Melbourne, Hong Kong and Brisbane, in several consulting firms, a major mining corporation, and a major university. Currently he is undertaking advisory work, advocacy work, research collaboration and mentoring in the university sector, and is a director of an energy technology startup.

Scott Hargreaves

Scott Hargreaves is Executive Director of the IPA, appointed in 2022. Prior to joining the staff of the IPA in 2015, he worked in various private sector roles with a heavy emphasis on the energy sector, including contract, consulting or staff roles with agencies of the Victorian Government, Meridian Energy, and Anglo American plc, and also Origin Energy. He has a Bachelor of Arts in Politics and Economics, a Post Graduate Diploma in Public Policy, an MBA from the Melbourne Business School, and a Master of Commercial Law.

REFERENCES AND NOTES

1 Bowen and Husic, *Joint media release: GenCost confirms renewables remain the cheapest form of energy, as the cost of nuclear reactors skyrocket*, https://minister.dcceew.gov.au/bowen/media-releases/joint-media-release-gencost-confirms-renewables-remain-cheapest-form-energy-cost-nuclear-reactors-skyrocket

2 Heinlein popularised this phrase in his 1966 novel, *The Moon is a Harsh Mistress*. As Milton Friedman said, 'The free lunch myth [is the] belief that, somehow or other, the government can spend money at nobody's expense.' (in answer to a question after delivering the 1991 Wriston Lecture presented in New York City on 19 November 1991). See also https://en.wikipedia.org/wiki/No_such_thing_as_a_free_lunch

3 Economists call this the fallacy of composition: the notion that something that works for one individual or locally can be scaled to an entire population or economy.

4 The misplaced notion that if something makes financial sense to me, then it must necessarily make economic sense for the nation is a specific example of the fallacy of composition.

5 Hargreaves, Unrealistic Unreliable Unaffordable, *IPA Review* (Winter 2022), 16 September 2022, https://ipa.org.au/ipa-review-articles/unrealistic-unreliable-unaffordable

6 Lehman, *Why our energy transition needs a price tag*, The Australian, 28 July, 2023, to take but one (very good) example. The article by Claire Lehmann quotes Stephen Wilson, Aidan Morrison, and David Carland. https://www.theaustralian.com.au/commentary/why-our-energy-transition-needs-a-price-tag/news-story/17af9fe36811cda805449e4e0505b895

7 You and Hargreaves, *Issues With the Levelised Cost of Electricity: Why a Simple Metric Cannot Determine Our Energy Future*, IPA, April 2024, ipa.org.au.

8 "The statistics which such a central authority would have to use would have to be arrived at precisely by abstracting from minor differences between the things, by lumping together, as resources of one kind, items which differ as regards location, quality, and other particulars, in a way which may be very significant for the specific decision. It follows from this that central planning based on statistical information by its nature cannot take direct account of these circumstances of time and place."

—Hayek, *The Use of Knowledge in Society*, American Economic Review, 1945.

9 "Our talent for division, for seeing the parts, is of staggering importance – second only to our capacity to transcend it, in order to see the whole. These gifts of the left hemisphere have helped us achieve nothing less than civilisation itself, with all that that means. Even if we could abandon them, which of course we can't, we would be fools to do so, and would come off infinitely the poorer. There are siren voices that call us to do exactly that, certainly to abandon clarity and precision (which, in any case, importantly depend on both hemispheres), and I want to emphasise that I am

passionately opposed to them. We need the ability to make fine discriminations, and to use reason appropriately. But these contributions need to be made in the service of something else, that only the right hemisphere can bring. Alone they are destructive. And right now they may be bringing us close to forfeiting the civilisation they helped to create."

—McGilchrist, *The Master and His Emissary: The Divided Brain and the Making of the Western World*, Yale, 2009.

10 *Authors' chart based on consumer price index (CPI) data from the Australian Bureau of Statistics (complete series). ABS (2024) Consumer Price Index, Australia, Cat no 6401.0*

11 IPA, Nov 2023

12 The extent to which *individual customer bills* reflect the costs of serving each individual customer depends on the pricing structure, any taxes on electricity, as well as any cross-subsidies within the electricity sector, and any subsidies from outside the electricity sector.

Avoiding or eliminating cross-subsidies between customers was part of the general philosophy of electricity market reform and the introduction of competitive free-market principles in the 1990s. Nonetheless, it is still possible for cross-subsidies to exist between customer sectors (residential consumers, commercial enterprises, and large industries) or between customers within a sector.

A cross-subsidy occurs where one customer's bill is larger than the cost of providing their service and another customer's bill is lower than the cost of providing their service. Such cross-subsidies can be implicit or explicit, they can be either intentional or unintentional: that is to say either deliberate or an unintended consequence of policy settings, regulation, or commercial strategies.

It should be noted here that economies of scale and also diversity of load—consumption at different times using the same shared fixed generation and network infrastructure capacity—means that large-scale electricity systems enable costs to be lower for customers overall than would be the case if everyone had to provide their own electricity service independently.

13 M. Boiteux, *Peak-Load Pricing*, The Journal of Business, Apr., 1960, Vol. 33, No. 2 (Apr., 1960), pp. 157-179, University of Chicago Press; originally published in French as Boiteux, 1949. *De la tarification des pointes de demande*. Revue générale de l'électricité, pages 321-340.

Marcel Boiteux (1922-2023) is the father of modern electricity economic theory. An award of the International Association of Energy Economics is named in his honour: "He wrote over 50 scientific articles and created two key pieces of modern energy economics: marginal pricing for peaks; second-best pricing for natural monopolies. Boiteux interacted deeply with the best economists of his time, and was the research assistant of Maurice Allais (Nobel Laureate 1988) and roommate of Gerard Debreu (Nobel Laureate 1983). He was also well connected to the international economists' community. Marcel Boiteux himself applied his new theories, and became Director for Economics at French utility EDF in 1958, then deputy Director General, DG, and President from 1967 to 1987. His theories are the basis for ticket pricing for airlines, AiRbnb, Uber, and others. Marcel Boiteux was a member of the French Academy since 1992, past President of the Econometric Society, and is Honoris Causa at the University of Yale."

Techno-economic computer models for the optimisation of the planning and operation of power systems, the theory of electricity market design pioneered by Schweppe and others at MIT, and merit-order dispatch computer algorithms such as NEMDE—Australia's National Electricity Market Dispatch Engine—used to schedule generation units, can all be traced from the theory in Boiteux's seminal paper.

14 Policies and prices for rooftop solar panels is an example of an implicit but intentional cross-subsidy between consumers.

15 Authors' chart based on Australian Energy Regulator (AER), 2022, *State of the Energy Market*, Figure 6.2 Composition of a residential bill – electricity. The 2023 edition of the report includes the chart on the gas bill composition, but not the chart on electricity bill composition. https://www.aer.gov.au/publications/reports/performance/state-energy-market-2022

16 While the paper seeks to be technically correct and accurate, no technical background is assumed. The paper is for the curious, non-specialist reader. It is not an academic journal paper, nor is it a technical report to a corporate or government client. References are provided for those who may wish to follow up and verify facts and logic presented in the paper.

17 Russ Ackoff, *Beyond Continual Improvement*, from a 1994 event hosted by Clare Crawford-Mason and Lloyd Dobyns to capture the Learning and Legacy of Dr W. Edwards Deming. Available under the title *If Russ Ackoff had given a TED Talk…* at https://www.youtube.com/watch?v=OqEeIG8aPPk

It is helpful for the purposes of the debate on climate and energy policy, and on electricity systems in particular, that Ackoff's talk from three decades ago addressed systems thinking in general and used examples from other industries.

18 It is noted that there are academic papers brochures from electrical equipment vendors, and published articles by technical staff from equipment vendors that propose grid forming (voltage source) inverters be used as a substitute for synchronous generators. An example is the article by Andrew Tuckey and Simon Round, *Grid-Forming Inverters for Grid-Connected Microgrids*, IEEE Electrification Magazine, March 2022, pp.39-51. doi: https://10.1109/MELE.2021.3139172

The article concludes as follows:

> To meet carbon-neutral targets, the electric grid must accommodate a high percentage of renewable energy sources, which are connected by inverters. Earlier inverter control systems assumed that the grid was strong, as a majority of the power was provided by SGs. As more inverters have been added, the grid has become weaker, with increasing voltage and frequency variations. IBRs must now be controlled so that they operate in compatible ways with the existing grid. This is achieved by making inverters act as a voltage source in a grid-forming mode. By adding additional control actions, inverters can behave as VSMs with tunable parameters so they are compliant with required grid behavior. Remote microgrids provide an example of the use of VSMs and the possibility to operate with 100% renewable sources when energy storage is added. Now, applying VSMs to grid-forming inverters, we can make the grid full of "good citizens" that provide stable operation and 100% renewable penetration with resiliency.

Without claiming to offer a full critique of the article, the following observations apply:

- The scope of this and other similar articles is (as the article title indicates) **micro-grids**, not very large, continent-scale, interconnected synchronous AC power systems such as the National Electricity Market in Australia.
- Nonetheless, the authors of the article jump in the first sentence of the conclusion to large power systems through the use of the general and unqualified term "the electric grid". We do not believe this is supported.
- The strong word 'must' in the first sentence of the conclusion is not supported and is easily refuted. There are other pathways to meet the goal of carbon-neutral targets, including carbon capture and storage (CCS) on coal plants, and the deployment of nuclear plants. The latter has been proven at large scale over decades. In such approaches, neither 'a high percentage of renewable energy sources' needs to be accommodated, nor must grid-forming inverters be relied upon, which remain unproven at very large scale in large systems.
- The statement that 'Earlier inverter control systems assumed that the grid was strong' is correct.
- Also correct is the statement that: 'As more inverters have been added, the grid has become weaker, with increasing voltage and frequency variations.'
- It remains an open question whether the application of grid-forming inverters at large scale is able to provide a full, stable, reliable, secure, economic and cost-effective alternative to the established approach to grid design and operation.

19 Note that any claim that broad (or even narrow) environmental impacts have been reduced would need to be assessed rigorously, not at the margin, but in depth at the broad system level. The stated aim or public policy justification of rooftop solar PV promotion programmes is to reduce CO_2 emissions. As that is a global issue, its success or failure can only properly be assessed at the global level. Such assessment includes the effects across the whole power system in which the panels are installed, and the wider effects up the supply chain through manufacturing up to raw materials, and end-of-life outcomes. Such an analysis is beyond the scope of this paper, which is focused on the costs within the power system.

20 https://minister.dcceew.gov.au/bowen/speeches/speech-australian-business-economists

21 Problems with the competitive market is a large topic, which requires a separate paper.

22 Hargreaves, Wild and You, *Liddell the Line in The Sand: Why It's Time To Hit Pause on the Closure Of Coal-Fired Baseload Power Stations in the NEM*, May 2023, https://ipa.org.au/publications-ipa/research-papers/liddell-the-line-in-the-sand

23 Although we don't comment on it directly here, we are aware of the theory of decarbonisation that involves large scale electrification of energy services historically served by other energy forms, and of the more recent extremely high forecasts of electric load growth for data centres and AI search services.

24 Prior to a change in the National Electricity Law (NEL) recommended by the Finkel Review, AEMO was required only to publish annually a *Ten Year Electricity Statement of Opportunities* (ESOO), *Ten Year Gas Statement of Opportunities* (GSOO), and a *Ten Year Transmission Network Development Plan* (TNDP). With the

statutory obligation to prepare the ISP, Australia has reverted to a strange combination of central planning under a supposed free market policy.

25 Tim Buckley, quoted by Anthony Klan, *The Clean Energy Finance Corporation: Lazarus with a triple bypass*, Michael West Media, Dec 29, 2019, https://michaelwest.com.au/the-clean-energy-finance-corporations-love-hate-relationship-with-the-coalition-part-1/

26 Paul Graham, Jenny Hayward, and James Foster, *GenCost 2023-24 Consultation Draft*, CSIRO, December 2023, p.54. https://publications.csiro.au/publications/publication/PIcsiro:EP2023-5586

27 Walter Short, Daniel J. Packey, and Thomas Holt, *A Manual for the Economic Evaluation of Energy Efficiency and Renewable Energy Technologies*, NREL, March 1995, NREL/TP-462-5173, Golden, Colorado; Table 3-1, p.36

28 Shen et al, 2020, 'A comprehensive review of variable renewable energy levelized cost of electricity,' *Renewable and Sustainable Energy Reviews* 133. The paper is authored by eight Australian researchers, including three from the CSIRO.

29 op cit, 5.

30 AEMO, *National Electricity Market 2023 reliability outlook*, 7 September 2023 https://aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/nem_esoo/2023/2023-esoo-publication-webinar.pdf?la=en

31 There are physical limits to the extent and duration for which aluminium smelter potlines can reduce load before the pots freeze and the asset is destroyed.

32 Owen Jacques, Energex remotely cuts power to 170,000 air conditioners six times in a month, ABC Sunshine Coast, 31 Jan 2024. https://www.abc.net.au/news/2024-01-31/energex-ergon-peaksmart-air-con-cuts-during-hot-weather/103385474

33 Dr Fatih Birol, Remarks at the International Atomic Energy Agency Summit on Nuclear Energy, Brussels, https://fb.watch/r0GMmI4tpE/ at 1hr53min.

34 This definition of energy security was first presented by the author at the IPA Retreat at the Hotel Canberra, 12th May 2023.

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