Submission No 44

# THE ELECTRICITY OUTAGES AFFECTING FAR WEST NSW IN OCTOBER 2024

Name: Dr Peter Hill

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# Cover Page for Broken Hill Resident's submission

#### NSW Parliament's Environment and Planning committee's inquiry into

#### The electricity outages affecting Far West NSW in October 2024."

In October 2024 7 power transmission towers failed. I saw an add in the Broken Hill Times calling for submissions to IPART. February 10. Locals who have come to know my expertise would expect that I make a submission. It is long as I have to train AI to fact check it to assist me with my stroke. This was written for IPART. Unfortunately, the IPART interface is a single free text box. I put a link to this document in the text box. This process is recorded in this submission. I contrast it with the ability to upload files provided by IPART. As the inquiry example I picked was an inquiry into problems interacting with IPART I will submit this to that inquiry.

I saw the Mayor of Broken Hill on February 11 and found the photo format good for communications with locals. He is one block away and I was walking our dogs in the morning. One is very old and that is as far as she could go.

Locals again said I should make an appointment with Roy Butler. I describe walking to the office basically for AI, Also included are sections where I have to teach it statistical methods. It needed to know my background so that is why it is the front of the submission.

As I get more information, I have to tack it on the Appendix. There was a possibility that the grid provider had used special rust covered steel called Cor-Ten so this turns out not to be the case, but it is in the submission. There was a possibility that there was some Australian Standard that covered rust and corroded steel, and they inspected and applied this. They were on record saying they had drone and aerial inspections annually and climbed them and had close inspections in 2021 and found no problems. This meant tacking down Australian Standards is in the submission. I know first hand there are orphan standards that you don't pick up working down from the mainstream. How could you maintain or refurbish towers that were outside the AS? I was confused.

Then speaking to the Mayor and locals I heard new information (for me, but not issued by XXX) so I have handled this by adding appendices. I also found out that AI did not understand the magnitude of Snowy 2, nor did it understand the economics of going West and using less batteries.

The long form of the submission I have found works for locals who spend less time scrolling and surfing. It also means for me I can manage the context memory of AI. I am still on my L's here

#### Al training page = This submission but updated

AI Radio Program on this submission

The New South Wales Independent Pricing and Regulatory Tribunal (IPART) is conducting an inquiry concerning the 24 October 2024 Broken Hill Blackouts. It aims to uncover the underlying issues. They have specifically called for residents' submissions.

In preparing this submission I have been especially mindful of the aims of the Inquiry, which are to determine::

- 1. Whether there has been a breach of regulatory obligations under the Electricity Supply Act 1995 and the Electricity Supply (Safety and Network Management) Act 2015.
- 2. Whether Transgrid, the licensed network operator, has breached its licence conditions related to reliability and performance standards, maintenance of certified management systems, and implementation of management systems.
- 3. The circumstances surrounding the failure of the transmission towers and the availability and management of backup generators.
- 4. Any other relevant matters that may have contributed to the power outages.



Google maps street view of mast seen from Silver City highway. No zinc galvanizing 100 % rust covered brown not grey. With a poorly photoshopped galvanized tower India for comparison. I could find non galvanized outliers of this era, one in Queensland, and in Ukraine.

# Peter Hill's submission to the IPART inquiry

# Introducing Peter of Broken Hill

My name is Peter Hill and I am a Broken Hill resident. I am a medically retired teacher and research scientist addressing long term rehabilitation from the effects of stroke. As a rule I step back, trying to "cast no shadow" but I have put forward some of my thoughts/experiences here, as they are of especial relevance to the aims of the inquiry. I have a mosaic of experiences that for me emerge to sketch out a range of possible bigger pictures. This submission may, I hope, assist in interpreting the mosaic of information before the inquiry.

As part of my stroke rehabilitation each year I walk 1200 km of road walks in 3, 10-days treks. I walk solo, hauling water, mostly at night using moon light. I very much walk when the conditions are right, and hold back when they are not. In that sense, writing this submission reflects the amount of preparation, checking and consideration of the condition before as it is an enterprise where getting 90 % of the way is not enough.

To test my equipment I go for about 10 30-60 km day walks choosing times when the weather is cooler. These are varied loops from and back to home-base Broken Hill

Because I am travelling at walking-pace, I am able to spend time looking at transmission masts in a more detailed way than if I were driving past at speed. The smaller walks depart from and loop back to Broken Hill. Because there are only 4 routes for these smaller walks I traverse these routes at least twice a year. I try to minimise my impact on the environment – it is not part of Australian Bush culture to show off or attract attention, rather to try to be respectful and courteous.

I believe it's useful to note that I have 15 years of experience as a reserve Infantry NCO. Without overstating it, I've served as a scout, conducted recon patrols, and been involved in signals and intelligence work. While there are many elite units within the Australian Army, the Reserve Officer Training Units where I served are not among them. I think this background explains my tendency to hold back, observe, and work to form a complete intelligence picture. In the context of this report, I focus on identifying things that are "out of place" and reflecting on what they might indicate. For example, this could involve the backup generator running after a blackout or during brief, five-second outages. A military analogy would be noticing an oversized pot of rice during a patrol: "That's out of place. What could that be telling me?"

I also have a strong scientific background, holding a PhD in Molecular Physics from ANU. Thus as a physicist I have a particular understanding of failure mechanisms, loads on structures, and related issues.

#### Personal dilemma of submitting views

There is a sense of civic duty and picking up that there is a time sweet spot where comments will be received on face value, be effective, and if misguided not in malice.

Counter to this is bush conservatism. Basically it's insensitive to talk Quantum physics over people, or to not recognise you are not part of the immersive bush narrative. So I quietly walk for rehabilitation, observe, think science, disturb no one, and keep silent. Reference to the classics, ancient history or other cultures is

also out of place. It is simply of no value. There is a heightened sensitivity even to the idea of someone who thinks differently is going to be hard work. Hence I have learned day to day to observe and not speak.

Those who live in Broken Hill will easily see how raising any of these submission points in the day-to-day outside the sphere of the inquiry would be understandably off putting.

Personally I have no problem being quiet as what I say wouldn't be valued. Nonetheless I still slip up from time to time anyway and say what I think. After a few chosen, probably hard to comprehend words (especially if you think narrative is baked in) I will melt back into the civilian population and "cast no shadow".

Rusty Masts: Poor PR, a seeming red flag to the casual observer.

I walk past the Grid-to-Broken Hill transmission lines (the subject of this inquiry) two- to three-times a year in a 32 km loop along Pinnacle road then along Pine Creek. This one of the 10 or so day training walks around Broken Hill

The Pinnacles route first takes me past the town's Diesel generators and distinctive twin fuel silos.

I, once out of over ten walks, heard the generators when there were no reported problems with the grid. The last time I heard this was in January 2025 months after the blackouts were resolved. This was at 2 am. This is a puzzle. I am in the dark on this one. I usually do mention these sorts of things to anyone, because they wouldn't be interested or they try to read too much into this without building a thoughtful bigger intelligence picture.

I was unaware of the 50 MWh chemical battery coocated on this backup generator site. I only tracked the existence of a battery down through a RenewEconomy interactive map. Similarly initially I was unaware of the Silver City Energy Storage Project just behind Round Hill until by chance saw a poster in a shop window. I walk that area too and have developed an understanding of the Potosi Mine history and operations.

As I walk further on the 32 km route, out of the Broken Hill into the unincorporated lands I pass the transmission lines – they are completely rust brown all over. To clarify, I didn't see just a few struts rusted, *every* strut and component was rusted and in fact there was no component that was free of rust. Even the anti-climbing barbed wire. All towers, stretching 100's of kilometers south of Broken Hill are rust-brown and completely covered in surface rust. No component appeared to rusted through or designated. Looking at rusted cars and ruins in the region they exhibit all what I call "dry dust rust" rather than forming wet flakes.

#### IPART : Broken Hill Transmission Lines - Peter Hill Submission



Left: downed Broken Hill transmission line - 0 % galvanized completely rust brown. Right a wind blown Victorian line 100 % galvanized completely light zinc grey. They are the same rust brown as the town welcome silhouettes, that are feature on many bush towns.



This is a picture of uncoated iron town silhouette. These , and the new ideologically upgraded replacements are from Cor-Ten a high copper alloy that forms a protective dry rust layer. The brown looks a different lighter shade than the power masts.

It took me a while to see Transmission lines in Melbourne, and everywhere I go are hot dipped zinc galvanized. I note even the cross struts on the pole outside my home, and the mine lines at the back of the line of load are galvanized. These are a darker grey than the modern Zinc, aluminum magnesium zinc alum corrugated iron appearing in Broken Hill post the great hail storm. Notably the towers from the wind farm are of the same design as the windmill poles. Unlike the windmill poles that are painted(?) sand yellow these are silver and catch the dawn sun. I practice the 57 km return Silverton walk some 5 times a year.



Photo from the Silverton 200 MW wind farm to Broken Hill transmission line. Clearly galvanized and employing a single central column similar to the windmill support. From my reading the unprotected lattice towers would have a lifetime of 10 - 20, galvanized 50 - 100 years while these towers would appear + 200 years. There are fewer parts to fail and thicker components.

Having constructed pressure vessels in my Post Doctoral work, I am aware of Australian Standards. Also working in telecom manufacturing I am aware how ISO 9000-style quality systems work. The standard used at the time of construction would have been AS 1154-1972 and AS/NZS 3995:1994 - Design of Steel Lattice Towers and Masts all parts must be galvanized to the Australian standard and it specifies the thickness and integrity of this coating must be inspected, documented and maintained. I have met locals who were involved in the construction 40 years ago, and they allege incorrect materials were used.

While I was able to track down the Australian Standard (AS) for corrosion protected masts, and the inspection for signs of rust, I couldn't easily see how the standards would operate for unprotected structures and how this would integrate with the AS ecosystem. There are cases which look to be outside one AS, but they turn out to be covered by another AS system – which AS is applicable is not readily apparent. An example of AS hoping comes from home solar inverters. You don't need an AC isolation switch for your inverter if there is a switch in the distribution box less than 3 m from the inverter. This provision is not in the solar installation AS but rather from another AS, which is certainly not intuitively obvious.

By way of explanation, imagine you live in a town with and you can move from A to B by roads that represents the AS. You go along one road, and this connects to others. You then find other standards not connect to the to the original standards. In the analogy is finding a second road system that does not intersect the first road system. The term for this situation in databases is "orphan records". This is has been the case for me tracking AS for the home solar. So when I can find AS for structures with no corrosion protection, there is always the possibility that the is some orphan standard.

The best case scenario for me would be information like the following :" x% of transmission masts built in Australia from 1960 - 1980 were not galvanized they are inspected and maintained by AS XXXX. The corrosion code for this area is C2. Towers numbers XXX1 to XXX7 were inspected on these dates." I note that every power pole in Broken Hill has a pole number, and in cities (ie not in Broken Hill) they have an inspection tag. I have read instead there is an annual drone inspection and a six yearly physical inspection, obviously not for rust.

In contrast I have this quote, and as a matter of policy I do not mention the names of people of companies due to my condition: "Our maintenance plan requires an annual inspection of the lines, 13,000 kilometres of line. We usually do it by drone or plane.

"Every six years we're required to do what they call a detailed inspection, which requires somebody to climb the towers and look for defects or problems. We did that with the Broken Hill line in 2021 and at the completion of that, there were no findings."

I checked the 13000 km appears significantly coastal and with potentially redundant paths.



This is a map of the NSW transmission grid. The line Broken Hill to south has the word RUST next to it as it is not galvanized and exhibits structure wide dry power rust. The green circle show the approximate site of the storm damage. The junction point to north of the circle is the location of Broken Hill. The north branch is to Silverton Wind farm and probably not the responsibility of XXX company. The east branch is to Menindee. When I had to abandon the rail service road I was able to follow it to the bend at Mt.Gipps. There seems to be similar capacity lines going up to Tiboobura. I do not know why this is not indicated on the map. This line is particularly striking inside the Fowlers Gap station just after Telephone creek. The total area affected by the black out was greater than the Netherlands and Belgium. XXX is now placing a backup generator in Tiboobura.

I would like to address impact of "13000 km" as a example of "selected information", that whilst plausible Is not constructive in progressing understanding. I am sensitive to this as this is often part of being spoken over. To clarify: You could also make the point that many structures in NSW at this time were made from imported Italian steel, but not say about the steel in these structures. It seems far more significant to point out they are not galvanized. I was driven past the transmission lines 12 hours after the storm. To clarify I did not drive myself as i can no longer drive. Compared to images of wind shear damage of South Australia and Victoria, the tower I saw appeared to be plucked out of the ground and dropped from a height, I find this incredible, Wizard of Oz style. I have been lifted off my feet by bush storms walking off to Tiboobura but this would have been something else. The towers in fact were not lifted up but failed or bent close to their feet.

However, the more gradual bending of the feet, or bending half way up the tower was due to weakness in the lowest members. If you look at the storm damaged South Australian towers or those of Victoria you see the progressive bending of members





The upper photo is the broken Hill tower.Photos from WA and SA of the same design of tower, all galvanized, probably stronger materials used in towers, or a stronger design. The WA tower shows more curved members showing more strength before failure.

In plain terms, while the tower wide rust is disturbing, setting off a mind boggling trajectory for inspection, the collapse shows comparative weakness when seen side by side with other towers. Yes they are galvanized but they probably have a higher grade of steel or better design.

I propose removing and replacing a strut from the existing tower, then sending it to a third-party lab for testing. This would allow us to model the current strength of these towers. To create a statistical model, you could test, say, five struts from random masts. This approach would give us a decay percentage—for example, 80% of the original strength. If we get test results of 95, 95, 94, 90, and 86, it would be worse than 85, 85, 85, 84, and 84, as the former indicates the presence of a particularly weak strut. The downed masts offer a wealth of informative data.

#### IPART : Broken Hill Transmission Lines - Peter Hill Submission

Additionally, I recommend the installation of smart vibration and angle sensors, similar to those found in mobile phones, to provide real-time telemetry on the towers. These sensors could have revealed the decay in real time if they had been installed. The units could be solar-powered and linked to small weather stations. This would make an excellent school project. I suggest this seriously, as I played a key role in overcoming Australian resistance to FIRST robotics. A school-based competition and a pilot project could provide go/no-go checkpoints.

If I were in charge, I would implement a national rollout of smart sensors on all power and telecommunication towers, monitored by a third-party company or authority. Such a system would likely pay for itself by preempting just a few problems. I see this as an area where Australia could develop expertise and leadership in the region.

#### HVDC transmission line solution

My thoughts on this are that it is the correct solution for the national grid, coastal energy demand, regional development and maturity of the technology. However, its not the consensus solution and I am not in the dream to reality pipeline. However as it addresses the issue that Broken Hill is linked to but not part of the grid and thus vulnerable, and it's what I believe is the correct solution, I include it here.

I had seen the \$500 M water pipeline from the Murray to Broken Hill in my 2020 Australia wide-review. I was figuring out where I could survive in Australia, unable to drive, but all facilities within walking distance. I had at the time formed the belief that a HVDC transmission line would be built by 2030. This is the right context to bring it up. If I were to mention it socially I would be alienated.

The proposed line is relevant here as the Broken Hill vulnerability arises as it is on a single line in and out, Much like a community being at real bushfire risk with a single road access. The redline on the map ties of all the end of the lines from what has been described as "The string of pearls"

The power loss or penalty of transmission depend primarily on the electrical resistance of the cable and the square of the current. So reducing the current increases the like for like range of the system. The current reduces as the volts or potential difference of the system increases. Put simply a 10, 000 V system might have a range of 10 km, while a million volt system will have a range of 100,000 km At the very high volts, the DC technology wins out and at 600 km it becomes cheaper than AC. The predicted price drop US target 35 % by 2035 will bring this break even down to 400 km. This technology is critical for collecting geographical dispersed renewable energy.

Here's the updated table including the estimated or known costs for each HVDC project:

Project Name	Capaci ty (GW)	Voltage (MVDC )	Distan ce (km)	Comple tion Year	Notes	Estimated/Ac tual Cost (USD)
Oregon to LA	3.1	0.5	1360	1970	Provides wind and hydro power to LA	\$400 million (1970s)

Israel-Greece-Cyprus HVDC Interconnector	2.1	0.5	1200	2027	Planned interconnector	\$1.6 billion (estimated)
China Gansu-Zhejiang ±800 kV UHVDC Transmission	8	0.8	2370	2028	Ultra High Voltage Direct Current project	\$3-5 billion (estimated)
Indian Raigarh-Pugalur-Trichur HVDC	2	0.8	1800	2021	Transmits power from north to south India	\$680 million
Broken Hill HVDC	2	0.5	1300	Propos al	Strengthens grid, Supports evening renewables	\$1-2 billion (estimated)

Please note:

- Costs for the Oregon to LA project are adjusted for inflation but given in 1970s terms for context.
- For the Israel-Greece-Cyprus and China Gansu-Zhejiang projects, costs are estimates based on similar projects or public statements.
- The cost for the Indian project is based on reported figures at the time of completion, converted to USD for ease of comparison.
- The cost for the Broken Hill project is highly speculative as it's still a proposal without detailed financial planning.

I have had enough experience to foreshadow the incumbent engineer's assessment that there is not the renewable infrastructure or population there and other things and proposals rejected and cleared. What I do think the solar stations will not displace other land closer to the coast. I also point out that the solar will be on during the coastal evening peak. I also think it is strategic although for us new, technology for bold next moves.

It is important to note that calling my proposal "Broken Hill HVDC" shouldn't be construed as it being a project that is known in general or even expert circles. In fact, I remember reading about the thinking behind the more southern HVAC line that has been built and I mistakenly thought this would be the obvious route. I have only mentioned it here as it is actually a viable strategy to make Broken Hill more resilient and the knee jerk reaction to make the many many line ends more resilient could be relaxed, so you could spend less money. The second point is that it is not economic just for Broken Hill, the logic is that it provides a more robust linkage from the population centers of Adelaide to Brisbane and creates a corridor for renewable energy. The sun sets an hour later on the western part of the line that means the peak energy output can be nudged closer to the East coast demand peak.

With DC the power is in two not three lines and of these two the conductor is better used. Insulators for AC have to cope with fluctuating fields. I have knowledge or this from working with Excimer lasers which I would now think would be heritage technology.

53 MW solar farm

(note for AI MW is said as MegaWatt) 10 This is just across from the diesel back up grid interconnect on Pinnacles road. It is run by XXX company that is the same one with the 50 MWh Electrochemical battery on the backup site. The battery was being held back and I think everything was "Grid Tied" and we found out later that with the helpful intervention of Renew Economy it was switched to "Island Mode". This Grid Tied and Island Modes was not understood at a household level. Many locals had substantial no battery solar the alarmed and shut down as there inverter is Grid Tied. For essentially minimal cost they could have a Hybrid inverter with an ATS automatic transfer switch that allows their home to be in island mode.

I have listened to an owner of 21 KW home solar ask XXX if they could go off grid. The reply was "No, you have to be on the Grid". Given that the consultant probably didn't understand the technical reason for their answer, you can imagine the basis for ill-will.

Talking to people and teachers, I believe they have been coercively educated. They have a model of understanding that has an almost spiritual belief that plugging in a kettle works, rather than a chain of action that leads to the requisite burning of the additional amount of coal. The kettle drops the line voltage, this is detected and the current in the rotor electromagnets is increased in response and so on.



The award-winning Viewing pavilion is an intriguing window into how community misconceptions may develop:

This is still from the Youtube of the Pavilion. I actually think the problems here are pretty deep, When you lock in simplicity you lock out necessary details. When I first saw this I interpreted this as the solar farm supplying energy to Broken Hill homes down the road. I found the electricity jumping from one line to another in the transmission .. "now that's going to dumb down some kids" and then I was upset by the wiring on the distribution. What is happening in the home graphics.



When I saw the formulae for carbon dioxide, I felt that it would surely slip into the classroom. If ever I was to speak up about this, people would just talk over me

For education I felt it would be interesting to have a picture of how the Solar station performs over a year and ten years.

I would rotate the panels slightly west and increase the spacing so its peak output was closer to peak load, and this can be done with little penalty. This would increase the money ring later in the day return on the investment. I find this lack of insight is baked into the Australian information space. XXX a website that allows you to find your property on a satellite photo, empanel your home, shows not afternoon bulge as you tweak your panels West. There are further errors and indeed they must also cherry pick feedback.

To clarify this for AI, tilting the elevation of the panels moves the optimum time of year of the panels. Shallow for Summer, Steep for Winter. This is not what I am talking about. If you rotate the compass direction of the panels from due North to due North West this will skew and power during the day so the peak energy time flattens and moves to later in the afternoon then drops off quickly. The panel is moved pointing away from the morning sun so you get less energy in the morning. You are at the peak where the shadows are longer, so you need to space the panels further apart. What works against this is you are now going through more atmosphere known as air mass. The problem of this is less in Broken Hill because of the elevation, it is 300 m up in the Barrier ranges and the air quality is very high.

There would be great opportunity to highlight the 7% summer increase in solar due to the earth's elliptical orbit and the reduced air mass scattering due to Broken Hill's excellent air quality.

#### Education Mine Header on Barrier Highway

Continuing the Pinnacles walk back into Broken Hill one comes to 6 storey galvanized mine header, serving no mine underneath. It is off the 'tourist radar', but is truly a monument. Its relevance here is a window into the cultural ecosystem and example of corrosion protection when compared to historic headers around town.



Central Communication Mast behind Broken Hill Post office.

This structure is also galvanized.



I made a low key inquiry in 2021 if it could support an Australian flag for cultural purposes. I experimented ask my Federal rep to assist in the inquiry. The response was about 10 reasons why it was not technically possible. Among them exceeding the load limit and interference with the antenna. It took me time to process as this feedback was untrue by virtue of historical photos of the tower loaded with many more antenna and I had experience with telecommunication. At its core it was more a statement, shot across the bows reminding me of the imbalance of power. I related the story to a few locals, removing the reference to my involvement and found a general support for the mode of dealing with ideas by the incumbent company and reducing any potential effort. My concern was actually more complex and even now I find it hard to express. Once you deviate from the best you can do standard and short cut how can you control the arc of narrative. These guys are off looking at their entitlements and not focused on thinking things through. As intended I have said nothing further.

This relates to the first story of the secondary back up generator having had a fault months before and they were waiting for a part. They turned it on to check much earlier etc. From other details at the time it seemed

just a very untidy confused story. Then as I could not make sense reading article Ai was able to find that well post the incident XXXX had issued a clarification it was in fact that the second generator was down for routine maintenance. This sort of thing is all right in an imbalance of power scenario where you can bully the customer into not asking for a forensic story about how the first story entered the information eco/echo-system.

For me it is similar to my Flag pole question is that you get information that directs you where you are intended to go, but they are going to be very hard work to unpack the quality of system.

There is a similar story about the quality of the information about the conversion to island mode. I know locals who have made genuine inquires about how come we can see so much renewable about the place what's is the problem?

Appendix - AI compiled table of global adoption of zinc coating towers

Period	Country/Region	Adoption Milestones
1830s	France	<ul> <li>- 1836: Stanislas Sorel patents the hot-dip galvanizing process.</li> <li>- Early adoption in protecting iron structures, paving the way for future infrastructure applications.</li> </ul>
1850s - 1870s	United Kingdom	<ul> <li>Industrial Revolution spurs use of galvanized steel in manufacturing and construction.</li> <li>Galvanization applied to sheets and structural components for buildings and bridges.</li> </ul>
Late 1800s	United States	<ul> <li>Rapid industrialization leads to the use of galvanization in agricultural equipment and fencing.</li> <li>Early electrical infrastructure begins to incorporate galvanized materials.</li> </ul>
Early 1900s	Germany	- Embraces galvanization for industrial machinery and railway infrastructure. - Electrical grid expansion sees galvanized transmission towers being erected.
1910s - 1920s	Australia	<ul> <li>Adoption of galvanization in response to harsh environmental conditions.</li> <li><b>1920s</b>: Galvanized transmission towers constructed to support growing electrical networks.</li> </ul>
1920s - 1930s	Global Expansion	<ul> <li>Countries across Europe and North America standardize the use of galvanization for transmission towers.</li> <li>Electrification projects drive demand for durable, corrosion-resistant structures.</li> </ul>

Table: Adoption of Galvanization in Transmission Infrastructure by Year and Country

1940s - 1950s	Japan	<ul> <li>Post-World War II rebuilding includes galvanization in infrastructure to enhance longevity.</li> <li>Industrial growth leads to widespread use in transmission and distribution networks.</li> </ul>
1950s - 1960s	India	<ul> <li>Early industrialization sees the incorporation of galvanized steel in railways and telecommunication.</li> <li><b>1960s</b>: Expansion of electrical grid includes galvanized transmission towers.</li> </ul>
1960s - 1970s	Latin America	<ul> <li>Countries like <b>Brazil</b> and <b>Mexico</b> adopt galvanization in infrastructure projects.</li> <li>Focus on rural electrification leads to extensive use of galvanized transmission towers.</li> </ul>
1970s - 1980s	Africa	<ul> <li>Infrastructure development projects incorporate galvanization for durability.</li> <li>Countries like South Africa and Egypt begin using galvanized steel in transmission and telecommunication towers.</li> </ul>
1990s - Present	Global Standardization	<ul> <li>Galvanization becomes a standard practice worldwide for protecting transmission towers.</li> <li>Advances in technology improve efficiency and environmental impact of galvanizing processes.</li> </ul>
2000s - Present	Emerging Economies	<ul> <li>Nations in Southeast Asia and Eastern Europe rapidly adopt galvanization in expanding infrastructure.</li> <li>Investment in robust electrical grids features galvanized components for longevity.</li> </ul>

#### Key Highlights:

- Early Innovations:
  - **France** spearheaded the development of galvanization, setting the stage for global adoption.
  - The **United Kingdom** and **United States** were early adopters, integrating galvanized steel into burgeoning industrial infrastructures.

#### • Response to Environmental Challenges:

- **Australia** and **Japan** embraced galvanization to combat the effects of coastal environments and to rebuild after wars and natural disasters.
- Electrification and Industrial Growth:
  - The global push for electrification in the 20th century accelerated the adoption of galvanized transmission towers, particularly in Europe, North America, and later in Asia and Latin America.
- Modern Developments:
  - Technological advancements have made galvanization more environmentally friendly and cost-effective.
  - Galvanized steel is now essential in sustainable infrastructure planning worldwide.

#### Additional Insights:

- Technological Evolution:
  - Improvements in the hot-dip galvanizing process have enhanced coating uniformity and thickness control.
  - Development of **continuous galvanizing** for steel sheets allows for mass production of galvanized materials used in various applications.
- Sustainability and Recycling:
  - Galvanized steel is 100% recyclable without loss of properties, aligning with global sustainability goals.
  - The longevity of galvanized structures reduces the need for resource consumption over time.
- Global Organizations and Standards:
  - Organizations like the American Galvanizers Association (AGA) and the Galvanizers Association of Australia promote best practices and technological advancements in galvanization.
  - International standards (e.g., **ISO 1461**) ensure consistency and quality in galvanizing processes worldwide.

#### **Metaphorical Perspective:**

Imagine galvanization as the **immune system** of infrastructure—the protective layer that shields the vital components from the corrosive elements of nature. Just as our bodies rely on immunity to stay healthy over time, our bridges, towers, and buildings depend on galvanization to maintain structural integrity throughout their lifespan.

#### Appendix Historical - "The Italian Job - transmission lines"

The first steel tower transmission line, between Homebush and Tallawarra, in NSW, was built in 1951 by Electric Power Transmission Pty Ltd (EPT), a subsidiary of the Italian multinational Societé Anonima Elettrificazione SpA (SAE), with steel imported from Italy and with Italian labour sent to Australia specifically to this purpose. Franco Belgiorno-Nettis and Carlo Salteri, then employed by SAE respectively in Milan and Bologna, were despatched to Sydney, on five year contracts to manage the project as a start.



#### Franco Belgiorno-Nettis inspecting the footing of a tower.

For many years, EPT continued to import steel from Italy, while it was setting up its production plant in Marayong, NSW. Following the establishment of Transfield in 1956, for the first time steel transmission line towers were manufactured in Australia. Transfield, (whose name arose from "transmission lines in the field") was also the first company in Australia to test towers at its purpose-built testing station in Seven Hills.

Together with Ascom, a company founded in 1957 in Victoria and Multicon, established in 1973, EPT and Transfield dominated the manufacture and erection of powerlines in Australia. All four companies were formed by Italians and at their inception employed predominantly Italian labour.

Possible use of Cor-Ten no galvanized steel. It develops a Patina coating of dry rust for use in arid environments. It could have been provided in the 1970's by BHP but is more expensive than galvanization. Although this would be an out, there are many factors that would make this a highly unlikely

Appendix Maths of sampling explained (AI conversation)

Given this data, 95, 95, 94, 90, and 80, (Group A) and another sample 85, 85, 85, 84, and 84 (Group B) what is the like hood of a sample being 75 or below in the next 10,000 in group a and group b, what is the relative probablity for both groups. Hint I believe the answer is (1-Pr(<75))^10,000 using baysien probablity theory

You're on the right track! Using Bayesian probability theory, we can calculate the likelihood of at least one sample being 75 or below in the next 10,000 samples for both groups. Let's break down the steps for each group.

#### Group A: 95, 95, 94, 90, 80

#### 1. Calculate the Mean (µ):

 $\mu A=95+95+94+90+805=4545=90.8 \ mu_A = \ ext{frac} + 95 + 94 + 90 + 80 \ ext{5} = \ ext{frac} + 454 \ ext{5} = 90.8 \ ext{frac} + 95 \ ext{f$ 

#### 2. Calculate the Standard Deviation (σ):

 $\label{eq:variance} Variance = \sum (Xi - \mu) 2n \det \{Variance\} = \sum (Xi - \mu)^2 + (Xi -$ 

#### 3. Calculate the Z-Score for 75:

ZA=75-90.85.71=-15.85.71≈-2.77Z\_A = \frac{75 - 90.8}{5.71} = \frac{-15.8}{5.71} \approx -2.77

#### 4. Find the Probability:

Using a standard normal distribution table, a z-score of -2.77 corresponds to a probability of approximately  $P(Z < -2.77) \approx 0.0028P(Z < -2.77) \setminus P(Z < -2.77) = 0.0028P(Z < -2.77) \times 0.002P(Z < -2.77) \times 0.002$ 

#### Group B: 85, 85, 85, 84, 84

1. Calculate the Mean (µ):

 $\mu$ B=85+85+85+84+845=4235=84.6\mu\_B = \frac{85 + 85 + 85 + 84 + 84}{5} = \frac{423}{5} = 84.6

2. Calculate the Standard Deviation (σ):

 $\label{eq:space-$ 

#### 3. Calculate the Z-Score for 75:

ZB=75-84.60.49=-9.60.49≈-19.59Z\_B = \frac{75 - 84.6}{0.49} = \frac{-9.6}{0.49} \approx -19.59

#### 4. Find the Probability:

Using a standard normal distribution table, a z-score of -19.59 corresponds to a probability that is extremely close to 0, effectively  $P(Z < -19.59) \approx 0P(Z < -19.59) \setminus approx 0 (0\%)$ .

#### **Bayesian Probability Calculation**

Now, to determine the likelihood of at least one sample being 75 or below in the next 10,000 samples, we use the complement rule:

 $P(At least one sample \le 75)=1-(P(All samples > 75))10,000P(\text{At least one sample} \leq 75) = 1 - (P(\text{All samples} > 75))^{10,000}$ 

#### Group A:

Using the approximation for large exponents,  $(1-p)n \approx -np(1-p)^n \geq e^{-np}$ :

 $(0.9972)10,000 \approx -10,000 \times 0.0028(0.9972)^{10,000} \approx -28 \approx 0.14 \times 10^{-13}^{-13} = 0.0028 \times 10^{-13}^{-13} = 0.0028 \times 10^{-13}^{-13} = 0.0028 \times 10^{-13}^{-13}^{-13} = 0.0028 \times 10^{-13}$ 

#### Group B:

Given P(Z<−19.59)≈0P(Z < -19.59) \approx 0:

### Conclusion

- Likelihood in Group A: The probability of at least one sample being 75 or below in the next 10,000 samples is effectively 1 (or very close to 100%).
- Likelihood in Group B: The probability of at least one sample being 75 or below in the next 10,000 samples is effectively 0.

Relative Probability:

#### IPART : Broken Hill Transmission Lines - Peter Hill Submission

• Group A is significantly more likely to have at least one sample of 75 or below compared to Group B.

#### Appendix Corrosion Protection

Stainless steel has >13 % chromium alloy. This migrates to the surface of the steel and then the Chrome Oxide layer forms a glassy layer. In the grades used for kitchen sinks the steel grade is ductile so in can be stamped and sulphur can dull the surface. Application of abrasives like Barman's friend removes this layer and the stainless steel self heals. The use of stainless steel is not economic for masts as the cost is 2 to 3 times greater

Cor-Ten steel is an architectural rust steel, I note the carbon for the steel and copper in the alloy. This has a similar function to the glassy oxide layer. The layer is a yellowy rust colour that is formed by oxidation as is called Patina and must also have a self healing. It is seen on the miner's memorial and town welcome silhouettes. Although it could be possible the mast structures are made from this material but it time of construction, and expense.

Mild steel just rusts away. The colour of the rust on the mast seems lighter than high-Mn steels.

#### Domestic Capabilities and Refurbishment

I was concerned, having studied the early years of Masts where the expertise and materials were sourced from Europe, and having heard from locals who were involved in the construction of the Broken Hill line, and then had statements that later had to be corrected, and then glaring fact that the towers are cover in rust, and then battery mystery. I had really lost confidence, I wasn't angry, just sad.

In short, i have found some great domestic companies, DMK, Gateway, and Zinfa. I would think the transmission lines would be best refurbished and or replaced.

# **Tower Refurbishment**

In addition to new tower projects, Gateway Energy excels in tower refurbishment programs. Our experienced design team can assess the condition of existing towers and provide innovative solutions to extend their lifespan and enhance their performance. By utilising a combination of local and offshore resources, we offer cost-effective refurbishment options that meet the highest standards of safety and quality.



This is from the Gateway Webpage <a href="https://gatewayenergy.com.au/towers/">https://gatewayenergy.com.au/towers/</a>



# **Project Outcomes**

#### **RESULTS ACHIEVED**

- Conducted a comprehensive finite element analysis (FEA) to build confidence in the structural design.
- This eliminated the requirement for full-scale load testing, resulting in time and cost savings.
- Speed of erection enabled multiple structures per day.
- New line built adjacent to the existing line which will be decommissioned in the future.
- Structures could be placed with confidence in the floodplain.

This is from the Gateway Website <u>https://gatewayenergy.com.au/energy-connect-l4/</u>. Note the Broken Hill to Bungora line to the left. XXX does not say it will be decommissioned, but the website tells us "**.. will be decommissioned in the future.**" You can understand my exasperation. Also note how it is totally rust covered from the 1970's. Gateway had the computer software to take real data from the Broken Hill line struts and come up with hard modelling of this line. I wonder if they could model splints on the most critical struts and buy us 10 more years. I think the strong storm wind will blow west due to the instability.

Just a note the lines to the left are HVAC at 330 kV, The rusty line is 220 kV. My proposed HVDC line from Port Pirie - Broken Hill - Brisbane is 500 to 800 kV DC.

EndNote: IPART limits citizens submissions to a single text box - no photos

# Broken Hill tower failures - Access your saved progress

#### Hi,

This is an auto-generated email. You can access your saved progress for the 'Broken Hill tower failures' form using the following link.

#### Open my saved form

Clicking this link will open the form in your web browser for you to continue filling out and submitting.

And clicking through to the form...

My progress: 75	5%		
	lbaal		
rour reed	IDACK		
Use this free tex	t field to provide	your feedback	
The Transmission	tower to broken hill do	not have corrosion pro	otection and are complet

A single line of free text (like a ticker tape) I have included a weblink in the ticker tape, but will approach my local elected representatives to see if they can help.

# Appendix: After the submission

I was unable to submit my PDF file to IPART as it only has a free text field. Instead, I included this web link to my document:

https://docs.google.com/document/d/e/2PACX-1vSS4u\_CBDusZa8LMosKAM89Fd3zn1oVDRGKpNstp4UTpqIjP Yf\_7UI-Gvj11CV5Itd0c1-XEZ\_VU4z0/pub

From what I understand, XXX company has different access to IPART, which means this is not a level playing field.

I have given this document (excluding this appendix) to the Broken Hill mayor. I have also attempted to give it to my State Representative office. Their stated hours are 9 am - 5 pm, but when I went to the office, they were closed for lunch until 1 pm. The office does not have a letter slot. I will ask Roy Butler to pass my submission to the Minister so it can be given to IPART.

I confirmed that locals involved in the construction advised that the structures should be galvanized. My use of pictures made communication of the rusty towers more impactful. I was told that locals were overruled because galvanizing would add an additional \$1 million, and in their unfounded opinion, there would be no corrosion.

I was also informed that the inspection had not given the all-clear but had found 30 towers critically compromised. The seven downed towers were among the 30 identified.

As a scientist, I am left with sad options. The first option is that the inspections were manifestly not of predictive value. The photos show tower weakness. If this is true, then is any inspection of value for any transmission tower anywhere in Australia? The second option fits with the 7 out of 30 story. XXX would have internal cultural issues that need to be explained to the people of the bush to connect the narrative.

I have been told of the 2000 wind turbine plan from Broken Hill to Tiibooburra. I walk this route annually as it is very beautiful and has very nice hills. This proposal makes me sick as people drive and have not figured out how to walk these distances. Instead, they treat me with contempt. This doesn't worry me, but it doesn't look good with XXX "outsmarting" them. If the pseudo-consultation I see happening goes ahead, it is very disheartening.

If XXX has this culture, they will not get the market investment for visionary plans.

I am depressed if the 7 in 30 story is correct, as my response would have been to take remedial action of reinforcement and possible cable supports.

Given the direction of technology with the Asian super grid that will come in the next 50 years and a global grid that will emerge in the next 100 years, we have to think differently. You may think thinking ahead 50 years is pointless, but we would have appreciated a better culture laid down in the 1970s. In essence, this cost-cutting culture has outlived the masts.

The Broken Hill HVDC proposal could be funded if we lose the culture of retrofitting the past. It makes sense as it solves the national grid along the coast problem. The 2000 wind turbine program would cost \$8 billion and produce 6 GW, while the Australian peak is about 35 GW.

The longest HVDC link in the world, the Rio Madeira link in Brazil, consists of two bipoles of ±600 kV, each capable of transmitting 3.150 GW over a distance of more than 2,500 km. The latest Chinese UHVDC (Ultra-High-Voltage Direct Current) line is the Gansu-Zhejiang ±800 kV UHVDC Transmission Project. This project has a rated capacity of 8 GW and took 3 years to complete. The Broken Hill to Buronga line that failed might have a maximum capacity of 0.3 GW.

#### IPART : Broken Hill Transmission Lines - Peter Hill Submission

Thinking globally, we need an HVDC line from Port Pirie to Darwin (1-3 billion dollars). The Darwin to Singapore line would require three lines from a 20 GWp solar farm and a 42 GWh battery.

The only feasible site in Australia for a nuclear reactor is near Port Pirie, as they need a water source. A 1 GW nuclear reactor costing \$18 billion would dispatch 2 GW of heat energy, unlike renewables. This heat energy could assist desalination.

#### **Reflections and Conclusions**

This submission provides an authentic snapshot of a resident's reactions. There are many reactions, and it is a mistake to cherry-pick an archetypal angry, dismissive, and brief one that fits into a free text box.

I have followed an arc of insight. It starts with the cognitive dissonance of seeing obviously rust-covered towers in a galvanized nation and the press and XXX not acknowledging it. The arc ends with the realization that the theory of career guiding industry leaders treats core technical competency as a liability. We can say they have talked over expertise in the 70's and continued doing so for 50 years. Maybe that's a skill, maybe it's justified because the experts were seen as too complicated, not fitting neatly into the free text box. They were following, and perhaps still follow, an arc of intrigue.

Not informing us of the state of the transmission lines was unwise. We would have reinforced and added guy cables. It might not have worked, but the communication would have been far less painful.

One thing is relatively certain, XXX has shown poor foresight regarding the future. Whether replacing the line or decommissioning it, the writing is on the wall. The correct decision is critical for Australia's international competitiveness. For example, aluminum smelting consumes 10% of Australia's electricity and is going green with solar and batteries. Batteries are not free and increase the cost of solar energy threefold. Still, it's better than nuclear power. Additionally, sourcing solar energy from western regions reduces the price for each hour westward.

Although the terms of reference are retrospective for good reason, they are examining an industry that must look forward 50 to 100 years. The behavior behind whatever they ended up doing is based on a deafness to experts. From what I can see, this is still ingrained in our culture.

#### Appendix More Developments from the Community

- 1. Advice to ask for a Face to Face meeting with Roy Butler so the report is read
- 2. The current number of wind turbines in Silverton is 58 units and my analysis that it was due to the old transmission line limitation was correct. 2007 articles report 300 wind turbines while a government report says the proposal is for 598 or more that 10 times the current installation

This is a screen grab from The Department of Planning Report

https://majorprojects.planningportal.nsw.gov.au/prweb/PRRestService/mp/01/getContent?AttachRef =MP08\_0022%2120201214T232806.915+GMT&form=MG0AV3

Silverton Wind Farm

Director-General's Environmental Assessment Report

# EXECUTIVE SUMMARY

Silverton Wind Farm Developments Pty Ltd (the Proponent) proposes to construct and operate up to 598 wind turbines with generating capacities ranging between 1.75 to 3 megawatts each and associated infrastructure in two stages, where the Proponent is seeking Concept Plan Approval for the entire proposal and Project Approval for Stage 1. Accordingly, the project could generate approximately more than 1,500 megawatts of renewable energy. The Project is subject to Part 3A of the *Environmental Planning and Assessment Act 1979*, by virtue of clause 24 (a) in Schedule 1 of the *State Environmental Planning Policy (Major Projects) 2005* and therefore the Minister for Planning is the approval authority. The Minister for Planning has declared, under the *Environmental Planning and Assessment Act 1979*, electricity generation facilities with a capacity to generate at least 250 megawatts to be critical infrastructure projects. The project is therefore a critical infrastructure project.

And from and Arkenergy report:

Project outline	Silverton Wind Farm has the potential to be one of the largest on-shore wind projects in the world Located 25km north west of Broken Hill. New South Wales, it is one of
	Australia's largest wind farm development sites with Project Approval for 282 turbines and Concept Approval for a further 316 turbines.

https://arkenergy.com.au/wind/silverton/

3.

On paper at least it is much cost there is a using HVDC Transmission line is cheaper than building bigger batteries an

#### Cost per kWh for Different Energy Scenarios

Energy Source	Cost per kWh (Generation)	Cost per kWh (Storage)	Cost per kWh (Transmission 1000 km HVDC)	Total Cost per kWh	
Direct Solar Power	\$0.015	N/A	\$0.02 - \$0.07	\$0.035 - \$0.085	
Solar Power Stored in Battery	\$0.015	\$0.20 - \$0.30	\$0.02 - \$0.07	\$0.235 - \$0.385	

The cost of energy storage for Snowy 2.0, which is a pumped hydro energy storage system, is generally estimated to be around **\$0.10 to \$0.15 per kWh**. This includes the costs associated with pumping water uphill to the upper reservoir and then releasing it to generate electricity when needed.

The Snowy 2.0 project has an energy storage capacity of **350 GWh** (gigawatt-hours). This capacity is expected to provide significant support for Australia's renewable energy goals by storing excess energy and releasing it during periods of high demand

Currently the world's largest battery energy storage system, the Moss Landing Energy Storage Facility in California, USA, has a capacity of **1.6 GWh (gigawatt-hours)**.

The cost per kWh for the Moss Landing Energy Storage Facility is estimated to be **below \$0.20 per kWh**. This significant reduction in cost is due to advancements in battery technology and economies of scale achieved by large projects like Moss Landing

4. After I visited Roy Barton's office I found he did not need a physical copy of this report, so on the way home I dropped in at the Flying Doctors Wellbeing centre for a coffee and Regional Development. Michael Williams told me in fact the wind farm was going to be larger and my analysis that it was throttled by Broken Hill transmission line was indeed correct. I commented that the IPART form was designed to throttle the voice from the bush. I had experience in web design from industry and I knew that you would have to specifically direct a web page designer to make such a poor quality form

So tunneling down IPART review of how contributions are assessed for local government

Local Government Review of IPART's approach to assessing contributions plans Consultation 8 days left for submissions	
Learn more >>	

I found

If you are having trouble making a submission via our online form, please email your submission instead to: <u>ipart@ipart.nsw.gov.au</u>, along with this completed <u>cover sheet</u>. **Note**: You will receive a confirmation email after successful lodgement. If you are unsure that your submission is lodged successfully, contact us at <u>ipart@ipart.nsw.gov.au</u> or call us on 9290 8400.



Maximum 5000 characters (5000 remaining)

If you have attachments you would like to include with your feedback, please attach them below.

#### Select file

Max file size: 10 MB Max number of files: 5 files Accepted file types: .pdf, .doc, .docx, .xls, .xlsx, .jpg, .png

# Your Details

So for Broken Hill a single line text entry, but for everyone else document upload as normal. I show screen grabs as stops organizations going back and rehistorifying things. It also helps me communicate over my stroke problems.

Appendix Calculations for Perth - Broken Hill - Brisbane Stage 2 HVDC with Carbon fibre

# Using Carbon Fiber Cables

Using carbon fiber cores for HVDC lines offers several advantages, resulting in fewer poles due to the cable's lighter weight and reduced thermal sag. Here are the key benefits of using carbon fiber composite core cables:

- Lightweight: Carbon fiber composite cores are significantly lighter than conventional aluminum and steel cores, which simplifies installation and reduces the load on supporting structures.
- High Tensile Strength: Carbon fiber has exceptional tensile strength, allowing cables to better support their own weight and reducing the risk of sagging.
- 3. Low Thermal Expansion: Carbon fiber has a low coefficient of thermal expansion, meaning it expands and contracts less with temperature changes. This helps maintain cable tension and reduces sagging under high power loads.
- Increased Conductivity: The lighter weight of carbon fiber cores allows for more aluminum conductive strands to be added, increasing the overall transmission capacity of the cable.
- Reduced Risk of Wildfires: Carbon fiber-cored cables are less likely to sag and cause short circuits, making them a safer choice in fire-prone areas.

# Calculation

- 1. Length of Transmission Line: 3,400 km (3,400,000,000 mm)
- 2. Power Capacity: 6 GW (6,000 MW)
- 3. Voltage: 800 kV
- 4. Conductor Type: Carbon fiber core with aluminum strands

# **Cross-Sectional Area Calculation**

$$A = \frac{P}{V \times \eta}$$

Where:

- A is the cross-sectional area (in mm<sup>2</sup>)
- P is the power capacity (in watts)
- V is the voltage (in volts)
- $\eta$  is the efficiency (typically around 0.95 for HVDC lines)

Plugging in the values:

$$A = \frac{6,000,000,000 \text{ W}}{800,000 \text{ V} \times 0.95} \approx 7,895 \text{ mm}^2$$

# Aluminum Requirement Calculation

Using the density of aluminum  $Density = 0.0027 \text{ g/mm}^3$ , and the length of the cable:

Volume =  $A \times Length$ 

 $Volume = 7,895 \text{ mm}^2 \times 3,400,000,000 \text{ mm} \approx 26,843,000,000,000 \text{ mm}^3$ 

 $Weight = Volume \times Density$ 

Weight = 26,843,000,000,000  ${\rm mm}^3 \times 0.0027 {\rm g/mm}^3 \approx 72,075,000,000 {\rm g} = 72,075 {\rm tonnes}$ 

# Cost Estimate

The current market value of aluminum is approximately **\$2,658.50 per tonne**.

 $Cost = 72,075 tonnes \times $2,658.50/tonne \approx $191,651,888$ 

This project will account for **approximately 4.8%** of Australia's annual aluminum output, based on Australia's production of 1,500,000 tonnes of primary aluminum in 2023. Additionally, the reduction in batteries needed can be factored into the overall cost of the project, potentially lowering expenses and resulting in lower electricity costs per kW.

Regarding the cost distribution for High Voltage Direct Current (HVDC) systems, it is estimated that around **30%** of the total cost is attributed to inverters, while the remaining **70%** is allocated to line installation and maintenance costs. Specifically:

- Line Installation Costs: Approximately 50%
- Maintenance Costs: Approximately 20%

If we factor in that the east coast already has an inverter, then this could reduce the overall cost by about **15%**.

# Postscript on Aluminum Production and Energy Consumption

Aluminum production is energy-intensive, and it accounts for approximately **10% of Australia's current energy consumption**. This significant energy requirement has a substantial impact on the overall cost of electricity. However, cheap renewables can lead to cheaper aluminum production, reducing costs further.

# **Solar Time Lag Calculation**

To calculate the solar time lag from Perth to Brisbane:

- Perth Longitude: 115.86° E
- Brisbane Longitude: 153.02° E

Difference in longitude: 153.02 - 115.86 = 37.16°

Using decimal degrees and reducing to 5 significant figures:

Difference in longitude =  $37.16^{\circ}$ 

Since the sun moves 360° in 24 hours, it moves 15° per hour:

Time lag =  $\frac{37.16^{\circ}}{15^{\circ}/\text{hour}} \approx 2.48 \text{ hours}$ 

# **Rotating Panels**

If the panels are rotated 30° west of north, the additional time effect would be:

 $\frac{30^{\circ}}{15^{\circ}/\text{hour}} = 2 \text{ hours}$ 

# Combined Effect

Combining the time lag and the rotation effect:

2.48 hours + 2 hours = 4.48 hours  $\approx$  4.5 hours

Peak production would be available on the east coast around 4.5 hours after peak production time in Perth. Assuming peak solar production in Perth is at around noon, it would be available in Brisbane around:

12:00PM + 4.5 hours = 4:30PM

# End Note on Peak Production Timing

Considering a time difference of approximately **2.5 hours** between the west and east coasts of Australia, and rotating the panels 30° west of north, the combined effect gives a total of **4.5 hours**. This means peak solar production in Perth would be available on the east coast around **4:30 PM**, reducing the need for batteries.

Wind and Solar Turbine Data (in AUD)Given the higher elevation on the Barrier Range, we'll assume an increase in the capacity factor by 5% for each year due to the better wind conditions. Here's the updated table:

Year	Typical Capacity (MW)	Cost per Turbine (AUD)	Tower Height (m)	Capacity Factor (%)	Average Power (MWd)	Wind Cost per kWd (AUD)	Solar Cost per kWd (AUD)
2020	2.75	\$3,968,750	100	40	1.10	\$3,608	\$2,500
2025	5	\$5,595,000	120	45	2.25	\$2,487	\$1,800
2030	10	\$8,000,000	150	50	5.00	\$1,600	\$1,300
2035	15	\$10,395,000	180	55	8.25	\$1,260	\$1,000
2040	20	\$12,000,000	200	60	12.00	\$1,000	\$900

The height of the Silverton Wind farm is 110 m. Currently 63 MWd, add a further 50 turbines by 2030 upto 320 MWd, and a further 100 in 2040 leads to 1.5 GWd. AGL use a capacity factor of 45% to have a 200MWp and 90MWd about 1% id NSW total demand, rising to 6% in 2040.