23 October 2023
The Secretary,
Independent Planning Commission (of NSW)
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Dear Madam/Sir,

**Submission re the Oxley Solar + Battery Energy Storage System (BESS) development Application ID: SSD-10346**

## Executive Summary

The Oxley Solar Farm, with a quoted installed capacity of 225 MW, spread over some 895 ha, comprising some 715,680 solar panels, would be expected to produce, given the Capacity Factor of similar installations in Eastern Australia (0.17), an average output of some 38.25 MW.

This output will be highly intermittent. After all, solar panels produce nothing, all night, every night, so there can be no argument as to their inherent intermittency. It might be argued that the on-site BESS, if fully charged, might supply back-up power during the dark hours, but the simple fact is that a 50 MWh battery, even when fully charged, can produce an output of 38.25 MW for a period of only 1.31 hours maximum before it is goes flat.

It does seem a rather disappointing performance from a generator and BESS comprising all that equipment, and having such a huge environmental footprint of so many hectares.

Furthermore, all of those solar panels, and the BESS battery modules, are manufactured from components that require huge amounts of energy in their manufacture. For example, one of the best kept secrets of the electronics industry – including the PV solar cell industry – is that huge amounts of electricity are required in both the conversion of silica to silicon, (incidentally releasing large quantities of $CO_2$), and in the process to produce the required high-purity silicion. Similarly, the Lithium-ion batteries require huge quantities of energy in their manufacture. All of this energy is provided by the burning of enormous quantities of fossil fuels, which of course produces similarly enormous quantities of $CO_2$.

If the intention, as stated in the developer's EIS, is merely that the NSW and Commonwealth governments meet some sort of self-imposed "target" of installed so-called "renewable" capacity, then perhaps this, clearly very disappointing, performance is of no consequence, nor is the fact that such facilities, having such a huge land-area footprint, constitute a horrendous environmental impact. The huge loss in grid operational stability and reliability, resulting from the attempted replacement of fossil-fuelled generation by such as this solar farm plus totally inadequate battery storage, might also be deemed to be of no consequence also.

Turning to the matter of end-of-life issues, there seems to be no thought given by the proponent, or required by NSW Planning, to the matter of waste disposal and recycling of the solar panels and battery components once they reach end-of-life. Contary to what the proponent states, (Section 4.8 – Decommissioning and Rehabilitation).

Lithium-ion batteries have a maximum operational life of some 10 years, perhaps much less depending on the severity of charge-discharge cycling, so the sheer quantity of the batteries required and their relatively short life cycle constitutes a serious waste disposal problem.
It should not need mention that the disposal at end-of-life of 715,680 solar panels constitutes a huge waste disposal problem.
Section 8.4 – Resource use and Waste Generation – of the proponent's EIS simply states some desirable principles but avoids discussion of the details of the waste disposal problem altogether.

Also discussed in this submission are a number of operational safety concerns resulting from the use of BESS that ought, as a matter of urgency, be given rather more serious consideration by Planning NSW.

Finally, should the achievement of significant CO2 emissions reductions be deemed to be important, an example of technological alternatives are presented for the Commission's consideration, and some of the advantages of these technologies *vis a vis* the "renewable" technologies are outlined.

These then are some of the matters which will be explored in this submission.

In summary, while the sheer scale of these types of facilities may seem impressive to the casual observer, a rudimentary engineering analysis demonstrates that an attempted deployment of even many hundreds of such installations can never hope to replace just one of NSW's coal-fired powerstations. Therefore, these installations are not fit for purpose. Any such deployment then is futile. Any attempted deployment will needlessly result in widespread environmental impacts, huge impacts to the wider economy, and the eventual collapse of the Eastern Australian grid, with no measurable reduction in CO2 emissions. Continued closure of coal-fired power stations under the deluded idea that they are being progressively replaced by the buildout of such installations as the Oxley Solar Farm plus BESS will merely lead to a situation of continued frequent, unpredictable, widespread blackouts, and, as earlier stated, the collapse of the Eastern Australian grid. Such are the engineering realities that governments seek to ignore.

Need it be stated that the possibility of any single collapse of the Eastern Australian grid, let alone a situation of repeated, widespread blackouts, would be an enormous disaster? To learn of the unexpected consequences that will occur during such events, the reader is directed to Petermann et al., (2011).

For the reasons elaborated in this submission, as stated in its Conclusion below, and indeed on engineering considerations alone, the Oxley Solar Farm and BESS, or indeed any such facility consisting of the same types of equipment, should be disallowed as being not fit-for-purpose either as a means of replacing existing fossil-fuelled power stations or achieving any meaningful CO2 emissions reductions.

## Preamble

It should not require mention that the nature of solar-generated electricity is inherently even more variable that that supplied by wind generation. It's intermittency is a given: no electricity is generated by any solar module at night, every night, on the 365 24-hour days of the year, every year.
Solar-generated electricity then, if anything, has an even greater potential to destabilise the electricity grid.

These inherent properties of variability and intermittency of both solar and wind generation are often completely overlooked by politicians and planners.

The relevance of these facts will become apparent as this discussion proceeds.

## Introduction

The NSW government has stated that, as an energy policy imperative, it is committed to closing all coal-fired powerstations in NSW, and replacing them with a mix of so-called “renewable” generation, which usually means solar and wind generation, coupled with a means of energy storage that is to be provided, for the most part, by so-called “Grid-scale Big Batteries”.

To support this policy position, the NSW government has provided no detailed, meticulously prepared plan. In fact the government has provided nothing whatsoever that could be construed to be some sort of rational, carefully-thought-out, technically-firmly-grounded, basis for this position.

What the government has done has been to continue to support the legislated process put in place by the Energy Minister of the previous government where he designated so-called “Renewable Energy Zones” (REZ), where these were to be regions of New South Wales where any proposed “renewable” energy developments might be fast-tracked through the planning process.

This is what might be regarded as an interesting first step, but nowhere is there articulated any careful planning as to how any “renewable” generation that arises in these regions is to replace the existing fleet of coal-fired powerstations.

The Independent Planning Commission needs to understand very clearly that, as far as an Energy Policy is concerned, the NSW government has no coherent, carefully-prepared, plan to bring about this transition. It has no plan at all.

As a last part of this “strategy”, the NSW governmental approach has been to have declared a deadline by which this transition is to occur. And that’s it. That’s apparently all that is necessary to define a coherent strategy. That is all.

It would appear that the NSW government expects, by allocating regions of the State in this fashion, that the precise mix of generation and storage required to replace the existing fossil-fuelled power stations will somehow, magically, appear, and perhaps, even overnight. It does not seem to have occurred to government politicians and planners that there might be a need for rather more planning in this matter, much less has it occurred to them that there might be a need for any careful engineering analysis.

To attempt to get them to think that they might do well to address this deficiency, it is useful to quote from a recent post in the UK, a country which is also suffering the woes of a similar attempted “transition to NetZero”:

“*I urge politicians in Holyrood and Westminster to suspend all new large-scale wind and solar developments and grid expansions until a comprehensive analysis and report on the real environmental and economic costs of current net-zero energy policy is presented to the public for scrutiny. This report must be based on sound thermodynamic and economic principles and not upon wishful thinking and net zero dogma that appears to underpin much of current energy policy.*”

This is a comment by a Dr Euan Mearns at:

https://wattsupwiththat.com/2023/09/25/public-anger-at-the-hidden-costs-of-net-zero-energy-policies/

This comment is equally relevant here in NSW, and for precisely the same reasons.

This then is the background against which this submission is being prepared.

Two points to keep in mind:

1. **The Electricity Grid does NOT operate like a Bank or other Financial Institution**

The electricity grid can never operate in the manner of a bank or similar lending institution. That is, it is not possible to deposit a quantity of energy into the grid at one time, then draw upon it at another, or *vice versa*. The grid operates second-by-second. Supply and Demand MUST be in balance AT ALL TIMES. When an intermittent generator commences operation, another operating, controllable, dispatchable generator must be backed out to maintain the balance. Conversely, when the output of an intermttent generator falls, or as so often happens, ceases altogether, another dispatchable generator must be called on immediately to supply the demand. Given the huge variability in the outputs of both solar and wind generators, to speak of such an intermittent generator to be able to supply so-many-thousand-homes, as so often appears in development proposals is, quite simply, a nonsense at those times that it is not operational, such as after sunset in the case of any solar plant, including the Oxley development under discussion here.

2. **Synchronous Inertia is critical to the stability and reliability of the Electricity Grid**

There is the little matter of what we electric power engineers call synchronous inertia – called, somewhat curiously, by the AEMO as “Ancillary Services” – the momentum that is the collective mechanical rotational inertia of all of the conventional turbines and generators connected to the grid. These “Ancillary Services” are hardly ancillary, the continued presence of synchronous inertia is absolutely critical to the operational stability of any electicity grid.
I will now attempt to define the meaning of the term “synchronous inertia”.
It is an unchangeable property of conventional generators that, when connected to the grid, they all turn together locked into synchronous speed, that is, each machine’s equivalent of 50 cycles per second, or, in mechanical terms, 3000 revolutions per minute. The collective mechanical momentum of all such machines locked into this speed is what provides the very important property of operational stability: any transient disturbance, such as a massive short-circuit caused by such as a tree falling on powerlines, or a lightning strike, as two common examples, can be absorbed by this mechanical inertia for a period that is sufficient for protective switching to isolate the fault and not cause the grid to collapse. Solar and wind generation, by their very design, can provide no synchronous inertia. As a result, the more wind and solar, coupled with the closure of conventional generation, the lower the stability, the more fragile the grid becomes.

## Questions that need to be addressed by NSW government energy planners

The following questions, in no particular order, are a subset of the sorts of essential questions that need to be asked by planners, both of their own stated criteria, and of the developers of proposed projects.

The first set of questions apply to so-called “renewable”-energy development proposals generally.

1. Does the proposed project actually deliver measurable $CO_2$ emissions offsets?

2. What are the actual, quantified, $CO_2$ emissions that would result from the energy expenditure required to manufacture the proposed plant and equipment, its transport to the proposed site and the site preparation, in setting up the proposed project prior to first operation, during its operation and the decommissioning of the project site?

3. What are the energy requirements, and hence any $CO_2$ emissions, resulting from the required recycling of any used equipment resulting from the operation of the proposed project? Note that dumping is NOT an acceptable alternative to recycling.

4. Given that intermittent generation such as the oxley Solar Farm requires the continuous availability of backup such as might be provided by the associated BESS, what provisions are in place such that any and all excess generation by the solar farm above a figure agreed with the AEMO as that which constitutes a dispatchable supply is used to charge the BESS at those times when it is not required to backup the Oxley Solar Farm? Reading the proponent's EIS, there does not seem to be any requirement whatsoever that the proponent purchase electricity for BESS recharge from the adjacent Oxley Solar Farm.

## Solar PV generators

Solar Farms connected to the Eastern Australian Grid hae a Capacity Factor, or Average Output percentage of about 17 percent of their rated capacity. The developer has stated that the Oxley Solar Farm is to have an installed capacity of some 225 MW. What this means is that when the sun is shining, and presuming that the solar collectors are all clean and free of any dust cover, and are at the optimum angle to receive the maximum amount of sunlight, and only then, then the output of the entire set of arrays might reach 225 MW. If though heavy cloud then comes over to obscure the sun, then the output of the arrays can be expected to drop, immediately and drastically. Such is not an infrequent event, happening during an afternoon thunderstorm, for example, and, of course, all night, every night. These are the reasons that the Capacity Factor of solar PV arrays is so disappointingly low. With this Capacity Factor percentage in mind then, the average output of the Oxley Solar Farm is easily obtained. It can be expected to be a maximum of: 38.25 MW. That figure is easily derived from the calculation: 225 MW x 0.17.

Given that the output of solar PV generation technology is inherently intermittent, it could be reasonably expected that any Solar Farm + BESS facility would be designed so that the solar farm generator, when it was producing any energy, would supply sufficient energy to the BESS so that the latter has sufficient energy available to supply the Grid at an agreed rated value for the entire period of the day that the generator is not operational, thus smoothing the output of the facility, enabling it to supply fully dispatchable power to the Grid.
For this desired operation, a battery that is able to provide a sufficient level of energy storage is required.

Having determined that the Average Output of the Oxley Solar Farm in its stated configuration is 38.25 MW, let's use that figure as the amount to be supplied to the Grid on a 24/7 basis. Now, it gets a bit complicated to determine what the BESS is to supply during daylight hours, that is while there can be expected to be at least some output from the solar PV generator. However, we can determine the energy storage requirement for the nighttime hours.
Let's presume, as a first approximation, that nighttime is the period between 6 pm one evening and 6 am on the following morning, that is, 12 hours. This period does of course vary through the year, but as a first approximation it provides a useful starting point.
For this period of 12 hours, the energy storage requirement for the Oxley BESS is:
38.25 MW times 12 hours = 459 MWh.

With a BESS of 50 MWh, to supply an output of 38.25 MW, presuming that the battery is fully charged at the beginning of the nighttime period, the battery will be fully discharged after:
50 MWh divided by 36.55 MW = 1.31 hours
Note that this figure of 1.31 hours is a maximum value. It does NOT take account of any of the round-trip losses that are inevitable from battery charge/discharge cycles.
We can see immediately from the figure above that a BESS of 50 MWh, the developer's stated value, is hopelessly inadequate as a means of providing an output throughout the night, let alone provide any covering output during daylight hours should clouds blot out the sunlight.
It may of course be possible to keep the plant fully operational 24/7, but the actual average supply to the Grid would be much, much less than 38.25 MW.

## Battery Energy Storage Systems

The following questions apply to battery storage development proposals.

1. The BESS of the current proposal is, according to the proponent, at Section 4.4.7 of the EIS, limited to a maximum energy storage of 50 MWh. The maximum output rating of the battery system is NOT given in this section. There is a definition given as to the meaning of the unit of measurement: "MWh", but this is a definition only. There is NO statement as to what the maximum output of the battery system in MW. We might presume from this latter definition that the maximum output rating of the battery may be 50 MW, but it may be a lot less. In any event, there is not sufficient capacity in the proposed battery system to back up the associated solar farm for even one night.

2. What is the actual battery storage requirement to even begin to properly backup the Oxley Solar Farm during those periods, such as is required every night, and during extended spells of cloudy days, when the latter is not capable of supplying electricity? Where has NSW Planning carried out such a calculation? Is the Department aware of the sheer scale of the battery requirement?

NSW Planning staff should be required to read Menton (2022), entitled "The Energy Storage Conundrum". Here Mr Menton demonstrates, lucidly, the complete folly in presuming that a number of solar and wind installations, plus an unspecified number of battery storage systems, can easily, simply, replace the existing fossil-fuelled generation fleet.

The specified BESS that is part of the proposal, contrary to the Department's Assesment, can never hope to supply sufficient energy to cover the lack of output of the associated solar farm.

### Management of Grid-scale Battery Fire Risk

1. What set of strategies and precautionary measures is the proponent putting in place to deal with Lithium-battery fires?

Here the Commission is directed to two recent publications in relation to the likelihood of Lithium-battery fires and the measures required to extinguish such fires.
The first is the announcement by the NSW government Fire and Rescue Service that they are commencing a research programme under whatthey are calling SARET: Safety of Alternative and Renewable Energy Technologies Research Program. The announcement may be found at: https://fire.nsw.gov.au/page.php?id=9402.
The several project streams are:
Fire Service response to lithium battery fires
End-of-life lithium battery hazard management
Electric vehicle fires in structures

Fire propagation in energy storage systems

Clearly, the last-mentioned stream is directly applicable to grid-scale battery storage systems – indeed the synopsis there specifically mentions “grid-scale applications”.

To quote from the project summary at the above link:

“*In late 2021, the Australian Government committed to a net zero emissions target by 2050 and invested $20 billion to support renewable and low emissions technologies, such as carbon capture and storage, clean hydrogen, low-cost solar power, and energy storage.*
*Energy storage in the form of Lithium-ion batteries (LiBs) has become increasingly used and accepted in a wide range of applications across the consumer, residential, commercial, and transport sectors. The same technologies used in portable devices such as mobile phones and laptops are now being used in increasingly larger applications as they have become cheaper and more efficient. Electric scooters, electric vehicles, residential solar battery systems, data centres, and grid scale energy storage systems commonly utilise lithium-ion technology.*

*With higher usage comes greater risk, and there has been a noticeable increase in reported LiB-related fires and casualties worldwide. Recent incident data from the first quarter of 2022 indicated that one in a hundred fire calls to Fire and Rescue NSW (FRNSW) involved a battery in thermal runaway, which is an uncontrolled and excessive rise in heat within a battery cell or several battery cells often leading to cell venting and fire.*

*Some of the potential challenges related to LiB fires for emergency responders and other stakeholders include: a greater fire intensity often accompanied with the violent ejection of vapours and other materials; exposure to toxic and corrosive vapours, gases and fire effluents; increased risk of vapour explosion in confined environments; stranded electrical energy from energised high-voltage battery cells; protracted processes for extinguishing and cooling the reaction; the risk of secondary ignitions following the initial event; difficulties rendering the site safe; the containment of contaminated fire water; and issues with handling, transporting, and disposing of fire-affected batteries.*

*There is a general lack of guidance and provisions in building codes, standards, and legislation in relation to safety to address the potential risks from these emerging technologies. Part of the problem is that we do not yet know enough about their probability of failure, their mechanisms of failure and potential consequences of failure.*”

The second was published by the ACCC on 5 October 2023.
The report is available at:
https://www.accc.gov.au/about-us/publications/lithium-ion-batteries-and-consumer-product-safety

Commissioners will not need to be reminded that Grid-scale batteries use the same lithium-ion technology as do consumer product batteries, but NSW planners may need to be alerted to this fact.

## Waste Disposal Matters

As mentioned in the Executive Summary, no mention has been given by the Proponent, and seemingly no requirement has been placed by NSW Planning on the proponent, to properly address in detail, the responsibilities of waste disposal and/or recycling of the vast quantity of material that constitutes the active components of this generation and battery storage facility. As to the

Department's attitude to these important matters, it is useful to quote from a letter of 15 October 2022, from the Executive Director, Energy, [NSW] Office of Energy and Climate Change to a colleague. In the matter of waste disposal / recycling, the Executive Director wrote:

"*The NSW Government is committed to playing its part in transitioning to a circular economy over the next 20 years. In June 2021, the NSW Government released the NSW Waste and Sustainable Materials Strategy 2041: Stage 1 – 2021-2027, which sets out the priority actions to be undertaken over the next six years to deliver on the government's long-term objectives.*
*These actions are backed by $356 million in funding to help deliver priority programs and policy reforms.*
*Protecting our environment includes embedding a circular economy in NSW that values resources by keeping materials and products in use, rather than simply disposing of them. This means we are working to ensure we have the infrastructure, programs and policies in place to increase the recyclability of all waste streams that we generate.*
*To address the management of solar panels and batteries at end-of-life, the NSW Government has created the $10 million Circular Solar fund to keep these items out of landfill. This fund is intended to future-proof the management of solar panels and battery systems waste and help NSW transition to renewable energy sources in the context of a productive circular economy. To-date, $9.4 million has been awarded to 8 projects.*
*If you would like to learn more about the Circular Solar program and its funded projects, visit: www.epa.nsw.gov.au/working-together/grants/infrastructure-fund/circular-solar-trials.*"

All of this is very fine-sounding, but it does absolutely nothing to address these problems in the here and now. Without the details, the specifics of exactly how the NSW government is to go about it, this statement is meaningless, aspirational, wishful thinking, nothing more. This is what the NSW Government is going to do starting exactly when sometime during the next 20 years? What on earth is a "Circular Economy"? At $10 million, the size of the so-called "Circular Solar Fund" is a mere token gesture: this one project itself, the Oxley Solar Farm, will require far more than a mere $10 million to address the disposal/recycling of 715,680 waste solar panels, for example.

In summary, the NSW goernment simply has not thought through what to do about what is a very serious waste disposal issue. These solar panels have the potential, over time, to leach large quantities of some extremely toxic materials into the environment. Similarly, the required more frequent replacement of batteries in what will result in a huge battery deployment represents another huge waste issue in itself.

It might be well to remind the NSW government that because exactly nothing is being done NOW, in the present, by the Departments, to address these huge waste/recycling issues, the little matter of Intergenerational Equity will loom large, particularly should development proposals such as these come under the scrutiny of, for example, the NSW Land & Environment Court.

## Consideration of Alternative Technologies

What is clear from any careful analysis of the production methods and the deployment required for wind and solar generation is that the burning of vast amounts of fossil fuels is required just for those activities. Similarly, fossil-fuelled generation is required at all times for backup of these intermittent sources, so there is limited. If any, scope for achieving any reductions in $CO_2$ emissions using these technologies. Two alternatives stand out.

1. Replace the present fleet of ageing coal-fired power stations with new-technology, high-efficiency HELE coal-fired plant. Such units are a drop-in replacement for existing power stations and achieve real, significant reductions in $CO_2$ emissions.
2. Should governments really want to reduce $CO_2$ emissions to the absolutely lowest possible amounts then the only choice is the nuclear power option. Similarly, a nuclear reactor is a drop-in replacement for an existing coal-fired power station. It occupies much the same amount of land, and unlike wind and solar, the nuclear industry takes full responsibility for the disposal of its, relatively small, quantities of waste.

**Conclusion**

On engineering considerations alone, the Oxley Solar Farm and BESS, or indeed any facility consisting of the same types of equipment, should be disallowed as being not fit-for-purpose as either a means of replacing existing fossil-fuelled power stations or achieving any meaningful $CO_2$ emissions reductions.

**Disclaimer**

The author of this submission has no financial interest whatsoever in any of the technologies discussed in this submission. Nor has the author made donations to political parties.
As a professional engineer, the author has made this submission in the full knowledge of the requirements of the Engineer’s Code of Conduct: that is the the full facts of the relevant engineering knowledge as presently understood are to be presented, for the express purpose of the betterment of society.

**References**

Kelly M 2023 *The green energy net-zero plan will require a command economy*
*And several technological impossibilities, and a massive drop in living standards*
Available at: https://www.telegraph.co.uk/news/2023/10/11/green-energy-net-zero-biden-command-economy-impossible/ Last accessed: 16 October 2023.

Menton 2022 *The Energy Storage Conundrum*. Briefing 61, The Global Warming Policy Foundation. Available for download at:
https://www.thegwpf.org/content/uploads/2022/11/Menton-Energy-Storage-Conundrum.pdf
Last accessed: 22 October 2023.

Petermann, T.; Bradke, H.; Lüllmann, A.; Poetzsch, M.; Riehm, U. 2011. What happens during a blackout: Consequences of a prolonged and wide-ranging power outage  Bureau of Technological Assessment for the German Bundestag (TAB) Available at:
https://publikationen.bibliothek.kit.edu/1000103292

**Appendix 1 – Recent article in the the UK Daily Telegraph by Professor Michael Kelly, Emeritus Professor of Engineering at the University of Cambridge, UK**
**(See Reference list for the complete reference)**
*11 October 2023*

*"Imagine the USA in 2050 has a net-zero emissions economy, as President Joe Biden has pledged that it will (the UK is also committed to this).*
*Three very large, interrelated, and multidisciplinary engineering projects will need to have been completed. Transport will have been electrified. Industrial and domestic heat will have been electrified. The electricity sector – generation, transmission and distribution – will have been greatly expanded in order to cope with the first two projects, and will have ceased to use fossil fuels.*

*I have had a long career in industrial and academic engineering, and recently retired as Professor of Technology in electrical engineering at Cambridge University. I've spent some time looking into the feasibility of these ideas, and these are the facts.*

*At the moment the USA uses on average 7,768 trillion British Thermal Units of energy every month, most of which is supplied by burning fossil fuel either directly for heat or transport, or indirectly to generate electricity.*

*Because an internal combustion engine converts the energy stored in its fuel into transport motion with an efficiency of about 30 per cent, while electric motors are more than 90 per cent efficient at using energy stored in a battery, we will need to increase the US electricity supply by about 25 per cent to maintain transport in the USA at today's level. Let's assume that replacing today's fossil-powered vehicles and trains with electric ones will cost no more than we would have spent replacing them anyway: it's not really true but the difference is small compared to the rest of this. I should note however that a small part of today's transport energy is used for aviation and shipping, which are much harder to electrify than ground transport, but we'll ignore that for now.*

*Next we need to electrify all the heat. If this heat was provided by ordinary electric heaters, we would need an extra electrical sector equal to the size of today's. But if we mostly use air-source and ground-source heat pumps, and assume a coefficient of performance of 3:1 – optimistic, but not wildly unreasonable – then we only need new grid capacity equivalent to 35 per cent of the size of the present grid for the heat task.*
*So far, the grid in 2050 will need to be more than 60 per cent bigger than its present size. We also need to work on the buildings. US building stock is made up of nearly 150 million housing units, commercial and industrial buildings, with an estimated floor space of 367 billion square feet. Some of this is well insulated, much of it is not. All of it would need to be, for our heat pumps to work at the efficiencies we need them to. Based on a UK pilot retrofit programme the national scale cost for this is $1 trillion per 15 million population. The figure in the USA could therefore be about $20 trillion. It might be as high as $35 trillion.*

*We should note here that as with transport, some specialist types of heating cannot at the moment be done electrically, for instance in primary steel production. These will involve extra costs if net zero is to be reached, but we'll ignore that for now, even though we're going to need an awful lot of steel.*

*Now let's get the power grid decarbonised and make it 60 per cent bigger and more powerful. Taken together, the US electrical grid has been called the largest machine in the world: 200,000 miles of high-voltage transmission lines and 5.5 million miles of local distribution ones. We will need to add a further 120,000 miles of transmission line. This will cost on the order of $0.6 trillion, based on US cost data.*

*The 5.5 million miles of local distribution lines will have to be upgraded to carry much higher currents. Most houses in the USA have a main circuit-breaker panel that allows between 100 and 200 amps (A) current into the house, although some new ones are rated at 300A. The 100A standard was set nearly a century ago, when the electric kettle was the largest single appliance. In a modern all-electric home, some of the new appliances draw rather higher currents: ground-source heat pumps may draw 85A on start-up, radiant hobs when starting up draw 37A, fast chargers for electric vehicles draw 46A, and even slow ones may draw 17A, while electric showers draw 46A. The local wiring in streets and local transformers were all sized to the 100-A limit. Most homes will need an upgraded circuit breaker panel and at least some rewiring, and much local wiring and many local substations will need upsizing. The UK costs have been estimated in detail at £1 trillion, which would scale to the order of $6 trillion on a per-capita basis.*

*As 60 per cent of the current electrical generation is fossil fuelled, we need to close all the fossil stations down and increase the remaining, non-fossil generation capacity four times over. There isn't much scope for new hydropower, and so far carbon capture doesn't exist outside fossil fuel production. Using a mixture of wind (onshore $1600/kW, offshore $6500/kW), solar ($1000/kW at the utility level) and nuclear ($6000/kW), the capital cost of this task alone is around $5 trillion, and we have not dealt with the enormous problem of wind and solar being intermittent.*

*So far we're up to $32 trillion as the cost of providing the insulated buildings and the generation, transmission and distribution of electricity in a net-zero world. Although not all borne by households, this figure is of the order of $260,000 per US household.*

*Now let's think about intermittency. Sometimes there is no wind and no sunshine, and our largely renewables-driven grid will have no power. Current hydropower storage would run a net-zero grid in the USA for a few hours; current battery capacity could do so for a few minutes. Net-zero advocates often suggest simply building huge amounts of battery storage, but the costs of this are colossal: 80 times as much as the power plants, hundreds of trillions of dollars. And indeed this is simply fantasy as the necessary minerals are not available in anything like the required amounts. If prices climbed, more reserves would become economic – but the prices are already impossibly high.*

*Straight away, we can see that <u>a net-zero grid with a large proportion of renewables simply cannot be built</u>. But for now let's just ignore the storage problem and look at some more numbers.*
*The UK engineering firm Atkins estimates that a $1-billion project in the electrical sector over 30 years needs 24 or more professional, graduate engineers and 100 or more skilled tradespeople for the whole period. Scaling up these figures for the $12 trillion of electricity sector projects just described, we will need 300,000 professional electrical engineers and 1.2 million skilled tradespeople, full time, for the 30 years to 2050 on just this part of the net-zero project. Based on the budget, we might expect the buildings retrofit sector to need a similar workforce of roughly three million people. This is a combined workforce roughly the size of the entire existing construction sector.*

*Now let's think about materials. A 600-megawatt (MW) combined-cycle gas turbine (CCGT) needs 300 tonnes of high-performance steels. We would need 360 5-MW wind turbines, each running at an optimistic average 33 per cent efficiency (and a major energy storage facility alongside which we are just ignoring as it would be impossibly expensive) to achieve the same continuous 600-MW supply. In fact, since the life of wind turbines at 25 years is less than half that of CCGT turbines, we would actually need more than 720 of them.*

*The mass of the nacelle (the turbine at the top of the tower) for a 5-MW wind turbine is comparable to that of a CCGT. Furthermore, the mass of concrete in the plinth of a single CCGT is comparable to the mass of concrete for the foundations of each individual onshore wind turbine, and much smaller than the concrete and ballast for each offshore one. We are going to need enormous* *amounts of high-energy materials such as steel and concrete: something like a thousand times as much as we need to build CCGT or nuclear powerplants, and renewed more frequently. This vast requirement is probably going to affect prices, both of materials and energy – and not in a good way – but for now we'll just assume costs remain at something like current levels.*

*So we can see that the infrastructure parts of the net-zero project which are theoretically possible would cost comfortably in excess of $35 trillion and would require a dedicated and highly skilled workforce comparable to that of the construction sector as well as enormous amounts of materials. Net zero would also require several things which today are completely impossible: scalable non-fossil energy storage, very high temperature electrical industrial processes, serious electrical aviation and shipping. There would also be the matter of decarbonising agriculture. These things, if they can even be achieved, would multiply the cost at least several times over, to more than $100 trillion.*

*So the real cost of net-zero, or more likely of trying and failing to achieve it, would be similar to – or even more than – total projected US government spending out to 2050. There is no likelihood of that amount of money being diverted from other purposes under anything resembling normal market economics and standards of living.*

*The idea that net zero can be achieved on the current timelines by any means short of a command economy combined with a drastic decline in standards of living – and several unlikely technological miracles – is a blatant falsehood. The silence of the National Academies and the professional science and engineering bodies about these big picture engineering realities is despicable.*

*People need to know the realities of net zero."*

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**Appendix 2 - Solar Farms on the Eastern Australian Grid – Actual Operational Data**

The operational data displayed here is taken from graphs and charts at the link:
https://anero.id/energy/solar-energy
The displays at this site require some explanation.
The source of the data displayed is the AEMO – the Australian Energy Market Operator – the operator of the Eastern Australian Electricity Grid.

The AEMO provides vast amounts of data, on a daily basis, and in many cases, on a 5-minute basis, at the website https://www.nemweb.com.au/.
The data is presented there in a truly inscrutable fashion. All that the casual visitor can see at the top level is a large number of directories having non-understandable names, and, within each of these directories, a vast quantity of .zip files, themselves similarly having names that are meaningless to the non-specialist.

The data of specific interest here is the collection of 5-minute-interval generator output readings for all the generators on the grid, or, as the AEMO describes them, the "Registered Participants".
The data is made available at the link:
http://www.nemweb.com.au/Reports/ARCHIVE/Dispatch_SCADA/
The visitor will find here a large set of .zip files having names of the form:
"PUBLIC_DISPATCH_SCADA_YYYYMMDD.zip
where the "YYYYMMDD" refer, unsurprisingly, to the particular date.
On unzipping the file, the visitor is then presented with 288 files, themselves .zip files.
There are 288 files, one for each 5-minute spot time of that particular date. (The reader can confirm that there are 288 5-minute time intervals in the 24-hour day.) Each file contains the output values of all the "Registered Generators" at the particular timestamp, where the line of data comprises the ID of the generator, the timestamp (Eastern Australian Standard Time), and the output of the generator in MW.
At the anero.id site, its author has done all of the necessary extractions and set up the graphical displays to display the outputs of all those generators in a readily readable form.

For the purposes here, it remains to provide, taken from the anero.id displays, data such as:
1. A graph of the total output through a single 24-hour day of all of the solar farm generators,
2. A graph of the same total output during a longer period, say one month.
3. The output across one day of a typical solar farm.
Then to discuss the characteristics of this data, and the likely consequences of the large-scale deployment of solar farms in the pursuit of the goals of the so-called NetZero agenda.

Figure 1 clearly shows that there is no output whatsoever during the period colloquially known as "nighttime" from any and all of solar farms connected to the Eastern Australian Grid. During this period, other generation of what would otherwise be huge amounts of battery storage would be required to make up to supply the electricity demand.

Figure 2 also shows clearly that the content of Figure 1 is NOT an isolated, "cherry-picked" example. The routine drops to zero shown there for each nighttime period shows that the failure of solar generation occurs every night, and for all of each night.

Note: Should the reader wish to choose displays of operational data for other days, other months, it is merely a matter of substituting the month and or date in the relevant link below. For example, to view the output 12 months earlier, in September 2022, the link to use is, as might be expected:
https://anero.id/energy/solar-energy/2022/september. In addition, what is required is that the user click on the "MW" button of the pair of buttons at the top right of the relevant chart.

To view the output for the date 3 July 2021, the link becomes:
https://anero.id/energy/solar-energy/2021/july/03.

Figure 3 shows the output of a single solar farm, that at Nyngan, NSW. This has a registered total installed capacity of 102 MW.

To obtain a chart for a single solar farm from a given page in this way, the user unticks all other boxes next to the respective generators in the table below the chart, as well as the “Total” and “Subtotal” boxes. The quickest way to do so is first to determine from the table below the chart which State the generaor is, then to untick the boxes against all the other States, then to untick the boxes against the remaining undesired generators.

Figure 3 shows clearly that the output of this solar farm is not constant through daylight hours, and, again, shows that there is no output at night.

From the same link, the drastic effects on outputs of individual solar farms as a result of variations in cloud cover can be seen by examining the outputs of such as the Hillston Sun Farm of 110 MW installed capacity, (untick the box adjacent to HILLSTN1), and, in particular, that of the Sunraysia Solar Farm, of 228 MW installed capacity, (untick the box adjacent to SUNRSF1). In the latter case, shown by the chart reproduced as Figure 4, the total output during the operational part of the day struggled up to some 80.2 MW for most of that time, with a short and sharp peak up to some 165.5 MW before sunset put an end to the day’s output. Incidentally, such short sharp peaks and dips in output are a classic example of a grid controller’s nightmare, and with the plethora of these intermittent renewables now present on the grid, they are now happening on an hourly, and even a minute-by-minute basis at some times.

Also note that on any of these pages opened at anero.id/energy/solar-energy, while opened in a browser, by moving the cursor across the displayed “Solar Energy Production”, the user may read the output of any of the displayed generators at any 5-minute timepoint throughout the time period being displayed. This is a quite handy feature.

Again, using any of the search techniques on these pages at anero.id, it is very easy to show that the charts below are by no means “cherry-picked”. They are truly indicative of routine variations in output, as would be entirely expected of any such weather-affected system of generation.

## Solar Energy Production During 20 October 2023

Link: https://anero.id/energy/solar-energy/2023/october/20

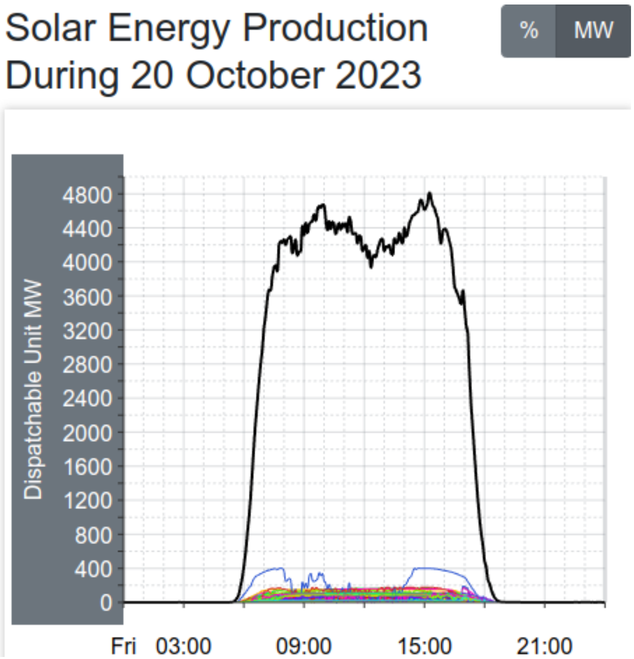


Figure 1 The total output of all Solar Farms to the NEM during the 24- hours of 20 October 2023.

## Solar Energy Production During September 2023

Link: https://anero.id/energy/solar-energy/2023/september

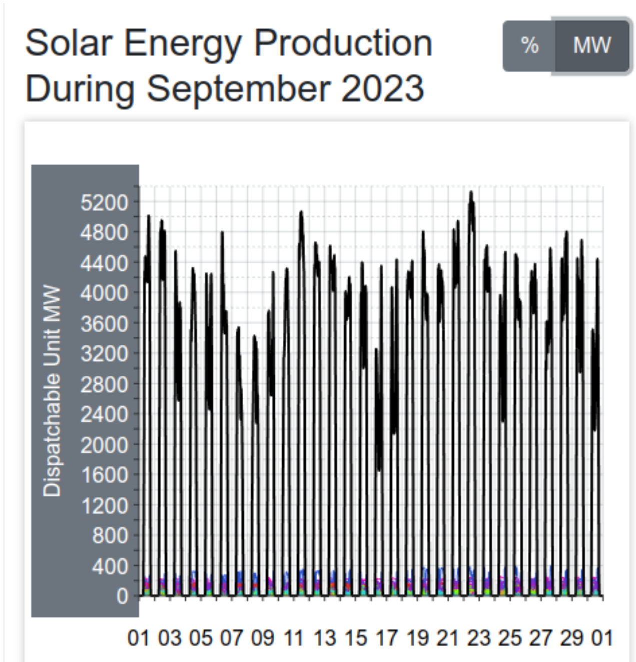


Figure 2 The total output of all Solar Farms to the NEM during the month of September 2023.

## Solar Energy Production of the Nyngan NSW Solar Farm on 20 October 2023

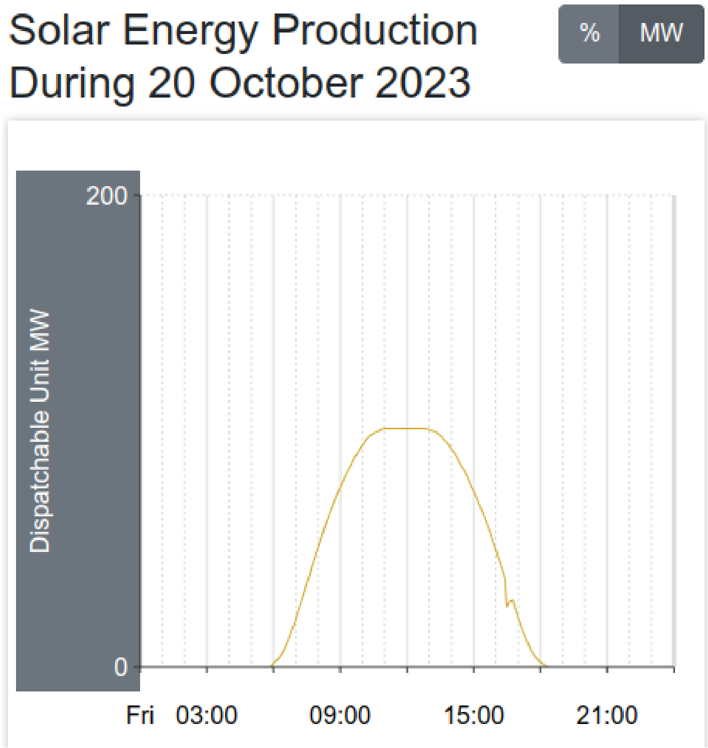


Figure 3 – Output of the Nyngan Solar Farm on 20 October 2023.

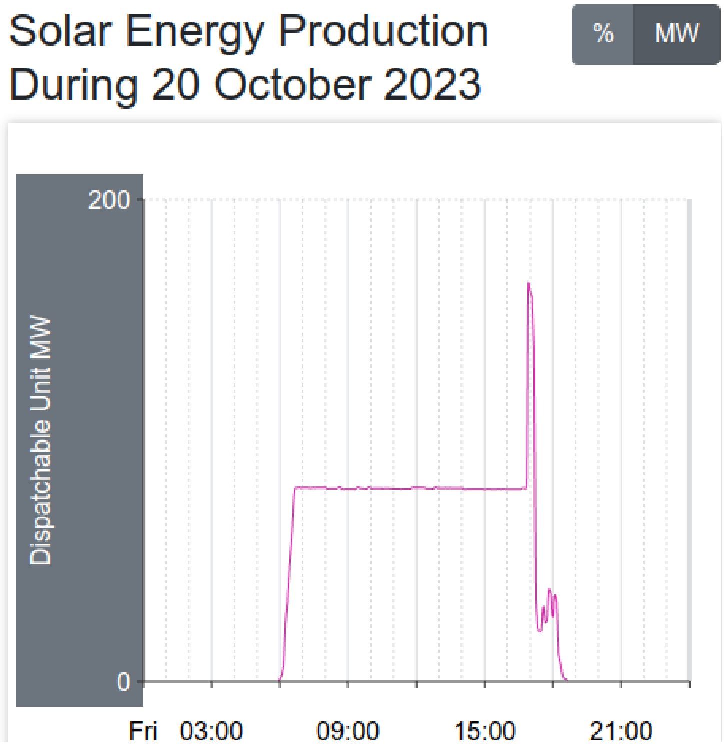


Figure 4 – Output of the Sunraysia Solar Farm on 20 October 2023.