“The Liddell Trigger”

Issues Associated With Replacement Of Coal Fired Generation With Renewable Sources In The Australian National Electricity Market (NEM)

(An Energy Industry Review)

Updated 31/05/18

Rubicon

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Note : Power Units : kiloWatt (kW) = 1,000 Watts ,
MegaWatt (MW) = 1,000,000 Watts (a million Watts) = 1,000 kW,
GigaWatt (GW) = 1,000,000,000 Watts (a billion Watts) = 1,000 GW

Energy Units : MegaWatt hour (MWh) = 1MW of Power for 1 hour,
GigaJoules = 1,000,000,000 Joules ,
TeraJoules (TJ) = 1,000,000,000 Joules,
PetaJoules (PJ) = 1,000,000,000,000,000 Joules (One PJ = 278 million kWh.)

Executive Summary

The need for this Paper

This paper has been released as a means of provoking a **vitally important discussion** regarding the risks we are now facing around energy in Australia. It is now obvious that a key Stakeholder of domestic energy (households, commercial and industrial), that is the **CUSTOMER**, has rightly become very dissatisfied with the performance of the energy Industry.

The very contentious proposed closure by AGL Energy Ltd. of their Liddell Power Station provides a timely opportunity to examine the need for a strategic approach as to where the Australian Energy Supply System(s) are heading and how we can address the current real challenges. Hence this paper's title : "***The Liddell Trigger***".

A key element of any informed Strategic process is the understanding of the fundamental difference between electricity capacity which is measured in terms of POWER (MegaWatts – MW) and what those plants can actually deliver in terms of ENERGY (MegaWatt hours – MWh). This difference is **CRITICAL**. The AGL replacement plan for Liddells' planned closure demonstrates this point by providing MW's but only minimal replacement dispatchable MWh.

The closure of Liddell without meaningful replacement of its Base Load Energy capability poses a possible **"TIPPING POINT"** which may lead to increasing instability of the National Electricity Market (NEM). Whilst the Federal Government is implementing its National Electricity Guarantee (NEG) policy , requiring dispatchable load be balanced against renewables, no new plants that can guarantee dispatchable load are being built except for high cost gas peaking plant. Australia is already facing an **energy crisis in that the current coal fired fleet is being closed down incrementally without as yet an identified dispatchable load replacement** . As a result of both the current energy position in electricity and gas as well as a setting up for a doubtful future the industry is very rapidly loosing its **SOCIAL LICENCE TO OPERATE**.

Executive Summary

Australian Energy Context

AGL plans the closure of Liddell Power Station, which is co-located with its Bayswater Power Station in the Hunter Valley of NSW. Liddell is currently producing 12% of the Electrical Energy in NSW and in 2016 produced over 9,000 GWh.

Federal and State Governments are committing to higher proportions of Renewable Energy being available to the Australian National Electricity Market (NEM) in the hope that reduced emissions will assist Australia to meet Paris Accord total emission targets. The percentage of Roof Top Solar PV continues to increase supported by Federal Government incentives.

Financial support for Renewables , along with over expenditure on Transmission assets has led both to very much higher domestic electricity prices and the closure of Coal Fired Power Stations . The Federal Government is also putting in place its National Energy Guarantee (NEG) policy to ensure dispatchable power remains available in the NEM. The Australian Competition and Consumer Commission (ACCC) has been tasked by the Federal Government to report on how domestic energy prices may be reduced.

This paper looks at what impacts the closure of Liddell will have on NSW and Eastern Australia through the interconnected NEM.

More generally this paper also examines the very significant issues faced by the NEM in trying to replace baseload coal fired power stations with expensive gas and renewable energy alternatives, combined in part with Energy Storage systems including Batteries and Pumped Storage Hydro schemes.

Executive Summary

Australian Energy Context – Gas Supply and Price

There was a general acceptance by both Federal and State Governments that Natural Gas would be the fuel that would enable Australia to have an orderly transition from a reasonably full reliance on higher emission Coal Fired Power Stations to a larger reliance on zero emission Renewable Energy sources; like Wind and Solar PV. In hindsight this was a high risk scenario for Australia and the NEM in respect of the following ;

- Reduced supplies of Natural Gas into the southern states from Bass Strait Gas supplies experiencing resource depletion.
- No Queensland Coal Seam Gas which is directed to Liquefied Natural Gas (LNG) export has been sequestered for supply to Australian domestic consumers and
- Coal Seam Gas supplies achieved by Fracking being banned by the very states where Natural Gas supplies are depleting namely Victoria and NSW.

As a consequence there is :

- **Restricted gas supply which has to be shared between Gas consuming industries and the production of Electricity which historically has been the domain of short period Peaking Plants and**
- **Considerable pressure on Gas is restricting its supply and increasing its price thereby impacting on its role as a transition to Renewables.**

Executive Summary

Australian Energy Context – Impact on Wholesale Prices in NSW

- It is important to realise that the NEM is in fact a set of separate Regions (based on States) that is interconnect by a few and limited physical connections.

- The relatively recent closures of both Northern Power Station in South Australia and Hazlewood Power Station in Victoria each have had dramatic impacts on the NEM and Wholesale Electricity supply prices in their respective States.

- In South Australia Wholesale Electricity prices increased from an average of $52.6 to $109.8 / MWh and in Victoria on the closure of Hazlewood in 2017 from $51.5 to $97.9 / MWh

- The NEG policy will have be operating by 2022 but there is no reason to believe that if the closure of Liddell takes place in 2022 that NSW Wholesale Electricity prices will not rise to the same degree as experienced previously with a base load station providing 12% of NSW's Electricity, prior to closure.

- The group of industries supporting the purchase of Liddell from AGL to ensure it keeps operating after 2022, therefore have very valid concerns about the direction of Wholesale Market prices should Liddell closure become a reality.

Executive Summary

AGL's Liddell Replacement Plan

The AGL replacement plan should produce at least 9,000 GWh **however there is a significant production shortfall of nearly 4,000 GWh with many flow on impacts likely both in NSW and the Eastern Australia. Only approximately 1,500 GWh are Dispatchable.**

Item No	Item	Nameplate (MW)	Net Dispatch (MW)	Remarks	Capital Est. ($M)	Est Annual Generation (MWh)
	Existing Liddell Power Station	2,000		Required to replace Liddell (Based upon 2016 Generation)		9,037,281
1	Newcastle gas peaker or other NSW sites	252	252	Constricted gas supply and high gas prices (60-74 $/MWh). Taking gas from other gas users	400	331,128
2	Renewables	1,600	1600	On-Shore Wind ≈ 1,700 (US$/kWh)[#1], Solar PV Grid Scale ≈ 1,400 (US$/kWh)[#1]	A$ 2,900 M to A$ 3,500 M	3,504,000
3	Bayswater upgrade	100				657,000
4	NSW Pumped Hydro		Net Loss	Feasibility. Reports AGL to purchase Mine 15 km away	?	0
5	NSW Gas Peaker	500		Constricted gas supply and high gas prices (60-74$/MWh). Taking gas from other gas users	800	657,000
6	Demand Response	150	0	Effect upon Customers	-	0
7	Liddell battery	250	Net loss	Li-Ion Grid Scale Battery ≈ A$ 3,000 /kW)[#2]	720	0
8	Liddell Synchronous Condenser	0	0	Makes no Technical sense based at Liddell	?	0
	Total notional	2,852		*Total estimated (MWh)*		5,149,128
				Estimated Shortfall (MWh)		3,888,153

Note #1 .

[#]2 *: Based* upon costs associated with the AGL Nygan and Broken Hill Solar Plants.

Executive Summary

Liddell Closure – NEM Impacts

- NSW NEM Region is connected to QLD by two Interconnectors and Victoria via a third. Since the closure of Hazelwood the Victorian NEM Region has become a net importer of Electricity as opposed to its historical position in the NEM as a major exporter. **On closure of Liddell, NSW too will also lose the capacity to export Electrical Energy via the Interconnected NEM grid.**

- The planned **second interconnector from western NSW to South Australia, if actually built, will have little to no use and will be of no benefit for securing energy supply to that state**.

- Queensland which is still holding fast to a 50% renewables target by 2030, will be the only state able to export energy with the possible exception of Tasmania ,in years of high rainfall. Once Bass link is restored to life. Should Queensland restrict production from its Coal Fired Stations to meet its 50% Renewables target then Queensland too might lose its export capacity to NSW.

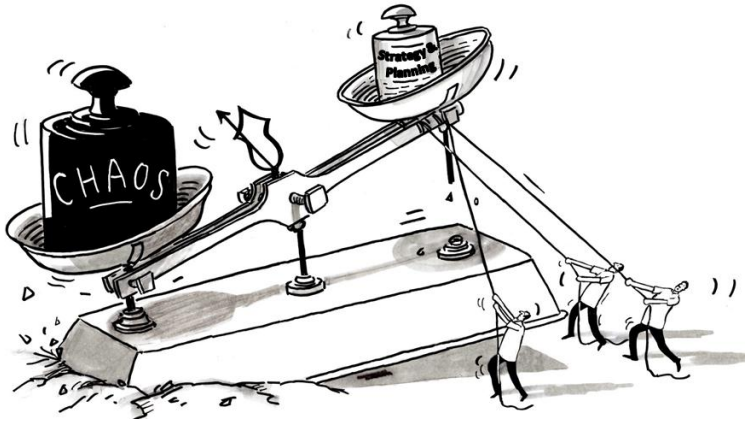
- One possible drastic but real scenario is that the states which largely go their own way on Electrical Energy matters, may restrict any export of Electricity to other states **and consequently the NEM too will have no "*raison de etre*" .**

- **The other parallel reality is that Liddell closure will constitute an NEM tipping point** with NEM wide blackouts like those recently experienced in South Australia and Victoria with longer and longer recovery times to supplying full demand.

Are We Reaching The "Tipping Point"

Could The Closure of Liddell Power Station Be "The Trigger" To Bring The NEM To The "Tipping Point"

What Is A "Tipping Point" ?



To date in the National Electricity Market (NEM) disruptions to supply to Customers have in the main been due to Transmission and Distribution Network issues. However, now it is feasible that we are approaching Supply / Demand "***Tipping Point***" in which a shortage of reliable supply may cause (and may already be causing) escalating prices for Customers but more concerning will be the increasing risk of a lack of reliable supply !

- ***Falling Base Load Capacity,***
- ***Older Fleet,***
- ***Under Investment in the Fleet,***
- ***A misunderstanding of Power (MW) of Installed Capacity versus Energy (MWh) that Customer needs,***
- ***Gas prices likely to remain high,***
- ***Intermittent Generation making Supply Balancing increasingly difficult.***

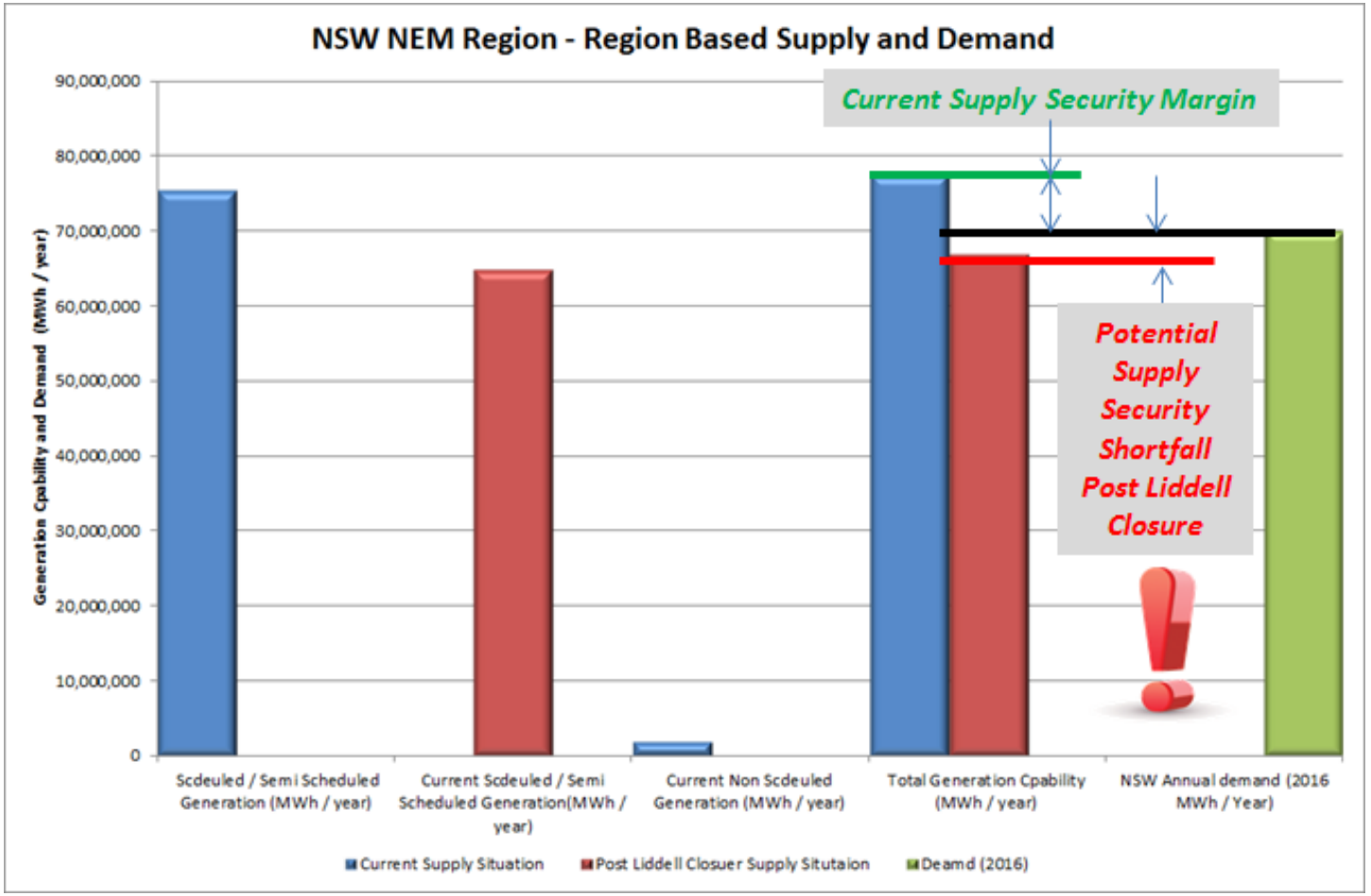
- ***Demand decline appears to have levelled out and is increasing with population,***
- ***Growing Infrastructure such as Electrified Metro Rail Systems need Energy (GDP)***
- ***A need to maintain Australia's GDP requires Energy (MWh),***
- ***New technologies such as Electric Vehicles may well accelerate the Demand again.***

Are We Reaching The "Tipping Point"

Could The Closure of Liddell Power Station Be "The Trigger" To Bring The NEM To The "Tipping Point"

Closure of Liddell, A Trigger

If we take a very simplified view of the New South Wales Electricity Supply / Demand Balance (in isolation) the following Graph illustrates the threat if New South Wales was considered a stand alone Network.



Are We Reaching The "Tipping Point"

Could The Closure of Liddell Power Station Be "The Trigger" To Bring The NEM To The "Tipping Point"

Note : Now clearly, the New South Wales NEM Region is not stand alone and is connected to the Queensland Region by two Interconnectors and Victoria via a third. However, it must now be noted that since the closure of Hazelwood the Victorian NEM Region has become a net imported of Electricity as opposed to its historical position in the NEM as a major exporter.

Also, the analysis behind the Graph is based upon Capacity Factors and Specific Yields (for Solar PV) and these are variable. However, it should be noted that Capacity Factors from the remaining Base Load Fleet will become increasingly hard to maintain as the Fleet ages and if the incorrect level of investment to maintain those assets would occur (or may be is occurring). The Author also points out the Graph is an annualised average approach and does not take account of seasonal factors which the Management of Generating assets usually take into account when planning their plant availability.

The above caveats having been made, the fact remains that the Graph is a valid illustration of the potential for significantly increased Supply Security issues to manifest themselves in New South Wales. This particularly so when one considers the effect of Hazelwood's Closure on the Victorian NEM Region. However, there have been a number of closures of Disputable. Base Load Generation in the NEM which it is reasonable to consider are having a compounding effect :

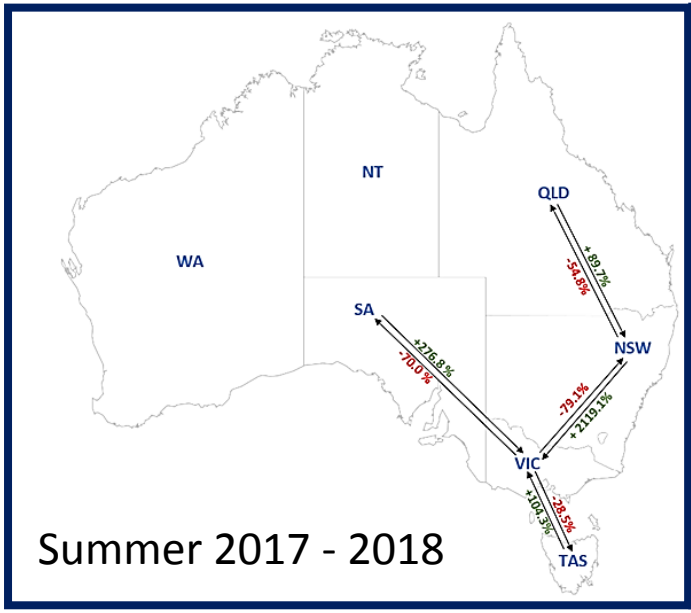
1. Swanbank 'B' Queensland, May 2012, 120 MW,
2. Wallerawang Units #7 & #8, New South Wales, April 2014, 1,000 MW,
3. Northern, South Australia, May 2016, 520 MW,
4. Hazelwood Victoria, March 2017, 1,600 MW

If one was to add to this list the closure of Liddell (2,000 MW) and the often discussed Yallourn 'W' in Victoria (1,450 MW) the situation the loss of Dispatachable Base Load would appear to become dire.

Are We Reaching The "Tipping Point"

Could The Closure of Liddell Power Station Be "The Trigger" To Bring The NEM To The "Tipping Point"

Since the closure of Hazelwood the Victorian NEM Region has imported more Electricity from all the other Regions with which it has Interconnectors .

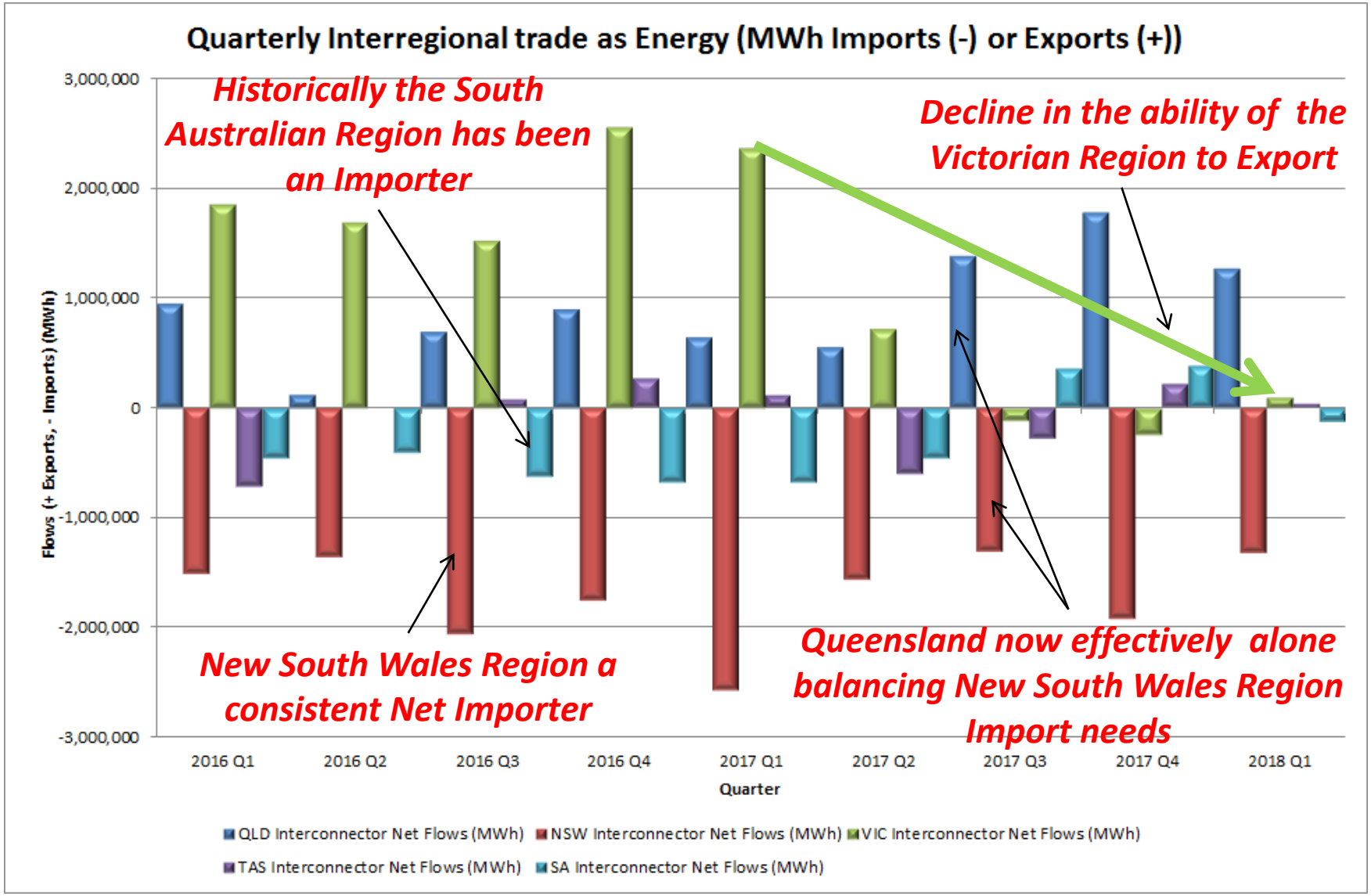


Exports from the Victorian Region into the New South Wales Region **fell 79 per cent,** while exports from NSW to Victoria increased substantially (2,199 per cent), although from a relatively small export amount of 452 GWh in the previous summer. Exports from Queensland into NSW also jumped by 89.7 per cent to help meet tighter supply-demand in the southern states.

Source : Tran, C., 2018, "Electricity exports: What did the NEM do last summer?", at : https://www.energycouncil.com.au/analysis/electricity-exports-what-did-the-nem-do-last-summer/, The Australian Energy Council, Melbourne, accessed 24th May, 2018.

Are We Reaching The "Tipping Point"

Could The Closure of Liddell Power Station Be "The Trigger" To Bring The NEM To The "Tipping Point"



A failure of the Queensland – New South Wales Interconnector (QNI) would poses a major supply problem to the rest of the NEM. It is worth noting that currently QNI is a double-circuit 330 kV lines maximum transfer capacity of 700 MW from New South Wales to Queensland and 1,200 MW from Queensland to New South Wales.

Introduction

Feasibility Replacement Of Coal Fired Generation With Renewable Sources

Introduction

Feasibility Replacement Of Coal Fired Generation With Renewable Sources

This paper is an outgrowth of a commissioned review of the closure of AGL's 2,000 MW Liddell Black Coal Fired Power Station in the Hunter valley of New South Wales. During the process of preparing the original work, it became very apparent that the issues at stake here were far more significant than those related to a single plant and thus this paper was separated and has developed a "life" of its own.

There would clearly seem to be a lack of informed discussion in the public domain regarding the ramifications on the change from Disputable (NON- Intermittent or Continual) Generation and Non-Dispatchable (Intermittent) Generation. The issue is basically one understanding the difference between POWER (MegaWatts – MW) and ENERGY (MegaWatt hours – MWh). Referring to installing MW of Capacity with clarifying would level of Energy (MWh) can be Generated is frankly misleading and in so taking the National Electricity Market (NEM) rapidly towards a "***tipping point***" which will result is a lack of Energy Security in the NEM.

It is the Author's view based on the current known information and on the existing Fossil Fuel technologies are not environmentally sustainable, in the context of Australia's emission commitments to meet the Paris Accord agreements. That does not mean that the issue is with the Fuels themselves but rather how we utilise them. The scope of the possible technologies is beyond the scope of this paper but is one that needs urgent evaluation.

Introduction

Feasibility Replacement Of Coal Fired Generation With Renewable Sources

It is time that rather than base our actions here in this Country on actions taken elsewhere, we must ensure we understand our specific situation and apply sound consideration (Scientific / Technical / Economic / Environmental / Social) of all facets of the Australian conditions. This means we have to do some work to analysis the situation and seek our own solutions. Perhaps the starting place is our consideration of SUSTAINABILITY :

…"sustainable development is development that meets the needs of the present <u>without compromising the ability of future generations</u> to meet their own needs …" (Brundtland Commission of the United Nations on March 20, 1987.)

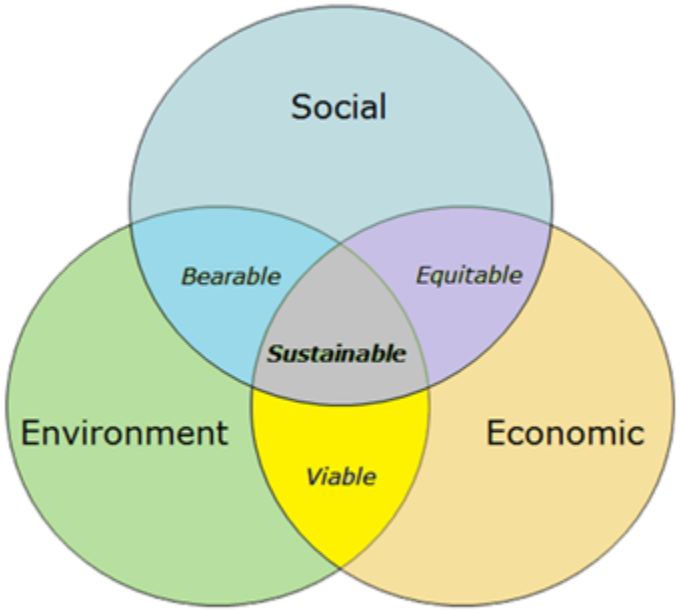


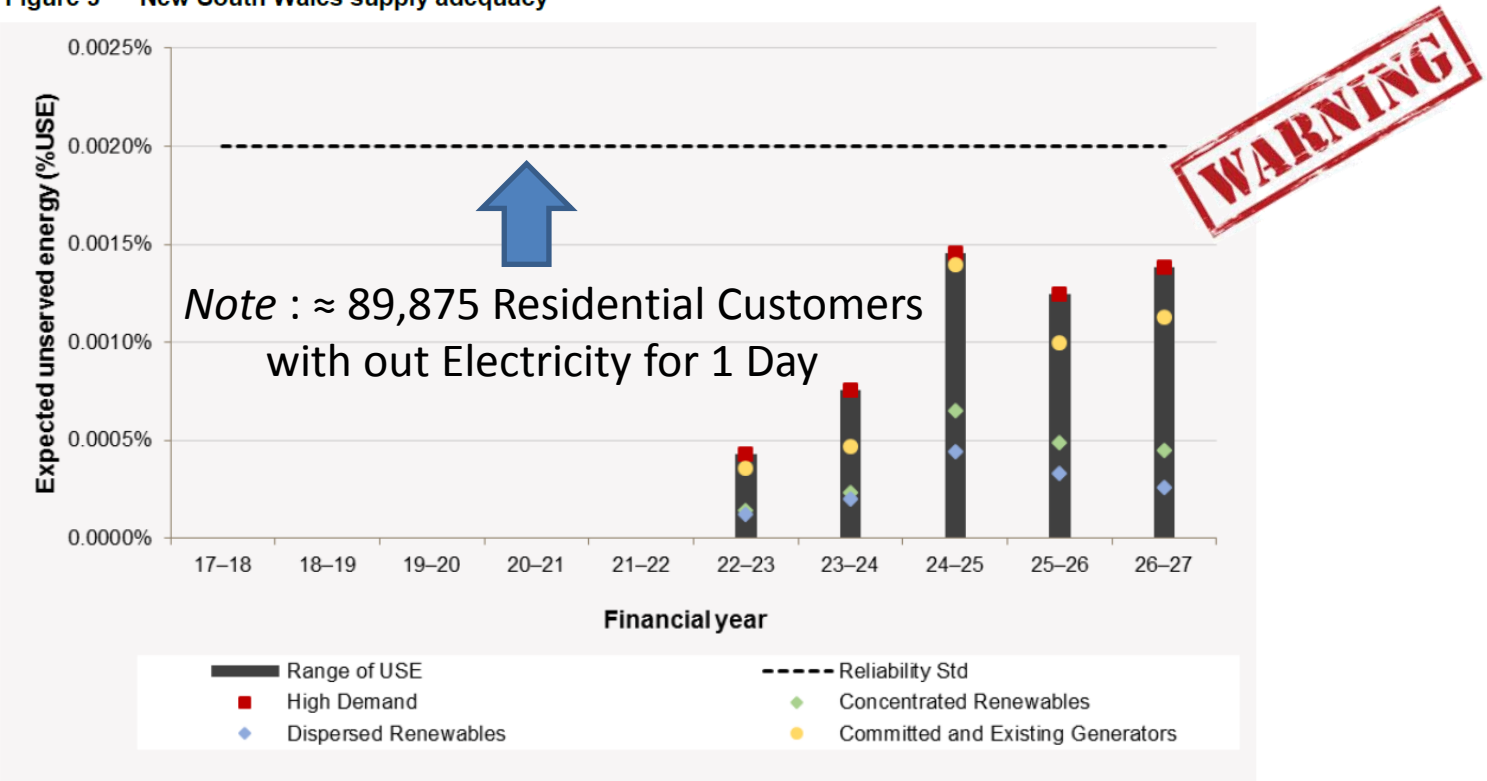
Image source : Dréo, J., 2006, "Sustainable development", based upon World Commission on Environment and Development (WCED), 1987, "Our Common Future", Brundtland Report (after Gro Harlem Brundtland), Center for Our Common Future, United Nations, New York.

AEMO's View

AEMO's View

Electricity Statement Of Opportunities - For The National Electricity Market Published: September 2017

Figure 9 New South Wales supply adequacy



In this figure:

- **Committed and Existing Generators** includes all existing generators and committed projects that meet AEMO's commitment criteria. Not all potential renewables required to meet State and Federal renewable energy targets and the Paris COP21 commitments are developed.
- **Dispersed Renewables** shows USE if, as well as all existing generators and projects meeting AEMO's commitment criteria, additional renewable generation was to be developed to deliver a national renewable generation outcome, leading to greater penetration than can be achieved if geographically concentrated.
- **Concentrated Renewables** shows USE if, as well all existing generators and committed projects that meet AEMO's commitment criteria, potential additional development after 2020 was geographically concentrated particularly in Victoria, driven by the Victorian Renewable Energy Target (VRET).
- **High Demand** shows the impact on USE if demand growth was in the upper range of expectations, assuming generation was developed according to the Dispersed Renewables pathway. The effect of higher demand on USE would be even greater if modelling assumed only Committed and Existing Generators.

Source : AEMO, 2017, "ELECTRICITY STATEMENT OF OPPORTUNITIES - FOR THE NATIONAL ELECTRICITY MARKET Published: September 2017", Australian Energy Market Operator Limited (AEMO), Melbourne, p. 25.

AEMO's View

Electricity Statement Of Opportunities - For The National Electricity Market Published: September 2017

Note : USE (UnServed Energy) is the amount of energy that cannot be supplied to consumers, resulting in involuntary load shedding (loss of customer supply), because there is not enough generation capacity, demand side participation, or network capability, to meet demand

USE is projected to be highest in 2024–25, where expected USE spans up to 0.0015%. The likelihood of USE in 2024–25 ranges between 29% and 46% and could last from two to six hours, depending on supply and demand conditions.

The increased risk of USE in New South Wales is driven by the retirement of Liddell Power Station (announced to retire in 2022) and an increase in forecast maximum demand.

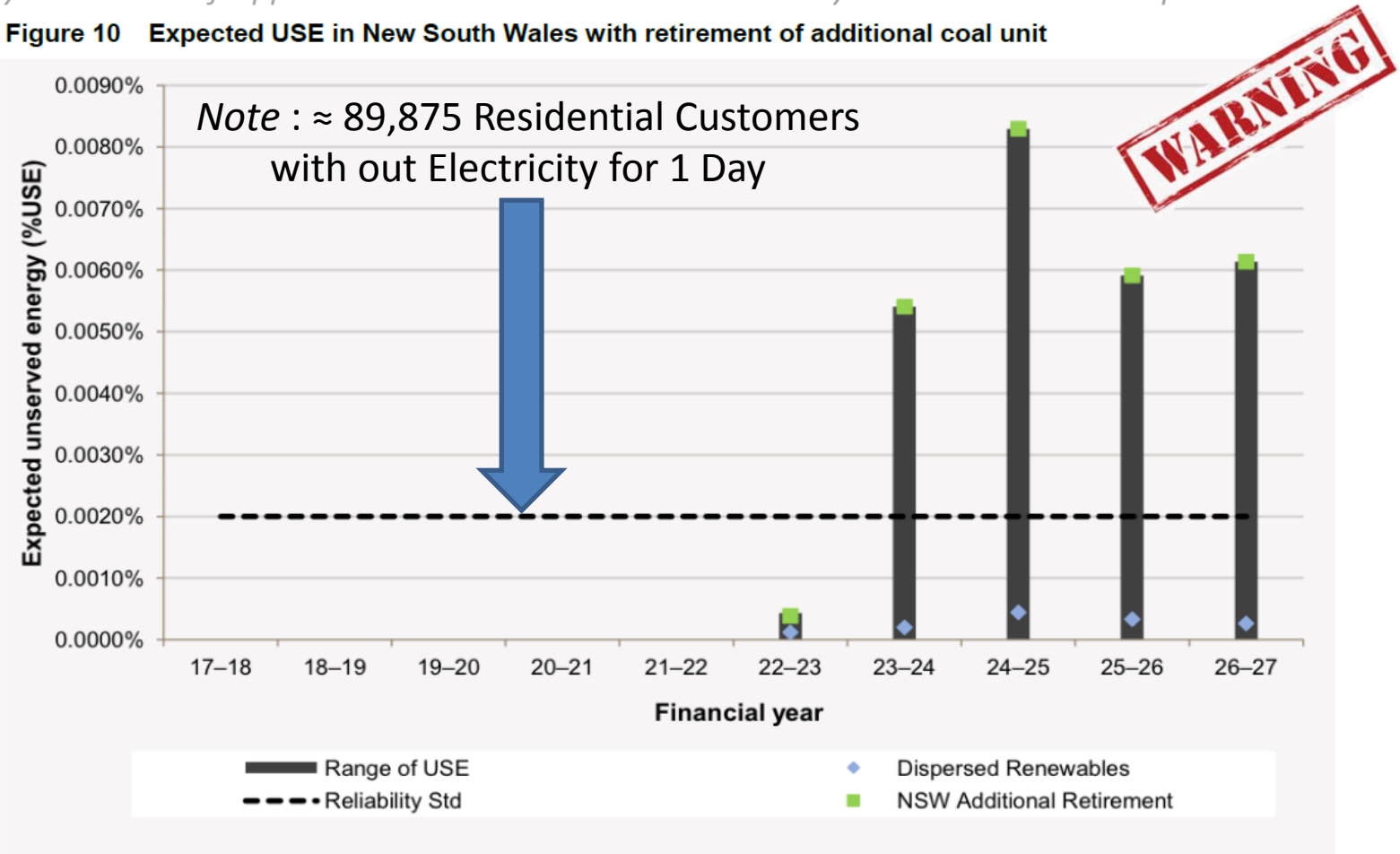
Forecast increases in appliance uptake, cooling load, and population put upward pressure on demand throughout the 10-year period, but are offset by projected increases in installed rooftop PV, leading to little net increase in demand until 2024. After 2024, the time of maximum demand is forecast to be delayed until after sunset where the effect of PV on peak demand is forecast plateau. Without the PV offset, increases in underlying demand leads to a net increase in forecast demand.

Source : AEMO, 2017, "ELECTRICITY STATEMENT OF OPPORTUNITIES - FOR THE NATIONAL ELECTRICITY MARKET Published: September 2017", Australian Energy Market Operator Limited (AEMO), Melbourne, p. 25.

AEMO's View

Electricity Statement Of Opportunities - For The National Electricity Market Published: September 2017

Figure 10 Expected USE in New South Wales with retirement of additional coal unit



In this figure:

- **Dispersed Renewables** includes all existing generators and committed projects that meet AEMO's commitment criteria, as well as potential additional renewable generation to deliver nationally coordinated renewable generation in line with currently announced state-based renewable targets.
- **NSW additional retirement** investigates the potential impact of a further retirement of a major coal fired power station in New South Wales after the announced retirement of Liddell Power Station, without replacement firm capacity.

Source : AEMO, 2017, "ELECTRICITY STATEMENT OF OPPORTUNITIES - FOR THE NATIONAL ELECTRICITY MARKET Published: September 2017", Australian Energy Market Operator Limited (AEMO), Melbourne, p. 26.

AEMO's View

Effect Of Closures

Following a request by Hon. Josh Frydenberg MP, Federal Minister for the Environment & Energy to the Australian Energy Market Operator Limited (AEMO) seeking an analysis by AEMO of AGL's plan to replace the energy and capacity currently delivered by the Liddell Power Station (Liddell) following its retirement in 2022. the result was :
AEMO, 2018, "Advice to the Commonwealth relating to AGL's proposal to replace Liddell", 18th March, 2018, Australian Energy Market Operator Limited (AEMO), Melbourne.

The following are some relevant points from that Analysis:

> "…
> To minimise this risk, AEMO's latest analysis using updated supply and demand information, shows approximately **850 MW of additional dispatchable** resources are needed by 2026-27. This additional capacity will reduce the risk of load shedding to a 1-in-10 year likelihood after the closure of Liddell.
> AEMO's analysis acknowledges the proposed addition of 3,700 MW of committed capacity in the NEM, of which 2,600 MW of new investment in renewable generation capacity has been committed since September 2017. **However, as there is insufficient interconnector capability for reliable delivery of additional new supply into NSW from other regions during peak periods, only the NSW committed**

Source : AEMO, 2018, "Advice to the Commonwealth relating to AGL's proposal to replace Liddell", 18th March, 2018, Australian Energy Market Operator Limited (AEMO), Melbourne, pp.6 & 9.

AEMO's View

Effect Of Closures

The following are some relevant points from that Analysis Con't,

"…

generation totalling 910 MW of nameplate capacity contributes to NSW resource requirements in the Base Case. These committed resources include AGL's 100 MW Bayswater upgrade and 200 MW Silverton wind farm.

…

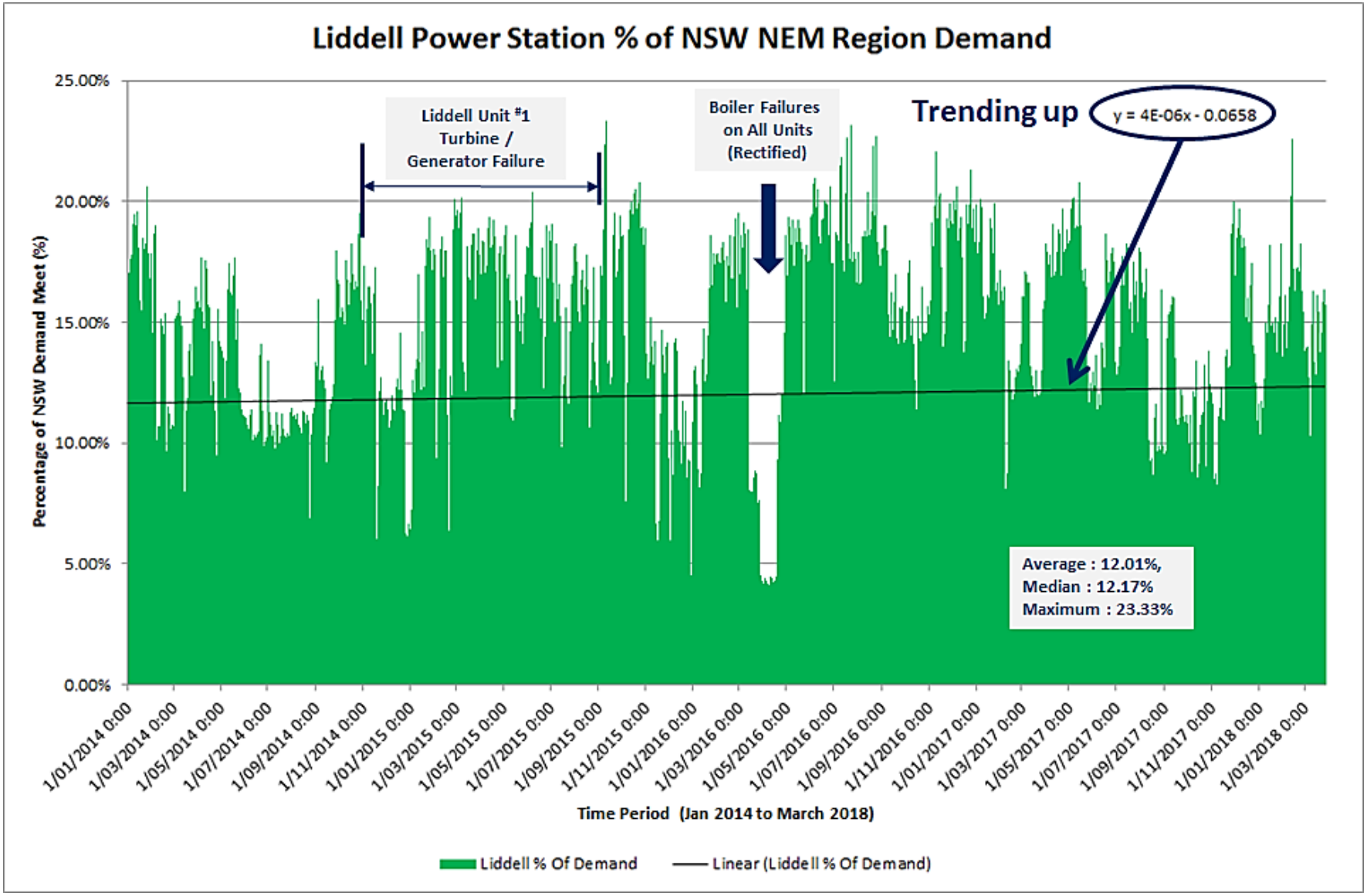
In conclusion, AEMO's analysis shows that an additional 850 MWs of resource capability are required to ensure reliability in NSW following the closure of Liddell. If all three stages of the AGL plan are completed, the resource gap will be eliminated. However, to ensure adequate resources are available at the time of Liddell's retirements, AEMO can only include those resources for which there is a clear commitment to construct. **Given at this stage AGL has only committed to install 100 MW of additional firm generation in its plan, unless AGL or others invest in sufficient replacement resource capability to serve NSW, there remains a significant resource gap of 850MW.**

…"

Source : AEMO, 2018, "Advice to the Commonwealth relating to AGL's proposal to replace Liddell", 18th March, 2018, Australian Energy Market Operator Limited (AEMO), Melbourne, pp. 6 & 9.

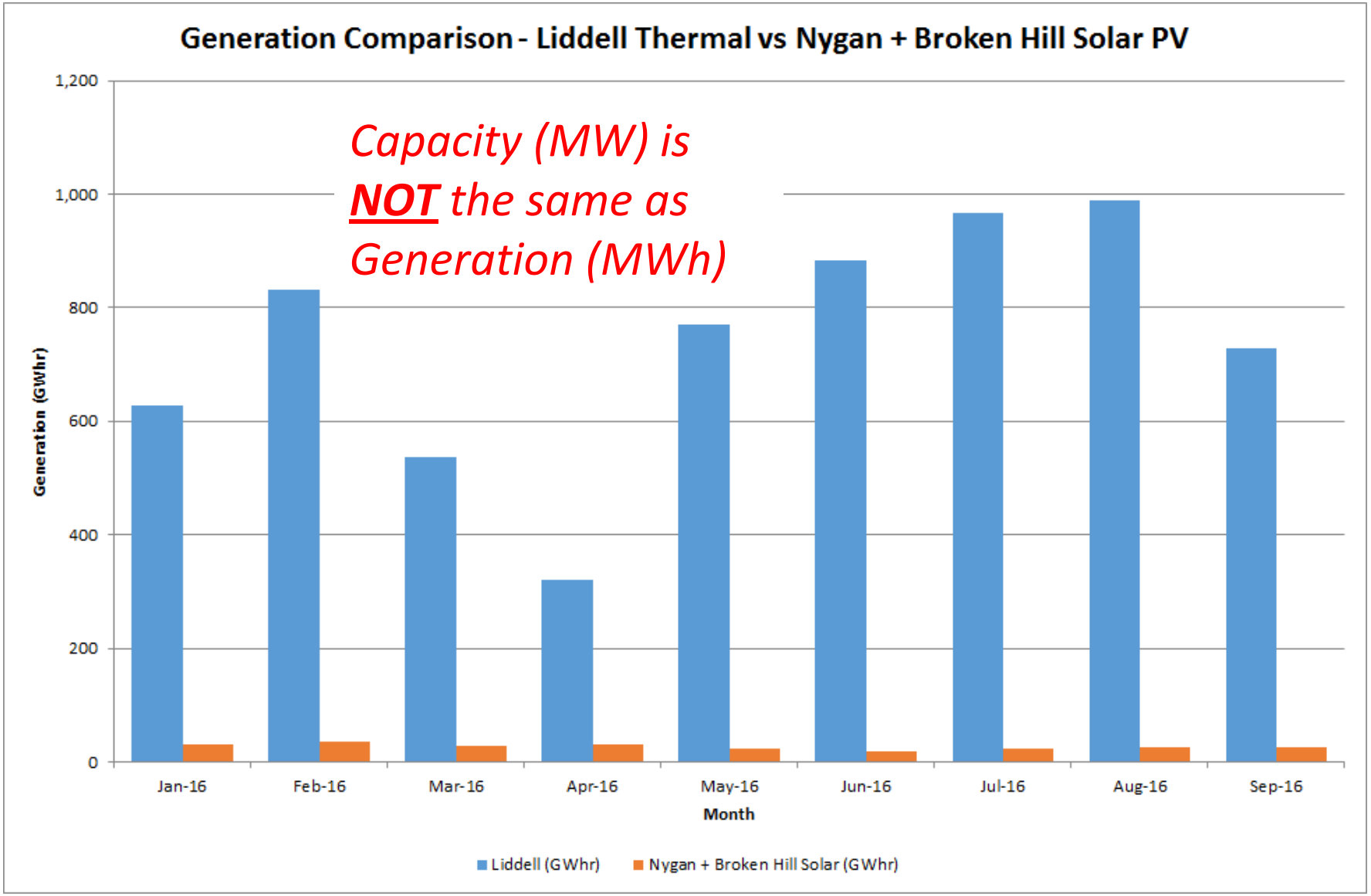
Liddell – A Trigger Point

Liddell's Performance



Closure of Liddell takes another 12% of NSW's current Electricity Energy Generation out of service.
Can the System cope with that ?

Liddell's Performance



Are Renewables able to replace that Base Load Generation – that is can they replace that Dispatchable Energy (MWh) ?

AGL's Comments

Earnings ?

AGL Energy Limited 2017 Investor Day webcast transcript, 13 December 2017

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"**Nick:**

Thanks Brett. Just there's been a lot of talk about the closure of Liddell and replacing the output with a variety of different technologies. **Liddell, at the moment, is clearly a good source of profits for the company.** They could roll forward and whilst the plan is to replace the output with the new technologies. If we take a view of that, all of the growth goes ahead as in that line, and it does hit your requisite rate of return. How confident are you that the earnings coming through from this new set of growth initiatives will offset the Liddell closure?

Brett: *(Brett Redman, AGL Energy CFO)*

Yeah. **We haven't published a detailed view of will one replace the other in an exact amount in earnings. I think it's reasonable to say the New South Wales generation plan in isolation in comparing to Liddell, you have an asset that's fully written off versus investing in new assets that will start to depreciate. It's hard to imagine that that alone will be the offset in an earning sense**. That's why we are continuing to push forward and look for other ways to grow and other ways to improve earnings. Whether it's the push into newer energy and new technologies, which are early days today, but in five years' time and beyond, we think we'll start to see those expand. Whether it's testing other markets. Whether it's thinking about new forms of large scale things coming into our market, like storage. All of these things are all about making sure that we're looking for good quality ways to reinvest, so that as those future dips in our future start to come out, and we've got other things that will replace them. I guess, about looking more broadly than just the New South Wales generation plan for an exact dollar for dollar replacement. I think maybe Robert was first, and then Andrew." *Note : **Emphasis** added*.

. . .

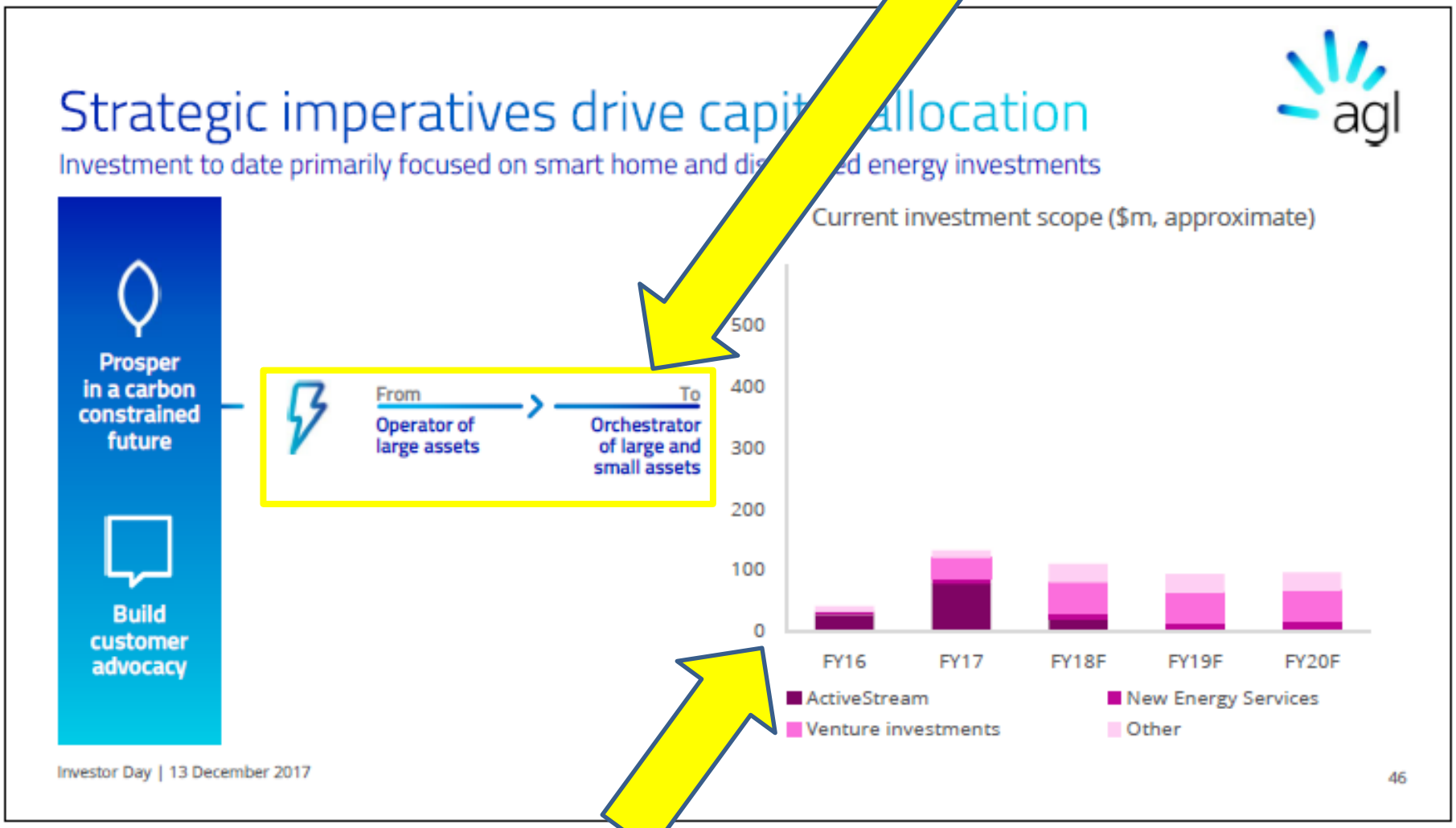
Source : AGL, 2017, https://www.agl.com.au/-/media/AGL/About-AGL/Documents/Investor-Centre/AGL-4_-Capital-allocation.pdf?la=en&hash=AA4D01F4388C41303E45CE17B00CA24E270FC731 Accessed : 24th April, 2018

AGL's Comments

Changing Role ?

What does "Orchestrator" mean ?

Who will Generate ?



No indication of Growth !

Source : AGL, 2017, https://www.agl.com.au/-/media/AGL/About-AGL/Documents/Media-Center/Investor-Center/AGL-Investor-Day-2017---Presentation-Slides.pdf?la=en&hash=CFEF07F182BD9ED347C66998CF5F13CB203DD9BD
Accessed : 24th April, 2018

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Liddell – AGL's Plan

AGL's Plan

NSW Generation Plan

Liddell replacement is AGL's preferred option compared with the proposal to extend the life of Liddell

Liddell replacement

Preferred option

Liddell Power Station closed in 2022 and repurposed with series of investments in new, low emissions generation and upgrades to existing generation

- Staged approach to bring new investment online ahead of Liddell retirement
- Each phase will track timing, deliverables and completion dates of each new investment

Newcastle gas peaker
250MW or other NSW sites

NSW gas peaker
500MW

Renewables
1600MW

Demand response
up to 150MW

Bayswater upgrade
100MW

Liddell battery
250MW

NSW pumped hydro
Feasibility

Liddell synchronous condenser
Inertia and reactive power

Total capital investment: ~$1,360m (~$490m in stage 1 projects)
Levelised cost of energy: $83/MWh
Asset life: 15 to 30 years

Liddell extension

Work undertaken at Liddell Power Station to enable AGL to operate the station beyond 2022

- Extending Liddell's life by five years to deliver 1000MW of peak capacity at reduced availability
- Analysis has been done to examine the costs and other risks associated with extending Liddell

Total capital investment: ~$920m
Levelised cost of energy: $106/MWh
Asset life: five years

Investor Day | 13 December 2017

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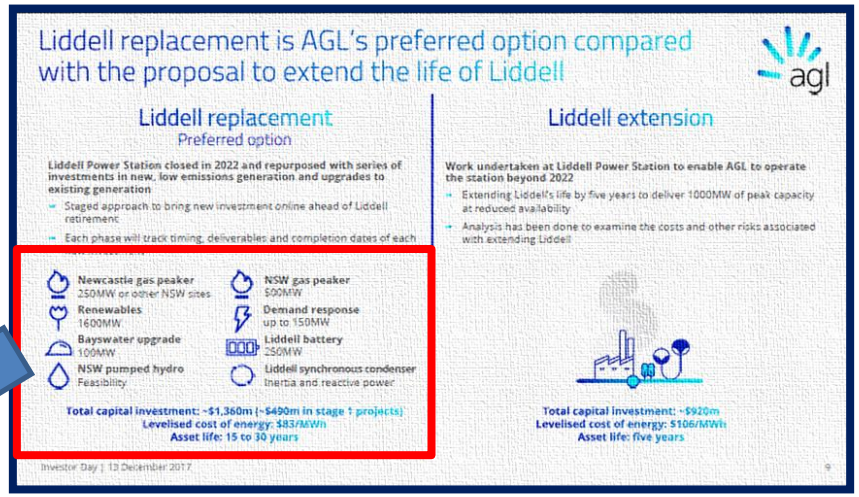
Source : AGL, 2017, https://www.agl.com.au/-/media/AGL/About-AGL/Documents/Media-Center/Investor-Center/AGL-Investor-Day-2017---Presentation-Slides.pdf?la=en&hash=CFEF07F182BD9ED347C66998CF5F13CB203DD9BD
Accessed : 24th April, 2018

AGL's Plan

NSW Generation Plan



Newcastle gas peaker
250MW or other NSW sites

NSW gas peaker
500MW

Renewables
1600MW

Demand response
up to 150MW

Bayswater upgrade
100MW

Liddell battery
250MW

NSW pumped hydro
Feasibility

Liddell synchronous condenser
Inertia and reactive power

Total capital investment: ~$1,360m (~$490m in stage 1 projects)
Levelised cost of energy: $83/MWh
Asset life: 15 to 30 years

Source : AGL, 2017, https://www.agl.com.au/-/media/AGL/About-AGL/Documents/Media-Center/Investor-Center/AGL-Investor-Day-2017---Presentation-Slides.pdf?la=en&hash=CFEF07F182BD9ED347C66998CF5F13CB203DD9BD
Accessed : 24th April, 2018

Analysis Of AGL's Plan

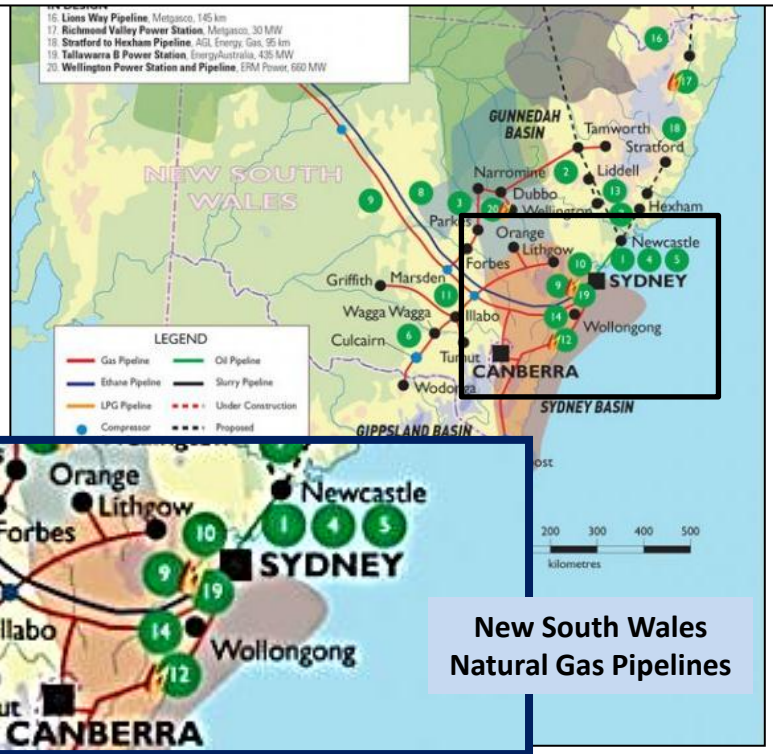
Natural Gas

Analysis Of AGL's Plan

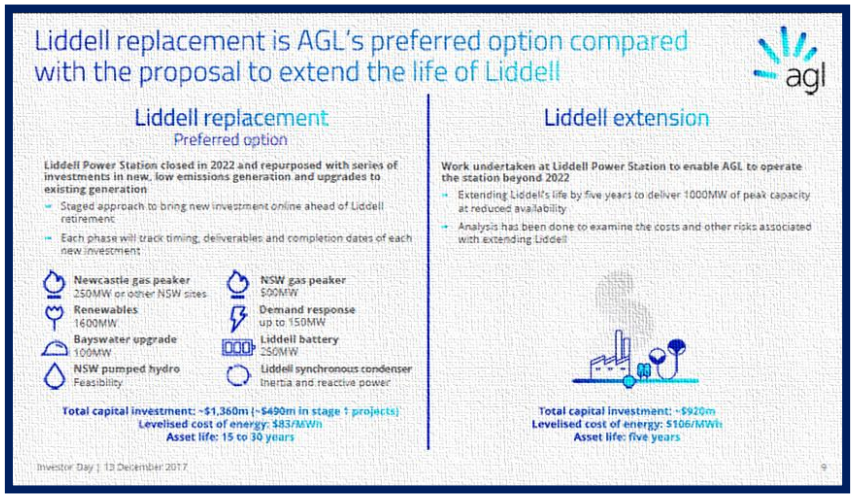
NSW Generation Plan

Newcastle gas peaker
250MW or other NSW sites

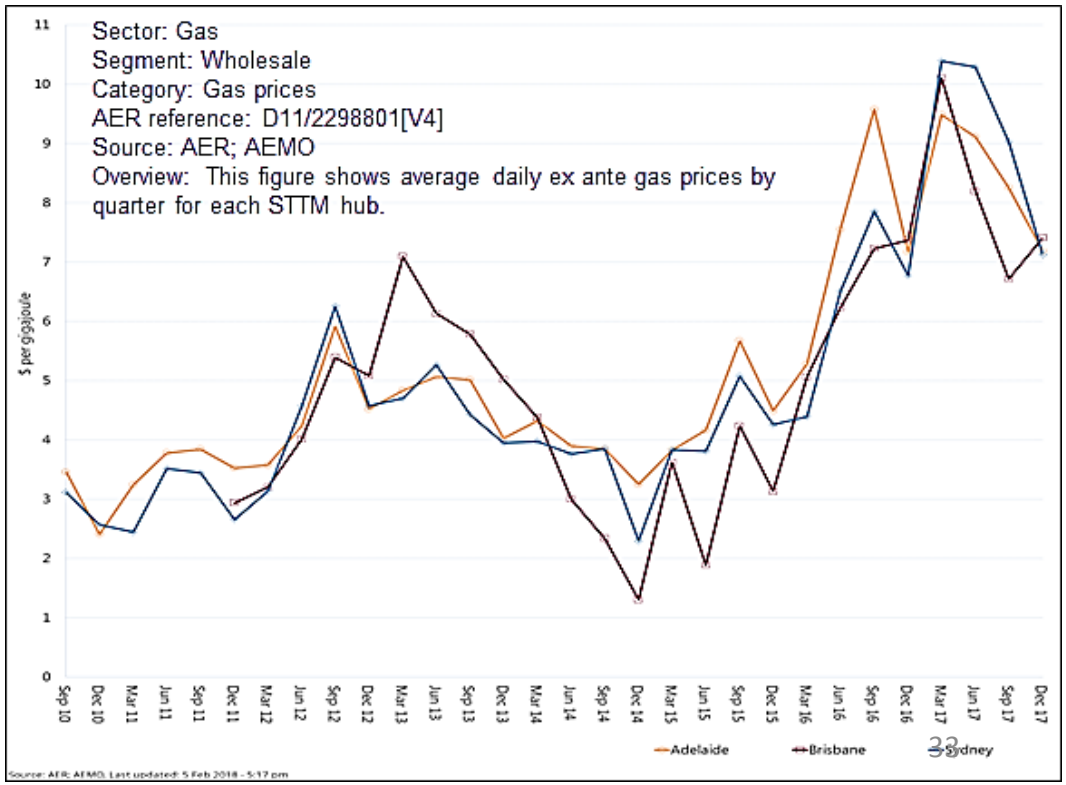
The Sydney – Newcastle pipeline is at the end of the stressed Moomba – Sydney system with a number of high volume gas consumers – Tomago Aluminium, Orica Kooragang Island etc.. Supply of Gas to Newcastle is limited. If the Queensland – Newcastle (Hunter) pipeline is not constructed, this situation may indeed worsen.



New South Wales Natural Gas Pipelines



Natural Gas prices are a real concern



Analysis Of AGL's Plan

NSW Generation Plan

Newcastle gas peaker
250MW or other NSW sites

AGL announces Newcastle gas-fired power plant to replace the Liddell power station

By Bellinda Kontominas and Alice Matthews

26/04/18

PHOTO: The Liddell Power Station will be replaced by a new gas-fired power plant in 2022. (ABC News: Kerrin Thomas)

AGL has released details for a gas-fired power plant in New South Wales, as part of its plans to replace the aging Lidell coal-fired station and move towards cleaner energy.

The company said it was investing up to $400 million in the 252-megawatt facility to be built near Newcastle and be completed during 2022.

Its announcement to the Australian stock Exchange follows pressure from the Federal Government to sell the Lidell coal-fired station in the New South Wales Hunter Valley, so it could stay open beyond its planned closure in 2022.
However, the energy company refused, announcing in December its plans to replace Lidell's output with renewables, upgrade the nearby Bayswater coal generator and reuse components of Lidell.

AGL said it was assessing sites for the project near the company's Newcastle Gas Storage Facility.

AGL managing director and chief executive Andy Vesey said the company was "committed to supporting the orderly transition of Australia's electricity generation capability to modern, clean and reliable energy supply".

The company said it also plans to "assess the potential" to develop a further 500 megawatts of gas-fired generation capacity, subject to demand from its commercial and industrial customers.

"Electricity generation is undergoing an increasingly rapid transition to lower cost, clean energy renewable and storage technologies," Mr Vesey said.

"This requires the complementary development of flexible, dispatchable gas-fired technology, as well as policies to support these developments."

AGL commits to new gas-fired power station in NSW

THURSDAY, 26 APRIL 2018

AGL Energy Limited today announced its commitment to build a **252 MW gas-fired electricity generation plant near Newcastle in NSW**. The commitment represents an estimated investment of up to $400 million and would comprise flexible, fast-start generation capable of delivering rapidly dispatchable peaking and firming capacity into the National Electricity Market.

AGL is assessing sites for the project near AGL's Newcastle Gas Storage Facility. **This power station will consist of 14 reciprocating engine units capable of generating 18 MW of capacity each.** Construction on this project would be targeted to complete during the 2022 calendar year.

Analysis Of AGL's Plan

NSW Generation Plan

Newcastle gas peaker
250MW or other NSW sites

AGL commits to new gas-fired power station in NSW

THURSDAY, 26 APRIL 2018

Source : AGL, https://www.agl.com.au/about-agl/media-centre/asx-and-media-releases/2018/april/new-gas-fired-power-station-in-nsw
Accessed 27th April, 2018

AGL Energy Limited today announced its commitment to build a **252 MW gas-fired electricity generation plant near Newcastle in NSW**. The commitment represents an estimated investment of up to $400 million and would comprise flexible, fast-start generation capable of delivering rapidly dispatchable peaking and firming capacity into the National Electricity Market.

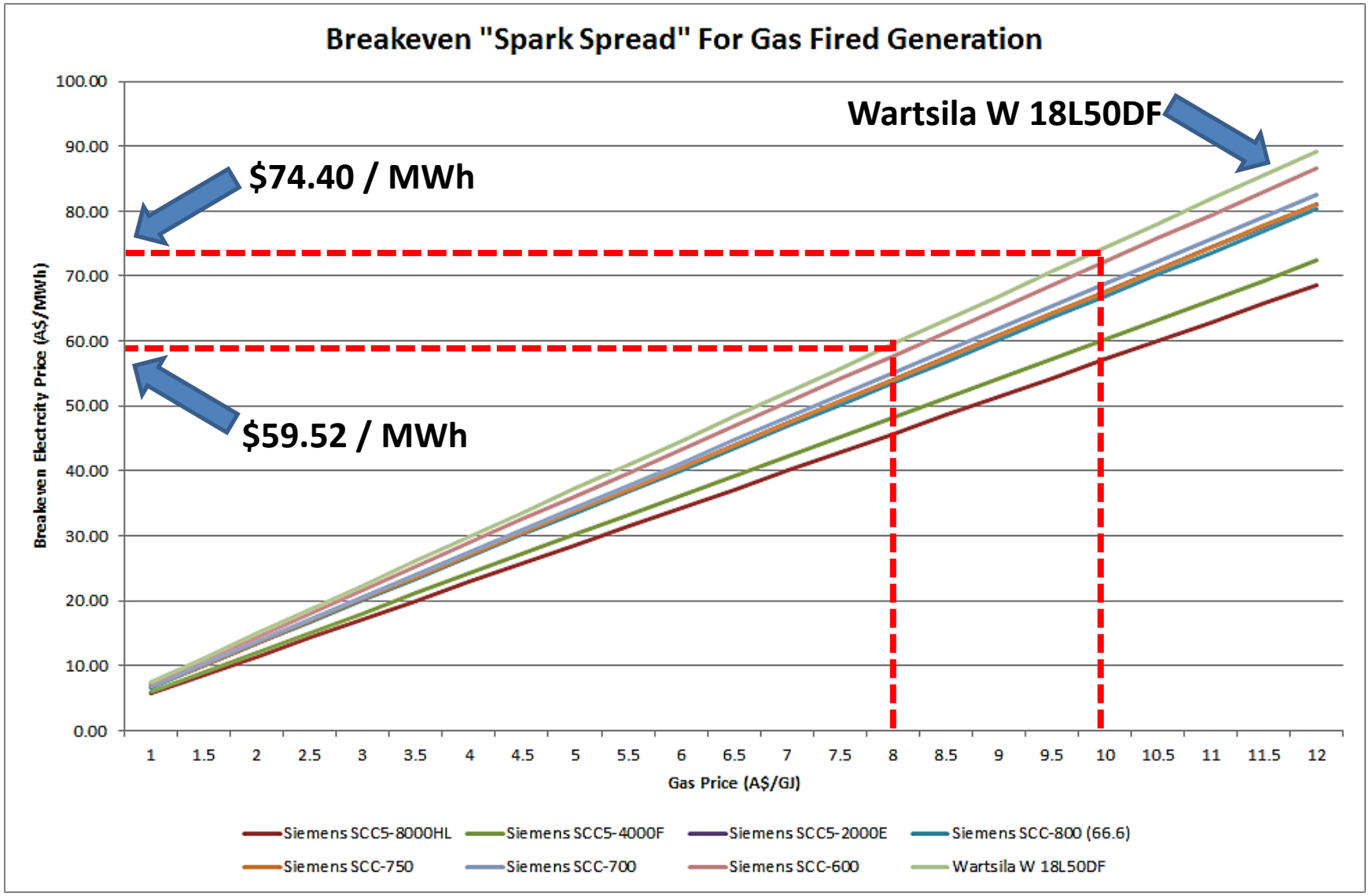
AGL is assessing sites for the project near AGL's Newcastle Gas Storage Facility. **This power station will consist of 14 reciprocating engine units capable of generating 18 MW of capacity each.** Construction on this project would be targeted to complete during the 2022 calendar year.

. . .

Assumed to similar to the Wartsila W 18L50DF Reciprocating Internal Combustion engines selected by AGL for Barker's Inlet Power Station in South Australia.

Analysis Of AGL's Plan

Plant Efficiency



AGL's Own Comments

NSW Gas Supply

"Solving for 'x' – the New South Wales Gas Supply Cliff"

"

Abstract

On Australia's east coast over the period 2013-2016, we forecast that aggregate demand for natural gas will increase three-fold, from 700 PJ to 2,100 PJ per annum, while our forecast of system coincident peak demand increases 2.4 times, from 2,790 TJ to 6,690 TJ per day. This extraordinary growth is being driven by the development of three Liquefied Natural Gas plants at Gladstone, Queensland. Almost simultaneously, a non-trivial quantity of existing domestic gas contracts currently supplying NSW will mature. Much of that gas has been recontracted to LNG producers in Queensland – thus creating a gas supply cliff in NSW. Compounding matters, recent policy developments have placed binding constraints over the development of new gas supplies in NSW. In this article, we present our dynamic partial equilibrium model of the interconnected gas system and produce forecasts with daily resolution. **We find that absent additional supply-side development, unserved load events will remain more than a theoretical possibility due to inter-temporal spatial constraints…**" *Note : **Emphasis** added.*

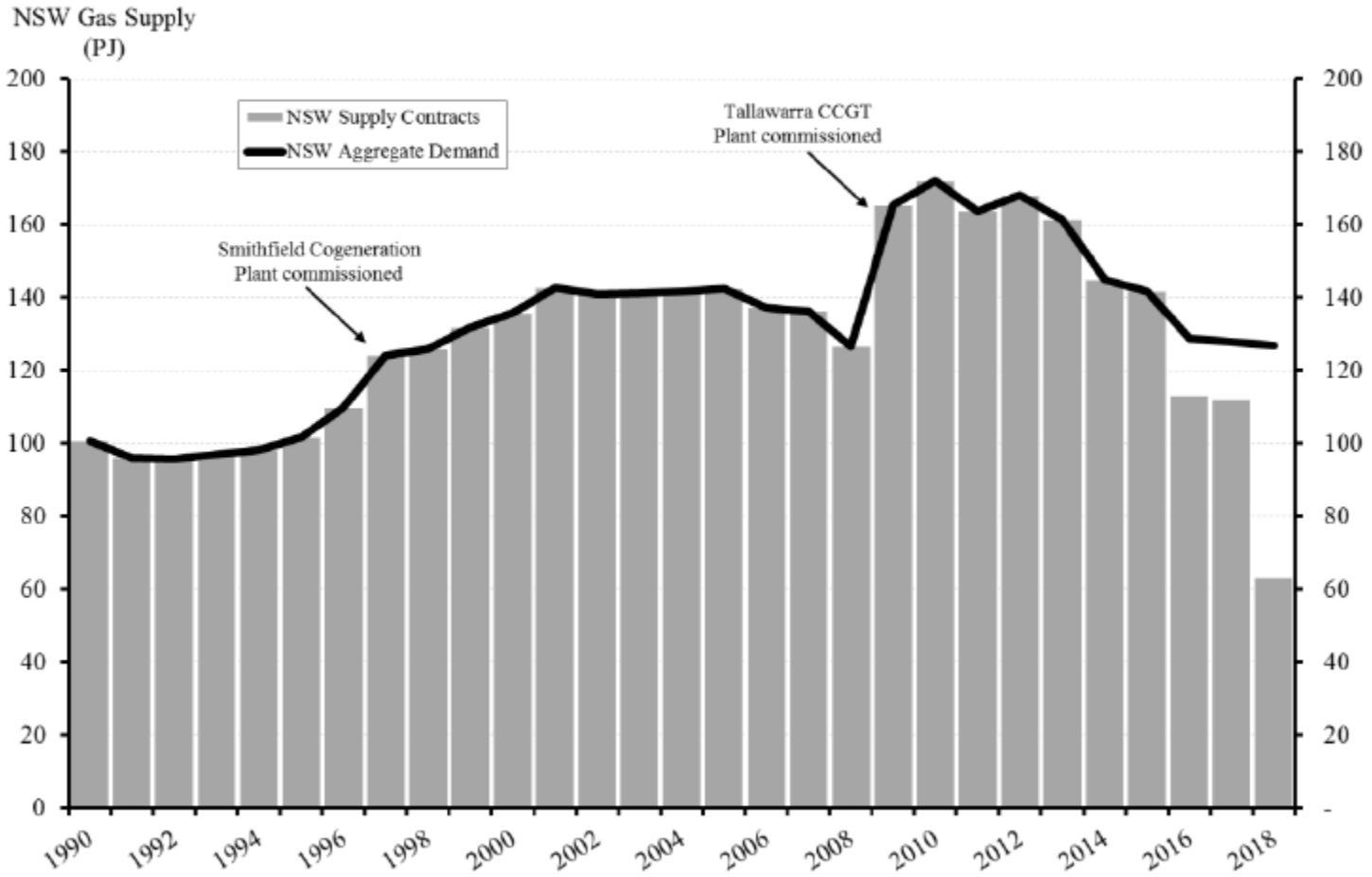
Source : Simshauser, P., and Nelson, T.[#1], 2014, "Solving for 'x' – the New South Wales Gas Supply Cliff", AGL Applied Economic and Policy Research Working Paper No.40 – Solving for 'x', March 2014, AGL Energy, Brisbane, March 2014, p. 26., ***Note* : [#]1 Tim Nelson is now AGL Energy Chief Economist and Head of Economics, Policy and Sustainability. In this role, A. Prof. Nelson is responsible for: AGL's sustainability strategy; greenhouse accounting and reporting; AGL's energy and greenhouse research; AGL's corporate citizenship program, Energy for Life; and energy and greenhouse policy.**

AGL's Own Comments

NSW Gas Supply

"Solving for 'x' – the New South Wales Gas Supply Cliff"

Figure 6: The NSW gas supply cliff: 1990-2018*f*



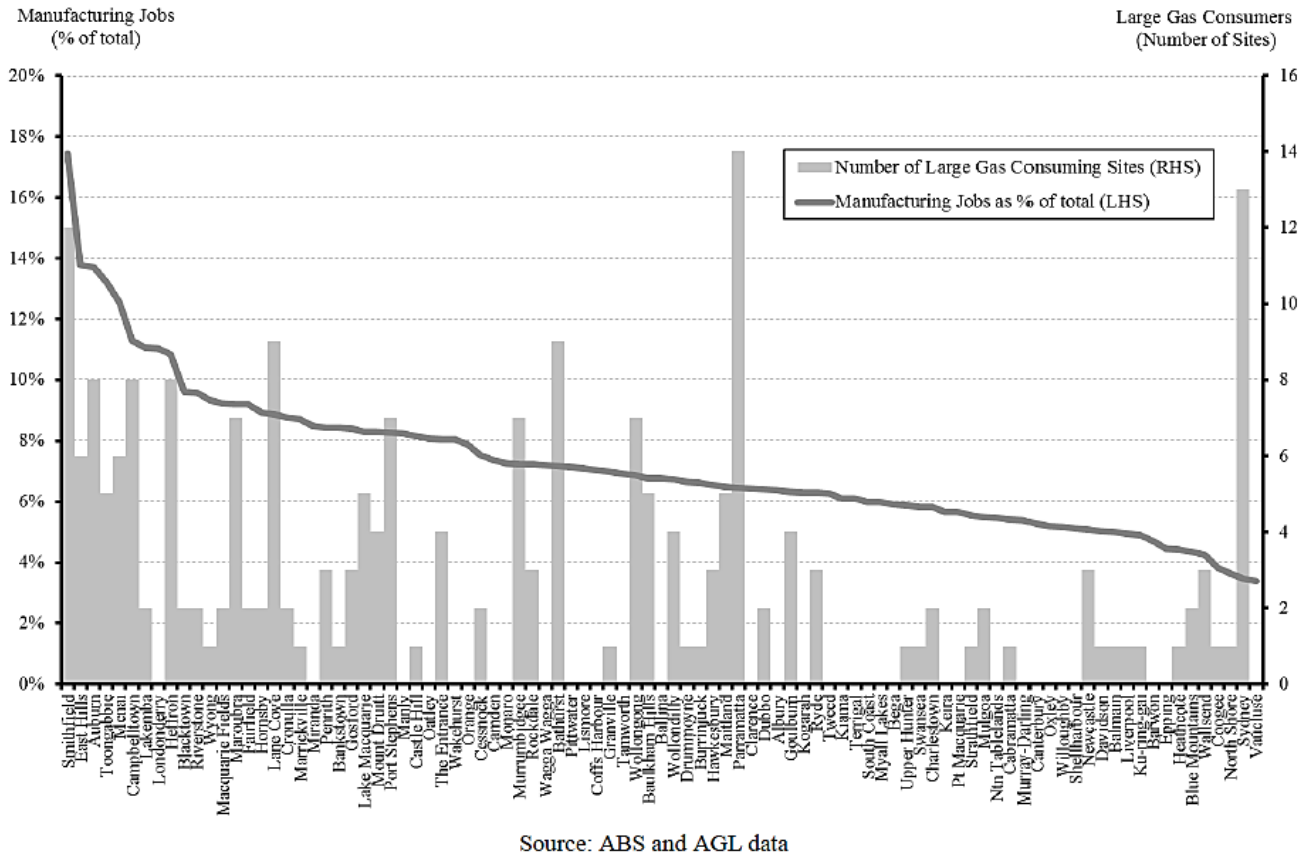
Source : Simshauser, P., and Nelson, T., 2014, "Solving for 'x' – the New South Wales Gas Supply Cliff", AGL Applied Economic and Policy Research Working Paper No.40 – Solving for 'x', March 2014, AGL Energy, Brisbane, March 2014, p. 7.

AGL's Own Comments

NSW Gas Supply

"Solving for 'x' – the New South Wales Gas Supply Cliff"

Figure 9: Proportion of manufacturing jobs and gas consuming sites by location in NSW



Source: ABS and AGL data

The potential for Gas Fired Electricity Generation to "starve" our existing Gas Customers is fraught with commercial, economic and social risks that may see Government intervention.

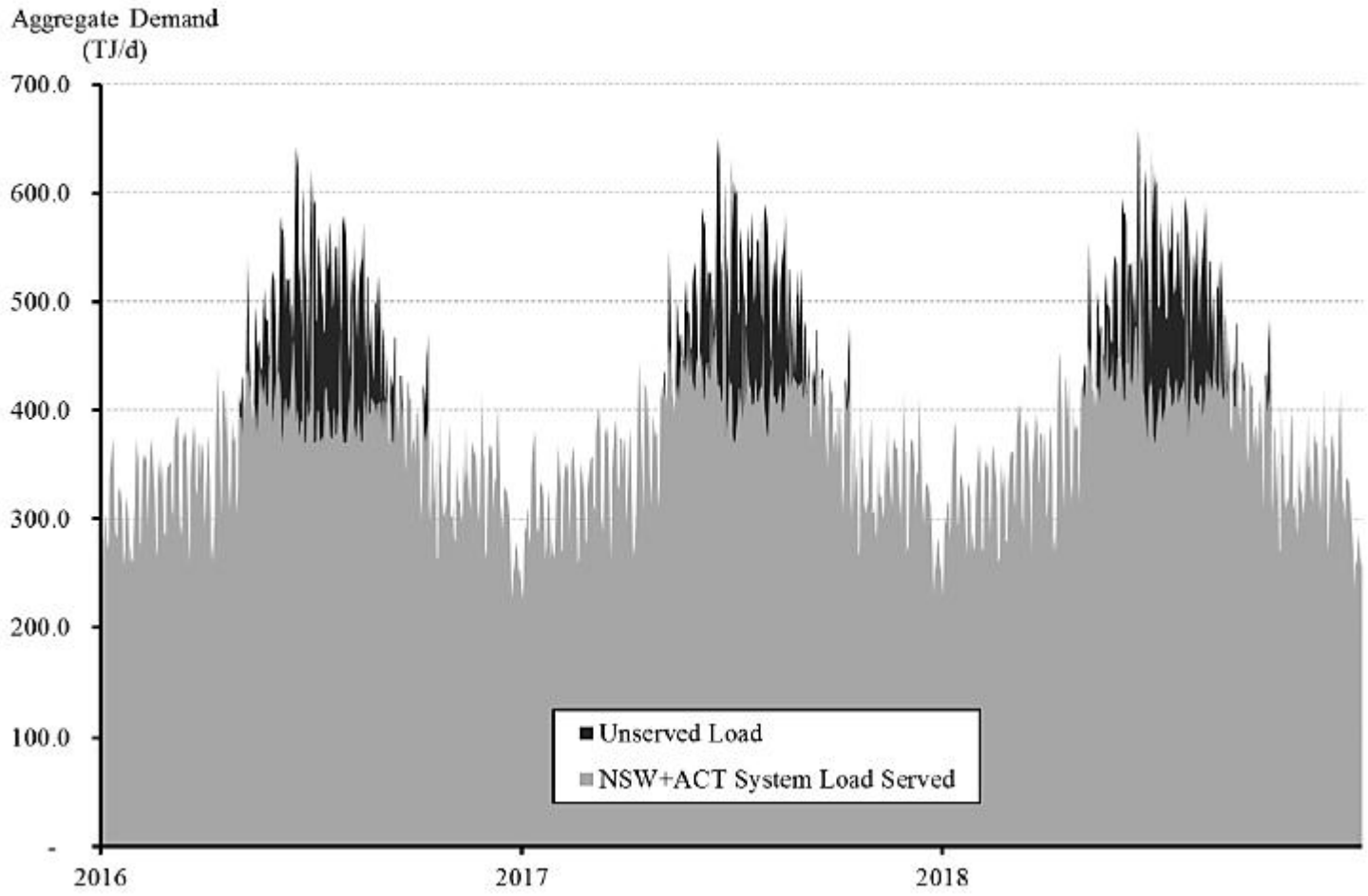
Source : Simshauser, P., and Nelson, T., 2014, "Solving for 'x' – the New South Wales Gas Supply Cliff", AGL Applied Economic and Policy Research Working Paper No.40 – Solving for 'x', March 2014, AGL Energy, Brisbane, March 2014, p. 10.

AGL's Own Comments

NSW Gas Supply

"Solving for 'x' – the New South Wales Gas Supply Cliff"

Figure 15: GPEM base case model results NSW and ACT - 2014-2018



Source : Simshauser, P., and Nelson, T., 2014, "Solving for 'x' – the New South Wales Gas Supply Cliff", AGL Applied Economic and Policy Research Working Paper No.40 – Solving for 'x', March 2014, AGL Energy, Brisbane, March 2014, p. 20.

AGL's Own Comments

NSW Gas Supply

"Solving for 'x' – the New South Wales Gas Supply Cliff"

. . .

"Our supply-side analysis must therefore turn to what is possible inside our NSW boundary constraint from 2017. At the time of writing, the policy and regulatory environment in NSW is still not conducive to investment commitment. However, if policy uncertainty can be resolved during early 2014 then the **20-25 PJ/a Gloucester project may be capable of entering into production by 2017**.

Gloucester Stage One has the requisite State and Federal Government approvals and production could commence once a particular pilot (known as the Waukivory Pilot) has been approved. Our understanding is that the **Narrabri project, which was also capable of producing from 2017, has (as with Gloucester) been adversely affected by dynamic inconsistency.**

Our view is that 2018 may be a more realistic date for field production from Narrabri given that, at the time of writing, requisite approvals from the State and Federal Governments are pending**. In Figure 23, we have opted to illustrate the impact of Gloucester on the security of energy supply in NSW, noting that the initial phase of Narrabri (i.e. feeding into the Central Ranges Pipeline) would in theory have an equivalent effect**."

Source : Simshauser, P., and Nelson, T., 2014, "Solving for 'x' – the New South Wales Gas Supply Cliff", AGL Applied Economic and Policy Research Working Paper No.40 – Solving for 'x', March 2014, AGL Energy, Brisbane, March 2014, p. 26.

AGL's Own Comments

NSW Gas Supply

"Solving for 'x' – the New South Wales Gas Supply Cliff"

. . .

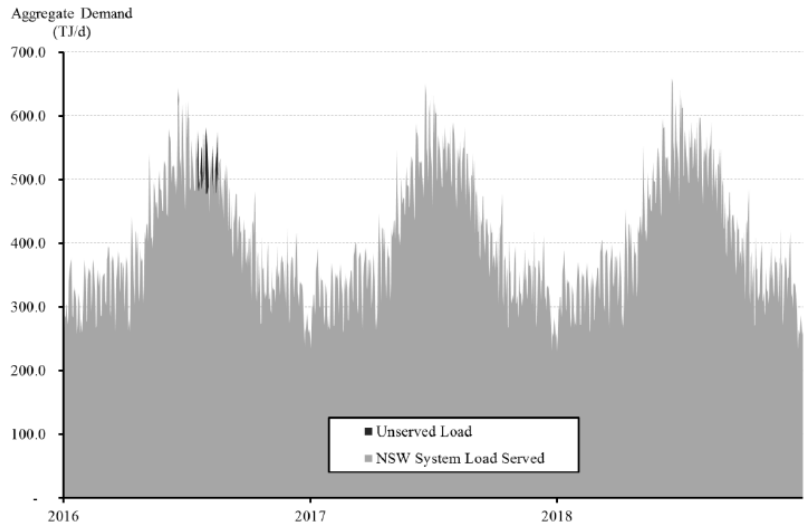
"The results in Figure 23 reveal that there are no shortages from 2017 due to local NSW production, which we assume to be 62 TJ/d or 22.6 PJ/a. Figure 24 *(not included here)* provides additional insights on energy security in NSW through the inventory balances of the Newcastle Gas Storage Facility. Note in Figure 24 that inventories are exhausted during 2016 (i.e. **unserved load events persist**). But inventory levels are non-zero throughout 2017 and 2018 which indicates that **once local NSW natural gas fields enter production, energy security in NSW is restored, albeit with no margin for error**."

Note **Emphasis** added.

. . .

Source : Simshauser, P., and Nelson, T., 2014, "Solving for 'x' – the New South Wales Gas Supply Cliff", AGL Applied Economic and Policy Research Working Paper No.40 – Solving for 'x', March 2014, AGL Energy, Brisbane, March 2014, p. 26.

Figure 23: GPEM Gloucester scenario NSW – 2016-2018



No New South Wales Gasfields have entered production. AGL's Gloucester Development proved unviable and has been abandoned whilst at AGL's Camden Gas Project, AGL announced in February 2016, that it will progressively decommission wells and rehabilitate sites.

AEMO's View

Gas Statement Of Opportunities For Eastern And South-eastern Australia (GSOO), March 2017,

. . .

"• Market responses could alleviate the risk of forecast gas or electricity shortfalls.

. . .

– Alternatives to GPG[#1] (such as other forms of generation, and storage) could reduce demand for gas while meeting demand for electricity.

. . .

• Continued upward pressure on gas and electricity prices may threaten the financial viability of some commercial and industrial customers.

– New gas supplies will help improve the reliability and security of energy markets, **but, given rising gas production costs, are unlikely to provide much relief for businesses at risk from high energy prices, potentially leading to closures**."

Note : **Emphasis** added.

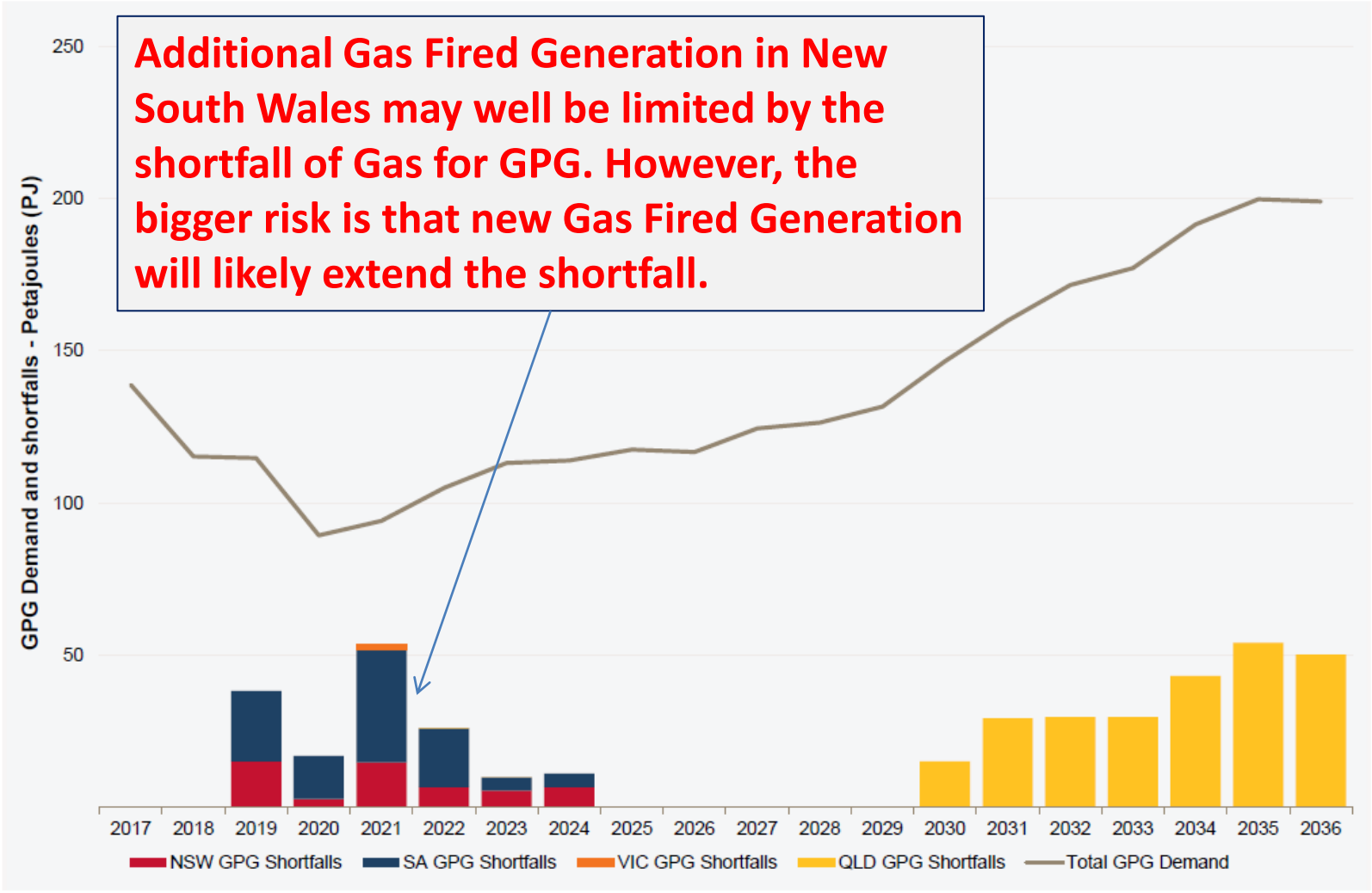
Note : [#]1 – GPG : Gas Powered Generation

Source : AEMO, 2017, "Gas Statement Of Opportunities For Eastern And South-eastern Australia" (GSOO), Published: March 2017, Australian Energy Market Operator (AEMO), Melbourne, p. 1.

AEMO's View

Gas Statement Of Opportunities For Eastern And South-eastern Australia (GSOO), March 2017,

Figure 2 Projected shortfalls in GPG supply by region, 2017–36

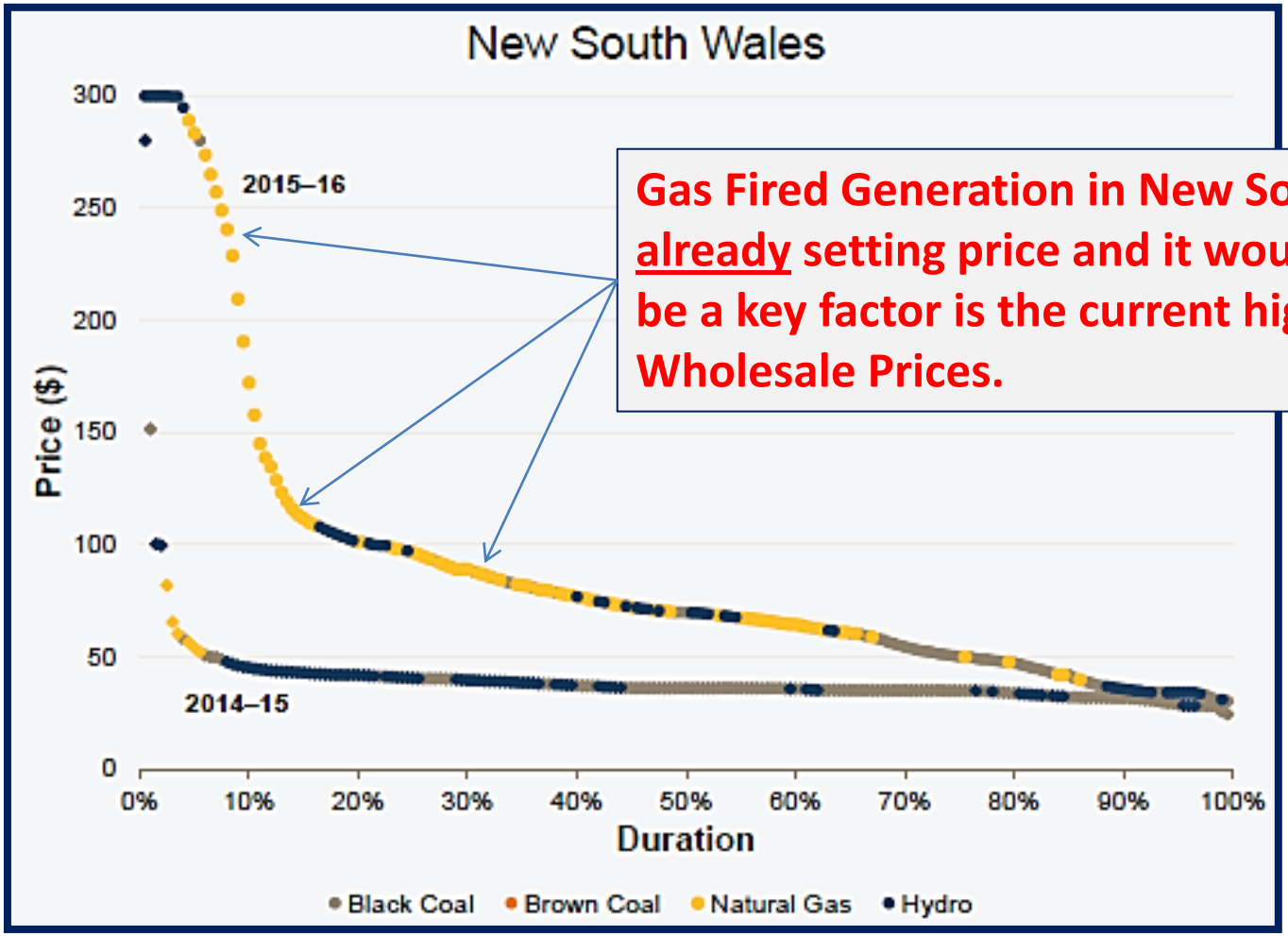


Source : AEMO, 2017, "Gas Statement Of Opportunities For Eastern And South-eastern Australia" (GSOO), Published: March 2017, Australian Energy Market Operator (AEMO), Melbourne, p. 3.

AEMO's View

Gas Statement Of Opportunities For Eastern And South-eastern Australia (GSOO), March 2017,

Figure 8 Regional price duration curve by price-setting fuel, 2014–15 compared to 2015–16



Gas Fired Generation in New South Wales is already setting price and it would appear to be a key factor is the current high Wholesale Prices.

Source : AEMO, 2017, "Gas Statement Of Opportunities For Eastern And South-eastern Australia" (GSOO), Published: March 2017, Australian Energy Market Operator (AEMO), Melbourne, p. 14. *Note* : New South Wales graph extracted from Figure containing all Regions.

AEMO – Issues Are Already Unfolding

System Event Report New South Wales, 10 February 2017

. . .

"New South Wales operational demand (energy demand provided from the grid) peaked at 1630 hours (hrs) at 14,181 megawatts (MW).1 The New South Wales record peak operational demand was on 1 February 2011, and was 14,744 MW.

The New South Wales Government publicly encouraged customers to reduce electricity use. AEMO observed demand reductions of approximately 200 MW below forecast at the time of peak demand on 10 February 2017, which may have been due to customer responses. However, AEMO cannot measure or verify the extent of the response.

Coincident with the peak of demand for the day, the following also occurred on 10 February:

- The forced outage of Tallawarra generators (408 MW) due to a fault in the gas turbine.
- **Colongra units unable to start (600 MW), due to low gas pressure in the fuel supply lines.**
- A number of thermal generators reducing output (details in Table 1).
- Reducing wind and solar photovoltaic (PV) generation of approximately 300 MW between 1700 hrs and 1800 hrs (approximately in line with forecasts).

Source : AEMO, 2017, "System Event Report New South Wales, 10 February 2017 Reviewable Operating Incident Report For The National Electricity Market Information As At 9.00 Am, Monday 20 February 2017", Published: 22 February 2017, Australian Energy Market Operator (AEMO), Melbourne, p. 20.

AEMO – Issues Are Already Unfolding

System Event Report New South Wales, 10 February 2017

These factors, all coinciding at approximately 1700 hours, combined to overload the New South Wales interconnections with Queensland and Victoria, creating an insecure operating state. With no further generation available to serve the demand and relieve the overloading interconnectors, as a last resort at 1658 hrs AEMO instructed TransGrid to reduce demand at the Tomago aluminium smelter (290 MW) to restore the power system in New South Wales to a secure operating state. The instruction was issued to restore load one hour later."

. . .

Source : AEMO, 2017, "System Event Report New South Wales, 10 February 2017 Reviewable Operating Incident Report For The National Electricity Market Information As At 9.00 Am, Monday 20 February 2017", Published: 22 February 2017, Australian Energy Market Operator (AEMO), Melbourne, p. 20.

10th February 2017,

"Smelter powered down to save electricity10 Feb 2017,

The record-high electricity demands forced AGL Energy to cut power to a large aluminium smelter in the state's Hunter Valley in order to avoid mass electricity blackouts across the state.

The Tomago aluminium smelter near Newcastle consumes 10 per cent of the state's electricity.

AGL said that if power to the smelter had not been cut, there would have been electricity cuts to schools, businesses and homes across NSW."

AEMO – Issues Are Already Unfolding

System Event Report New South Wales, 10 February 2017

. . .

"5. SUPPLY INTERRUPTION

After the trip of the Tallawarra generating unit at 1622 hrs, the power system was not in a secure operating state due to breaching limits on the interconnectors which filled the 408MW gap left by Tallawarra tripping and were carrying all reserves. **The four Colongra generating units received an instruction to start generating at 1625 hrs, but all four generating units failed to start and were bid unavailable at 1640 hrs.**

At 1658 hrs, AEMO directed TransGrid to shed the No. 3 potline at the Tomago aluminium smelter (290 MW). This was in accordance with jurisdictional load shedding procedures. The load was shed by 1706 hrs and this action restored the power system to a secure operating state. At 1801 hrs AEMO requested TransGrid to restore all load."

. . .

Source : AEMO, 2017, "System Event Report New South Wales, 10 February 2017 Reviewable Operating Incident Report For The National Electricity Market Information As At 9.00 Am, Monday 20 February 2017", Published: 22 February 2017, Australian Energy Market Operator (AEMO), Melbourne, p. 20.

Colongra Natural Gas Pipeline

Rubicon

"Colongra Gas Transmission and Storage Pipeline

The Colongra gas transmission and storage pipeline was designed and built by Jemena to deliver gas to Snowy Hydro Limited's 667MW gas turbine facility near the existing Munmorah power station on the Central Coast of NSW. The pipeline not only transports gas to the power station but also stores **enough gas to allow the power station to run at full capacity for five hours**. Take a look at the Colongra Gas Transmission and Storage Pipeline map.

The existing Sydney to Newcastle gas supply cannot meet the peak demand of the power station and so the Colongra pipeline is designed to be pressured over a 24 hour, off peak period and held at pressure until the power station is brought on line during peak periods.

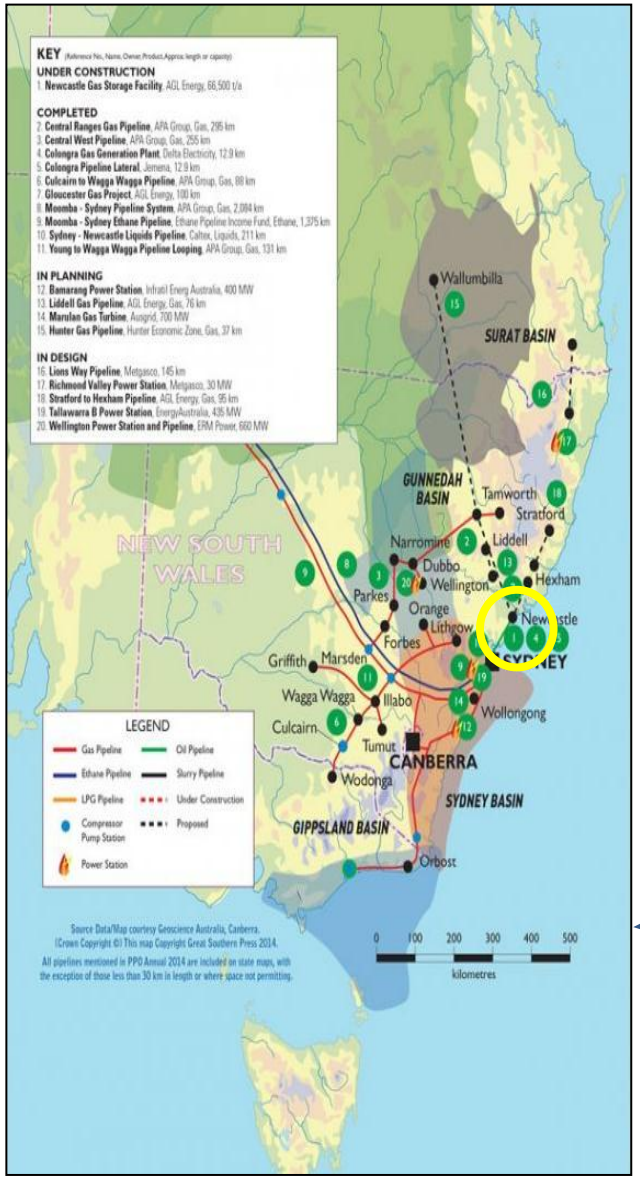
The Colongra pipeline includes 3.5 kilometres of 10 inch feeder pipeline, a 42 inch storage pipeline, a compressor station that increases gas pressure from 3.4MPa to 13MPa and a let-down station. It is the largest on-shore gas pipeline in Australia and is double looped to create nine kilometres of pipeline storage in a three kilometre stretch of land."

Emphasis added

Despite the design of the Colongra Pipeline, Colongra Power Station was unable to source Gas during the event of 10th February, 2017

Source : http://jemena.com.au/industry/pipelines/colongra-gas-transmission-and-storage-pipelinen , accessed 16th March, 2018

Colongra Natural Gas Pipeline



New South Wales Natural Gas Pipelines

Toward proposed AGL Newcastle Gas Fired Power Plant

Colongra Lateral from the Sydney – Newcastle Pipeline

Analysis Of AGL's Plan

Gas Supply – A Major Challenge

Analysis Of AGL's Plan

Gas Supply – A Major Challenge

AGL constructed the Newcastle Gas Storage Facility (NGSF) in part to help address the Natural Gas supply limitations experienced in the Newcastle Region. It is assumed that the full value of the NGSF would have included recharging from the then proposed AGL Gloucester Gas Field which has been abandoned. It is interesting to consider AGL's own view of the value of the Facility:

"The Newcastle Gas Storage Facility (NGSF) is A processing plant that converts pipeline natural gas to liquefied natural gas (LNG) by cooling it to -162°C. It is capable of processing up to 66,500 tonnes of LNG per year.
An insulated, non-pressurised LNG storage tank capable of containing 30,000 tonnes or 63,000 m³ of LNG, equivalent to 1.5 PetaJoules (PJ) of natural gas, and an associated containment area."

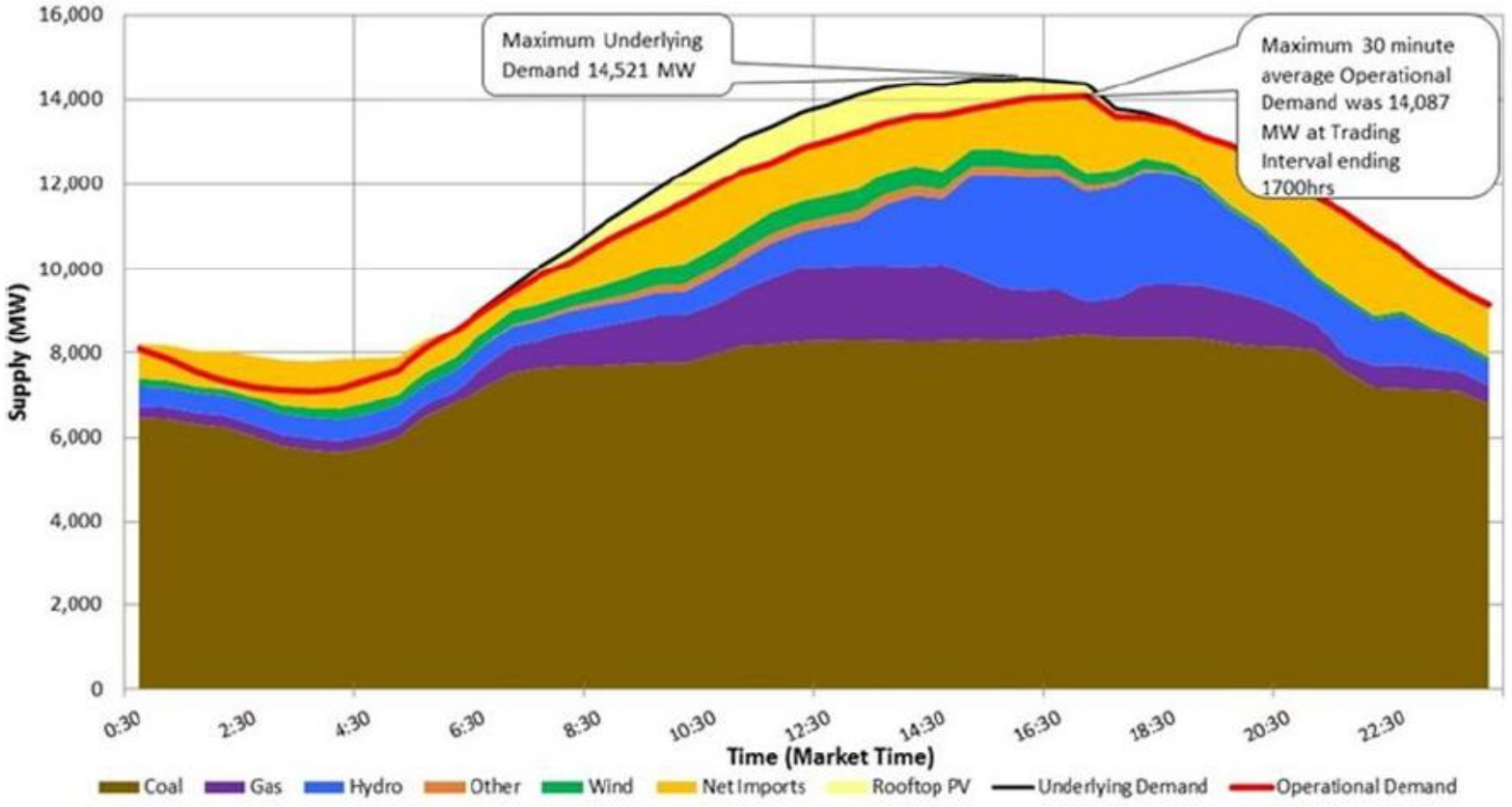
Source : AGL, https://www.agl.com.au/about-agl/how-we-source-energy/gas-storage/newcastle-gas-storage-facility-project accessed 30th April, 2018

Is AGL going to rely upon NGSF to support the their proposed Newcastle Gas Fired Generation Plant ?
If so, what becomes of other customers ?
What is the true cost of the stored Fuel ?

AEMO – Issues Are Already Unfolding

System Event Report New South Wales, 10 February 2017

Figure 1 New South Wales electricity supply mix on 10 February 2017[A]



A Maximum underlying demand includes all generation behind the meter (on customers' premises), including but not only from rooftop PV.

Source : AEMO, 2017, "System Event Report New South Wales, 10 February 2017 Reviewable Operating Incident Report For The National Electricity Market Information As At 9.00 Am, Monday 20 February 2017", Published: 22 February 2017, Australian Energy Market Operator (AEMO), Melbourne, p. 10.

Analysis Of AGL's Plan

Gas Supply – A Major Challenge

"**NSW can only provide five per cent of its annual gas consumption** of 160 PetaJoules (PJ). The other 95 per cent is imported from Victoria, South Australia and Queensland.
This disparity between locally available gas and supplies from other States is the motivation for NSW's acute focus on finding new supplies of gas to power future generations.
On average about 22% of NSW's annual gas intake is used by households and commercial. Manufacturing commands 49.8% with **26.9% being used by gas-fired power generators**."

NSW GOVERNMENT Planning & Environment Resources & Energy

Source : News South Wales Government Department of Planning and Environment - Resources and Energy at : https://www.resourcesandenergy.nsw.gov.au/energy-consumers/energy-sources/gas accessed 30th April, 2018

Note : **Emphasis** added

Analysis Of AGL's Plan

Gas Supply – A Major Challenge

The risk remains high that this Project does not proceed or at least be significantly delayed.

Santos Narrabri Gas Project

Environmental Impact Statement (EIS):

- A copy of the EIS is available on the Major Projects site of the Department of Planning and Environment (DPE) at www.majorprojects.planning.nsw.gov.au
- Work is well under way to respond comprehensively to the submissions received from the exhibition of the Narrabri Gas Project Environmental Impact Statement.

Western Slopes Pipeline:

- APA Group is continuing preliminary studies for construction of the Western Slopes Pipeline to connect natural gas from the proposed Narrabri Gas Project to the Moomba-Sydney Pipeline.
- The Pipeline Community Consultative Committees had a combined North and South meeting on 6 March 2018.
- Further information on the Western Slopes Pipeline is available from www.apa.com.au/about-apa/our-projects/western-slopes-pipeline/

Santos Activities Update March 2018

Santos

Proposed upcoming work program – Narrabri Area (PEL 238)

Timeframes are indicative as schedules are dependent on factors such as approvals, weather and rig availability.

References to pilot wells are grouped in well sets as follows: Bibblewindi East includes Bibblewindi 12 – 21 & 27 - 29; Bibblewindi West includes Bibblewindi 22 – 26. Bibblewindi 9 Spot includes Bibblewindi 3 – 9; Dewhurst North includes Dewhurst 6, 22 – 25; Dewhurst South includes Dewhurst 26 – 29

Environmental Impact Statement (EIS):

- A copy of the EIS is available on the Major Projects site of the Department of Planning and Environment (DPE) at www.majorprojects.planning.nsw.gov.au
- Work is well under way to respond comprehensively to the submissions received from the exhibition of the Narrabri Gas Project Environmental Impact Statement.

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- Further information on the Western Slopes Pipeline is available from www.apa.com.au/about-apa/our-projects/western-slopes-pipeline/

Drilling of exploration core holes, workovers and decommissioning of wells:

- No activities planned for March.

Pilot wells:

- Bibblewindi East, Bibblewindi West, Dewhurst South and Tintsfield pilot wells are on-line.

Leewood:

- The lucerne crop at Leewood is not currently being irrigated and is relying on rainfall.

Other work:

- The Wilga Park Power Station will be shut-down for approximately one week in mid-March for annual maintenance.
- Groundwater monitoring activities for Environmental Protection Licence compliance are ongoing.
- Rehabilitation is continuing at legacy sites, including revegetation activities at Bibblewindi.

Community:

- Community Site Visits are scheduled for the third Thursday of each month. To register for a site tour, contact 6792 9035 or email Energy.NSW@santos.com
- The next meeting of the Narrabri Gas Project Community Consultative Committee will be held on Tuesday 17 April 2018.
- Communiques and presentations from previous CCC meetings are available from www.narrabrigasproject.com.au/community/consultative-committee/
- Santos is a proud sponsor of the following:
  - Central North Junior Rugby Union – 2018 Season
  - Baradine Pastoral Agricultural and Horticultural Society – 2018 Show
  - Wee Waa High School – FIRST International Robotic Competition 2018
  - Narrabri and District Community Aid Services – Harmony Day Celebration
  - Narrabri Shire Community Science Hub – Teacher IT Training

Other:

- The CSIRO Gas Industry Social and Environmental Research Alliance (GISERA) has released the final report for the project *Social Baseline Assessment: Narrabri project* in February 2018. This is available from https://gisera.csiro.au/wp-content/uploads/2018/03/Social-7-Final-Report.pdf The report documents community perceptions of the CSG sector in the Narrabri Shire and establishes baseline levels of wellbeing, resilience, and attitudes towards CSG development.

Analysis Of AGL's Plan

Gas Supply – A Major Challenge

If the Santos Narrabri Gas Project does proceed it is now apparent that the Santos favoured Pipeline option is the APA Western Slopes Pipeline.

Statements

Santos not working with Queensland Hunter Pipeline

Posted on May 15, 2017

There have been a number of newspaper articles recently about the Queensland Hunter Pipeline and the proposal to build a pipeline through the Hunter Valley.

Santos is not working with Queensland Hunter Pipeline and has no plans to send any of the gas from the Narrabri Gas Project via that proposed pipeline route through the Hunter Valley.

Santos has always been clear that the natural gas from the Narrabri Gas Project will be made available to the NSW domestic market.

Santos has entered into a Project Development Agreement with the APA Group to construct a proposed pipeline running south west from Narrabri to join into the Moomba to Sydney pipeline. This pipeline – the Western Slopes Pipeline – will be the most efficient and timely way to bring much needed natural gas to the NSW domestic market.

More information on APA's Western Slopes Pipeline is available at **www.apa.com.au**

Bruce Clement
Santos Vice President Asia, NSW & WA Oil Assets

The likelihood of the Queensland – Hunter Gas Pipeline is looking to be declining.

Analysis Of AGL's Plan

Gas Supply – A Major Challenge

"On 31 January 2017, APA announced it had entered into a Project Development Agreement with a subsidiary of Santos Limited to commence work with regulators and the community towards the development of a new 450km (approximate) pipeline - the **Western Slopes Pipeline. The purpose of the Project is to connect a new source of gas from Santos' proposed Narrabri Gas Project to the NSW gas transmission network, via the Moomba Sydney Pipeline.**

We commenced a formal planning approval process for the Project in February with the submission of a Preliminary Environmental Assessment (PEA) in support of an application to the NSW Department of Planning and Environment to carry out State Significant Infrastructure. The Secretary's Environmental Assessment Requirements (SEARs) to guide the preparation of a comprehensive Environmental Impact Statement are now available.

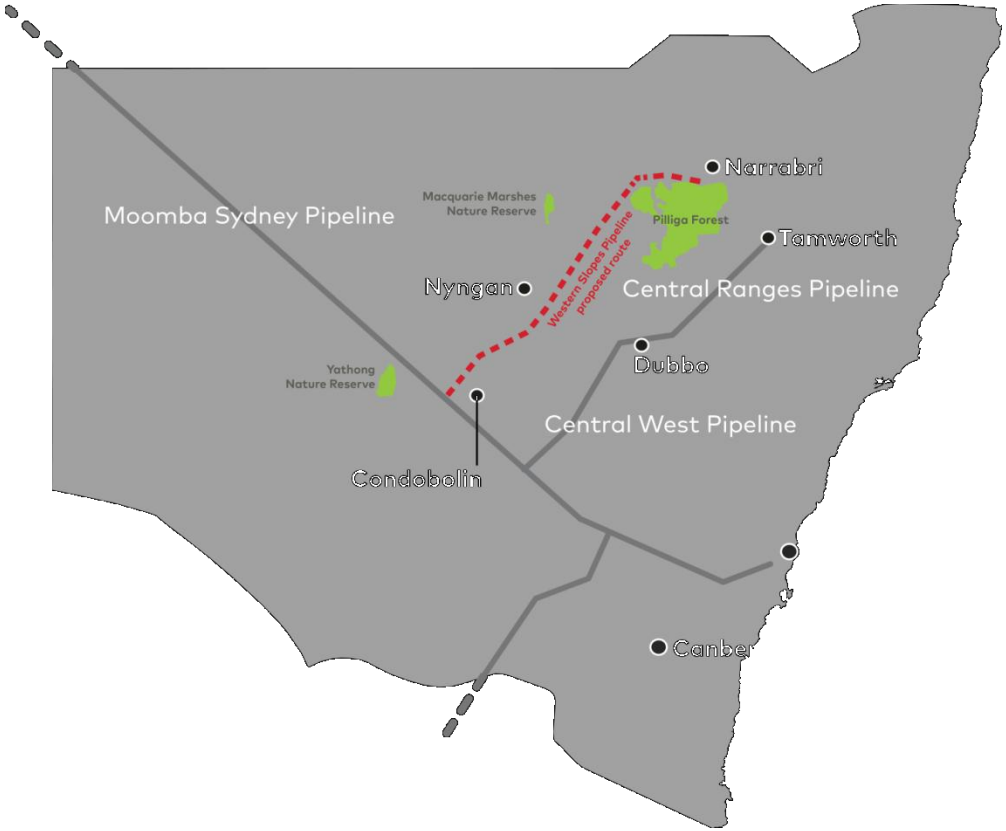
A range of factors were taken into account in selecting the preliminary pipeline alignment (see map). These included environmental values, complexity of terrain, the number of land parcels and landowners, and current land use considerations. Its design will be further refined during the planning phase through landowner and community consultation, detailed environmental studies and consideration of public comment. The Project is ultimately subject to various statutory and other approvals or arrangements being obtained, including Ministerial approval."

Source : APA at https://www.apa.com.au/about-apa/our-projects/western-slopes-pipeline/, accessed 24th April, 2018.

Analysis Of AGL's Plan

Gas Supply – A Major Challenge

"Santos estimates the proposed Narrabri Gas Project has the potential to supply up to 50 per cent of the natural gas needs of more than 1.1 million homes and 30,000 business and industrial customers in NSW. It further estimates about 300,000 jobs rely on a safe and secure supply of natural gas. Accordingly, the Western Slopes Pipeline has the potential to significantly increase the supply of natural gas to the NSW market and play a key role in helping the State achieve greater energy security and economic sustainability."



The likelihood of the Queensland – Hunter Gas Pipeline is looking to be declining.

Source : APA at https://www.apa.com.au/about-apa/our-projects/western-slopes-pipeline/, accessed 24th April, 2018.

Analysis Of AGL's Plan
Renewables

Foe a detailed analysis of the potential for Renewables to replace Liddell's Dispatachable Energy, refer Appendix 'A'

AGL's Plan

NSW Generation Plan

Renewables 1600MW

What Renewables ?

Table 5 Regional modelled generation in New South Wales by generation type (MW)

Status/type	Coal	CCGT [A]	OCGT [B]	Gas other	Solar	Wind	Water	Biomass	Other	Total
Existing [C]	10,160	591 [D]	1,530	147	254	665	2,706	131	9	16,193
Withdrawn	0	0	0	0	0	0	0	0	0	0
Publicly announced withdrawals [E]	2,000	0	0	0	0	0	0	0	0	2,000
Committed	0	0	0	0	145	173	0	0	0	318
Proposed	0	0	500	15	837	4,466	0	16	0	5,834
Additional generation in modelled pathways above existing plant										
Committed and existing	0	0	0	0	145	173	0	0	0	318
Concentrated renewables	0	0	0	0	515	1,196	0	0	0	1,711
Dispersed renewables	0	0	0	0	1,225	1,996	0	0	0	3,221

A. Combined-cycle gas turbine.
B. Open-cycle gas turbine.
C. Existing includes a full snapshot of the current generation fleet as at 7 July 2017. This includes both announced withdrawals still active and non-scheduled generators which are offset in AEMO's electricity demand forecast.
D. Existing CCGT includes Smithfield Energy Facility. In AEMO's 5 June 2017 generation information update, Smithfield Energy Facility published its intention to retire at the end of July 2017. As at August 2017, Smithfield has informed AEMO it intends to return to service in summer 2017–18, with the same generation capacity as was advised to AEMO prior to it withdrawing.
E. These are withdrawals that have been announced to occur within the next 10 years.

Appendix 'B' contains an illustrative example of the extent of Renewables needed to replace the Liddell Generation

Table 6 New committed generation in New South Wales since the 2016 ESOO

Generator	Region	Fuel type	Capacity (MW)	Announced full commercial use date
Large-scale Solar			135	
Manildra PV Solar Farm	NSW	Solar	50	Winter 2018
Parkes Solar Farm	NSW	Solar	55	Summer 2017/18
Griffith Solar Farm	NSW	Solar	30	Summer 2017/18

*Capacity (MW) is **NOT** the same as Generation (MWh)*

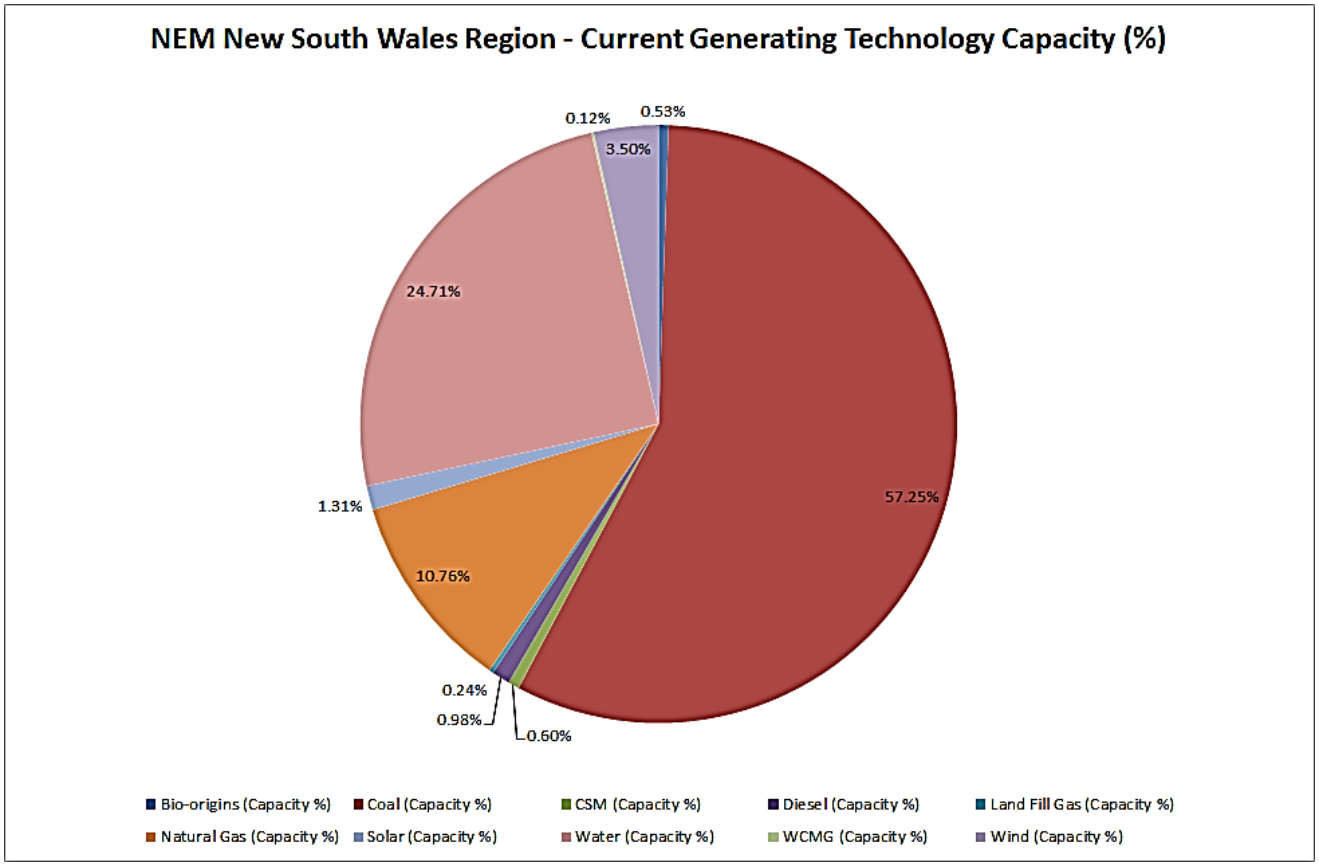
Source : AEMO, 2017, "ELECTRICITY STATEMENT OF OPPORTUNITIES - FOR THE NATIONAL ELECTRICITY MARKET Published: September 2017", Australian Energy Market Operator Limited (AEMO), Melbourne, p. 23.

AGL's Plan

NSW Generation Plan

Renewables
1600MW

What Renewables ?



*Capacity (MW) is **NOT** the same as Generation (MWh)*

Source : Based upon AEMO, 2016, Source: http://www.aemo.com.au/About-the-Industry/Registration/Current-Registration-and-Exemption-lists (dated 03/06/2016)

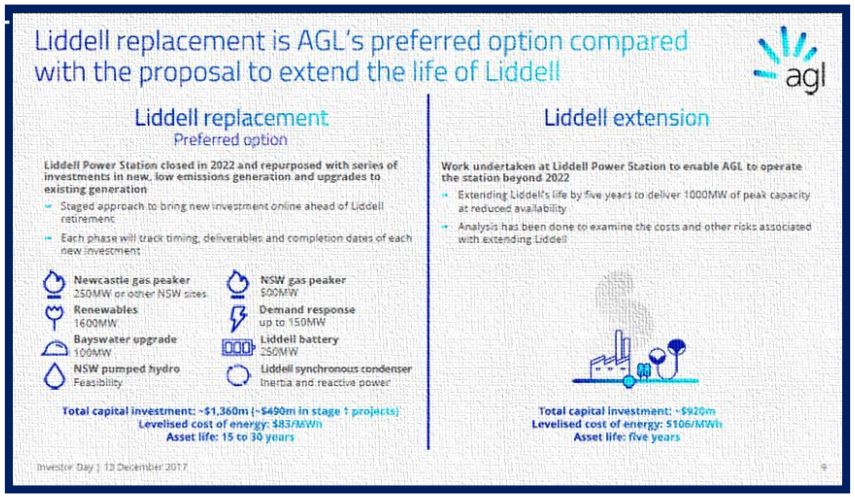
CAPACITY (MW)

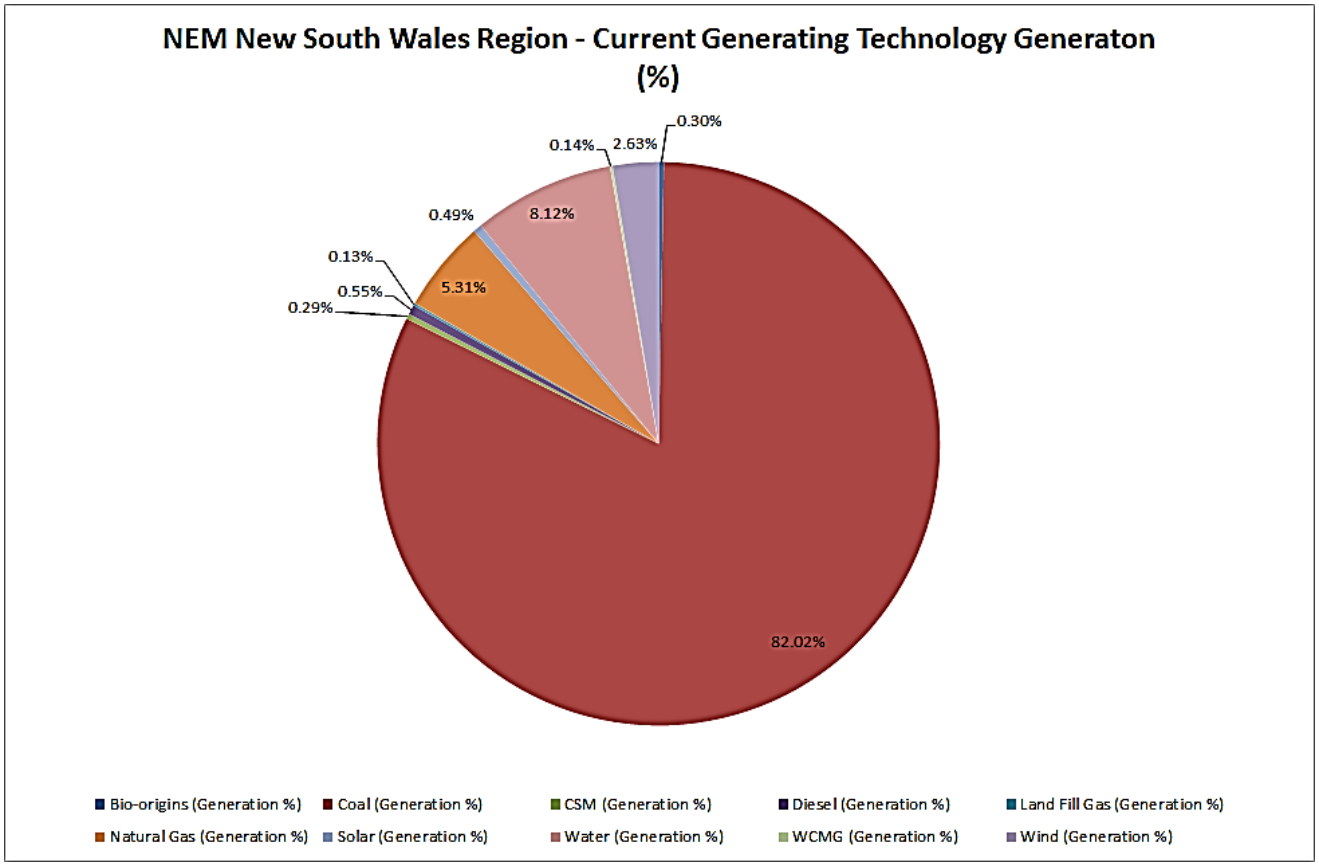
AGL's Plan

NSW Generation Plan

Renewables
1600MW

What Renewables ?





*Capacity (MW) is **NOT** the same as Generation (MWh)*

Source : Based upon AEMO, 2016, Source: http://www.aemo.com.au/About-the-Industry/Registration/Current-Registration-and-Exemption-lists (dated 03/06/2016)

ENERGY (MWh)

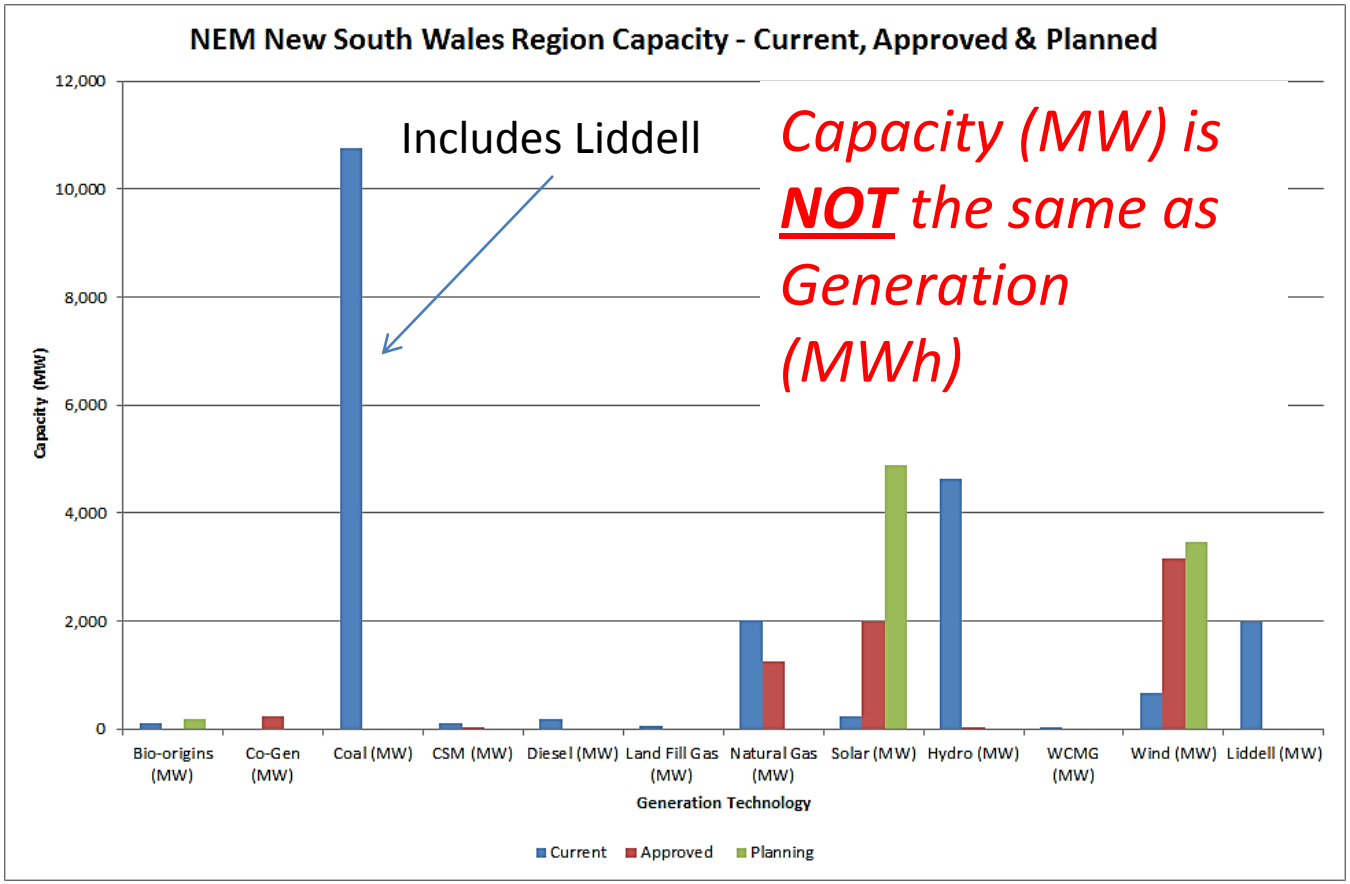
AGL's Plan

NSW Generation Plan

Renewables 1600MW

What Renewables ?

Note : The following Analysis is based upon AEMO and NSW Department of Planning's Major Projects Register with adjusted Capacity Factors and Project Probabilities



NSW GOVERNMENT Planning & Environment Resources & Energy

Source : New South Wales DP&E – R&E, 2017, http://majorprojects.planning.nsw.gov.au/page/project-sectors/transport--communications--energy---water/generation-of-electricity-or-heat-or-co-generation/ , accessed 2nd May, 2018
And
AEMO, 2016, Source: http://www.aemo.com.au/About-the-Industry/Registration/Current-Registration-and-Exemption-lists (dated 03/06/2016)

CAPACITY (MW)

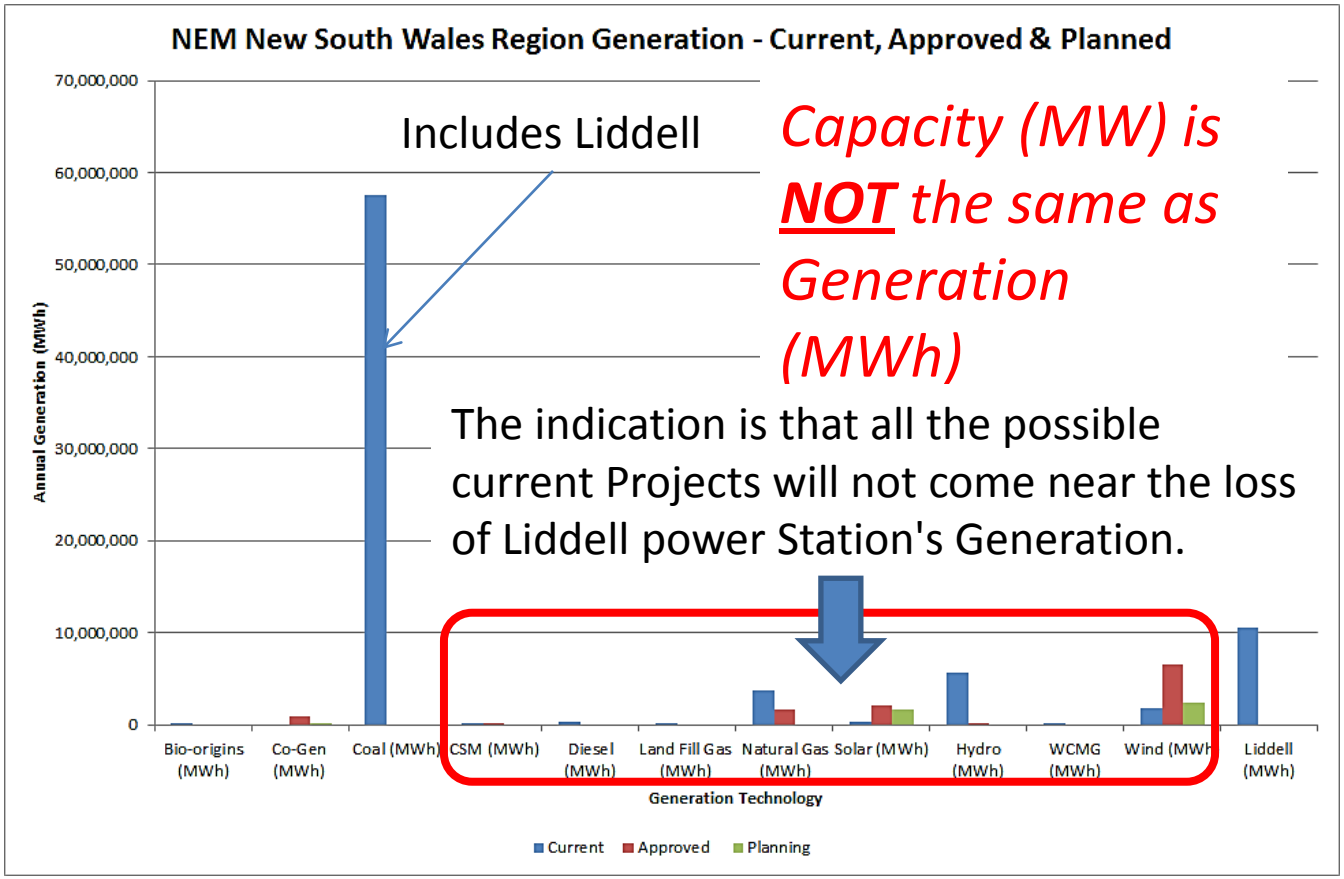
AGL's Plan

NSW Generation Plan

Renewables
1600MW

What Renewables ?

Note : The following Analysis is based upon AEMO and NSW Department of Planning's Major Projects Register with adjusted Capacity Factors and Project Probabilities



NSW GOVERNMENT | Planning & Environment Resources & Energy

Source : New South Wales DP&E – R&E, 2017, http://majorprojects.planning.nsw.gov.au/page/project-sectors/transport--communications--energy---water/generation-of-electricity-or-heat-or-co-generation/ , accessed 2nd May, 2018
And
AEMO, 2016, Source: http://www.aemo.com.au/About-the-Industry/Registration/Current-Registration-and-Exemption-lists (dated 03/06/2016)

ENERGY (MWh)

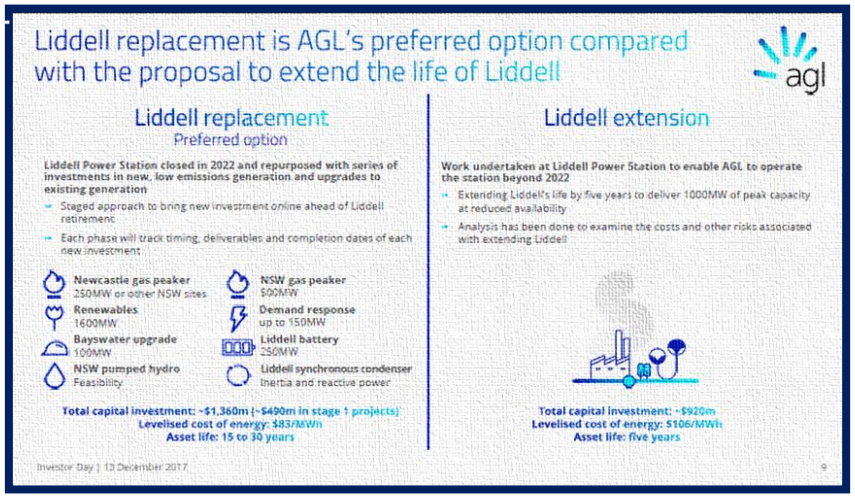
AGL's Plan

NSW Generation Plan

Renewables
1600MW

What Renewables ?

Note : The following Analysis is based upon AEMO and NSW Department of Planning's Major Projects Register with adjusted Capacity Factors and Project Probabilities



Appendix 'A' contains an illustrative example of the extent of Renewables needed to replace the Liddell Generation

	Bio-origins	Co-Gen	Coal	CSM	Diesel	Land Fill Gas	Natural Gas	Solar	Hydro	WCMG	Wind	Liddell
Capacity Factor	24%	60%	61%	21%	24%	24%	21%	16%	14%	50%	32%	60%

	Projects Approved	Projects In Planning
Probability Of Projects Proceeding	75%	25%

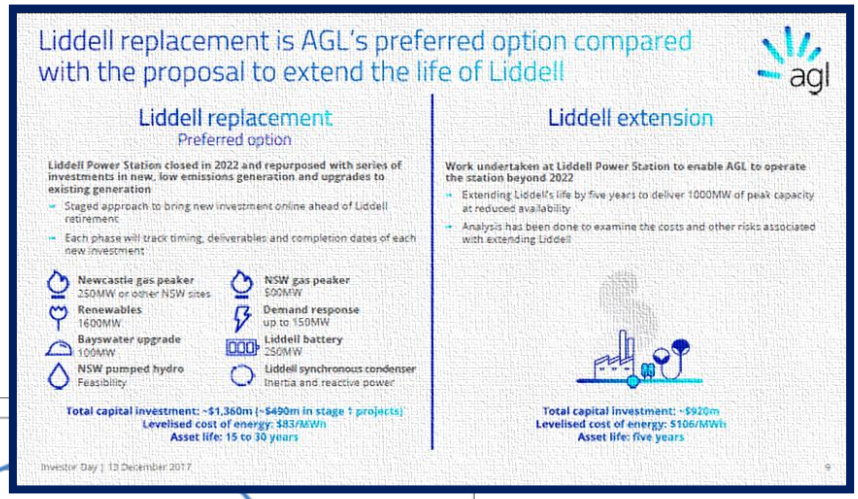
P
Probability

Capacity (MW) is ***NOT*** *the same as Generation (MWh)*

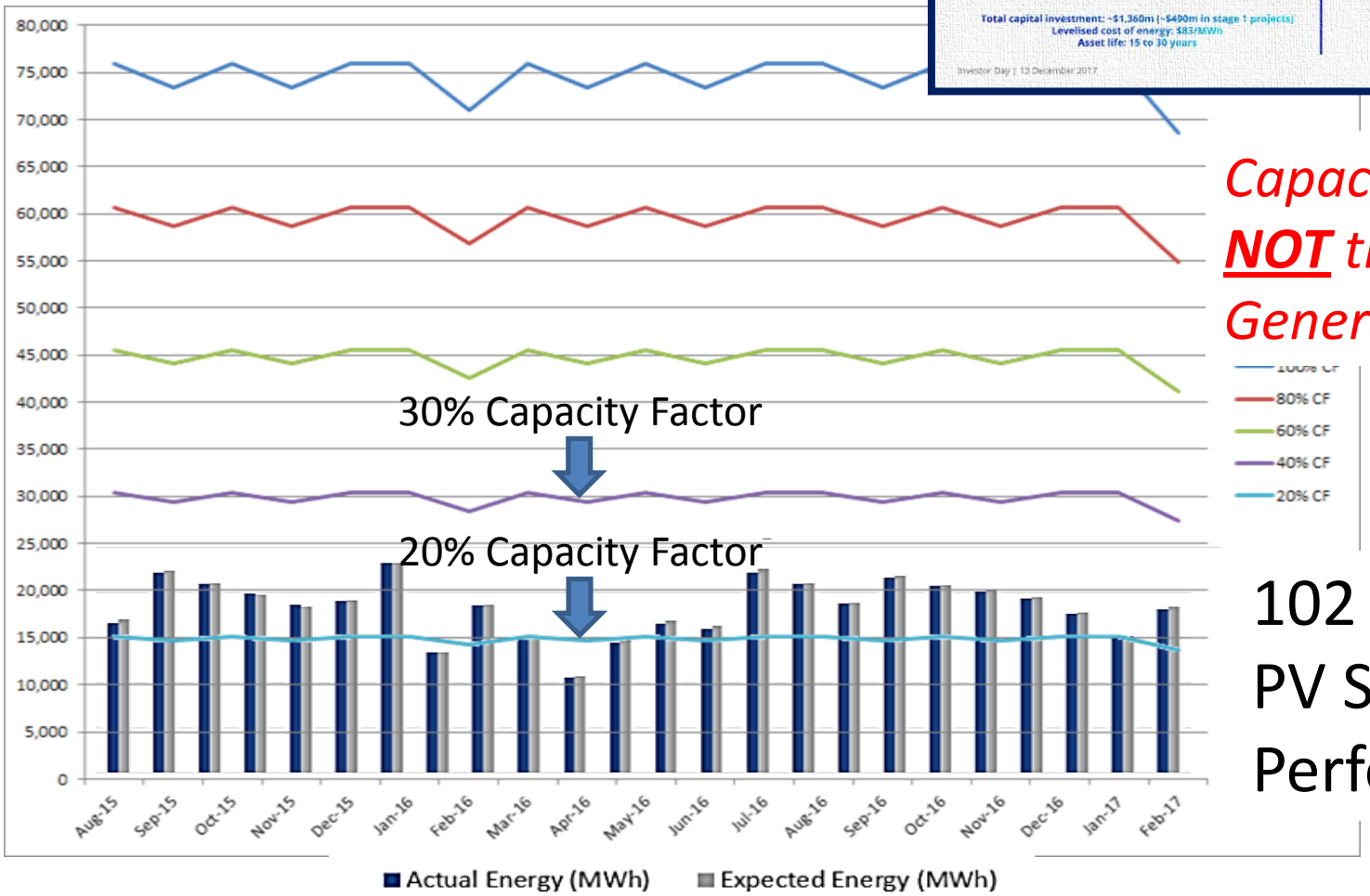
AGL's Plan

NSW Generation Plan

Renewables
1600MW



*MW are **NOT** the same as MWh*



*Capacity (MW) is **NOT** the same as Generation (MWh)*

102 MW Nyngan PV Solar Plant Performance

Analysis Of AGL's Plan

Bayswater Upgrade

AGL's Plan

NSW Generation Plan

Bayswater upgrade
100MW

Planning is understood to be underway. The question is around the future reliability of the upgraded plant. Bayswater's "sister" station, Eraring Power Station underwent A capacity upgrade between august 2009 and October 2011.

Eraring was upgrades from a capacity of 660 MW to 720 MW. The plant's subsequent performance has been lacklustre.

It is also questionable if AGL only undertake a Turbine upgrade with out considering other plant items such as Boilers.

Eraring Power Station Performance

Plant availability is trending downward due to plant failures and upgrades

Performance Information

Operational Performance

Eraring Energy manages a diverse portfolio of generating assets comprising thermal coal, hydro and wind. Most of its generation comes from Eraring Power Station, which uses thermal coal. The power station produced 11,895 gigawatt hours of electricity in 2011–12 (13,971 2010–11).

Generation has trended downwards over the past three years primarily due to planned outages for work undertaken on the capacity upgrade project at Eraring Power Station and recent plant failures.

Some of the indicators Eraring Energy uses to assess its electricity generation performance are shown below.

Year ended 30 June	Actual			
	2012	2011	2010	2009
Generation of electricity - gigawatt hours as generated				
Thermal coal	11,895	13,971	14,116	15,426
Hydro	450.3	350.0	123.0	101.0
Wind	23.0	23.0	27.0	30.0
Total	**12,368.3**	**14,344.0**	**14,266.0**	**15,557.0**
Eraring PS Plant availability (%)	67.4	74.6	78.7	86.1
Thermal efficiency as generated (%)	37.7	37.9	37.8	37.8

Source: Eraring Energy (unaudited).

Source : Audit Office of New South Wales, 2012, "Eraring Energy - Audit Office of New South Wales" at http://www.audit.nsw.gov.au/ArticleDocuments/253/08_Volume_Four_2012_Eraring_Energy.pdf.aspx?Embed=Y Accessed 24th April 2018

Rubicon

AGL's Plan

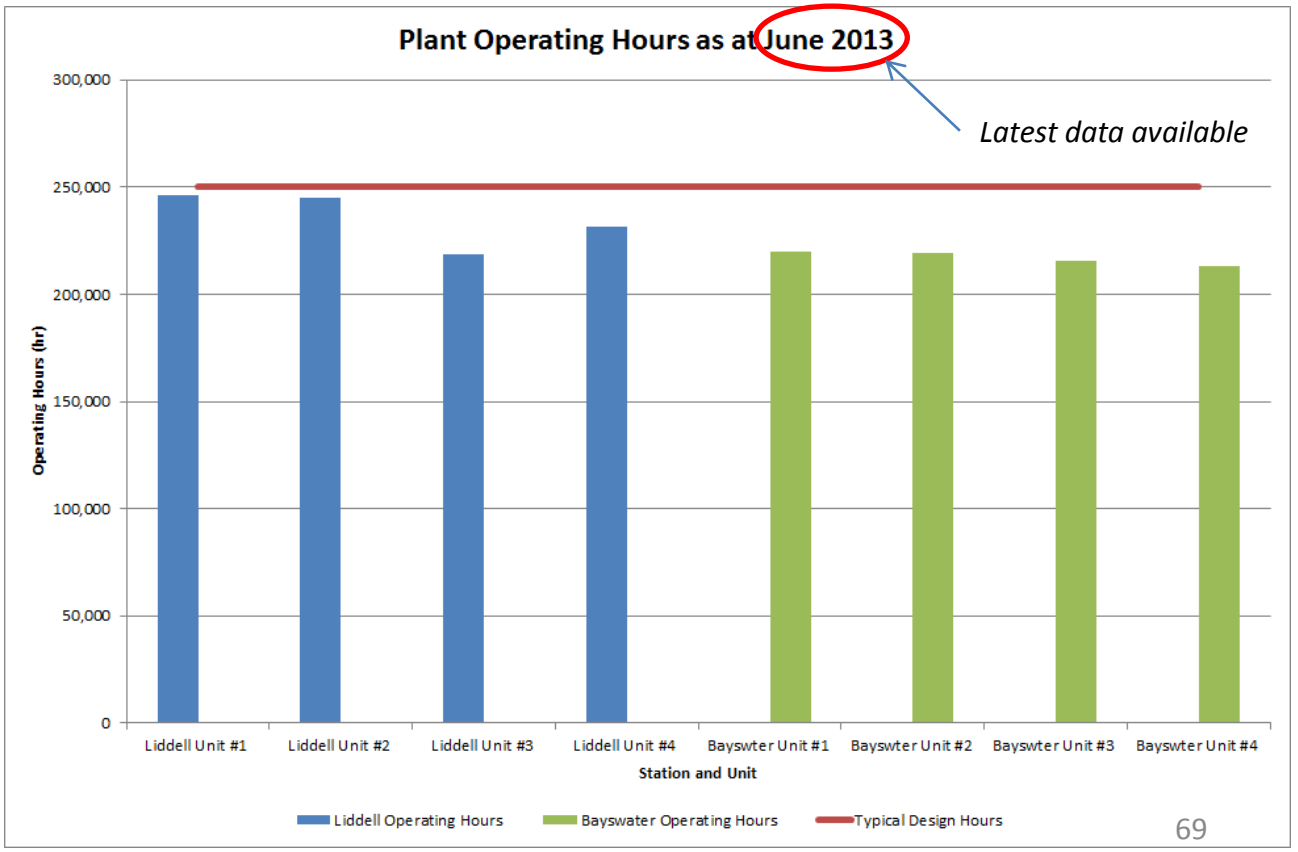
NSW Generation Plan

Bayswater upgrade
100MW

It is worth noting that the critical issue of Thermal (Coal and Gas) Fired Power Station life, this is a rather complex subject. Terms such as "50 Year Old" Power Stations is somewhat misleading.

The designs of such plants worked on operating hours along starts and start conditions as a basis for deign. It is all around about Stress in metal components really.

So interestingly, when we compare the Operating hours of Liddell with those of Baysawater, the difference is only marginal.



Analysis Of AGL's Plan

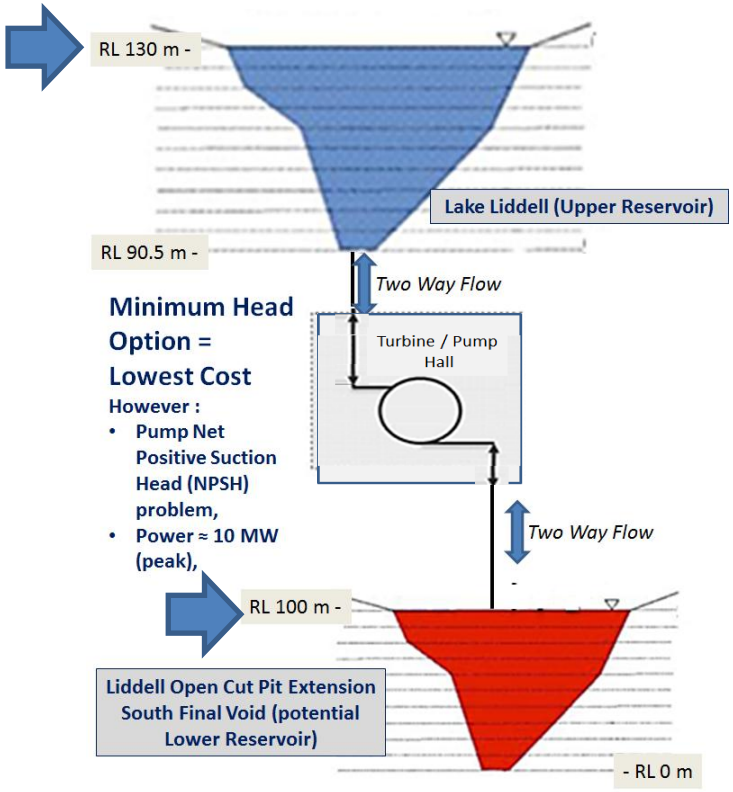
Pumped Storage Hydro

AGL's Plan

NSW Generation Plan

NSW pumped hydro Feasibility

If based upon Lake Liddell, long horizontal distances to any potential mine voids, whilst offering only low head difference



Liddell Open Cut Pit Extension Void Option

Net Head (Δh) ≈ 30 m

Water Conduit Length (L) ≈ 3,500 m

Length to Head Ratio ≈ 167

Typical Pumped Storage Hydro (L/Δh) Ratios ≈ 3 to 13

Therefore : L/Δh = 167

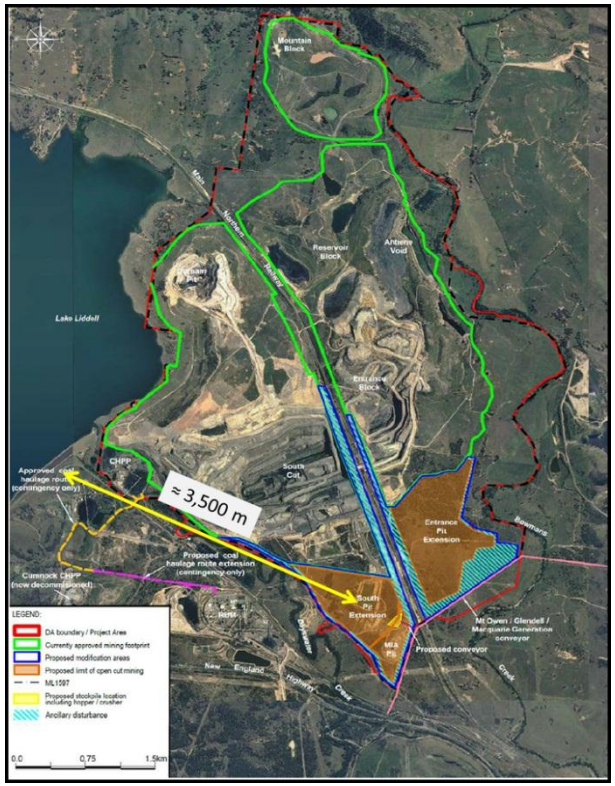
This is Not A Generating Facility But Rather Represents A Loss Of Energy Generated !

AGL's Plan

NSW Generation Plan

NSW pumped hydro
Feasibility

If based upon Lake Liddell, long horizontal distances to any potential mine voids, whilst offering only low head difference



This is Not A Generating Facility But Rather Represents A Loss Of Energy Generated !

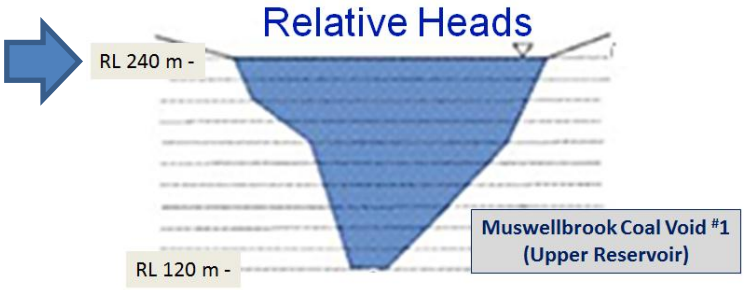
"… A low utilization factor essentially makes it a very expensive monument with no actual utility. Also, the costs of construction can quickly balloon out of control such as with the Helms Pumped Storage facility, whose initial cost estimate of $200 million ballooned to $600 million in the course of several years. Severe caution needs to be taken to ensure that that does not happen, as a $2,327/kW capital cost would overshadow any potential savings that could be earned from the difference in O&M."

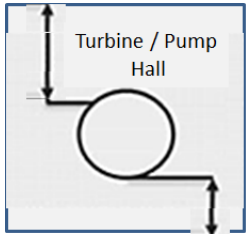
Source : Oscar Galvan-Lopez,), 2014, "The Cost of Pumped Hydroelectric Storage" December 11, 2014, PH240, Stanford University, Stanford, California.

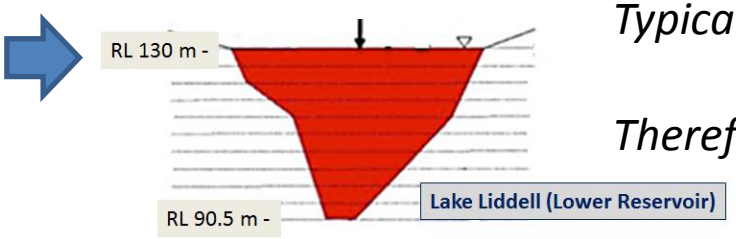
AGL's Plan

NSW Generation Plan

NSW pumped hydro
Feasibility







If based upon Lake Liddell, there would be long horizontal distances to any potential mine voids, whilst offering only low head difference

Muswellbrook Coal Mine Voids Option

Net Head (Δh) ≈ 110 m

Water Conduit Length (L) ≈ 15,000 m

Length to Head Ratio (L/Δh) ≈ 136

Typical Pumped Storage Hydro (L/Δh) Ratios ≈ 3 to 13

Therefore : L/Δh = 136

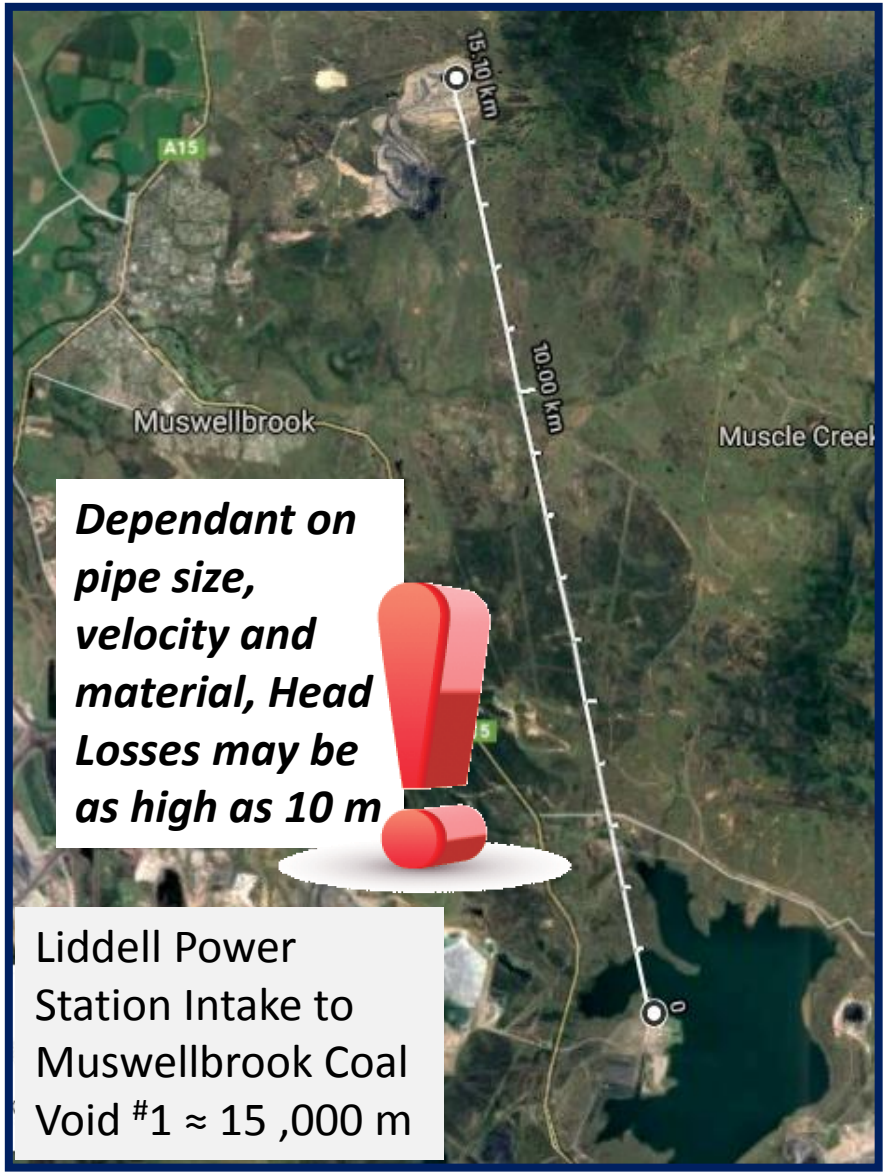
This is Not A Generating Facility But Rather Represents A Loss Of Energy Generated !

AGL's Plan

NSW Generation Plan

NSW pumped hydro
Feasibility

Rubicon



Dependant on pipe size, velocity and material, Head Losses may be as high as 10 m

Liddell Power Station Intake to Muswellbrook Coal Void #1 ≈ 15 ,000 m

Liddell Power Station Intake to Muswellbrook Coal Void #2 ≈ 13,430 m

AGL's Plan

NSW Generation Plan

NSW pumped hydro Feasibility

Pump Storage Hydro clearly does offer large storage capability. However, the opportunities in Australia are rather limited and Low Head concepts such as may be being put forward by AGL at Liddell do not seem realistic if at all feasible.

- Liddell generation in 2016 = 9,037,281 MWh
- Existing Australian (High Head) Pump Storage Plants :
  - Wivenhoe Pump Storage Hydro ≈ **5,000 MWh** Max. Storage
  - Tumut #3 Pump Storage Capability ≈ **10,000#1 MWh** Max. Storage,
  - Shoalhaven Pumped Storage Hydroelectric Scheme ≈ **2,500#1 MWh** Max. Storage.

Note #1 – Calculated from Publically available data

Analysis Of AGL's Plan

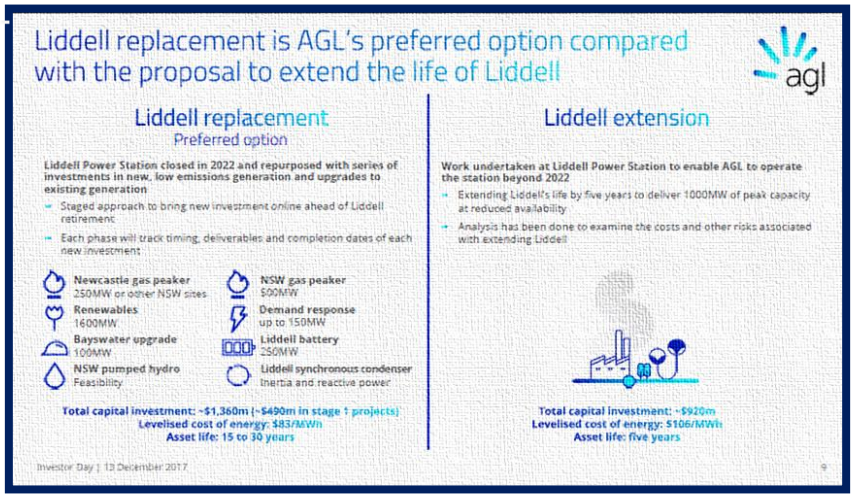
NSW Gas Peaker

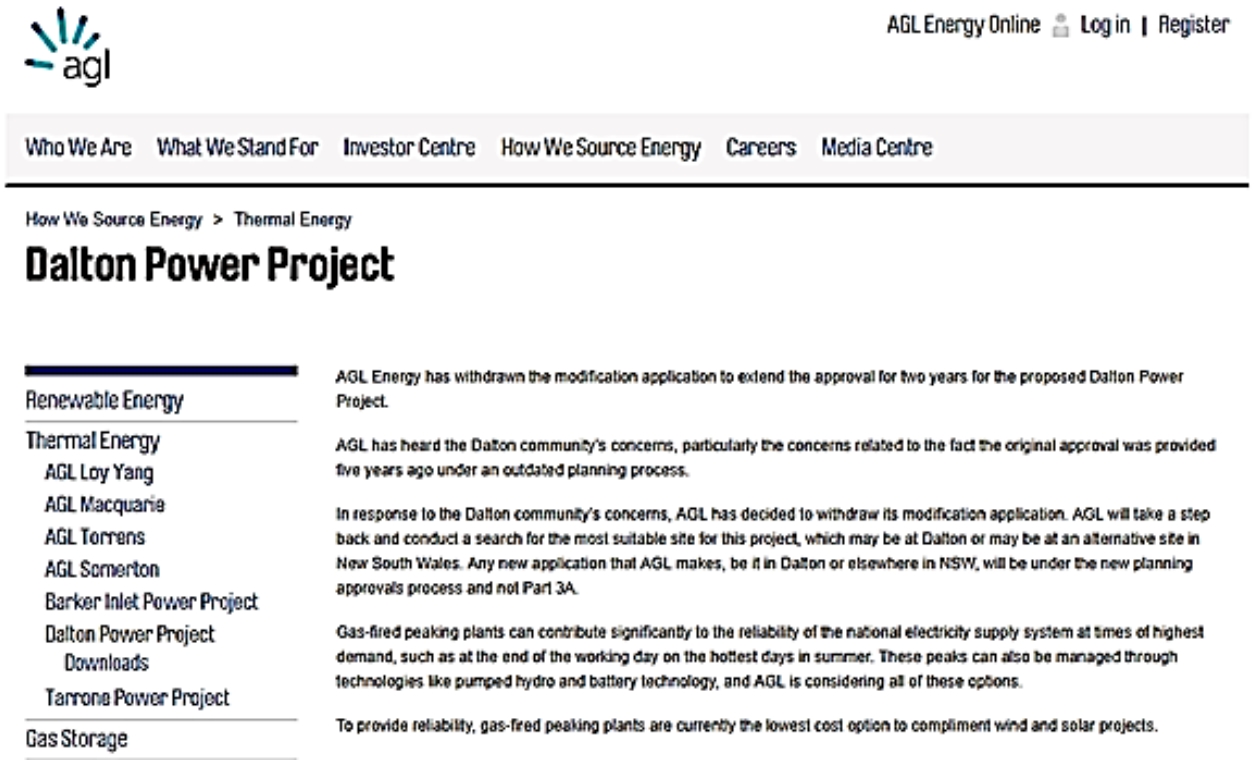
AGL's Plan

NSW Generation Plan

NSW gas peaker
500MW

Dalton Gas Turbine Project abandoned. So, what next ?





Source : AGL Web Site at : https://www.agl.com.au/about-agl/how-we-source-energy/thermal-energy/dalton-power-project, accessed 24/04/18.

Analysis Of AGL's Plan

Liddell Battery

AGL's Plan

NSW Generation Plan

Liddell battery
250MW

Why place such s facility In tThe Hunter Valley ?

What Technology ?

This is NOT a Generating Facility but rather represents a net loss of Energy Generated !

An analysis of "The World's Largest Battery", the Horsndale Battery in South Australia is included in Appendix 'A' of this Paper.

When Examining Generation And Storage Care MUST Be Taken To Understand The Importance Of The Terms POWER and ENERGY.

Energy is 'Joules', Power is 'Joules per second'.

OR

Power is 'Watts' and Energy is 'Watt-hour'. Energy can be stored whereas Power cannot be stored. While energy comes with a time component, Power is an instantaneous quantity.

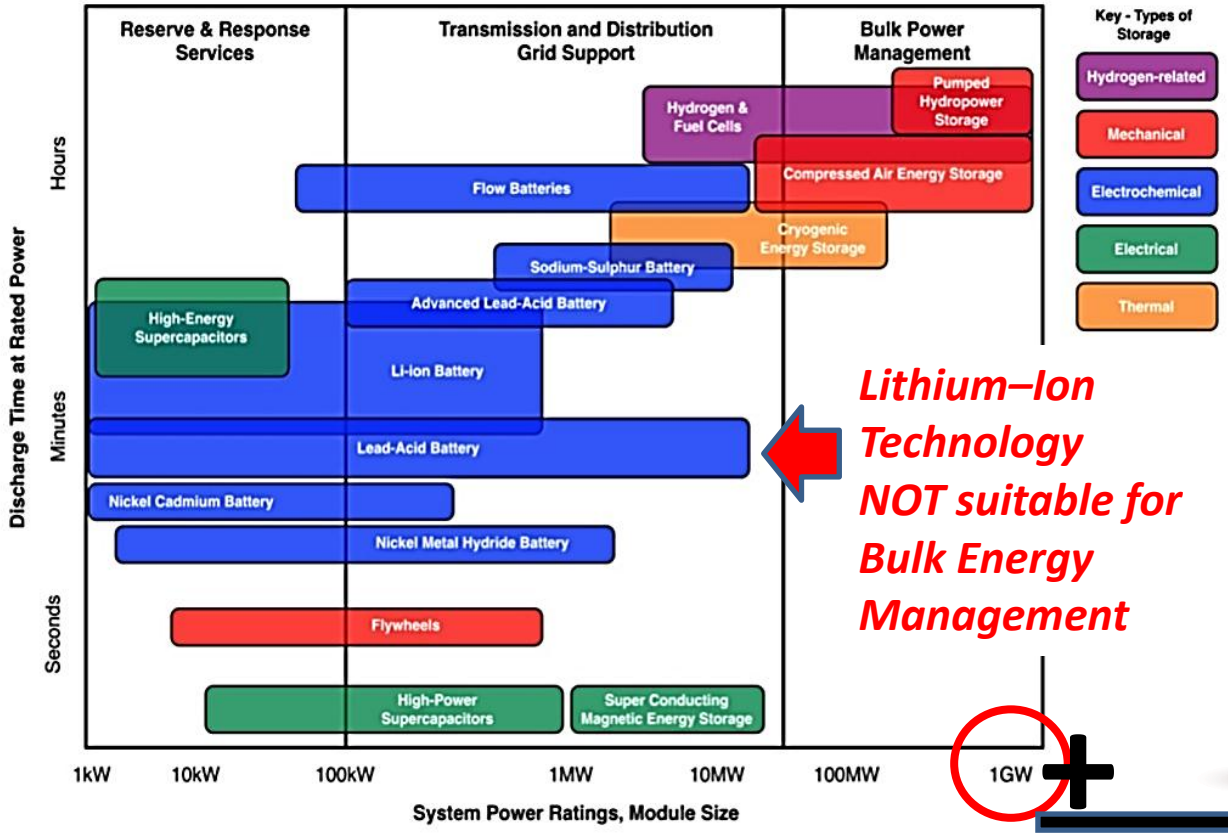
*MW are **NOT** the same as MWh*

AGL's Plan

NSW Generation Plan

Liddell battery
250MW

If Energy Storage (Batteries etc) are seen as a means of Firming Renewables to replace Liddell Energy, the size of Storage would be vast.



Lithium–Ion Technology NOT suitable for Bulk Energy Management

Storage Size Example :

- Liddell Generation at 60% Capacity Factor ≈ 10,512,000 MWh/pa.
- Replacement by Wind with a Capacity Factor of 32% means Wind Farm Capacity ≈ 3,750 MW.
- This means that the Storage Capacity to Firm the Wind ≈ 1,750 MW, and Energy Capacity for 16 hrs = 1,750 x 16 = **28,560 MWh**. !

Analysis Of AGL's Plan
Synchronous Condenser

AGL's Plan

NSW Generation Plan

Liddell synchronous condenser
Inertia and reactive power

There is currently no real market for the services of such a plant.

Why place such a facility in the Hunter Valley near a large operating Power Station rather than near a major load centre ?

This is Not A Generating Facility But Rather Represents A Loss Of Energy Generated !

AGL's Plan

Synchronous Condensers

Source : AGL, 2017, Investor Day Webcast Transcript – Business Update, https://www.agl.com.au/-/media/AGL/About-AGL/Documents/Investor-Centre/AGL-4_-Capital-allocation.pdf?la=en&hash=AA4D01F4388C41303E45CE17B00CA24E270FC731 p.17, Accessed : 24th April, 2018

AGL Energy Limited 2017 Investor Day webcast transcript, 13 December 2017

. . .

"**Speaker 8:**

We've got a question on the web chat from a gentleman by the name of Rob in South Australia. He's asking about the synchronous condenser. What is its role and the need for it in the context of South Australia where there's already a high degree of renewables penetration operating without similar technologies? Could you go into more detail about the role of the synchronous condenser in New South Wales?

Andy: *(Andrew Vesey , AGL Energy Managing Director and CEO)*

Doug, why don't you give us **everything** you know about synchronous condensers?

Doug: *(Dough Jackson, AGL Energy Executive General Manager Group Operations)*

Alright, thank you. Synchronous condensers are fairly low cost and proven technology **way of creating inertia**. The South Australia example, inertia's required. There's some options to think about and we're looking at that as well. In New South Wales it's not only creating inertia for the future, because there will be a time when a lot of that generation starts retiring, as Brett pointed out in 10 years plus. The question for us is, what do you with the existing asset to create inertia? When you take the retirement of Liddell into account, you will lose inertia in the system. Yes, there will be other inertia. There's also localized voltage support that will be possible as well. As we take a 1,600 megawatts of generation out, that will make a difference. This gives you the opportunity to repurpose existing assets, continue them on to provide ongoing services to the grid, **both for inertia, but also for voltage support in the shorter term.** That helps you bring renewables and intermittent generation forms in, in a more

" *Note : **Emphasis** added*. . . .

AGL's Plan

NSW Generation Plan

Liddell synchronous condenser
Inertia and reactive power

The comments made during the *AGL 2017, Investor Day Webcast Transcript – Business Update* (quoted above), are somewhat curious. If the suggestion is the location of Synchronous Condensers on the Liddell site this seems to show a surprising lack of understanding of holistic Electricity Generation + Transmission Systems work.

Why place such a facility in the Hunter Valley near a large operating Power Station rather than at the end of the transmission lines near a major load centre ?

Long transmission lines, when un-energised or carrying reduced loads, tend to experience voltage rises **towards consumers** due to the lines' capacitive effect.

When transmission lines are charged, they tend to experience **voltage drops as the lines run further *from* generation sources** due to the effects of mutual induction and of a typically inductive network load.

Synchronous condensers, installed **where they are most needed**, help support transmission voltage and improve transmission line capacity and efficiency.

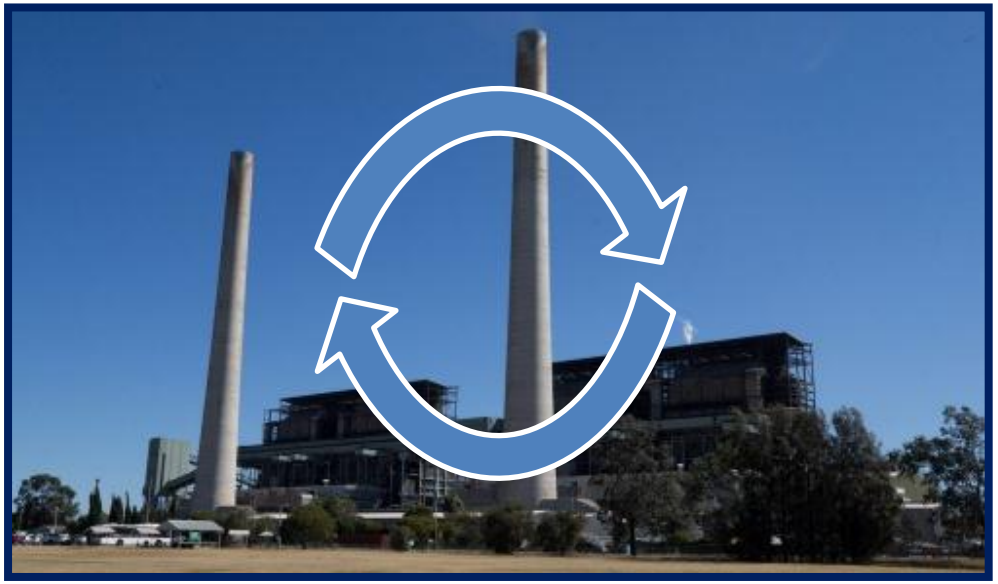
Grids with low short-circuit power capacity and high instability are optimised with Synchronous Condensers, due to their intrinsic characteristics of adding short-circuit power capacity and Network inertia **to the connection point**.

AGL's Plan

NSW Generation Plan

Liddell synchronous condenser
Inertia and reactive power

It is not technically correct to suggest placing such a facility in the Hunter Valley near a large operating Power Station (Bayswater PS) rather than at the end of the transmission lines near a major load centre ?



This does not make sense on this site !

Analysis Of AGL's Plan

Likelihood, Effect and Cost

AGL's Plan

NSW Generation Plan

Projects to replace Liddell have been staged to adapt to an evolving market

Stage	Description	Projects	Cumulative capex[1]	Cumulative LCOE[2]
Approved Projects	Projects are under construction having already achieved Final Investment Decisions	**Wind** - Coopers Gap| 453MW - Silverton| 200MW	Committed	$62/MWh
Stage 1 Feasibility 2019 or earlier[4]	Stage 1 comprises projects required to balance AGL's committed customer needs consistent with the Government's proposed National Energy Guarantee	**Approved in NSW Generation Plan** - Bayswater upgrade| 100MW - Solar offtake (NSW)| 300MW - Synchronous condenser Liddell - Demand response| up to 20MW **Feasibility** - Newcastle gas peaker[3] | 250MW	$490m	$76/MWh
Stage 2 Feasibility 2020[4]	Stage 1 and 2 comprise projects required to meet AGL's potential uncontracted customer demand (C&I) assuming that other market participants respond to market signals	- NSW gas peaker| 500MW - Renewables| 500MW - Demand response| up to 50MW	Stages 1 and 2 $1,100m	$83/MWh
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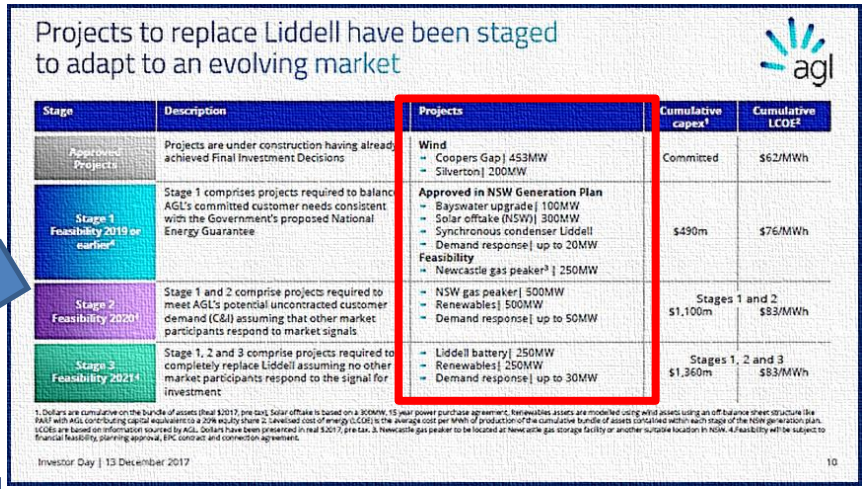
Source : AGL, 2017, https://www.agl.com.au/-/media/AGL/About-AGL/Documents/Media-Center/Investor-Center/AGL-Investor-Day-2017---Presentation-Slides.pdf?la=en&hash=CFEF07F182BD9ED347C66998CF5F13CB203DD9BD
Accessed : 24th April, 2018

AGL's Plan

NSW Generation Plan



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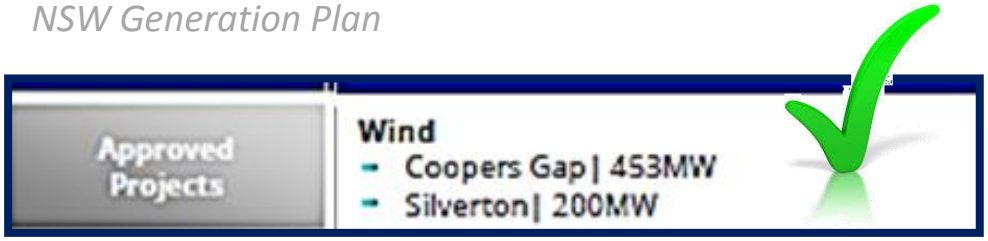


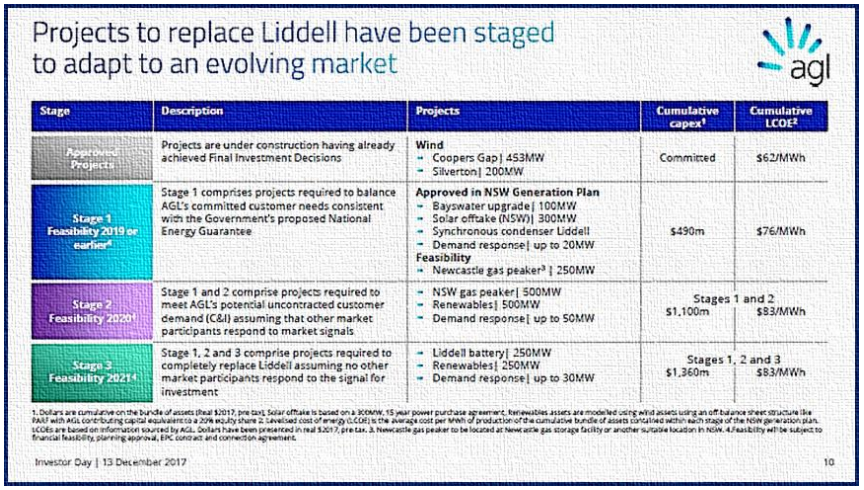
Construction Underway.

Coopers Gap is in Queensland !

Silverton is near Broken Hill with significant Transmission losses !

Both are NOT new and have been on the AGL project list for a number of years

*MW are **NOT** the same as MWh*



Projects to replace Liddell have been staged to adapt to an evolving market

agl

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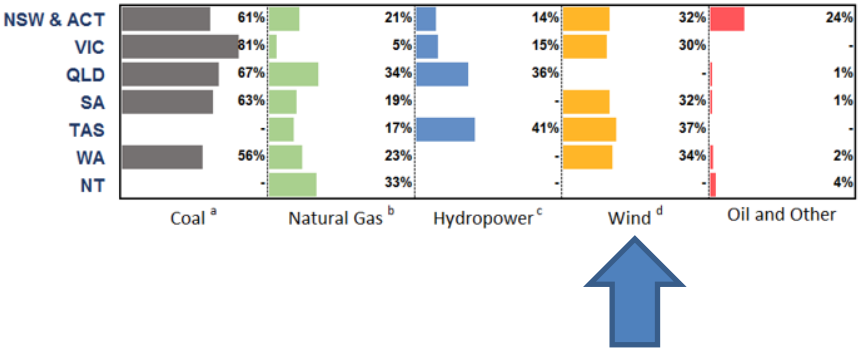
*Capacity (MW) are **NOT** the same as Generation (MWh)*

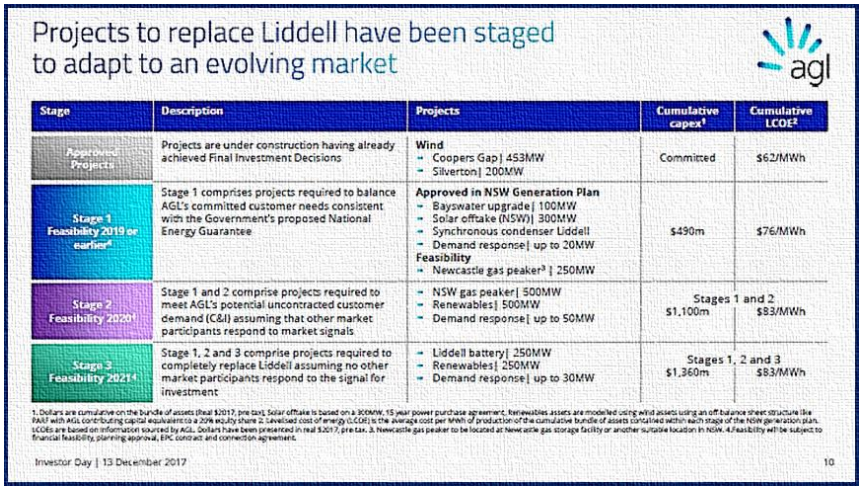
Principal plants' capacity factor (%) in 2015-16



Source: Electricity Gas Australia 2017, Australian Energy Council
Note: The figures exclude solar and FY 2015-16 is a leap year, 8,784-hour was used in calculation a) In South Australia, Northern Power Station was the only operating coal power station, which operated for 314 days during FY 2015-16 before its final closure on 10th of May 2016. Capacity load factor is calculated based on the 314 day period. b) Including coal seam methane and coal waste methane c) Excluding pump storage plants d) Including both principal and embedded wind generators

AGL's Plan

NSW Generation Plan



Projects to replace Liddell have been staged to adapt to an evolving market

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Bayswater Upgrade. ✓

Newcastle Gas Peaker. ?

Solar Offtake.
No New Generation !

Synchronous Condenser at Liddell. No new Generation !

Demand Response.
No new Generation !

AGL's Plan

NSW Generation Plan

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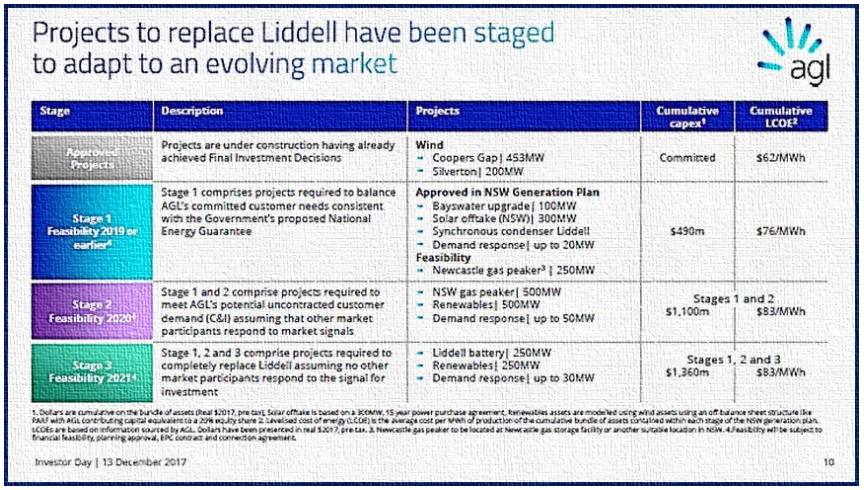

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NSW Gas Peaker. ?

Renewables. ?

Demand Response ! 

*Capacity (MW) is **NOT** the same as Generation (MWh)*

50 MW ?

For how long ?

For 1 day that ≈ 76,433 Homes without Electricity

Note : On Average a New South Wales Home uses 15.7 kWh / day. *Source* : Ausgrid 2016-17 Local Council Community Electricity Report.

*MW are **NOT** the same as MWh*

Rubicon

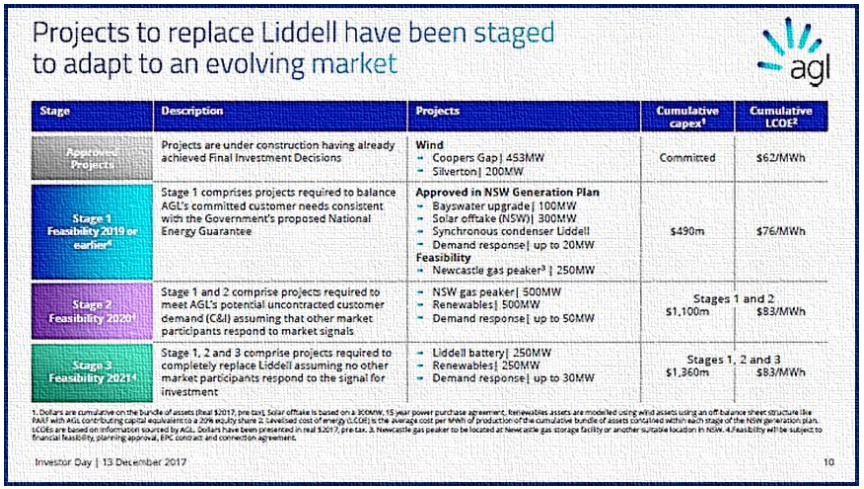
AGL's Plan

NSW Generation Plan

Stage 3 Feasibility 2021[4]

- Liddell battery| 250MW
- Renewables| 250MW
- Demand response| up to 30MW

?



Projects to replace Liddell have been staged to adapt to an evolving market

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Liddell Battery ! ?

Why at Liddell ?

Renewables. ?

Demand Response ! 

*Capacity (MW) is **NOT** the same as Generation (MWh)*

30 MW ? IS this additional to Stage 2 ?

For How Long ?

For 1 day that ≈ another 45,860 homes without Electricity

Note : On Average a New South Wales Home uses 15.7 kWh / day. *Source* : Ausgrid 2016-17 Local Council Community Electricity Report.

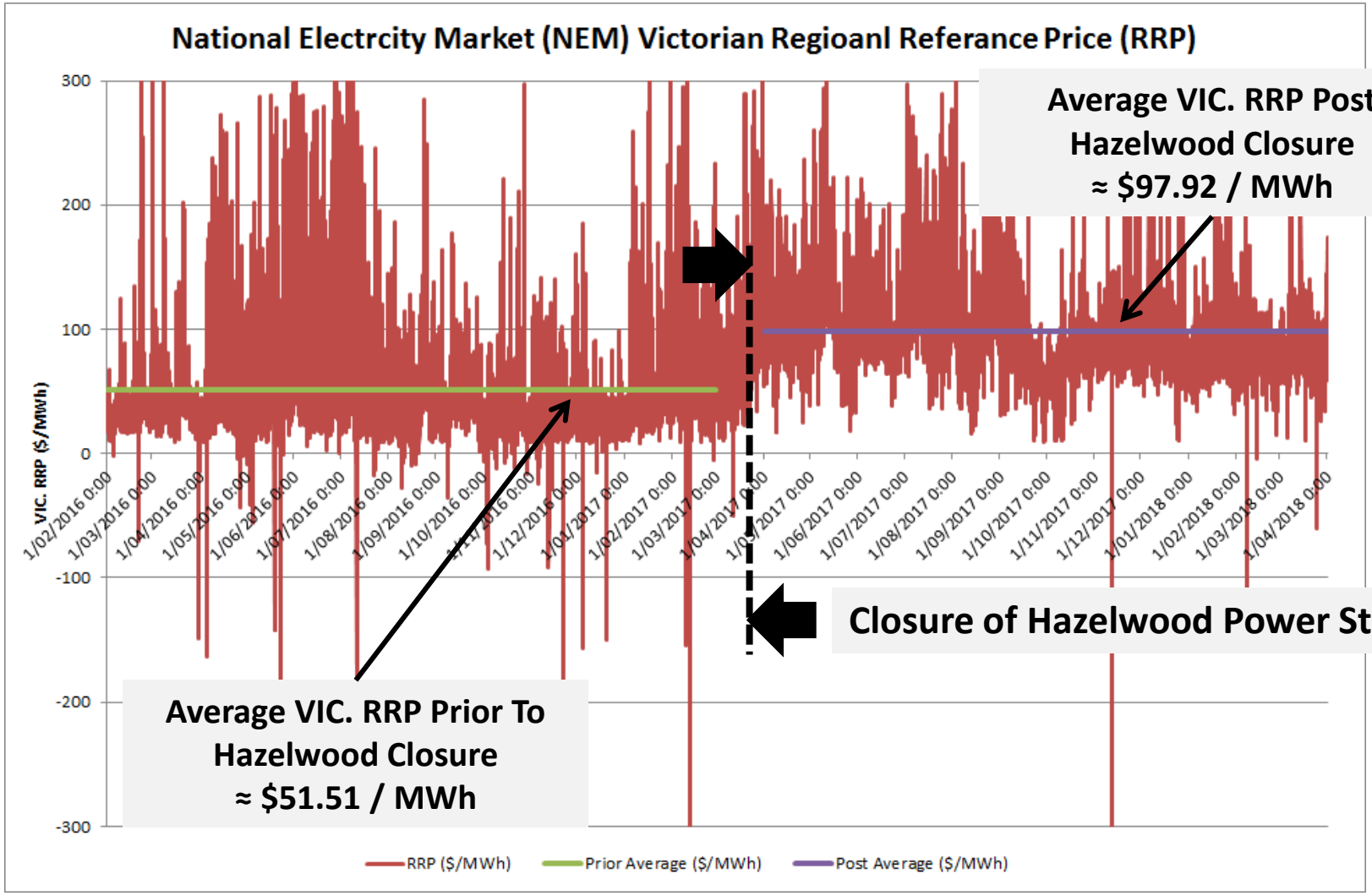
*MW are **NOT** the same as MWh*

Rubicon

Effect Of Closures Of Base Load

Effect Of Recent Base Load Coal Station Closures

Closure of Hazelwood Power Station, Victoria

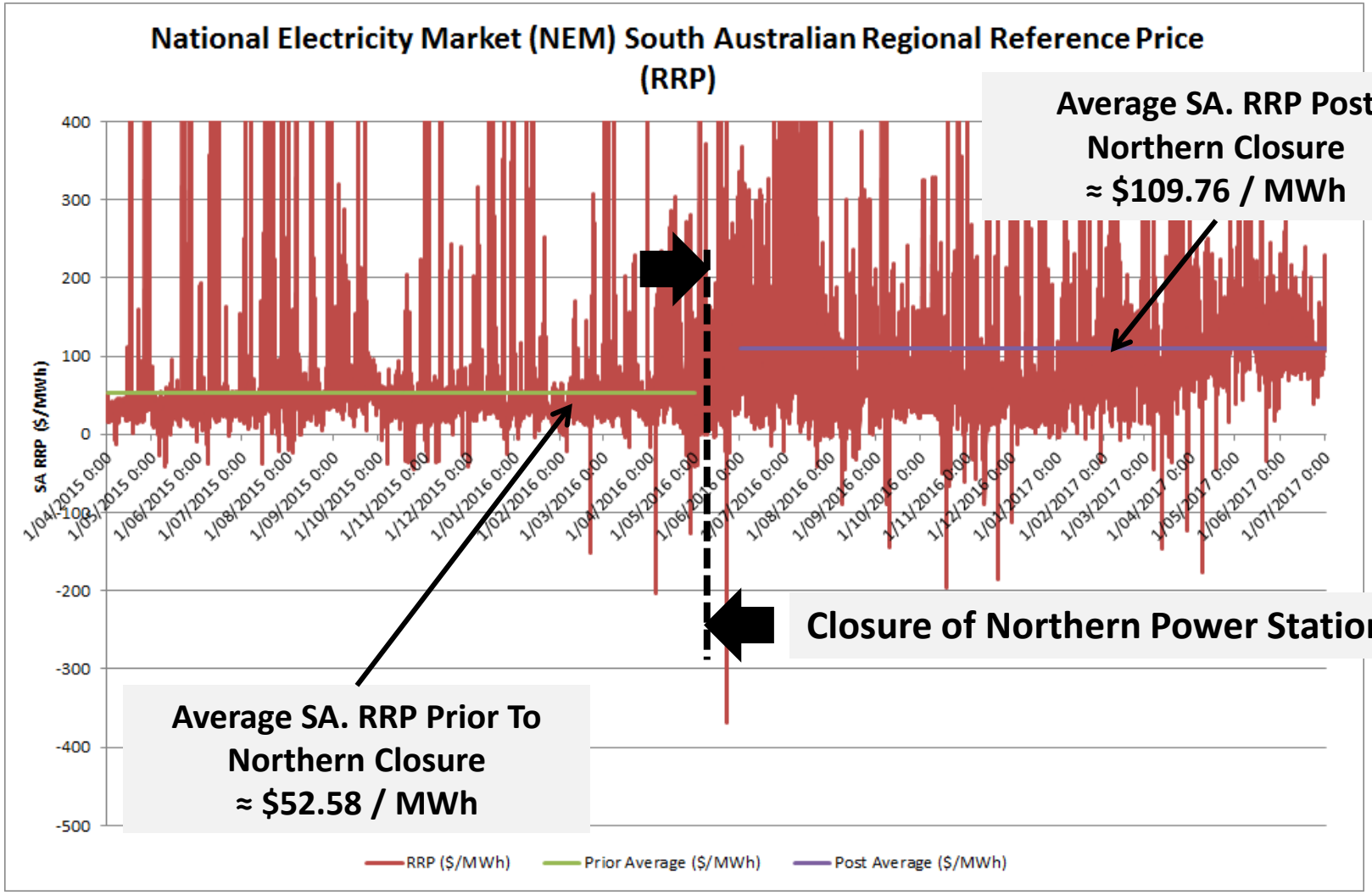


Comparing the Average VIC. RRP for 1 Year Prior and 1 Year Post Hazelwood Closure is showing Step Change of ≈ 90% Increase.

Effect Of Closures Of Base Load

Effect Of Recent Base Load Coal Station Closures

Closure of Northern Power Station, South Australia

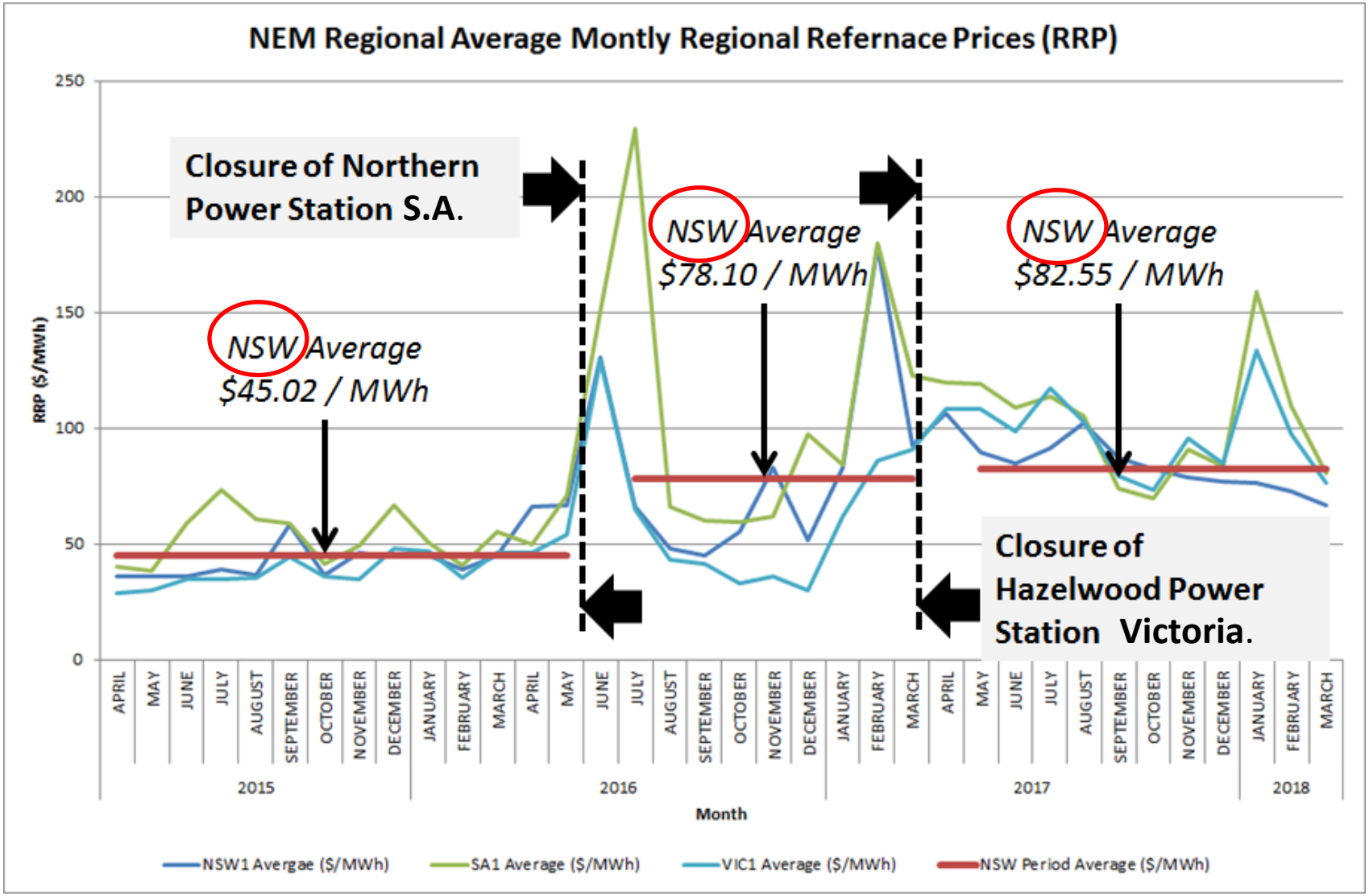


Comparing the Average SA. RRP for 1 Year Prior and 1 Year Post Northern Closure is showing Step Change of ≈ 109% Increase.

Effect Of Closures Of Base Load

Effect Of Recent Base Load Coal Station Closures

Closure of Base Load Plant in South Australia and Victoria are having effects across the NEM



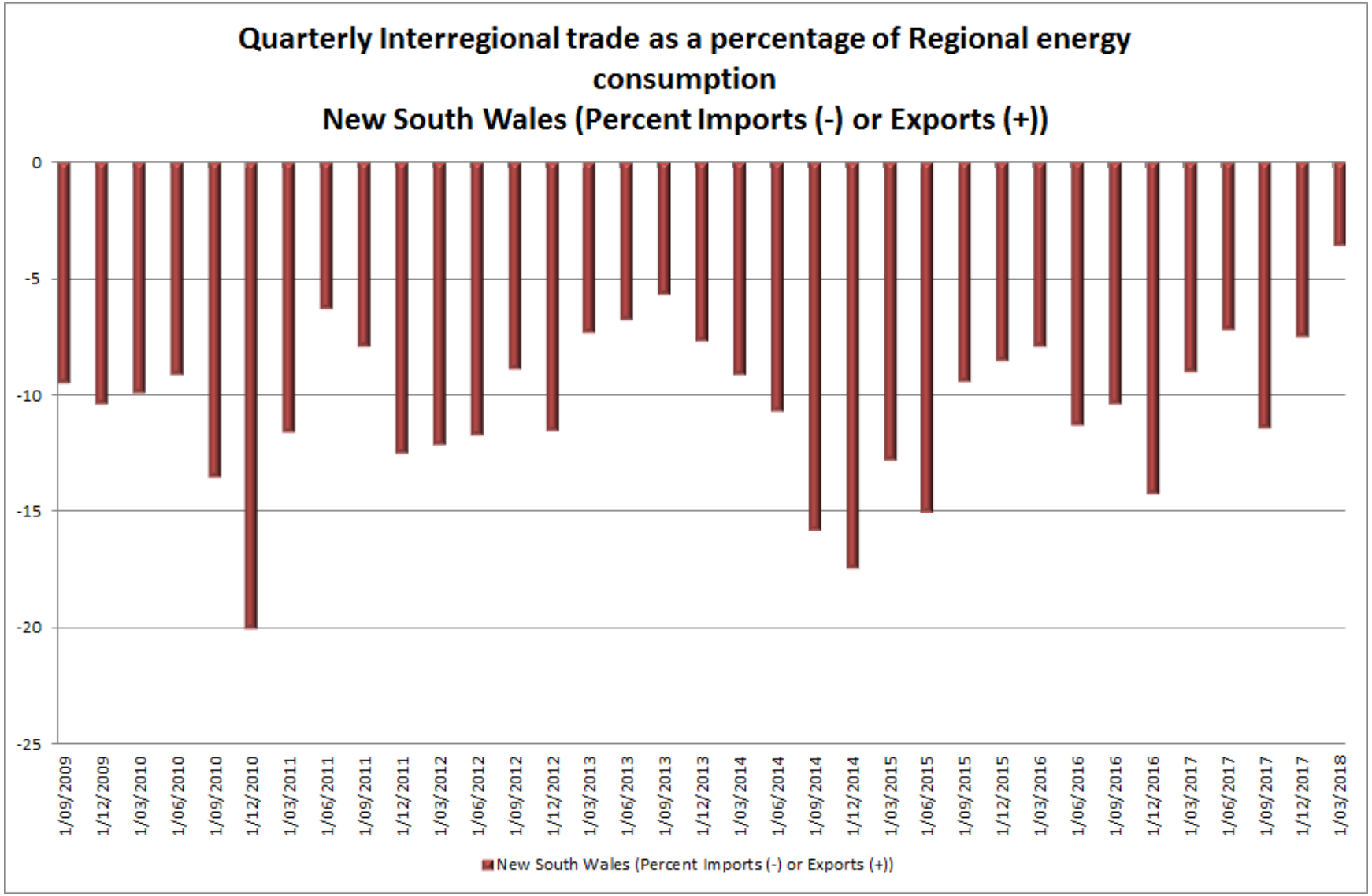
The closure of Base Load Generation Across The NEM is having a compounding effect. This may mean the potential magnifying effect of Liddell's closure.

Rubicon

Effect Of Closures Of Base Load

Effect Of Recent Base Load Coal Station Closures

New South Wales IS a net Importer of Electricity



Exports

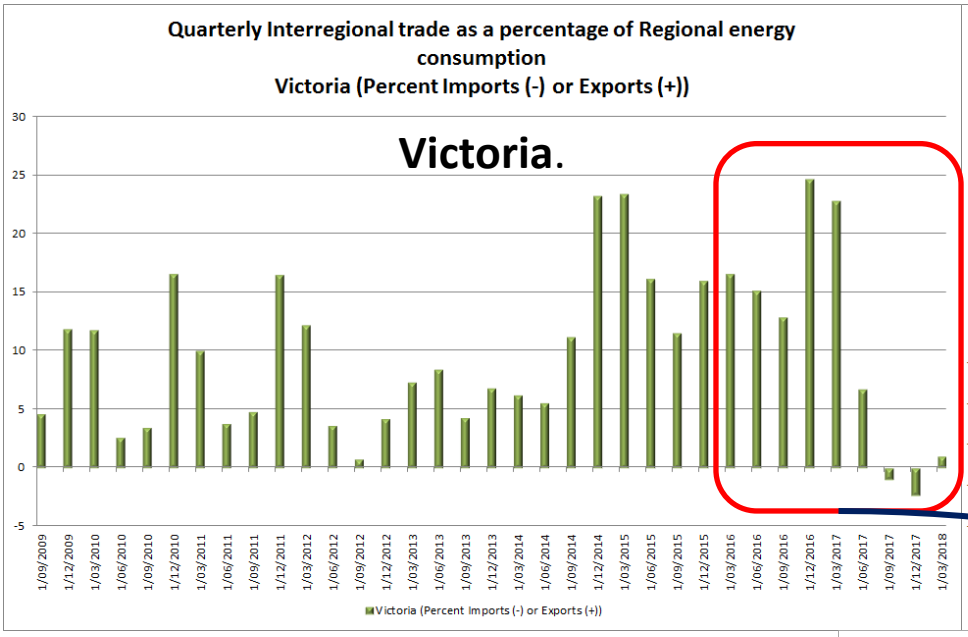
Imports

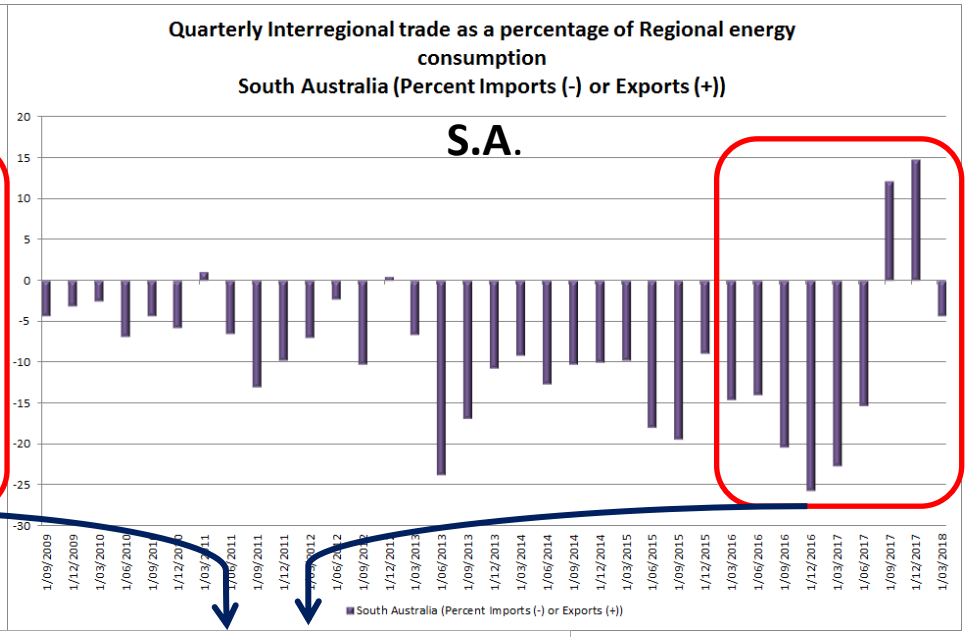
Effect Of Closures Of Base Load

Effect Of Recent Base Load Coal Station Closures

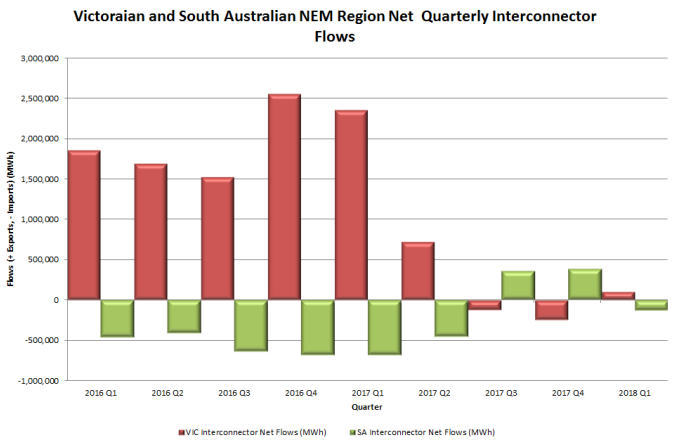
Victoria WAS a net Exporter of Electricity. That has changed with Hazelwood's Closure

Despite the publicity from time to time, South Australia cannot be a reliable as a net Exporter of Electricity.





When Flows are examined in Energy (MWh) terms, it becomes clear that the situation is not now in balance. South Australia can in NO WAY replace the Base Load Generation lost in Victoria.



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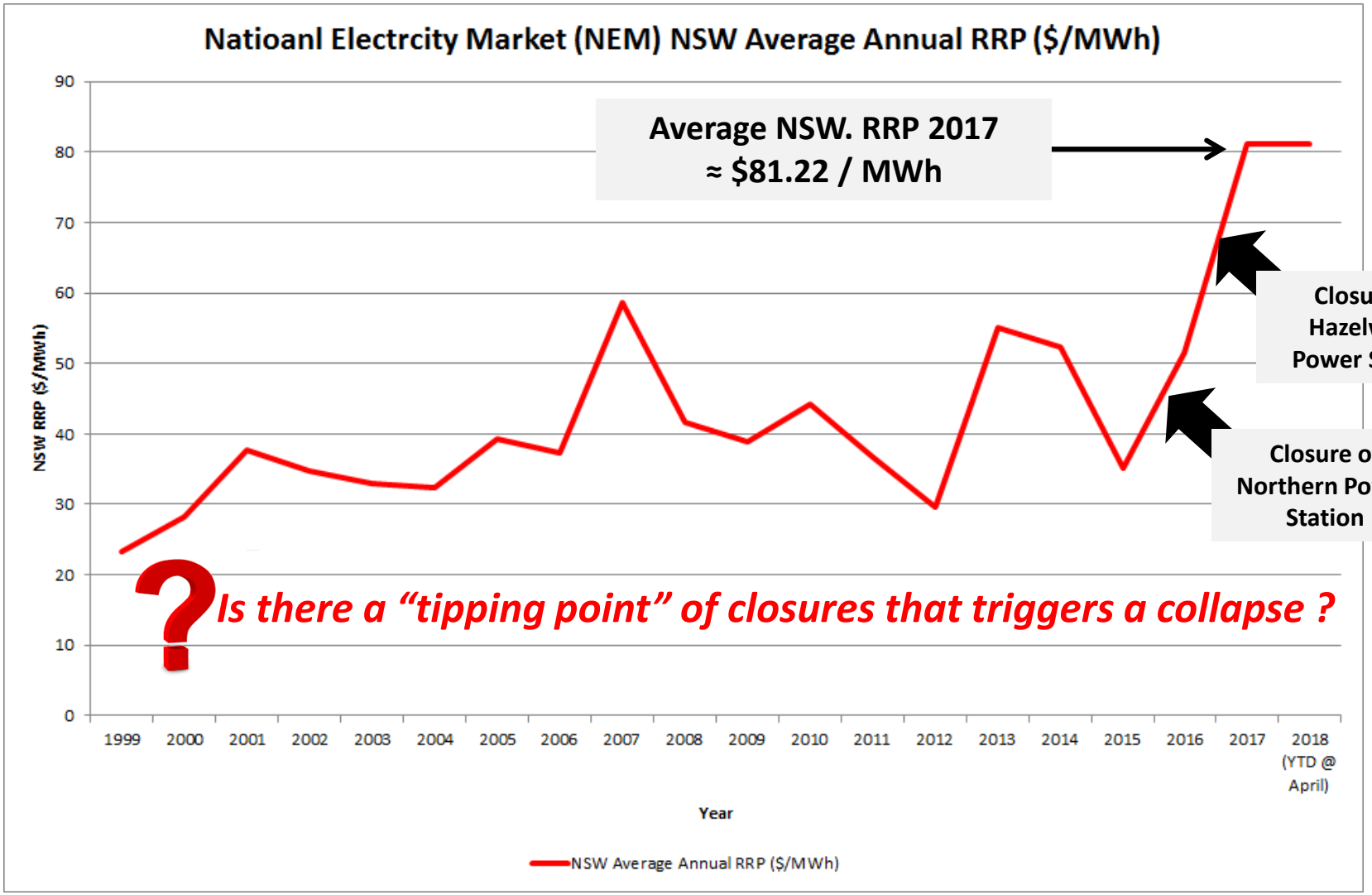
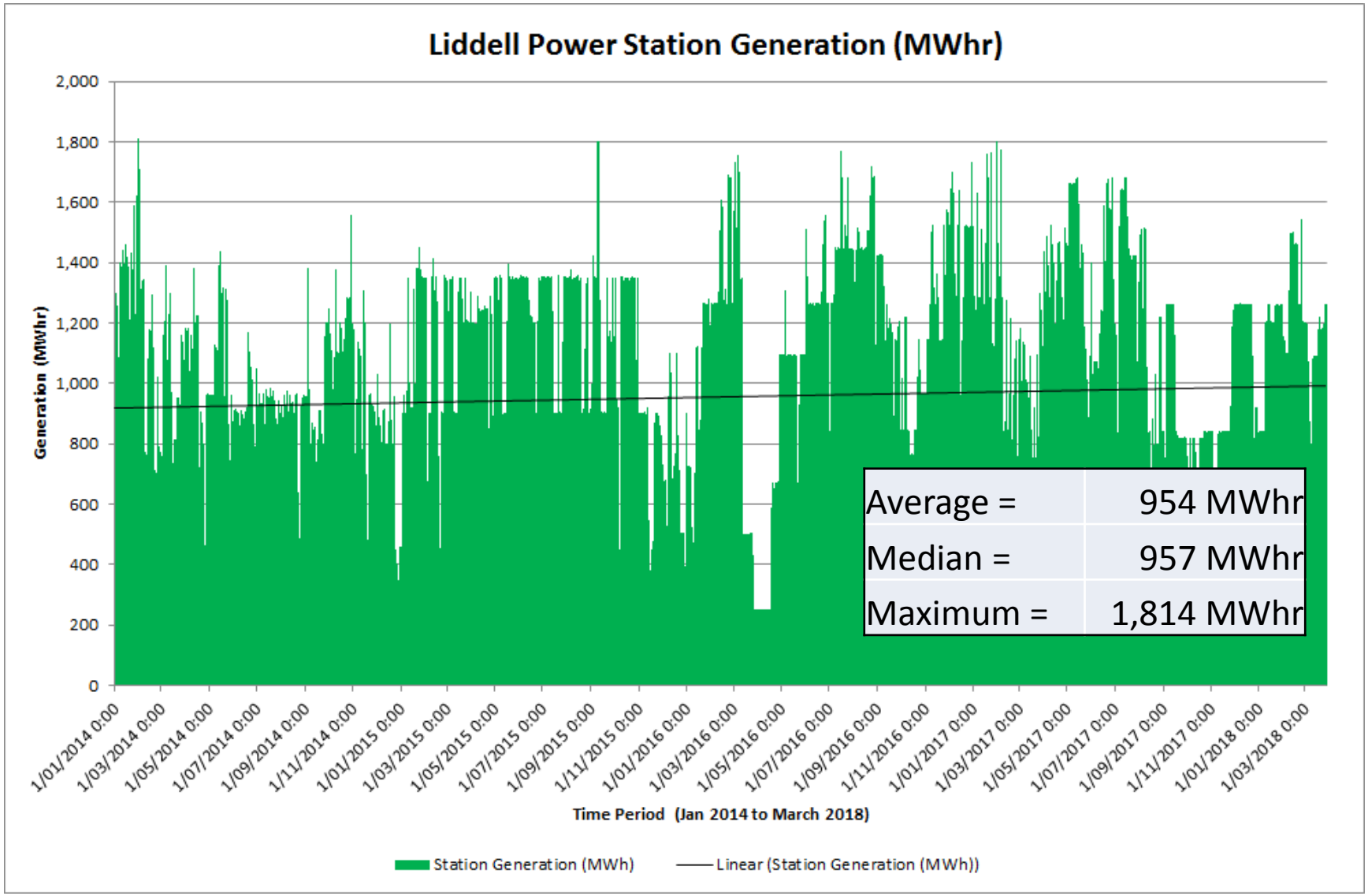


The closure of Base Load Generation Across The NEM is having a compounding effect. This may mean the potential magnifying effect of Liddell's closure.

Effect Of Closures Of Base Load

What MUST be replaced in closing Liddell



Replacing Base Load Coal Fired Plant

Using Solar PV

Rubicon

Plant	Capacity (MW)	Number of Solar PV Panels	Area (Ha)	Estimated Annual Generation (GWhr/Year)
Nyngan	102	1.3 million	250	233
Broken Hill	53	677,760	140	126
Total	**155**	**1,977,760**	**390**	**359**
Liddell	2,000	n/a		9,037#1

Note : #1 Actual achieved Generation

If we take the Nyngan + Broken Hill annual Generation expectation i.e., 359 GWhr and divide it by the area covered we get :

359 / 390 = 0.92 GWhr / Ha / Year,

Therefore if you were to replace Liddell's actual 2016 Generation with Solar, you would need :

9,037 / 0.92 = 9,817 Ha = **98.17 km²**

THIS WOULD REQUIRE STORAGE OF A VAST SIZE TO MAKE IT POSSIBLE

Replacing Base Load Coal Fired Plant

Using Solar PV

Rubicon

Area	Maximum Solar Yield (kWhr/kWp Day)	Minimum Solar Yield (kWhr/kWp /Day)	Average Solar Yield (kWhr/kWp/Day)
Nyngan / Broken Hill	11.5	0.8	7.06
Rutherford / Liddell	2.6	0.1	1.47

So if Liddell's 2016 Generation was to be Generated in an area with a Solar Irradiation levels found at Nyngan + Broken Hill the area ≈ **98.17 km²**

However,

If this Generation was to be replaced in an area with the level of Solar Irradiation a found in the Hunter Valley the area would increase to :

≈ 98.17 (7.06 / 1.47)

≈ 472 km²

THIS BECOMES UNVIABLE

Hunter Valley area ≈ 29,145 km², therefore the necessary area need for a Solar Farm ≈ 1.62% of the total Hunter Valley area.

Summary

Summary

We Need To Think Again About The Options

1. Replacing Liddell Power Stations current Generated Energy (MWh) is a huge challenge, and therefore concrete solutions are need.

2. Caution should be exercised when discussing replacement **CAPACITY (MW**) as a number of technologies such as PV Solar have very low Capacity Factors and thus for a given Capacity and much smaller **GENERATED ENERGY (MWh)** are achievable. Refer Appendix 'B'.

3. AEMO is already "sounding" a responsible warning, to Government.

4. With the closure of other Base Load Generators (most notable Hazelwood) there is potentially a compounding effect on the Market supply side and so no future closure can be viewed in isolation.

5. It should be remembered that New South Wales has already lost 1,000 MW of Coal Fired Base Load Generation with the closure of Wallerawang Power Station.

6. Clearly many of the items within the AGL "*NSW Generation Plan*" have a role to play but, none offer a clear means of significantly replacing Liddell Generated Energy (MWh).

Summary

We Need To Think Again About The Options

7. Extremely small Base Load element in the AGL Plan.

8. Based on AGL's own information that they do not appear to have a full New South Wales solution.

9. On close examination there are concerning signs within AGL's Plan of a lack of complete technical understanding. This is perhaps best illustrated by the suggestion of Pumped Storage Hydro based on Lake Liddell. It is assumed that the proposal would to be to also utilise old mine voids. If that is the case, none appear to offer and effective Head necessary for Pumped Storage Hydro and most are some significant distance from Lake Liddell. A number are still with operating mines which will be operating beyond 2022.

10. The addition of Peaking Power and Non-Despatchable Generation is increasing risk of Market volatility and thus increased upward price pressures. Whilst the inclusion of Demand Side Management is a reasonable System Management strategy but, has no place in replacing Base Load Generation.

11. The reduction in Base Load Generation is increasing the risk associated with the reliability of the remaining fleet as they continue to age, with a decreasing spread of Capacity to mitigate plant failures. ***"Our eggs are in fewer and older baskets"*** !

Summary

We Need To Think Again About The Options

12. The "***shock***" of Hazelwood's closure is still reverberating and AGL's mantra of "*Orderly Withdrawal*" is hollow without real ENERGY (MWh) replace options,

13. The Industry risks the potential repetition of the Market effect of the closure of Northern Power Station in South Australia and Hazelwood in Victoria,

14. There are clear signs that the Energy Industry may lose (if we have not already) our **Social License To Operate**. This is an Energy Industry issue not only an AGL issue. Refer to Appendix 'D',

15. We as an Industry are facing a scenario which is not in the interest of our Customers (increasing Energy costs, supply shortages), nor is it in the longer term interests of Investors (potential Government intervention, loss of customers / markets, loss of reputation),

16. **It is arguable that if we as the Energy Industry do not act decisively to address many of our current issue, we may face the same challenges currently being faced by the Banking Industry here in Australia.**

Discussion

Discussion

We Need To Think Again About The Options

There is clear need for an informed debate surrounding technologies to replace existing Fossil Fuel Electricity Generating assets (as well as Coal, the current Generation Fleet contains significant Natural Gas Fired plants of some age and capacity such as AGL's Torrens Island Power Stations in South Australia).

A view that the replacement of the total or indeed majority of the existing Base Load Fossil Fuel plants in the NEM by existing Renewable technologies is frankly wrong. Many commentators on the future role of renewables have attempted to resolve the problem of Intermittence by talk about Storage. To this point, this is something of a wish rather than a current reality in both economic and technical terms. This paper has included a worked example (Appendix 'B') as a means of engendering an informed debate based on facts not wishes.

It is of the utmost importance that the difference between Installed Capacity (MW) and Dispatchable Energy (MWh) is made very clear.

Australia could face a situation whereby we have large Renewable investments in terms of Capacity (MW) but we are unable to meet the Customers demand for Energy (MWh).

Discussion

We Need To Think Again About The Options

The proposed closure of Liddell Power Station by AGL in 2022 provides those of us in the Australian Energy industry an opportunity to stop and asses where we are and where we may be heading.

With the Federal Government response to AGL's proposed closure being one of forcing AGL to publically put forward a plan to indicate how the Generating capacity of Liddell will be replaced, we have had an opportunity to carry out an analysis of what one Market Generator Participant envisages as the way forward.

However, on examination the AGL *NSW Generation Plan* it has frankly been found wanting. There are signs of a hurried cobbling together of separate concepts in an attempt to present something that is comprehensive. On close examination, the Plan can be shown to be very lacking in rigour and acknowledgement of some key fundamentals of Electricity Generation and Transmission / Distribution.

In fairness to AGL, it is likely that they are in no worse a position regarding rigorous, well thought through strategic planning for the future of Electricity Generation in this Country than any other stakeholder (this includes Governments, Regulators and Market Participants).

AGL's intransigence regarding the closure of Liddell in 2022 and their poor alternative Plan is creating a dangerous situation for the Industry and indeed the Nation as a whole.

Discussion

We Need To Think Again About The Options

We strongly need to understand the situation that we face in Australia. The Australian National Electricity Market (NEM) is a totally isolated set of Interconnected sub-Networks and thus to all intensive purposes, the solutions required must be based within the NEM.

A number of plans currently exist to import either Natural Gas or Liquefied Natural Gas (LNG) as a fuel stock for both Electricity Generation and / or introduction into the Gas Market. This may or may not occur but is likely only to be a “stop gap” measure that may arouse major public scientism around the ability of the Australian Energy Industry, in arguably the World’s richest Energy country to manage itself !

The currently level of debate in Australia regarding Energy has largely been one of a qualitative nature with events such as the recent five days of non coal generation in the UK being sighed as setting the path Australia should aspire to. However, when a quantitative lens is taken to such matters the outcome is quite different. Refer to Appendix ‘C’.

Discussion

We Need To Think Again About The Options

Rubicon

However, perhaps the most significant matter is the loss of our Industries ***"Social Licence To Operate"***. In the 1990'a and 2000's its was popular to adopt the management strategy of the "***Triple Bottom Line***" (or otherwise noted as TBL or 3BL). This was seen as a means of evaluating a businesses' performance in a broader perspective to create greater business value and aligns with the view of SUSTAINABILITY put forward in the Introduction to this paper. It is arguable that in essence the Australian Energy has only focused upon two elements :

1. Economic,
2. Environmental.

We have in large ignored or worse "played lip service" to the :

3. **Social.**

Our failure to understand the importance of Energy in modern Societies and the ramifications of Energy cost and availability / security are now arguably placing not only the Industry but the wider Australia Economy at risk.

Elkington, J., 1994, "Triple Bottom Line" in The Economist. November 17th, 2009.

Discussion

We Need To Think Again About The Options

If we accept ***Fuel Poverty*** as an quantitative indicator of the relationship of the Energy Industry with the wider Australian Society, the picture painted in Appendix 'D' should indeed be "ringing alarm bells" now.

If we take an honest assessment of where we are with Domestic Energy supply in Australia currently we see :

- Rising prices to Customers (Gas and Electricity),
- The appearance of a lack of reliability of supply,
- Aging Dispatchable Generation Infrastructure,
- Decaling Reserve of Dispatchable Generating capacity,
- System instability issues increasing,
- Actual Black Outs occurring,
- Industry off loading,
- Industry indicating Energy costs are a decision making point,
- Government Policy and Regulatory turmoil,
- Industry lack of direction,
- The Industry has come under increasing Media focus,
- Public disquiet moving to anger …

It is the Author's view that we (Australia) are already in

AN ENERGY CRISIS

Discussion

We Need To Think Again About The Options

And that we may be fast approaching a "***Tipping Point***" in terms of Supply Stability.

If the Energy Industry does not take a co-operative, collaborative and strategic approach with Governments to put forward real solutions in a plan and comprehensive manner, we run the risk of future Government intervention in the Australia Energy Sector. Governments are already being forced to act in less than ideal ways (e.g., installation of emergency Diesel Fuelled Reciprocating Engine Power Plants in Victoria, Tasmania and South Australia) as well as in changing Regulations and perhaps in future even more draconian measures.

Government MUST response to Community / Customer pressure and those applying that pressure. We as an Industry must ensure we are not adding cause to that pressure. Put simply, **HAVE WE STOPPED CARING ABOUT OUR CUSTOMERS ?**

We are facing the "***Perfect Storm***" now, but is will get worse if we act incorrectly.

Conclusion

Conclusion

We Need To Think Again About The Options

There is clear need for an informed debate surrounding technologies to replace existing Fossil Fuel Electricity Generating assets (as well as Coal, the current Generation Fleet contains significant Natural Gas Fired plants of some age and capacity such as AGL's Torrens Island Power Stations in South Australia).

A view that the replacement of the total or indeed majority of the existing Base Load Fossil Fuel plants in the NEM by existing Renewable technologies is frankly wrong. Many commentators on the future role of renewables have attempted to resolve the problem of Intermittence by talk about Storage. To this point, this is something of a wish rather than a current reality in both economic and technical terms. This paper has included a worked example (Appendix 'B') as a means of engendering an informed debate based on facts not wishes.

It is of the utmost importance that the difference between Installed Capacity (MW) and Dispatchable Energy (MWh) is made very clear. We could face a situation whereby we have large Renewable investments in terms of Capacity (MW) but we are unable to meet the Customers demand for Energy (MWh).

Conclusion

We Need To Think Again About The Options

We strongly need to understand the situation that we face in Australia. The Australian National Electricity Market (NEM) is a totally isolated set of Interconnected sub-Networks and thus to all intensive purposes, the solutions required must be based within the NEM. A number of plans currently exist to import either Natural Gas or Liquefied Natural Gas (LNG) as a fuel stock for both Electricity Generation and / or introduction into the Gas Market. This may or may not occur but is likely only to be a "stop gap" measure that may arouse major public scientism around the ability of the Australian Energy Industry, in arguably the World's richest Energy country to manage itself !

The currently level of debate in Australia regarding Energy has largely been one of a qualitative nature with events such as the recent five days of non coal generation in the UK being sighed as setting the path Australia should aspire to. However, when a quantitative lenses is taken to such matters the outcome is quite different. Refer to Appendix 'C'.

Conclusion

We Need To Think Again About The Options

"…

In its entirety, all three stages of AGL's plan would deliver sufficient dispatchable resources to fill the identified 850 MW resource gap. However, under Scenario 1, there remains a resource gap of around 590 MW exposing the power system to a high risk of involuntary load shedding, especially in 1-in-10 year maximum demand conditions. For example, in 2026-27:

- For Scenario 1, there is a risk of load shedding every 4 years, resulting in approximately 174,000 households without power for 3.6 hours.
- For Scenario 2, this risk of load shedding reduces to 1-in-20 years, resulting in approximately 172,000 households without power for 2.2 hours.

. . ." AEMO, 2018, pp. 8 – 9

Note : AEMO basis of analysis (AEMO, 2018, p. 3.) -

- Base case – Committed only, Liddell to close end of 2022. The Base Case includes the 100 MW Bayswater upgrade and 810 MW's of other resources (primarily variable renewable generation) that have reached the stage of the commitment that AEMO relies on to determine new supply arrangements, are scheduled to be available prior to Liddell's closure and can serve NSW. The new resources that have committed since AEMO's September analysis are included in Table 2 *(not included here).*
- Scenario 1 – Base case plus AGL Stage 1 implemented to capacity and on time.
- Scenario 2 – Base case plus AGL Stage 1 - 3 implemented to capacity and on time.

It is clear Australia needs NOW to develop a collective Stagey Energy Plan to overcome the coming "***Tipping Point***". This MUST include new forms of Generation technology and not be Fuel focused but Sustainable. This is **URGENT** !

Appendix 'A'
Grid Lithium-Ion Battery Analysis

The South Australian Experience – So Far

Appendix 'A' – Battery Analysis

The South Australian Experiment

Some Battery Facts

NEWS RELEASE

Hon Jay Weatherill MP

Premier

Friday, 7 July, 2017

Tesla to pair world's largest lithium ion battery with Neoen wind farm in SA

The world's largest lithium ion battery will be installed in South Australia under a historic agreement between French renewable energy company Neoen, US sustainable energy company Tesla and the South Australian Government.

The energy storage [illegible] from Tesla will be paired with Neoen's Hornsdale Wind Farm and installed before summ[illegible]

Confirming the commitment from Tesla CEO Elon Musk to deliver the battery within 100 days or it is free, it has been agreed between Tesla and the South Australian Government that the starting date for the 100 days will be once the grid interconnection agreement has been signed.

After leading the nation in renewable energy, the [illegible]129MWh battery places South Australia at the forefront of global energy storage tech[illegible]

The battery will operate at all times providing stability services for [illegible]ewable energy, and will be available to provide emergency back-up power if a shortfall in e[illegible]redicted.

The deal will also bring other investments by both Neoen and Tesla into So[illegible]tralia's economy, with details to be announced in the future.

The selection of Neoen will also strengthen South Australia's links with France's high-tech [illegible]

"The World's Largest Battery"

"South Australian taxpayers will be subsidizing its operation with up to $50 million over the next 10 years," ABC reports.

Source : NPR, December 1, 2017, https://www.npr.org/sections/thetwo-way/2017/12/01/567710447/worlds-largest-battery-is-turned-on-in-australia-as-tesla-ties-into-power-grid, National Public Radio (US), accessed 28th May, 2018.

In 2016 Liddell Generated = 9,037,281 MWh (Needing around 200 of "The World's Largest Batteries" to replace it) Liddell a Capacity of 2,000 MW (or if we accept derating ≈ 1,600 MW

"The World's Largest Battery", the NEOEN ***Hornsdale Power Reserve*** (Hornsdale Battery) near Jamestown in South Australia has the following characteristics :

Power Output (MW) = 100 MW
Energy Output (MWh) = 129 MWh.

The Hornsdale Battery is really two systems[#1] :

i. 70 MW/39 MWh is contracted to the South Australian state government for the purpose of providing grid stability services;

ii. The remaining 30 MW/90 MWh can be used by the Hornsdale (NEOEN) operator to trade in and arbitrage the energy market.

Appendix 'A' – Battery Analysis

The South Australian Experiment

Some Battery Facts

In 2016 Liddell Generated = 9,037,281 MWh (Needing around 200 of "The World's Largest Batteries" to replace it) Liddell a Capacity of 2,000 MW (or if we accept derating ≈ 1,600 MW

Rubicon

"The World's Largest Battery", the NEOEN ***Hornsdale Power Reserve*** (Hornsdale Battery) con't,

Whilst Tesla warranties the Tesla ***PowerPack 2*** commercial/utility-grade battery system for 10 years, literature is indicating a life of 5,000 Cycles [#2].

Indication s from the performance of Hornsdale Battery to date indicate the level of cycling is quite high although, the level of Discharge would appear to be mainly limited to the %)% of the Battery's Capacity available to NEOEN[#2].

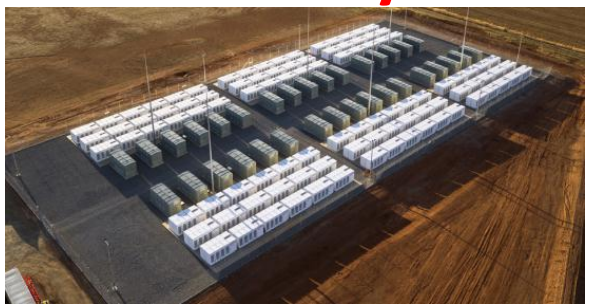
Estimated cost of the Hornsdale Battery ≈ AA45 million to A$60 million + Project costs and profit [#3].

Assuming an Efficiency of 82% [#1], the Energy required to charge the Battery would ≈ 157 MWh (thus is a **NET LOSS DEVICE**),

Appendix 'A' – Battery Analysis

The South Australian Experiment

Some Battery Facts



The Hornsdale Battery

In 2016 Liddell Generated = 9,037,281 MWh (Needing around 200 of "The World's Largest Batteries" to replace it) Liddell a Capacity of 2,000 MW (or if we accept derating ≈ 1,600 MW

"The World's Largest Battery", the NEOEN ***Hornsdale Power Reserve*** (Hornsdale Battery) con't,

Thus :

- The Battery can operate at full POWER for 1.29 hrs (assuming the battery is fully charged and full discharge can be reached), or 45 minutes if the NEOEN component alone is used,
- It can supply ≈ 3.3% of the South Australian Region Maximum Demand[#4] for that period,
- If the Battery was to cycle each day, life MAY be as low as 7 years!

Note : [#]1 : *Source* - Petkovic, M., 2018," Four months in, SA Tesla battery is showing mixed results in energy arbitrage", Energy Synapse, at : https://energysynapse.com.au/south-australia-tesla-battery-energy-market/, accessed 28th May, 2018.
[#]2 : *Source* - Shahan, Z., 2015, "Tesla Powerwall & Powerpacks Per-kWh Lifetime Prices vs Aquion Energy, Eos Energy, & Imergy", CleanTechnica, at : https://cleantechnica.com/2015/05/09/tesla-powerwall-powerblocks-per-kwh-lifetime-prices-vs-aquion-energy-eos-energy-imergy/ accessed 28th May, 2018.
[#]3 : *Source* - Based upon : Berckmans, G.,Messagie, M., Smekens, J., Omar N., Vanhaverbeke L., & Joeri Van Mierlo , J., 2017, "Cost Projection of State of the Art Lithium-Ion Batteries for Electric Vehicles Up to 2030", MOBI Research Group, Vrije Universiteit Brussel, Brussels, Belgium; Academic Editor: K.T. Chau, Published: 1 September 2017 in Energies - Multidisciplinary Digital Publishing Institute (MDPI), Basel, Switzerland, p. 11.
[#]4: Based upon 2017 AEMO data.

Appendix 'A' – Battery Analysis

The South Australian Experiment

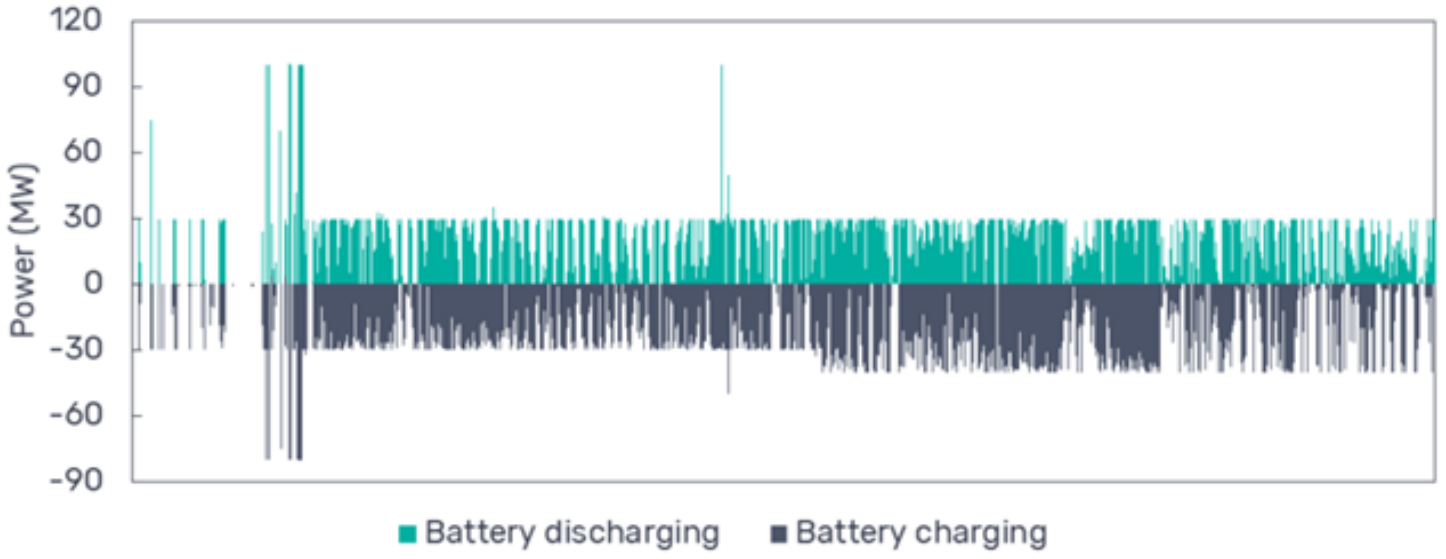
In 2016 Liddell Generated = 9,037,281 MWh (Needing around 200 of "The World's Largest Batteries" to replace it) Liddell a Capacity of 2,000 MW (or if we accept derating ≈ 1,600 MW

Rubicon

In the period between December 2017 and March 2018, the Hornsdale Battery has been in some form of operation 63% of the dispatch intervals, the battery was either being charged or discharged.

Source : Petkovic, M., 2018," Four months in, SA Tesla battery is showing mixed results in energy arbitrage", Energy Synapse, at : https://energysynapse.com.au/south-australia-tesla-battery-energy-market/, accessed 28th May, 2018.

Figure 1: Tesla battery 5 min operation (Dec17-Mar18)



Appendix ‘B’
Illustrative Example

Replacement With Renewables

Appendix 'B' - Illustrative Example

Replacement With Renewables

Rubicon

Note

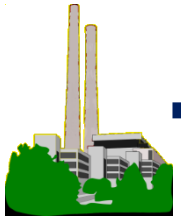
This Appendix contains an illustrative example aimed at quantifying the size of Generating / Storage / Firming Plant that may be needed if one was to replace of the current output (Generation – MWh) of Liddell Power Station.

The example is based upon the swop of one technology for another whilst in realty their would be a more complex change in resources required to replace Liddell (higher levels of Generation from existing plants as well as a mix of new Generation and potentially a reduction is Supply / System Security).

That being acknowledged, what has been absent in the discussion around Liddell's replacement has been some quantifying of the infrastructure required to replace the existing plants Generation. This example is not exacting but, even if a Probability of 50% (P_{50}) was applied to the calculations, the plant sizes remain massive and somewhat beyond current capabilities.

Appendix ‘B’ - Illustrative Example

Replacement With Renewables



Liddell Power Station

LIDDELL POWER STATION - 2016		
TOTAL (Actual)	9,037,281	MWh
AVERAGE (Actual)	1,029	MWh
MEDIAN (Actual)	1,093	MWh
TOTAL CAPACITY (Name Plate, Power)	2,000	MW
ANNUAL CAPCITY (Name Plate x Time, Energy)	17,520,000	MWh
Therefore: CAPACITY FACTOR	52%	%

9,037,281 MWh

Customers

Possible Replacement With Renewables

Supply Remains Intermittent

Required Annual Capacity = 9,037,281 MWh

Wind

Capacity Factor ≈ 32%

Therefore Total Capacity = 9,037,281 / 32% / Time

= 3,224 MW (Plant Size)

Assume 3.0 MW Turbines = 1,075 Turbines

Area[#1] ≈ 419 km²

Supply Remains Intermittent

Required Annual Capacity = 9,037,281 MWh

PV Solar

Specific Yield (kWh/kWp)[#2] ≈ 11.5 Maximum / Day, ≈ 0.8 Minimum / Day, ≈ 7.06 Average / Day,

Therefore Total Capacity = Annual Energy / Specific Yield x 365,

= 2,153 MW (Maximum Specific Yield) ≈ 27,440,196 PV Panels

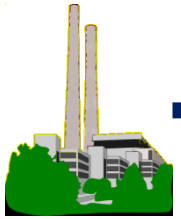
= 30,950 MW (Minimum) !

= 3,507 MW (Average) ≈ 44,696,715 PV Panels

Note : [#]1 Based up Macarthur Wind Farm data.
[#]2 Based upon Nyngan Solar Farm data.

Appendix 'B' - Illustrative Example

Replacement With Renewables + Storage



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Therefore: CAPACITY FACTOR	52%	%

9,037,281 MWh ≈ 26,000 MWh / Day

Customers

Possible Replacement With Renewables + Storage

≈ 26,000 MWh / Day

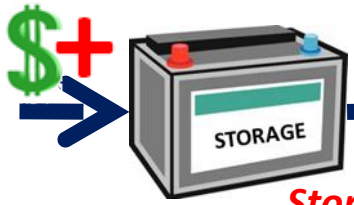
Wind

Plant Size = 3,224 MW (Plant Size)

Assume 3.0 MW Turbines = 1,075 Turbines

Area[#1] ≈ 419 km²

Assume full output over approx.' 8.0 hrs / day



≈ 26,000 MWh / Day

Storage[#1]

Size : Over 8 hours Storage must store approx', 2,200 MWh every hour ≈ 17,000 MWh @ 2,000 MW !

NOT VIABLE

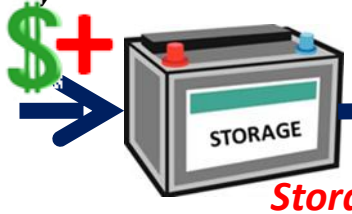
≈ 26,000 MWh / Day

PV Solar

Plant Size = 3,507 MW (Average)

≈ 44,696,715 PV Panels

Assume full output over approx.' 7.5 hrs / day



≈ 26,000 MWh / Day

Storage[#1]

Size : Over 7.5 hours Storage must store Appro.' 2,400 MWh every hour ≈ 18,000 MWh @ 2,000 MW !

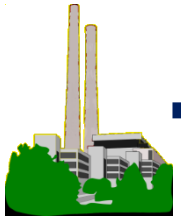
NOT VIABLE

Note : [#]1 Assumes a daily cycle which may not be totally true of Wind. However, allowance also needs to be made for total days without Wind.

Appendix 'B' - Illustrative Example

Replacement With Renewables + Storage

Rubicon



Liddell Power Station

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Therefore: CAPACITY FACTOR	52%	%

9,037,281 MWh ≈ 26,000 MWh / Day

Customers

Possible Replacement With Renewables + Storage

However, ALL Storage Mechanism Are Net loss Systems. Assume Efficiency of 80%

≈ 32,500 MWh / Day

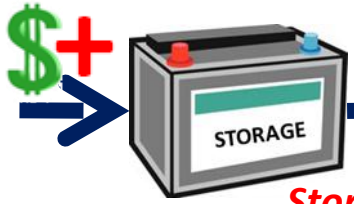
Wind

Plant Size = 4,063 MW (Plant Size)

Assume 3.0 MW Turbines = 1,354 Turbines

Area#1 ≈ 502 km²

Assume full output over approx.' 8.0 hrs / day



Storage#1 Size : ≈ 23,800 MWh @ 2,000 MW !

≈ 26,000 MWh / Day

NOT VIABLE

≈ 32,500 MWh / Day

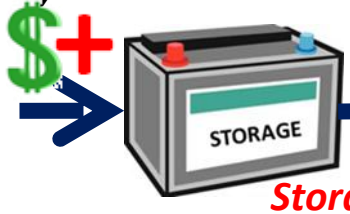
PV Solar

Plant Size = 4,333 MW (Average)

≈ 55,230,000 PV Panels

(Estimated Capital ≈ A$ 6,000,000,000)#2

Assume full output over approx.' 7.5 hrs / day



Storage#1 Size : ≈ 24,400 MWh @ 2,000 MW !

≈ 26,000 MWh / Day

NOT VIABLE

Note : #1 Assumes a daily cycle which may not be totally true of Wind. However, allowance also needs to be made for total days without Wind. #2 Based upon Lazard analysis.

Appendix 'B' - Illustrative Example

Replacement With Renewables + Storage

Liddell Power Station

LIDDELL POWER STATION - 2016		
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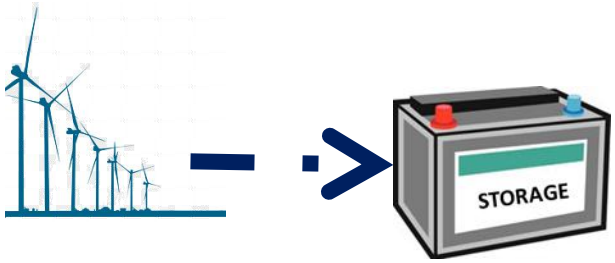
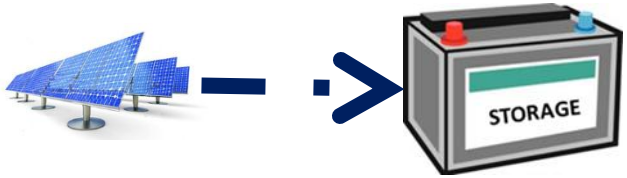
9,037,281 MWh ≈ 26,000 MWh / Day

Customers

Possible Replacement With Renewables + Storage



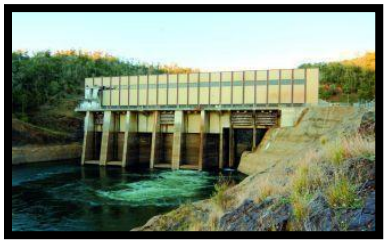
Storage#1 Size : ≈ 23,800 MWh @ 2,000 MW !



Storage#1 Size : ≈ 24,400 MWh @ 2,000 MW !

Storage ! How do we quantify it ?

- Wivenhoe Pump Storage Hydro ≈ **5,000 MWh** Max. Storage
- Tumut #3 Pump Storage Capability ≈ **10,000 MWh** Max. Storage,
- Shoalhaven Pumped Storage Hydroelectric Scheme ≈ **2,500 MWh** Max. Storage.



OR

Tesla "Power Wall" (13.5 kWh) **NOT VIABLE**

Lithium-Ion ≈ 1.8 million batteries (estimated at A$6.5 Billion#2)

Note : #1 Assumes a daily cycle which may not be totally true of Wind. However, allowance also needs to be made for total days without Wind.
#2 Based upon US$(2014)200 / kWh for Tesla Nickel Manganese Cobalt (NMC) lithium cells for stationary storage (Powerwall and Powerpack), Tesla refer to their Batteries as the '21-70', Samsung refer to the size as '21700'. Source : Andreas Karius: Studie: Tesla-Gigafactory bedroht andere Batteriehersteller. in automobil-produktion.de Volume 3. March 2014

Appendix ‘B’ - Illustrative Example

Replacement With Renewables + Storage

Ammonia for energy storage & transport

eg: Pilbara ammonia plant

- 80,000 tonne ammonia storage ~$80M
- Equivalent to ~200 GWh of electricity
- Projected cost of equivalent battery storage: $20-25B

Ammonia energy storage

- Capital cost – $0.40/kWh
- Permanent storage, near zero losses or degradation
- Liquefies easily at 10 bar or -33°C
- Transportable in bulk, using existing refrigerated ships &carriers – same as LPG

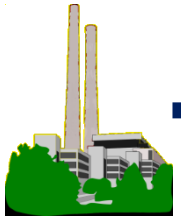
Cost of energy storage as ammonia ~0.3% of battery storage

* Projected 2030 battery storage cost USD$100/kWh, Source Bloomberg NEF; NH_3 conversion to electricity 3.1MWh per tonne

Source : Harris, D., 2018, “Role of carbon resources in emerging hydrogen energy systems”, Low Emissions Technologies, Commonwealth Scientific and Industrial Research Organisation (CSIRO), Pullenvale, Queensland.

Appendix 'B' - Illustrative Example

Replacement With Renewables + Storage + Firming



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Therefore: CAPACITY FACTOR	52%	%

9,037,383 MWh ≈ 26,000 MWh / Day

Customers

Possible Replacement With Renewables + Storage + Firming

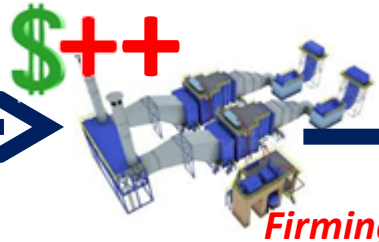
Wind

Plant Size = 4,063 MW (Plant Size)

Assume 3.0 MW Turbines = 1,354 Turbines

Area#1 ≈ 502 km²

Assume full output over approx.' 8.0 hrs / day



Firming#1

Gas Fired Generation

Up to 2,000 MW Capacity

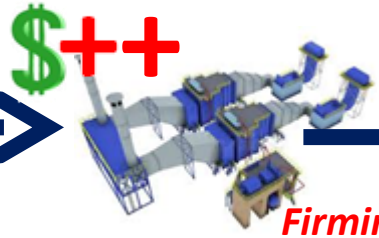
≈ 26,000 MWh / Day

PV Solar

Plant Size = 4,333 MW (Average)

≈ 55,230,000 PV Panels

Assume full output over approx.' 7.5 hrs / day



Firming#1

Gas Fired Generation

Up to 2,000 MW Capacity.

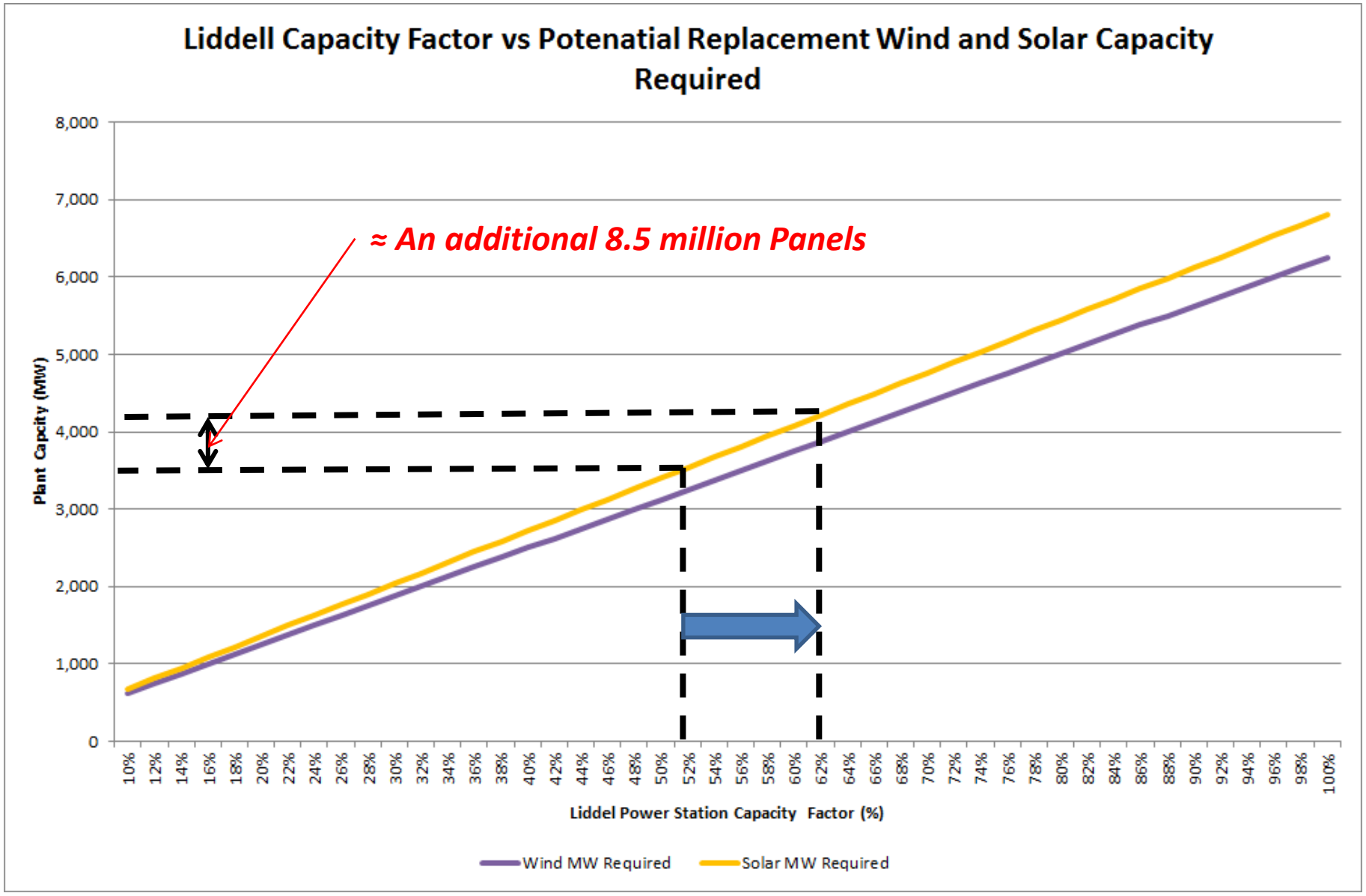
(Estimated Capital ≈ A$ 2,000,000,000)#2

≈ 26,000 MWh / Day

Note : #1 Would allow a reduction in the size of Wind / Solar Plants and Storage. However, overall costs would be very high and Gas Fired Peaking Generation would be expensive. #2 Based upon Lazard analysis.

Appendix ‘B’ - Illustrative Example

Replacement With Renewables



Appendix ‘B’ - Commentary

Reliability Of Renewables

There would appear to be some views that the wide spread geographical location and diversified technologies (Wind and PV Solar) will bring about a stability in supply. This is perhaps linked to Systems Theory.

In Systems Theory a System is a cohesive conglomeration of interrelated and interdependent parts. Every system is delineated by its spatial and temporal boundaries, surrounded and influenced by its environment, described by its structure and purpose or nature and expressed in its functioning. **In terms of its effects, a system can be more than the sum of its parts if it expresses synergy or emergent behaviour**. Changing one part of the system usually affects other parts and the whole system, with predictable patterns of behaviour.

The goal of systems theory is systematically discovering a system's dynamics, constraints, conditions and elucidating principles (purpose, measure, methods, tools, etc.) that can be discerned and applied to systems at every level of nesting, and in every field for achieving optimized equifinality (a given end state can be reached by many potential means).

However, the current evidence of Renewables in Australia is indicating that the view of the “***the sum of the whole being greater than the sum of the parts***” is not holding. This is illustrated by the performance across the NEM in June 2017

Appendix 'B' - Commentary

Reliability Of Renewables

In June 2017 climatic conditions were such across the area covered by the NEM that Wind generated electricity reach the lowest level in five years despite considerable increase in Wind Generation Capacity over that five year period.

The following analysis illustrates the issue :

SettlementDate	NEM-wide Daily Total Wind Production	NEM-Wide Daily Total *"Scheduled Demand"*	Percentage	note that this measure of percentage contribution **will be a slight over-estimatation** as it looks at "Scheduled Demand" and not "Operational Demand"
MAX	73,698 MWh	548,124 MWh	13.4%	on Monday 11th July 2016
	17,389 MWh	655,542 MWh	2.7%	on Friday 10th Feb 2017
	69,842 MWh	437,152 MWh	16.0%	on Sunday 30th Oct 2016
# DAYS > 10%			53 days	
AVERAGE	28,724 MWh	523,665 MWh	5.5%	
MEDIAN	26,040 MWh	522,628 MWh	5.0%	
# DAYS <2%			43 days	
MIN	3,415 MWh	533,704 MWh	0.6%	on Thursday 11th May 2017
	5% of MAX above			
	14,196 MWh	432,871 MWh	3.3%	on Sunday 16th April 2017
	3,415 MWh	533,794 MWh	0.6%	on Thursday 11th May 2017
Analysis produced for the period 1st Jan 2016 to 29th June 2017, with data from NEM-Review v6 www.NEM-Review.info			www.WattClarity.com.au Making Australia's electricity market understandable	

Source : McArdle, P., 2017, "Where's the wind gone? NEM-wide wind farm operation lowest in 5 years (maybe ever, on like-for-like basis?)", WattClarity, at http://www.wattclarity.com.au/page, accessed 30th April 2018.

Appendix 'B' - Commentary

Reliability Of Renewables

. . .

"There clearly are some highs and lows in the above – as would be expected from an intermittent supply:

THE HIGHS:

- Highest percentage contribution up at a large 16.0% on a weekend day (Sunday 30th October), when total demand was below average (437,152 MWh on the day); but
- A higher total output from wind on Monday 11th July 2016 up at 73,698MWh for the day (part of the reason that I had come to see winter as windier months, I believe).

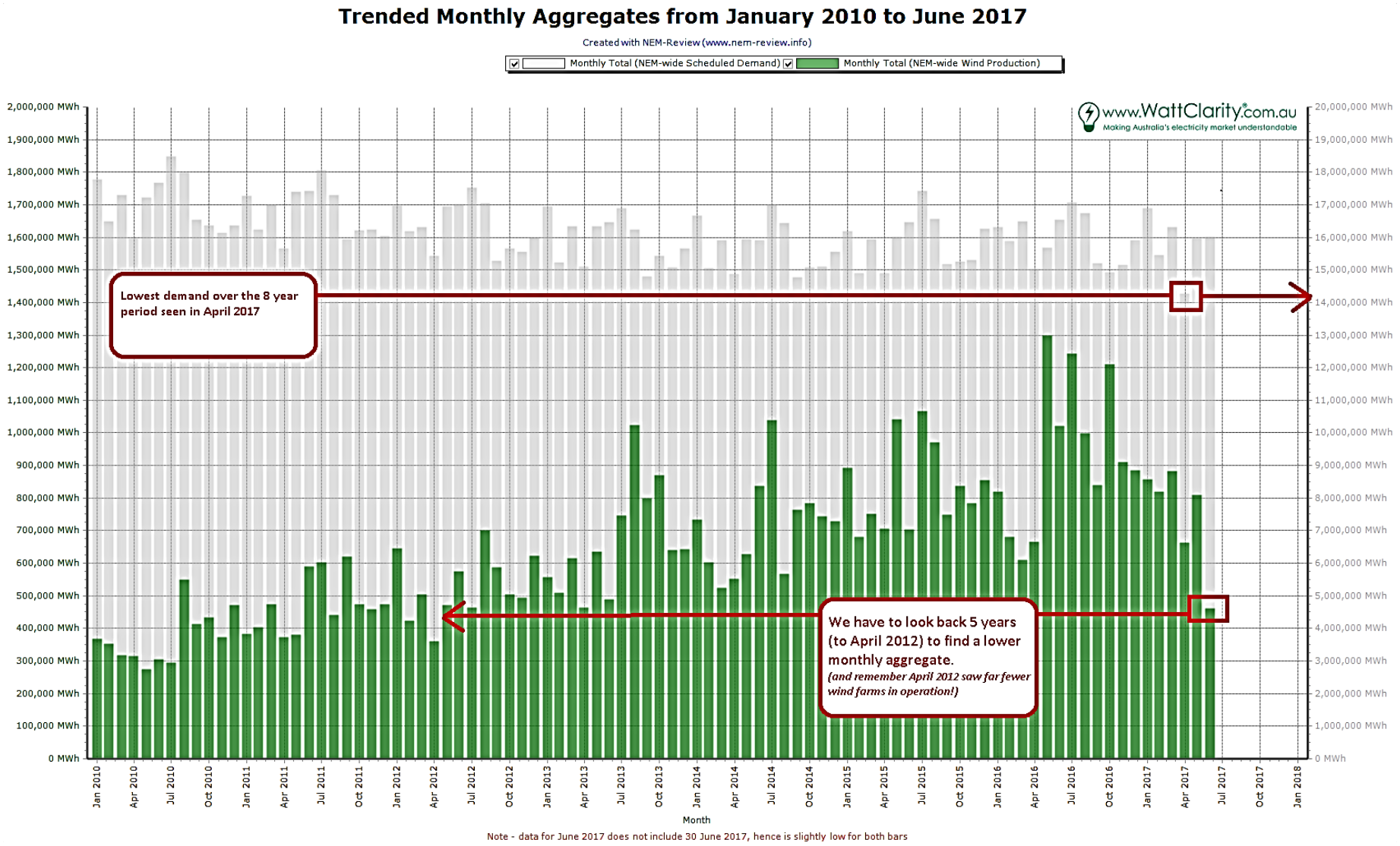
THE LOWS:

- Wind contributed only a meagre 0.6% on a remarkable day of Thursday 11th May 2017 when everything across the NEM was becalmed (incidentally a day for which load shedding was initially forecast on the Monday, and part of a run of low production days spanning May and June);
- As noted in the table above, the production of only 3,415 MWh on that day represents only 5% of the peak daily output seen 11 months earlier on 11th July, and only 12% of the average over the period."

Source : McArdle, P., 2017, "Where's the wind gone? NEM-wide wind farm operation lowest in 5 years (maybe ever, on like-for-like basis?)", WattClarity, at http://www.wattclarity.com.au/page, accessed 30th April 2018.

Appendix ‘B’ - Commentary

Reliability Of Renewables



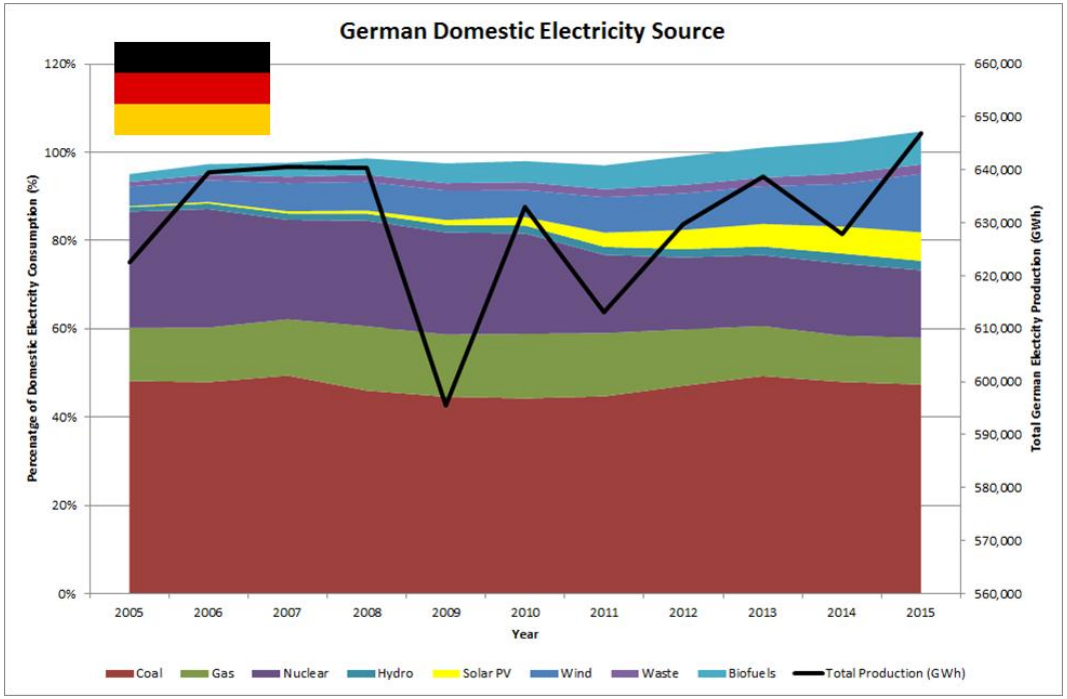
Source : McArdle, P., 2017, “Where’s the wind gone? NEM-wide wind farm operation lowest in 5 years (maybe ever, on like-for-like basis?)”, WattClarity, at http://www.wattclarity.com.au/page, accessed 30th April 2018.

Appendix ‘B’ - Commentary

Reliability Of Renewables

The other possible element of some thinking regarding the integration of renewables in terms of System Thinking is around the fluctuations in output of Renewables such as Solar PV and Wind can be overcome by either / or Storage (already explored above) and other forms of Generation. This assumption may well be based on experiences in such locations as the Federal Republic of Germany (Germany) with relatively high penetration of Renewables. The facts have been some what more complex with German still maintaining a very diverse array of technologies including Base Load Coal.

The following graph illustrates this clearly :

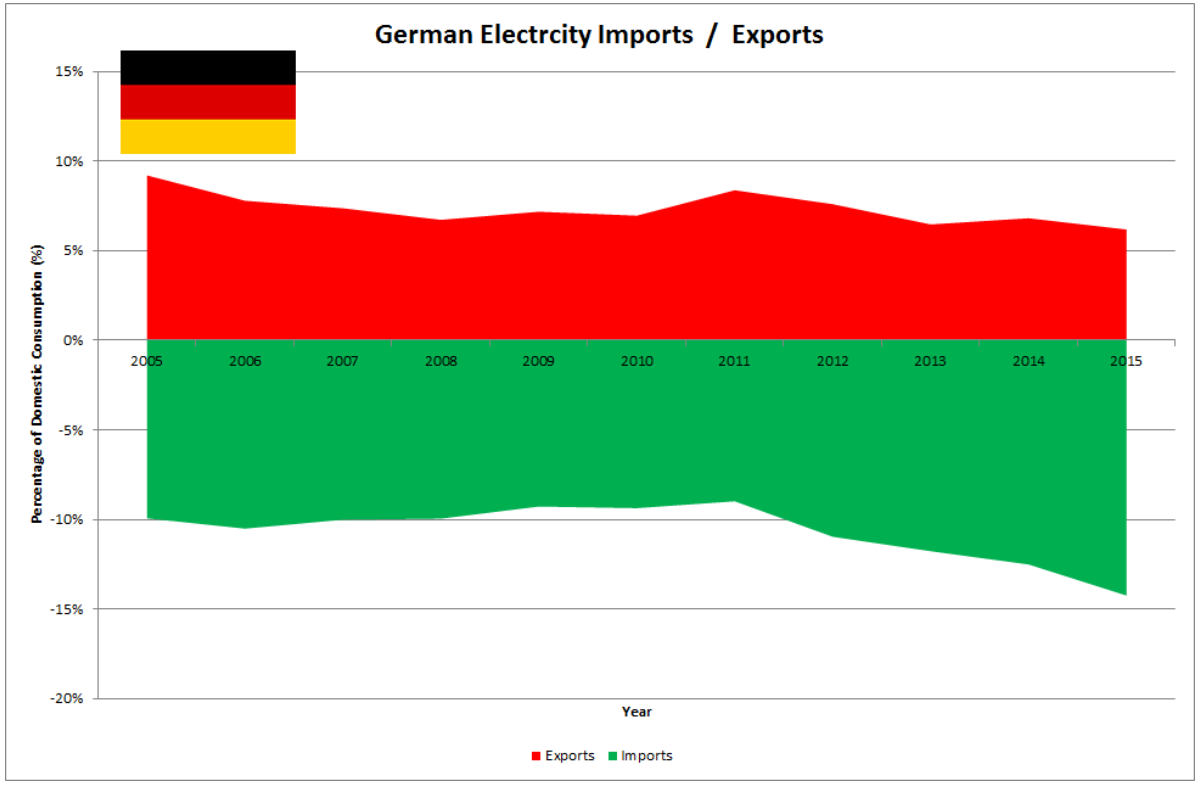


Source : Based upon data from IEA, at https://www.iea.org/statistics/statisticssearch/report/?year=2015&country=GERMANY&product=ElectricityandHeat
International Energy Agency (IEA), Paris, accessed 30th April, 2018

Appendix ‘B’ - Commentary

Reliability Of Renewables

In addition, the German Electricity System is NOT Stand ALONE in the same manner that the Australian National Electricity Market (NEM) is. Germany is interconnected with surrounding counties such as Poland and France. Thus, German is able to import (as well as export) Electricity when need. See below :



International Energy Agency

Secure • Sustainable • Together

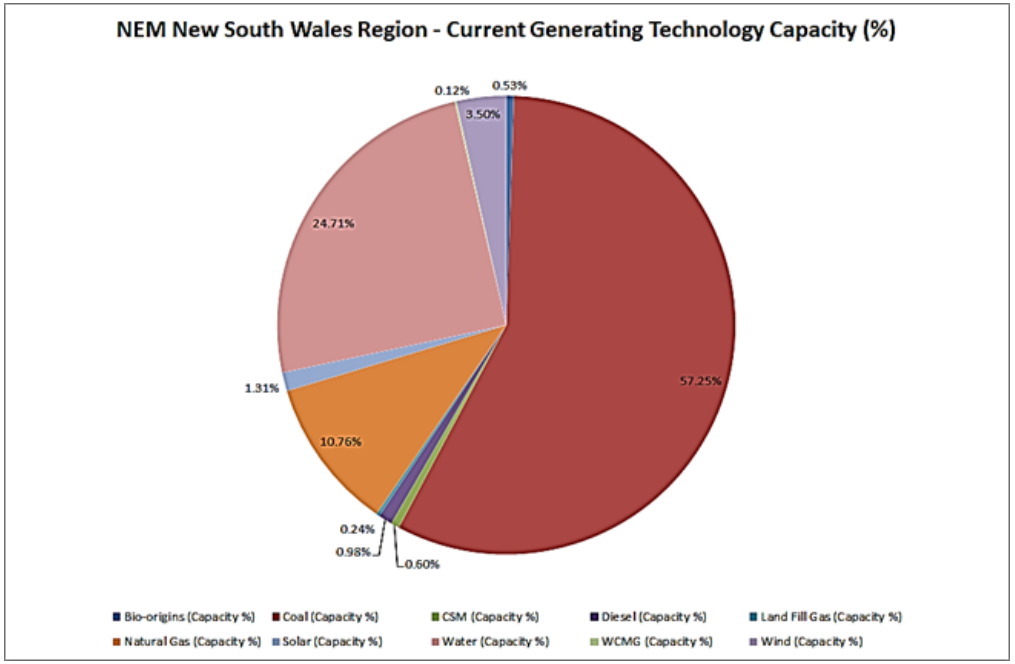
Source : Based upon data from IEA, at https://www.iea.org/statistics/statisticssearch/report/?year=2015&country=GERMANY&product=ElectricityandHeat
International Energy Agency (IEA), Paris, accessed 30th April, 2018

Appendix ‘B’ - Commentary

Reliability Of Renewables

The assumption that intermittent supply from some Renewables can be made up for with Generation from more controllable sources has a major problem which was well illustrated by the challenges faced by Alinta’s Northern Power Station in South Australia since the rapid jump in Renewables in that NEM Region. It is challenging for Base Load Coal Fired Power Station to operate with the flexibility need to support the fluctuation in Renewable supply. The cost of having Coal Fired Plants “idling” in order to support Renewables is likely commercially not viable.

The loss of additional Base Load capability in the NEM (such as Liddell) may bring about a “tipping point” in Generating Capacity (the Australia fleet is quite small and any changes now have magnified effects as each Power Station represents an disproportionate percentage of Capacity and Generation (Hazelwood as ≈ 24% of Victorian Capacity and Lidded is currently Generation ≈ 10 to 12% of New South Wales Electricity.



Appendix ‘B’ - Commentary

Reliability Of Renewables

So, Gas Fired generation is seen as the “firming” element. This is now also problematic with the current high prices and supply issue associated with Natural Gas in Australia.

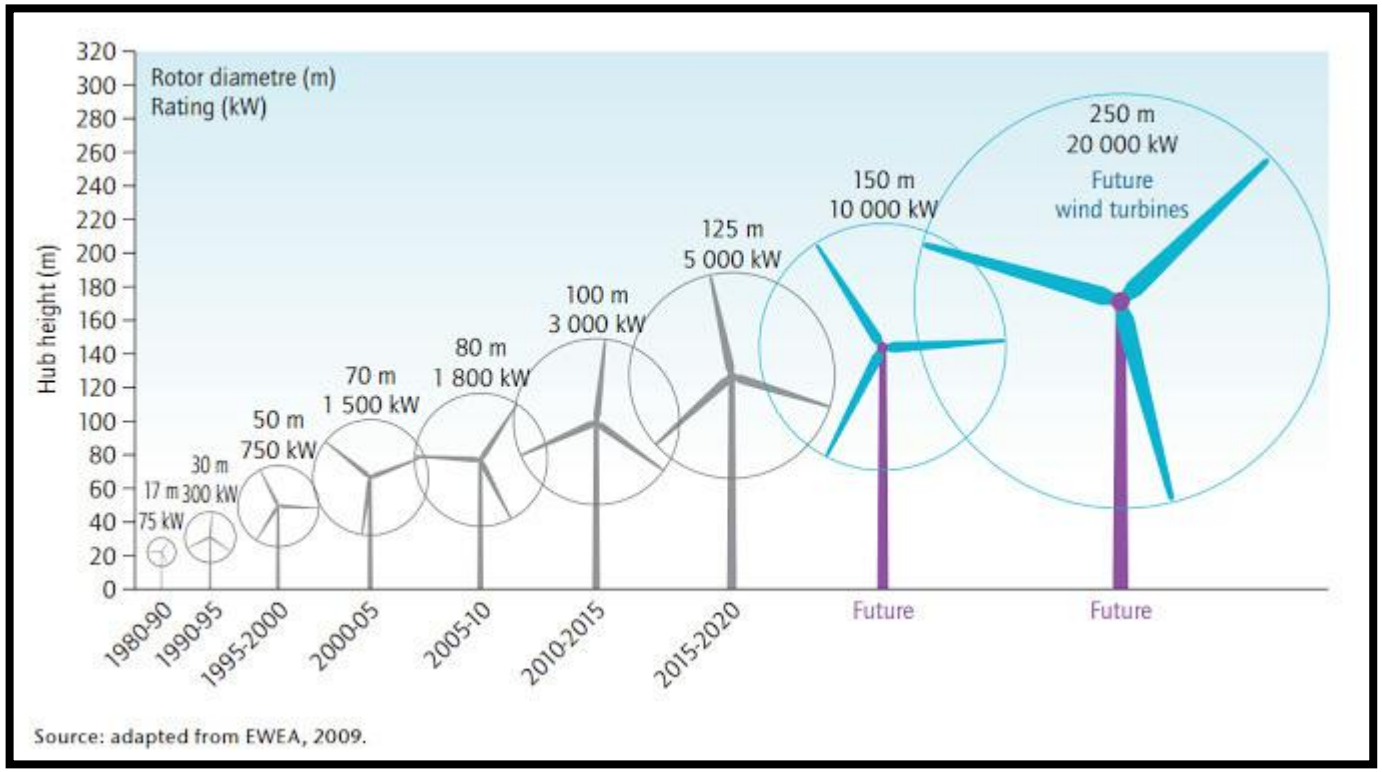
The need to have Gas supplies and Gas Haulage contracted or be able to purchases Gas quickly on the Spot market makes starting and running Gas Fired Power Plants additionally challenging when the need to “run” may be short term due to Renewable variations. The bulk of Gas Fired Power Stations which have been built in the NEM are less efficient Open Cycle Gas Turbine (OCGT) plants (as compared to Combined Cycle Gas Turbine – CCGT plants) and thus they have a very wide “spark spread”. In addition, the critical item in determining Gas Turbine life is the number of starts of the machine. Thus, frequent stop / start cycles consume plant life rapidly and add to costs and reliability concerns.

It appears that AGL Energy may be trying to address some of the concerns with Gas Turbines for opting for Reciprocating Engines of relatively small unit size (18 MW per Unit). The facts regarding Gas supply and cost however still remain.

Appendix ‘B’ – Supporting Information

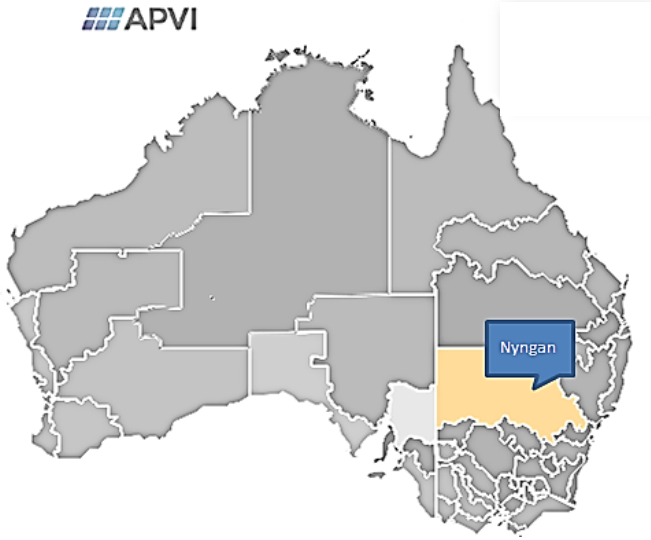
Replacement With Renewables + Storage + Firming

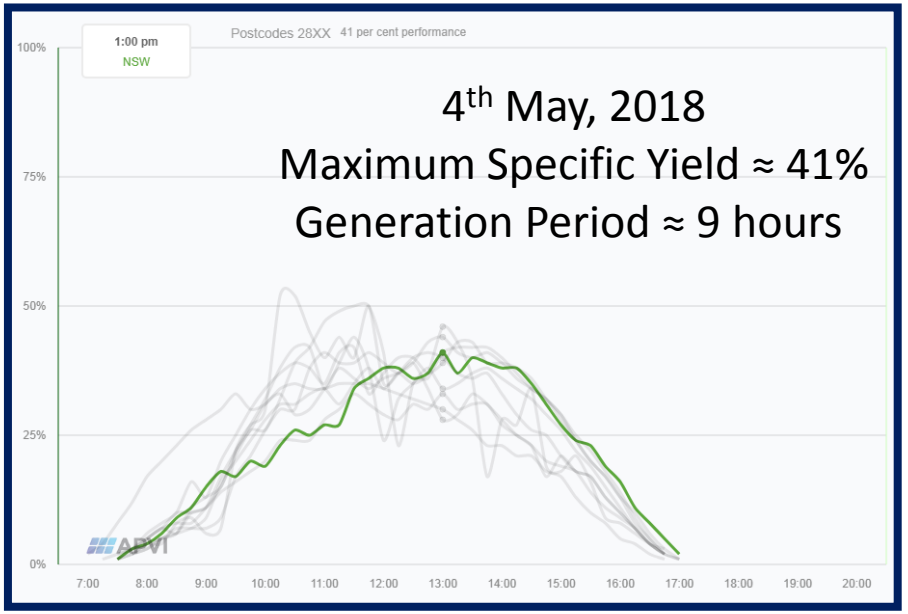
The Macarthur Wind Farm is a wind farm located in Macarthur, Victoria, Australia, near Hamilton, 260km west of Melbourne. It is on a 5,500 ha site which has an installed capacity of 420 megawatts (MW). Based on the prevailing wind speeds at the site, it is estimated that the long-term average generation will be approximately 1,250 GWh per year, operating at a capacity factor of around 35%. The actual wind speed varies year-to-year, and during FY2015 the farm produced 977.9 GWh. The wind farm comprises 140 Vestas V112-3.0MW wind turbines manufactured in Denmark.

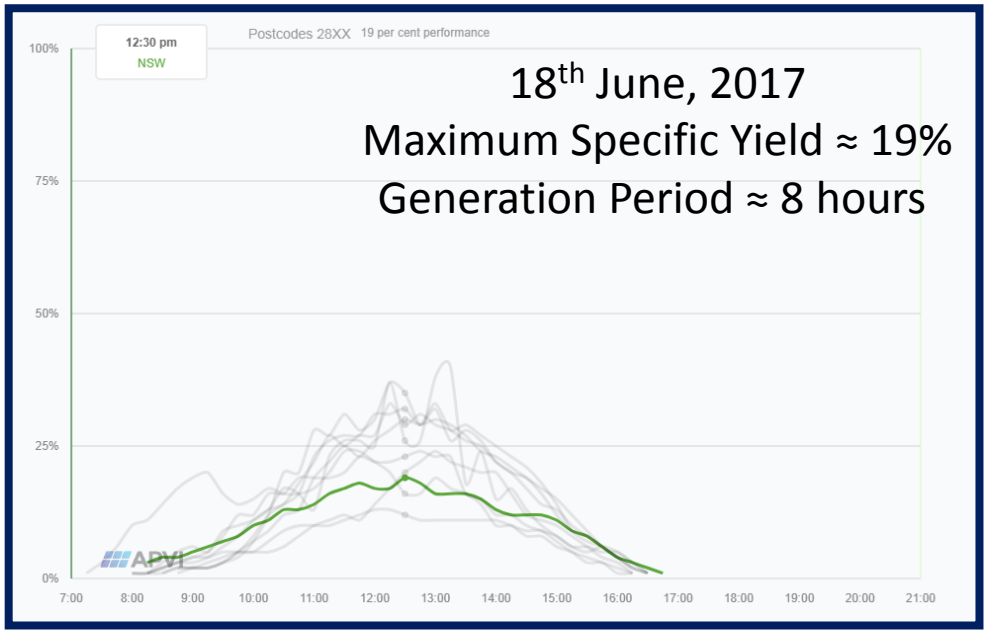


Appendix ‘B’ – Supporting Information

Replacement With Renewables + Storage + Firming







The Nyngan Solar Plant is located approximately 10 kilometres west of the Nyngan township. The solar plant occupies approximately 250 hectares (ha) of land in a 460 ha site to the north of the Barrier Highway.

Nyngan receives strong and consistent solar radiation, making it an ideal location for a solar power plant. The site is well-located between the regional centre of Dubbo to the east, and a number of mining loads at Cobar to the west, meaning there is significant need for electrical power in the region. The existing Nyngan - Cobar 132kV transmission line is located just south of the site, allowing for relatively efficient connection into the electrical grid. The project site is flat, rural land with a good buffer from Nyngan and nearby residents.

The plant is expected to operate for 30 years. The solar field comprises more than 1.35 million solar photovoltaic (PV) modules installed on steel frames, supported by approximately 150,000 steel posts. First Solar supplied the advanced cadmium telluride (CdTe) thin film photovoltaic modules rated at 1.26 kW and weighing 12kg each. The CdTe modules are capable of producing the same amount of power produced by traditional crystalline modules while consuming lesser amount of semiconductor material. The modules are fixed at an angle of 25°.

Source : Australian PV Institute (APVI), Solar Map Database : http://pv-map.apvi.org.au/live#2016-06-18 , accessed 12th April, 2018.

Appendix ‘B’ – Supporting Information

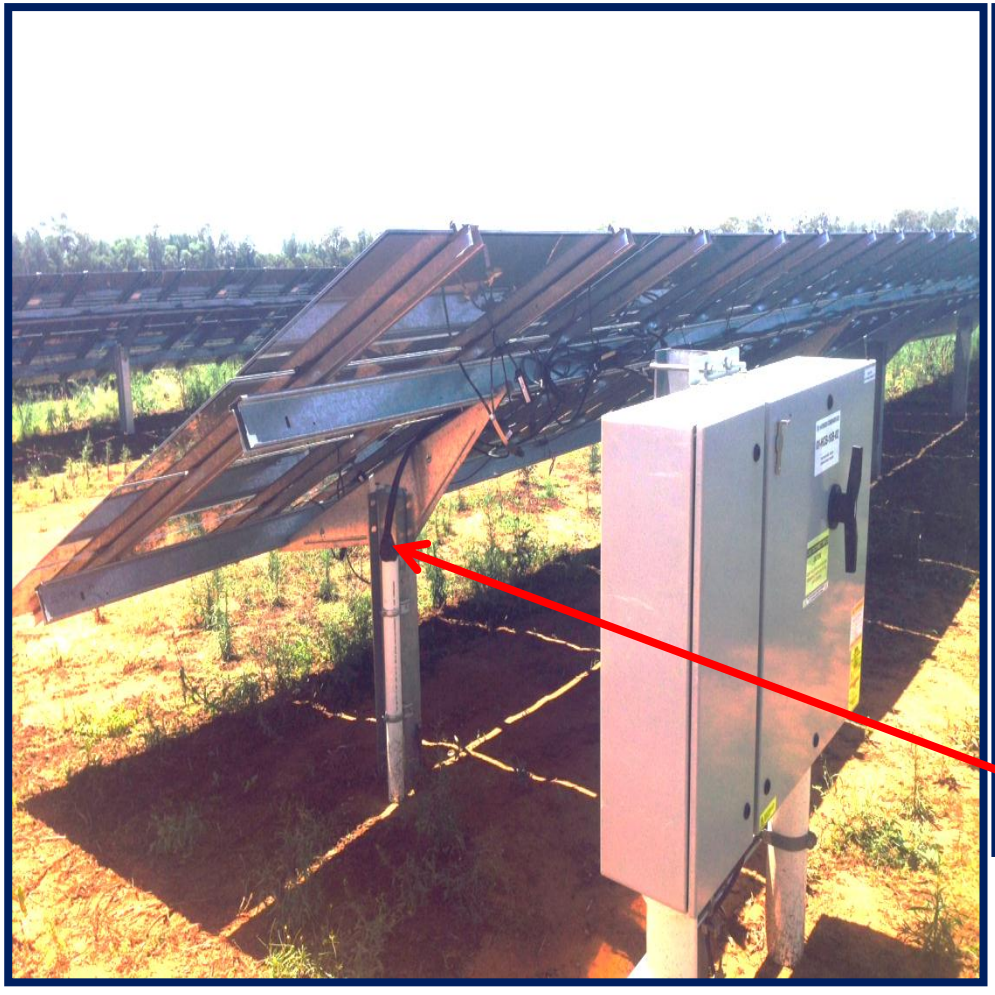
Replacement With Renewables + Storage + Firming

The modules are wired together in arrays which will be connected to inverters to transform the DC current produced by the modules into AC current that can be fed into the grid network.

The Logistics Of Grid Scale Solar PV Are Massive

Appendix ‘B’ – Supporting Information

Solar PV, a Maintenance Nightmare and Reliability Threat



Note the plastic coated cables and plastic connectors

The Nyngan Solar Plant Panel Arrangement (Underside).

Appendix 'B' – Supporting Information

Replacement With Renewables + Storage + Firming

Solar Irradiation data for the Zone in which the Nyngan Solar Farm sits

(Specific Yield kWhr / kWp / Day for 1 Year)

Maximum kWhr / kWp / Day ≈ 11.5

Minimum kWhr / kWp / Day ≈ 0.8

Average kWhr / kWp / Day = 7.06

Source : Australian PV Institute (APVI), Solar Map Database : http://pv-map.apvi.org.au/performance#4/-28.77/134.91 accessed 12th April, 2018.

CAPITAL COST COMPARISON

Technology	Range (US$/kW)		Range (A$/kW)	
Diesel Reciprocating Engine	500	800	649	1,039
Natural Gas Reciprocating Engine	650	1,100	844	1,429
Gas Peaking	800	1,000	1,039	1,299
Gas Combined Cycle	700	1,300	909	1,688
Assumption: 1 A$ ≈ 0.77 US$				

Based upon : Lazard, 2017, "Lazard's Levelised Cost Of energy Analysis – Version 11.0", November 2017, Lazard, New York, p. 11.

Appendix ‘C’
Decline of Coal Fired Generation In The UK

Replacement Of Coal or Maybe NOT

Appendix ‘C’ – Decline of Coal Fired Generation In The UK

Replacement Of Coal

Rubicon

Note

Given the recent publicity surround the demise of Coal Fired Generation in the United Kingdom, this Appendix examines the UK Generation situation is some detail.

Appendix ‘C’ – Decline of Coal Fired Generation In The UK

Replacement Of Coal

BBC

NEWS

Britain powers on without coal for three days

24 April 2018

Image copyright GETTY IMAGES

Image caption : The Drax power station in North Yorkshire has been switching some furnaces from coal to biomass

Britain has not generated electricity from coal for more than three days - the longest streak since the 1880s.

The new record comes just days after the last record of 55 hours was set, National Grid said.

The coal-free period began on Saturday at 1000 BST and has continued into Tuesday afternoon.

Power generated from wind and gas dominated the mix of energy for users in England, Scotland and Wales.
Just last week the UK grid recorded its first two-day period without using any power from the fossil fuel, which the government has pledged to **phase out by 2025**.

- **UK's greenest year yet**
- **Coal plants to close by 2025**

Coal accounted for less than 7% of the power mix last year, according to official figures.
In April, 2017 Britain went its **first full day without coal** since the 19th century.

Image copyright GETTY IMAGES

Image caption : A wind farm in mid-Wales

However, experts warned that power generated by coal was largely being replaced by gas, another fossil fuel, rather than renewable sources.

Andrew Crossland, of the Durham Energy Institute, said gas generated 40% of the UK's electricity and fuelled the vast majority of domestic heating: "As a country we consume nearly eight times more gas than coal."
The daily consumption of gas was **outstripped by wind on just two days** last year, while all sources of renewable energy - including wind, solar, biomass and hydropower - beat fossil fuels for just 23 days of 2017.

A reliance on gas made the UK vulnerable to the whims of international markets and was "nowhere near clean enough" to meet the UK's legal targets to cut greenhouse gas emissions, Mr Crossland said.

The 2008 Climate Change Act requires greenhouse gas emissions to be reduced by 80% compared with 1990 levels by 2050.

Hannah Martin, from Greenpeace UK, called on the government to provide more support for onshore wind and solar power - the "cleanest and cheapest energy sources".

"Offshore wind has proven to be popular and able to provide affordable clean energy, as well as skilled jobs and fair bills," she said.

"As we have more and more days without coal, we need to make sure it is replaced with the renewable technologies of the future."

Mr Crossland also called for more investment in renewable technologies, such as solar panels and batteries, to store power for homes and businesses, along with better energy efficiency to reduce power use.

Source : BBC, 2018, “Britain powers on without coal for three days” at : http://www.bbc.com/news/business-43879564 , accessed 19th May, 2018, BBC, London.

Appendix ‘C’ – Decline of Coal Fired Generation In The UK

Replacement Of Coal

BBC

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24 April 2018

- **UK's greenest year yet**
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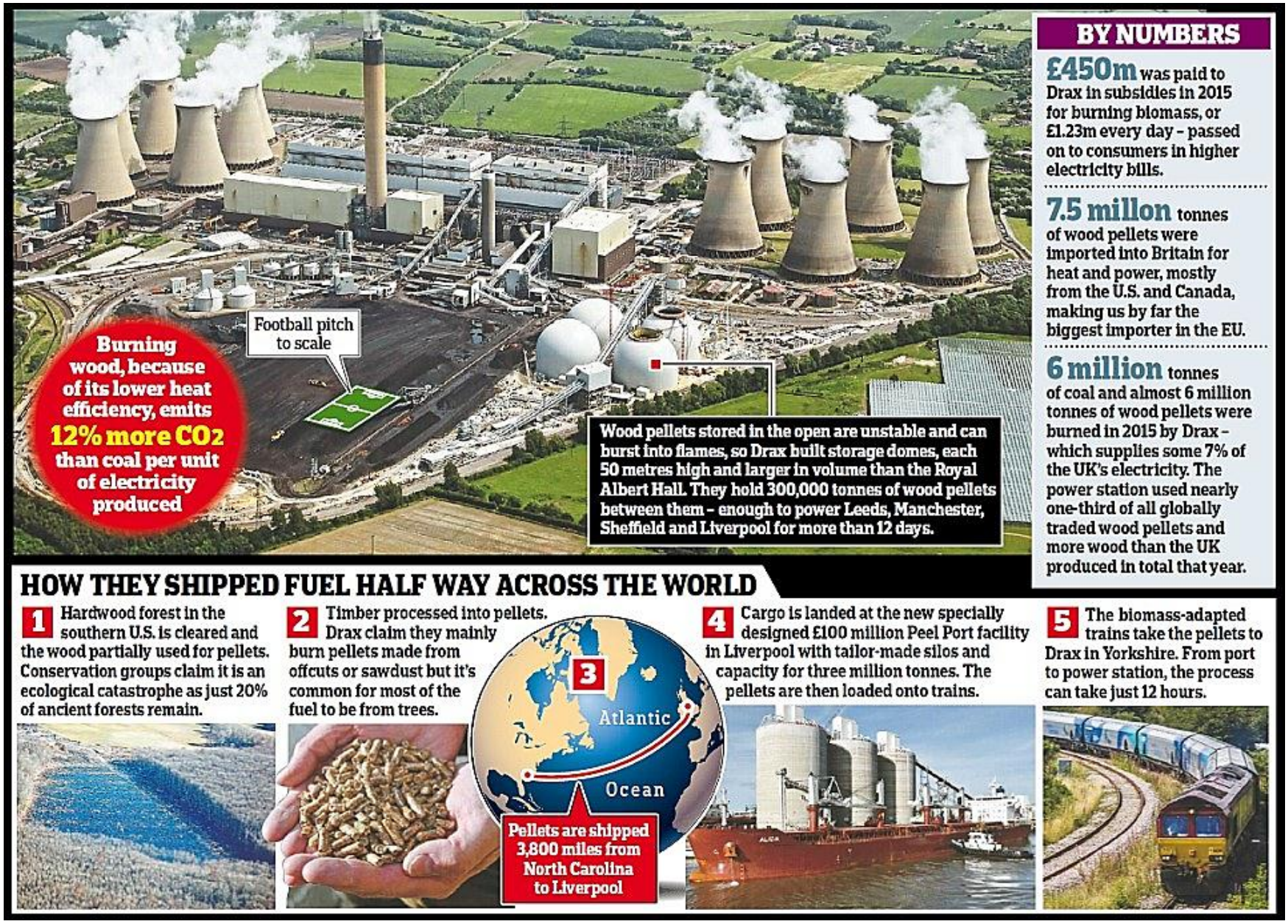
Appendix ‘C’ – Decline of Coal Fired Generation In The UK

Replacement Of Coal



Appendix ‘C’ – Decline of Coal Fired Generation In The UK

Replacement Of Coal

Daily Mail

Pure idiocy! How spending billions on subsidising an efficient coal-burning power station to burn wood is actually WORSE for the planet than before

By Christopher Booker For The Daily Mail

PUBLISHED: 12:24 AEST, 24 February 2017

Almost exactly four years ago, I revealed details in the Daily Mail of what I described as the perfect symbol of Britain’s ‘mad energy policy’.

It demonstrated more vividly than anything just how far the politicians in charge had become so lost in ‘green’ make-believe that their behaviour amounted to collective insanity.

What I was writing about in 2013 was development plans for Yorkshire’s giant Drax coal-fired power station, then the largest, cleanest and most efficient of its kind in Europe, supplying some 7 per cent of Britain’s energy needs.

Source : By Christopher Booker, C., 2017, “Idiocy of replacing coal power stations with burning wood”, at http://www.dailymail.co.uk/news/article-4255010/Idiocy-replacing-coal-power-stations-burning-wood.html#ixzz5GC3fnOAz
The Daily Mail, London, accessed : 20 April 2018.

Appendix ‘C’ – Decline of Coal Fired Generation In The UK

Replacement Of Coal

Daily Mail

Pure idiocy! How spending billions on subsidising an efficient coal-burning power station to burn wood is actually WORSE for the planet than before

Con’t,

Drax was about to spend £700 million, as a direct result of ‘green’ government policy, to convert half of its six giant furnaces from burning coal — the cheapest source of energy — to burning millions of tonnes a year of wood pellets, shipped over from America.

For Drax the commercial logic of this switch had become unavoidable. For a start, the Government was just about to introduce a steeply rising ‘carbon tax’ which would eventually make burning coal wholly uneconomical.

At the same time, burning wood, or ‘biomass’ as it is now termed, was deemed to be so ‘green’ and environmentally friendly that the Government was also offering a new subsidy so lavish that it would **pay Drax two-and-a-half times more for the electricity it produced from wood than the cost of nasty, polluting coal.**

Appendix ‘C’ – Decline of Coal Fired Generation In The UK

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The crucial point was that burning wood had been officially ruled by the EU to be ‘carbon neutral’ on the grounds that any CO_2 it emitted would eventually be recovered from the atmosphere by new trees planted to replace those which had been chopped down.

By switching to wood, it was claimed, Drax — the single largest producer of CO_2 emissions in Britain — would not only help ‘save the planet’ but also make a huge contribution to meeting the EU’s target that Britain must generate nearly a third of its electricity from so-called ‘zero-carbon’ sources of renewable energy.

Even before this huge project got under way, serious questions were being raised over these claims as well as the extraordinary cost. Now, a report published this week by the man who was formerly a special adviser to Chris Huhne — the minister in charge of Britain’s energy policy when the Drax project was first discussed in 2012 — has confirmed those concerns in spades.

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The fact it is by someone so close to the subject matter — Duncan Brack worked for Huhne when he was minister of state at the Department for Energy and Climate Change — only adds to the sense of outrage.

The most telling point in his report for Chatham House, the respected think-tank, and one which is supported even by ardent green lobby groups such as Greenpeace, is that in reality Drax hasn’t been making any savings on CO_2 emissions at all.

Firstly, it is ludicrous to claim that wood is ‘carbon neutral’ on the grounds that replacement trees would eventually absorb the carbon emitted when a felled tree is burned. The report says it could take a replacement tree hundreds of years to grow to maturity — which would be far too long to have any supposed effect on any climate change.

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Second, burning wood, because of its lower heat efficiency, emits 12 per cent more CO_2 than burning coal per unit of electricity.

Yet the report points out that the Government’s assessment of the impact on the climate from coal to wood pellets totally ignores emissions from burning the pellets in power stations. The Government only counts emissions caused by harvesting, processing and transporting the wood pellets to the power station.

This brings us on to the deeply alarming process involved in the production of this ‘green’ fuel from forests in North Carolina where the wood is turned into pellets and then transported no fewer than 3,800 miles across the Atlantic to Yorkshire.

It has been abundantly documented, not least in the U.S. itself, that a huge quantity of the millions of tonnes of wood turned into pellets is not just offcuts and waste material such as sawdust, as is claimed.

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Con’t,

Duncan Brack’s report says that about three-quarters of the pellets from the southern U.S. came from whole trees, while such ‘residues’ accounted for just a quarter.

What’s more, these trees are growing in some of America’s most prized and wildlife-rich virgin hardwood forests.

Little wonder that wood-pellet production has been described by conservation organisations as ‘an ecological catastrophe’. So the net result of giving Drax £450 million a year in subsidies to meet our EU ‘green’ target — and this sum is due to double when its conversion to biomass is complete — is that far from reducing the UK’s carbon emissions, we are actually increasing them while at the same time doing huge damage to the environment. And to make matters worse, we are all funding this lunatic exercise through hugely increased electricity bills.

Appendix ‘C’ – Decline of Coal Fired Generation In The UK

Replacement Of Coal

Daily Mail

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Con’t,

Of course, while we are having to dig into our pockets, those at the top of government who were behind this crazy policy have happily used their ‘expertise’ in greenery to enrich themselves.

Scarcely had Chris Huhne himself been released from prison in 2013, for perverting the course of justice after persuading his wife to take his speeding points, than he became the European chairman of a firm called Zilkha Biomass Energy . . . which makes its money supplying wood pellets from North America to Europe.

In fact, nearly all our other former energy ministers have no sooner left office than they are snapped up for lavish financial rewards to work for ‘green’ companies which are making millions from policies which those same ministers put in place.

Appendix ‘C’ – Decline of Coal Fired Generation In The UK

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After leaving office Charles Hendry, another former minister of state at Environment, replaced yet another former environment minister, Lord Deben (John Gummer), as chairman of the foreign-owned company which is building the largest (and most heavily subsidised) offshore windfarm in the world in the North Sea.

Ed Davey, former Lib Dem energy secretary in the Coalition, now advises three companies in the low-carbon energy sector. And Lord Barker of Battle, formerly energy minister Greg Barker, advises both a renewable heat firm and a solar panel outfit.

The fact is that these individuals — along with then party leaders such as David Cameron, Nick Clegg and Ed Miliband, all desperate to burnish their green credentials — have presided over an energy policy that is nothing short of a catastrophe.

Appendix ‘C’ – Decline of Coal Fired Generation In The UK

Replacement Of Coal

Daily Mail

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Con’t,

Scarcely a week now goes by without some new horror story over yet another ‘green’ fiasco wasting huge sums of our money while failing to reduce CO_2 emissions or achieving any of the environmental benefits which were claimed for it.

Only last month there was the collapse of the Northern Irish government over the scandal of the Renewable Heat Incentive scheme, designed to increase production of heat from renewable sources.

It emerged that businesses had been flocking to join it because for every £100 they spent on wood pellets to heat their buildings, they would automatically get £160 back from UK taxpayers.

Appendix ‘C’ – Decline of Coal Fired Generation In The UK

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Con’t,

Unsurprisingly they were working their boilers round the clock to get the money, even when their premises were found to be disused or empty, and costs are heading towards £1 billion. Then there are the giant new ‘anaerobic digesters’, subsidised to the tune of another £200 million a year, to make gas from waste and specially grown farm crops.

These have caused a succession of environmental disasters when toxic ammonia used in the process spills out into farmland and rivers.

At least the Government has not yet given the go-ahead to the ludicrous £40 billion project to build six vast coastal tidal lagoons, to generate ridiculously small amounts of electricity in return for absurdly large subsidies.

Appendix ‘C’ – Decline of Coal Fired Generation In The UK

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Minimal or negative returns for taxpayer largesse are, of course, the problem with virtually all these renewable energy schemes — above all the windfarms and solar farms for which we pay £5 billion a year in subsidies for electricity that is often not there when we need it because the wind isn’t blowing or the sun isn’t shining.

And yet, all the time, the Government uses the tax system to punish those coal and gas-fired power stations that still provide two-thirds of our electricity whenever we need it, and without a penny of subsidy.

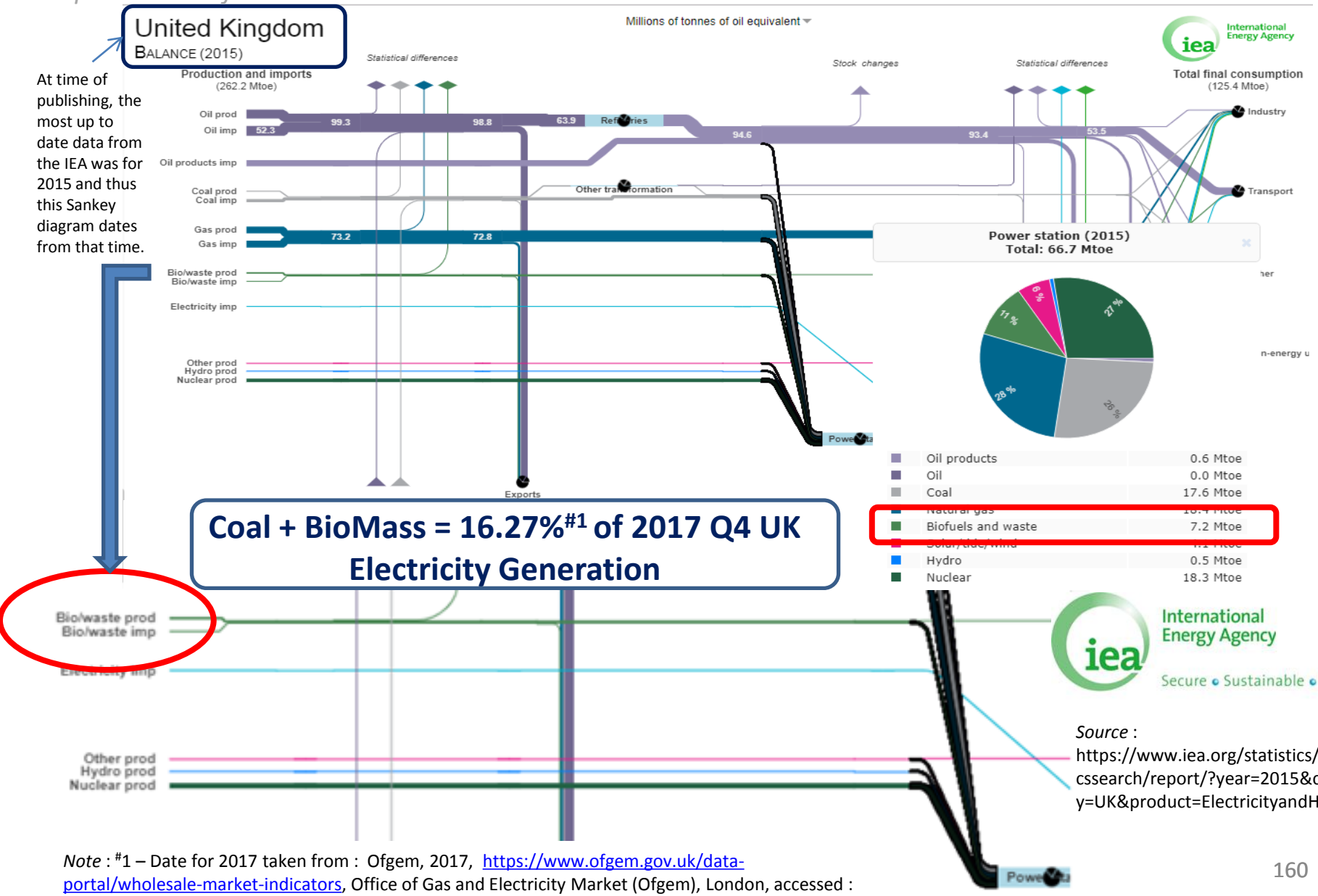
The truth is that where energy is concerned, those who govern us, including MPs of all parties who just meekly go along with it, are in the grip of a total madness.

Who is going to stop it, before our lights really do go out?

Appendix ‘C’ – Decline of Coal Fired Generation In The UK

Replacement Of Coal

At time of publishing, the most up to date data from the IEA was for 2015 and thus this Sankey diagram dates from that time.



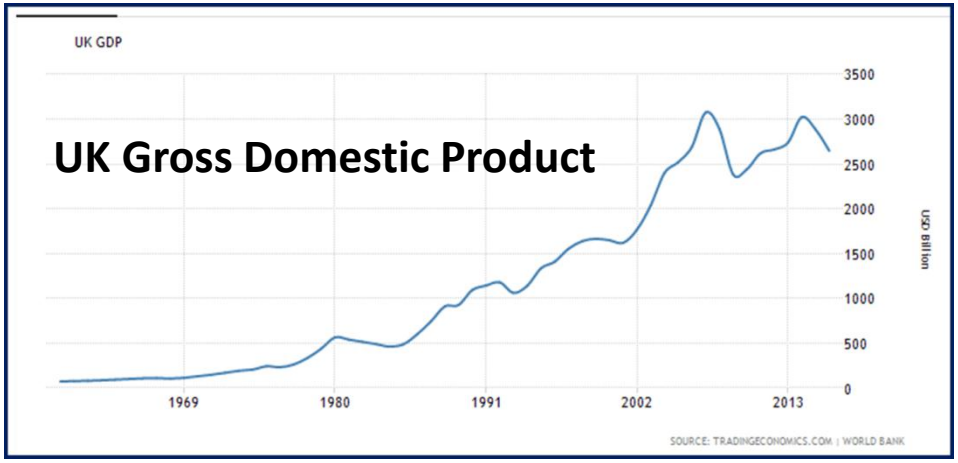
Source : https://www.iea.org/statistics/statisticssearch/report/?year=2015&country=UK&product=ElectricityandHeat

Note : #1 – Date for 2017 taken from : Ofgem, 2017, https://www.ofgem.gov.uk/data-portal/wholesale-market-indicators, Office of Gas and Electricity Market (Ofgem), London, accessed :

Appendix 'C' – Decline of Coal Fired Generation In The UK

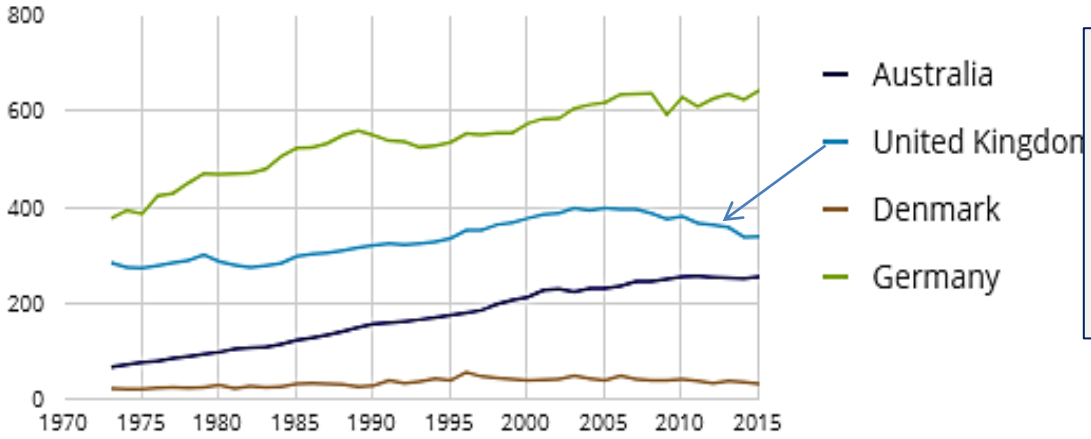
Replacement Of Coal

These data are extracted from the 2017 edition of the Electricity Information book published by the International Energy Agency. This publication brings together in one volume the basic statistics compiled by the IEA on electricity and heat production. It also includes information on installed capacity, consumption, trade and prices.



Comment **: Given the UK's economic situation and the focus in the UK of reducing Energy demand (a good thing if it is not at the expense of GDP and/or the well being of Society), the UK does not represent a good example for Australia.**

Electricity Generation (TWh)



T**he UK's imports a vast amount of its raw energy – Natural Gas, Coal, BioMass (wood pellets) and is interconnected to Europe for Electricity.**

Source : IEA, 2017, http://www.energyatlas.ie.org/-#1/tellmap/-1118783123, IEA, Paris.

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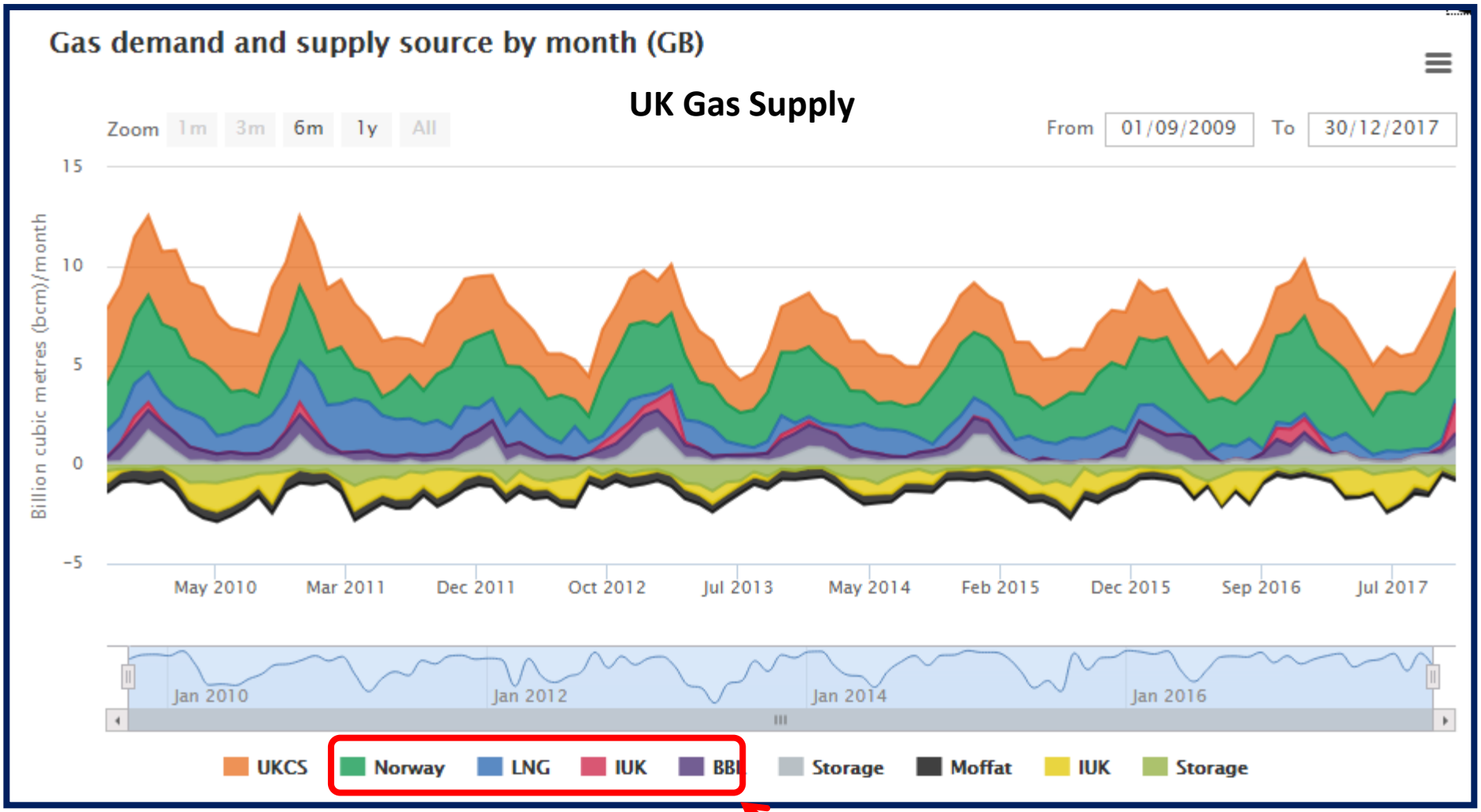
Appendix ‘C’ – Decline of Coal Fired Generation In The UK

Replacement Of Coal



Imports – Refer following page

Source : Ofgem, 2017, https://www.ofgem.gov.uk/data-portal/wholesale-market-indicators, Office of Gas and Electricity Market (Ofgem), London, accessed :

Appendix 'C' – Decline of Coal Fired Generation In The UK

Gas demand and supply source: At-a-glance summary

Source : Ofgem, 2017, https://www.ofgem.gov.uk/data-portal/wholesale-market-indicators, Office of Gas and Electricity Market (Ofgem), London, accessed :

In recent years gas demand has fallen across all consumers as boilers have become more efficient and demand for gas from power stations has fallen.

Around 75% of our gas comes from the UK continental shelf **and Norway,** with the **remainder coming from continental Europe and global LNG.**

Relevance and further information

The gas supply mix is a useful indicator of the diversity and origin of the gas supplied in GB. Having diverse sources of supply suggests greater resilience for GB gas supply.

Methodology

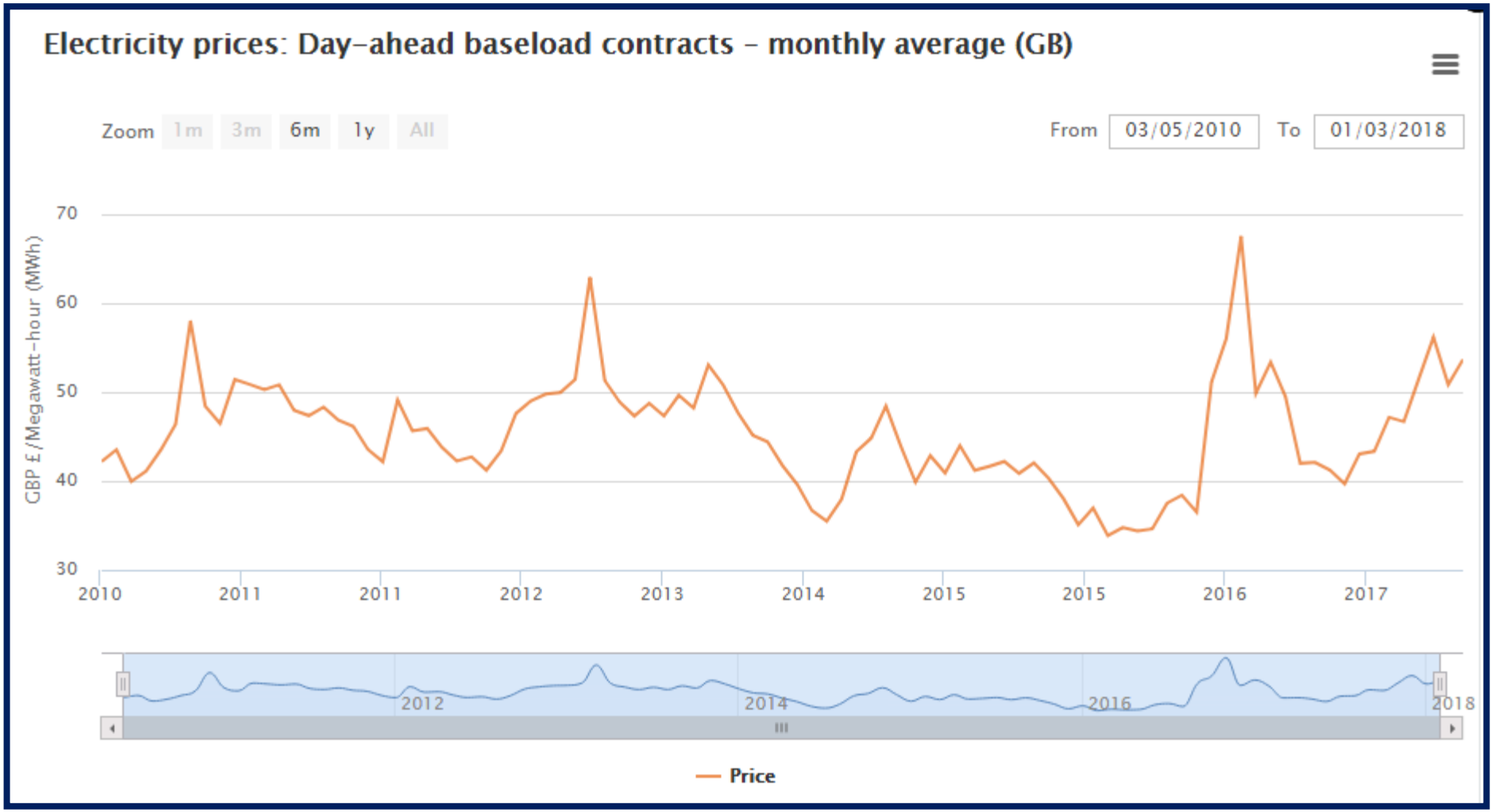
Positive values represent supplies to the GB system. This includes domestic production from UKCS, **imports at LNG terminals**, withdrawals from storage and imports via pipelines and interconnectors.

Negative values represent supplies from the GB system (excluding end-consumer demand). This includes injections to storage and exports via interconnectors. **GB has three interconnectors linking us with Belgium (IUK), the Netherlands (BBL) and Ireland and Northern Ireland (Moffat).**

For simplicity, we have assumed gas entering at the St. Fergus terminal to be from the UKCS for the Mobil subterminal, and from Norway for the Shell and Total subterminals. This is likely to marginally overstate gas flows from Norway.

Appendix ‘C’ – Decline of Coal Fired Generation In The UK

Replacement Of Coal



Note : 1 GBP (£) ≈ 1.77 Australian Dollar (A$). Therefore : 50 £ ≈ 88.49 A$

Source : Ofgem, 2017, https://www.ofgem.gov.uk/data-portal/wholesale-market-indicators, Office of Gas and Electricity Market (Ofgem), London, accessed :

Appendix ‘C’ – Decline of Coal Fired Generation In The UK

Replacement Of Coal

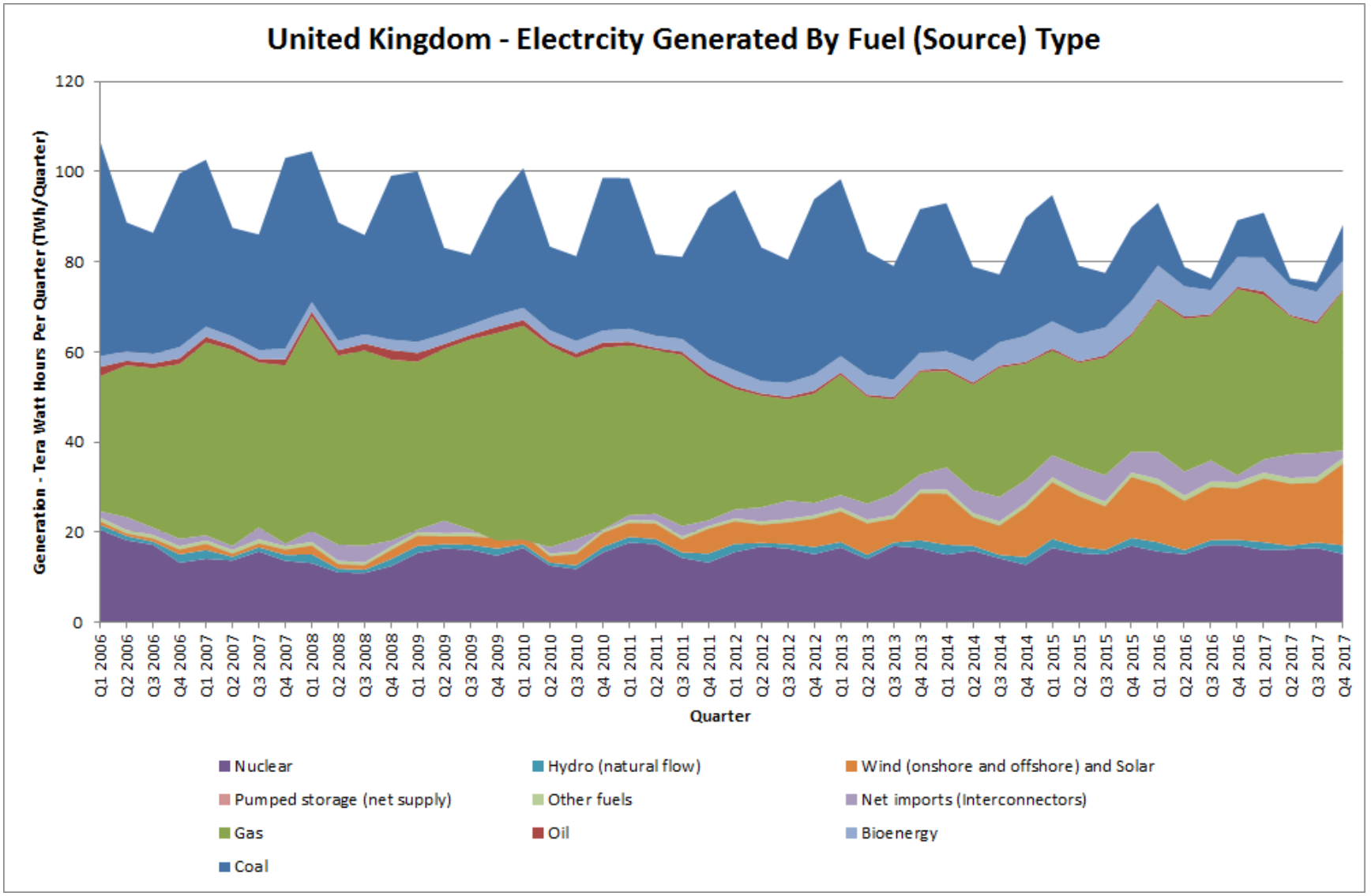
Note : 1 GBP (£) ≈ 1.77 Australian Dollar (A$) 1 GBp ≈ 1.77 A¢ . Therefore : 50 GBp ≈ A¢88.49

1 therm (thm) = 0.11 GJ. Therefore, 50 GBp / thm ≈ 8.05 A$ / GJ

Source : Ofgem, 2017, https://www.ofgem.gov.uk/data-portal/wholesale-market-indicators, Office of Gas and Electricity Market (Ofgem), London, accessed :

Appendix ‘C’ – Decline of Coal Fired Generation In The UK

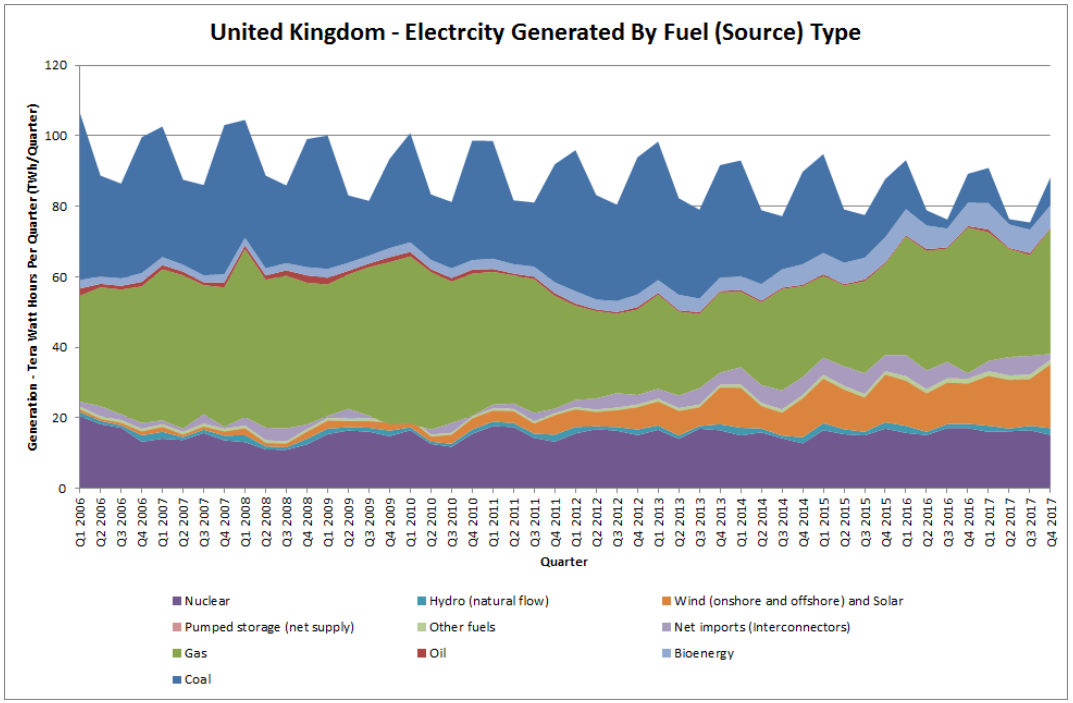
Replacement Of Coal



Source : Based upon data drawn from - Ofgem, 2017, https://www.ofgem.gov.uk/data-portal/wholesale-market-indicators, Office of Gas and Electricity Market (Ofgem), London, accessed :

Appendix ‘C’ – Decline of Coal Fired Generation In The UK

Replacement Of Coal



Note : Australia Does Not Have Nuclear Generation To Provide A Base Load.

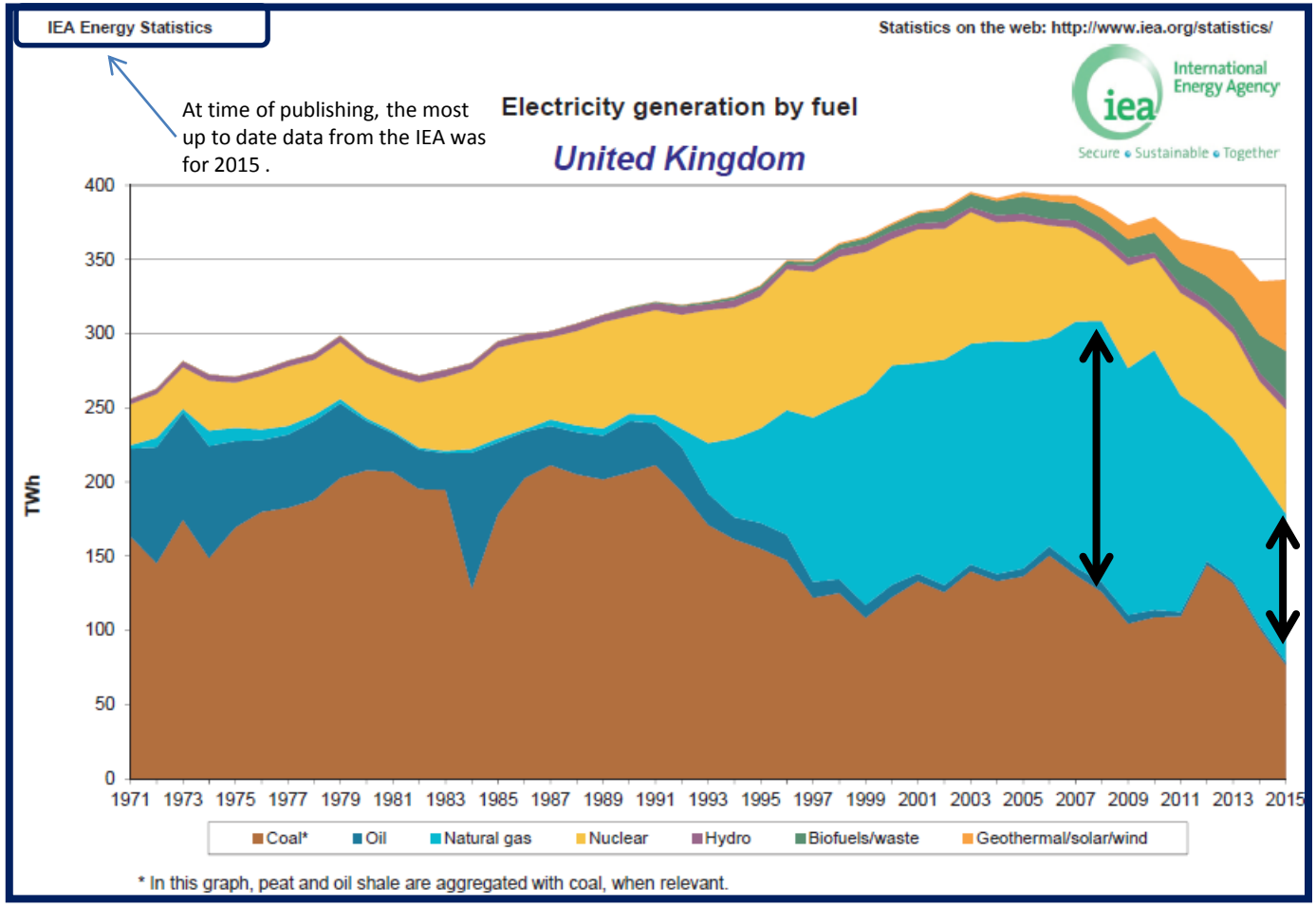
Comment **:**

1. **The overall Generation is declining,**
2. **Coal is “doing” the seasonal cycling,**
3. **The Bioenergy (BioMass) is in the main imported Wood Pellets burned in Coal Power Stations,**
4. **Natural Gas remains the largest single Energy Source for Electricity Generation but when a longer historical view is taken, its importance is declining,**
5. **Renewables remain a relatively small portion of the over all Generation mix,**
6. **There are Electricity imports.**

Source : Based upon data drawn from - Ofgem, 2017, https://www.ofgem.gov.uk/data-portal/wholesale-market-indicators, Office of Gas and Electricity Market (Ofgem), London, accessed :

Appendix ‘C’ – Decline of Coal Fired Generation In The UK

Replacement Of Coal



Comment **:**

1. **Natural Gas (Gas) was the replacement Fuel for Coal during the “*Dash For Gas*” triggered by the then Thatcher Government,**
2. **Gas as a Fuel for Electricity Generation in the UK is now declining dramatically and this may be due to cost and availability.**

Source : IEA, 2017, http://www.energyatlas.ie.org/-#1/tellmap/-1118783123, IEA, Paris.

Appendix ‘D’
Fuel Poverty In Australia

Social Licence To Operate

Appendix 'D' – Fuel Poverty In Australia

Social Licence To Operate

Rubicon

Note

If we are to consider the matter of loss of Social Licence To operate by the Australian Energy Industry, the mere reference to "Qualitative Measures" such as media coverage can easily be dismissed. Thus, the application of a Quantitative Measure that is repeatable at intervals is perhaps very necessary.

Simshauser, P., *et al* (2011) in their landmark paper : "The Boomerang Paradox, Part II: Policy Prescriptions for Reducing Fuel Poverty in Australia" brought together an Australia definition of "Fuel Poverty" which is one means of allowing a "Quantitative Measure" of Energy Costs to the Australian Society and thus, can provide a measure of what may be an economic drive of Social dissatisfaction with the Energy Industry. Thus, Simshauser, P., *et al* (2011) are quoted at length in this Appendix.

Whilst other Qualitative Measures may be able to be developed, this is beyond the scope of this paper. The purpose here is to illustrate in a "concrete" manner that there is indeed a real driver to Social concern around Energy.

Appendix ‘D’ – Fuel Poverty In Australia

Social Licence To Operate

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III. Defining Fuel Poverty in Australia

A consumer is said to be experiencing fuel poverty if they spend more than 10 percent of income on energy to maintain an adequate household. In the UK, this is defined specifically as expenditure to maintain an adequate level of warmth within the dwelling. This definition requires researchers to estimate expenditure on energy rather than use actual energy expenditure per household. The UK government has established a specific UK Fuel Poverty Strategy and progress against goals is reported annually. The ultimate aim of the UK Fuel Poverty Strategy is that by 2018, no household in the UK should live in fuel poverty.

Despite the focus of governments for the best part of a decade, the number of households experiencing fuel poverty in the UK has increased from 2 million to 4 million since 2004 (DECC, 2009).

Source : Simshauser, P., Nelson, T., & Doan, T., 2011, "The Boomerang Paradox, Part II: Policy Prescriptions for Reducing Fuel Poverty in Australia', in : The Electricity Journal, March 2011, Vol. 24, Issue 2, Elsevier Inc.., pp. 65 – 68.

Appendix ‘D’ – Fuel Poverty In Australia

“…

III. Defining Fuel Poverty in Australia *con’t,*

Fuel poverty in this study is defined as a condition in which a household actually spends more than 10 percent of its income on energy, with our focus being on the all-electric housing stock for ease of analysis. This is different to the definition of fuel poverty adopted by the UK. A key limitation of the UK definition is that it prescribes a level of ambient temperature within a dwelling. This ignores household options for warming and cooling unrelated to consuming energy (e.g. putting on an additional layer of clothing in winter).

Rather than estimating household expenditure given ambient temperature targets, this article utilizes actual energy consumption spending and real incomes to determine the proportion of household income spent on energy. As such, the measure of fuel poverty provided in this article could be argued to be more reflective. For a more comprehensive study on fuel poverty, expenditure on all forms of energy (including natural gas) would need to be incorporated.

Appendix ‘D’ – Fuel Poverty In Australia

Social Licence To Operate

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IV. The Creation of Fuel Poverty in Australia

To determine the impact on different households, we have utilized disposable income data broken into quintiles published by the Australian Bureau of Statistics for NSW and QLD. We have then estimated the proportion of disposable household income spent on electricity using our price estimates for FY08 and FY15 in Section II *(not included in this extract*). Figure 3 outlines outlines the proportion of disposable income spent on electricity in FY08 by household quintile. Even in the lowest quintile, the proportion spent on electricity is less than the 10 percent threshold required to define a household as fuel poor. Figure 3 demonstrates that as incomes increase, the proportion of household expenditure on energy declines. This is not surprising given electricity is an essential service rather than a luxury good. The implication for studying fuel poverty is that it is only the bottom quintile which requires specific consideration by policymakers. Other households should be able to adjust their budgets accordingly and absorb price increases.

…”

Appendix ‘D’ – Fuel Poverty In Australia

Social Licence To Operate

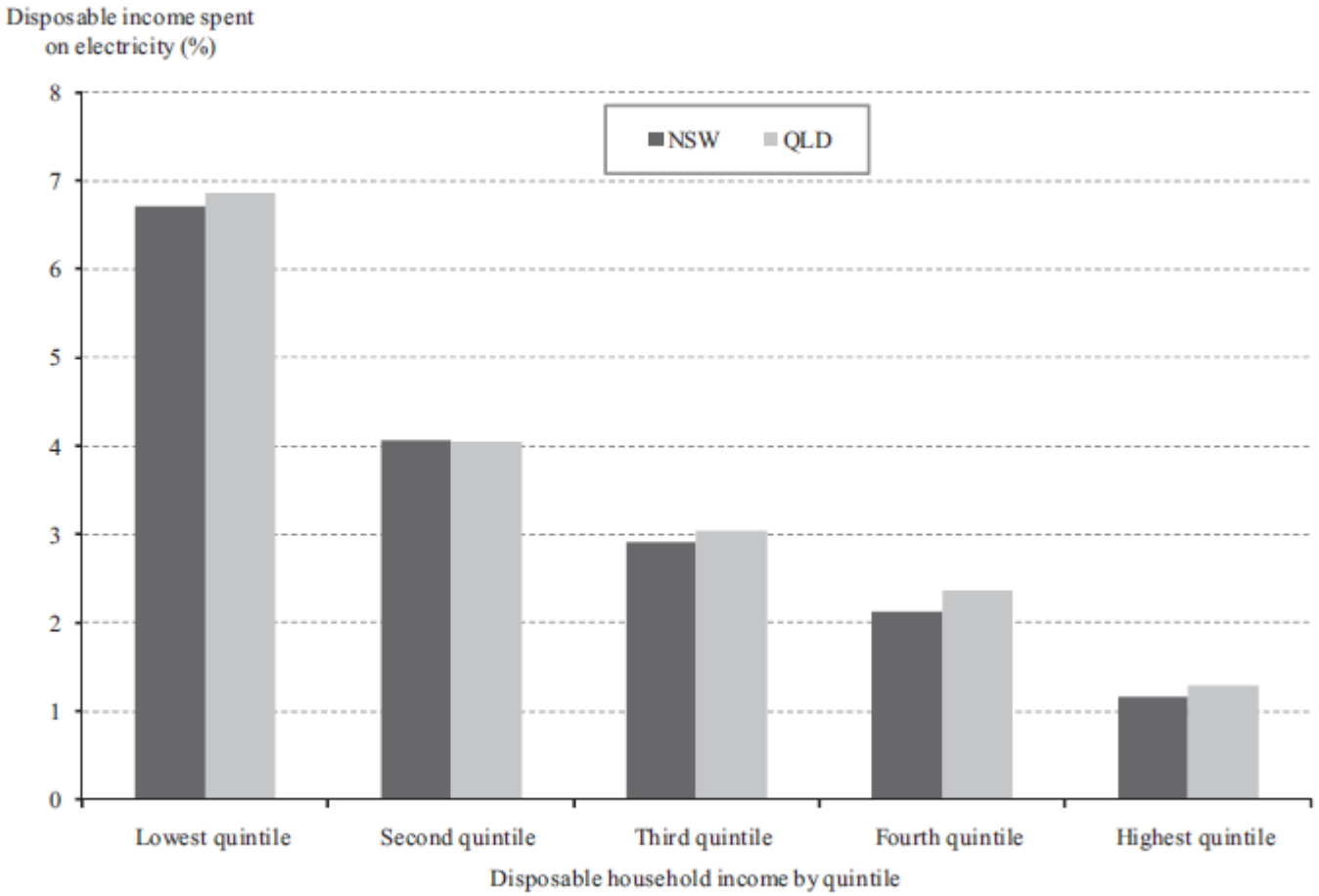

Figure 3: Proportion of Disposable Household Income Spent on Electricity in FY08

Source : Simshauser, P., Nelson, T., & Doan, T., 2011, "The Boomerang Paradox, Part II: Policy Prescriptions for Reducing Fuel Poverty in Australia', in : The Electricity Journal, March 2011, Vol. 24, Issue 2, Elsevier Inc.., p. 67.

Appendix 'D' – Fuel Poverty In Australia

Social Licence To Operate

Simshauser, P., *et al* (2011) go onto forecast the possible Fuel Poverty situation for New South Wales and Queensland Households with the Lowest Quartile of Disposable Incomes for the Year 2015.

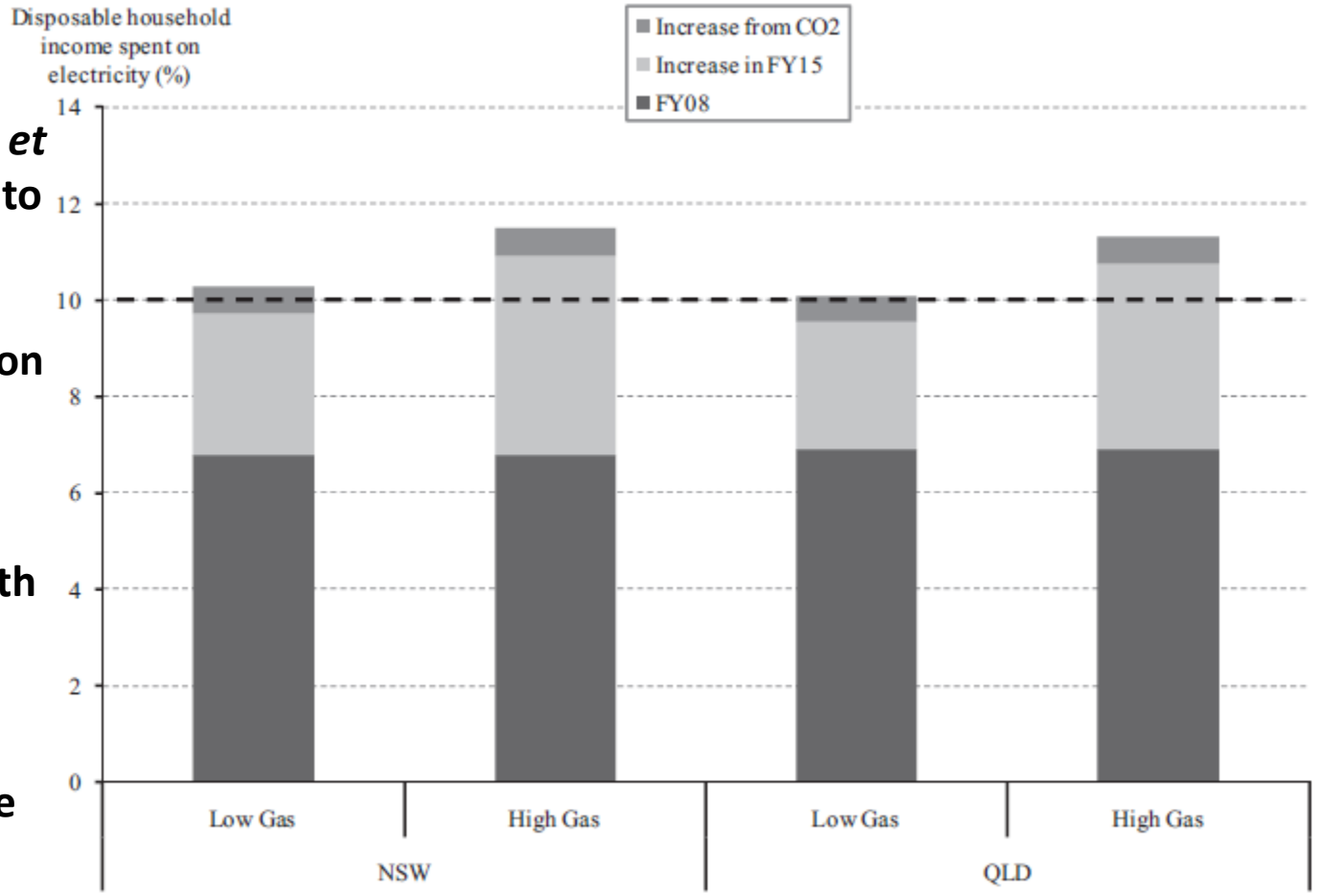

Figure 4: Disposable Household Income Spent on Electricity in FY15 (lowest quintile)

Source : Simshauser, P., Nelson, T., & Doan, T., 2011, "The Boomerang Paradox, Part II: Policy Prescriptions for Reducing Fuel Poverty in Australia', in : The Electricity Journal, March 2011, Vol. 24, Issue 2, Elsevier Inc.., p. 68.

Appendix ‘D’ – Fuel Poverty In Australia

Social Licence To Operate

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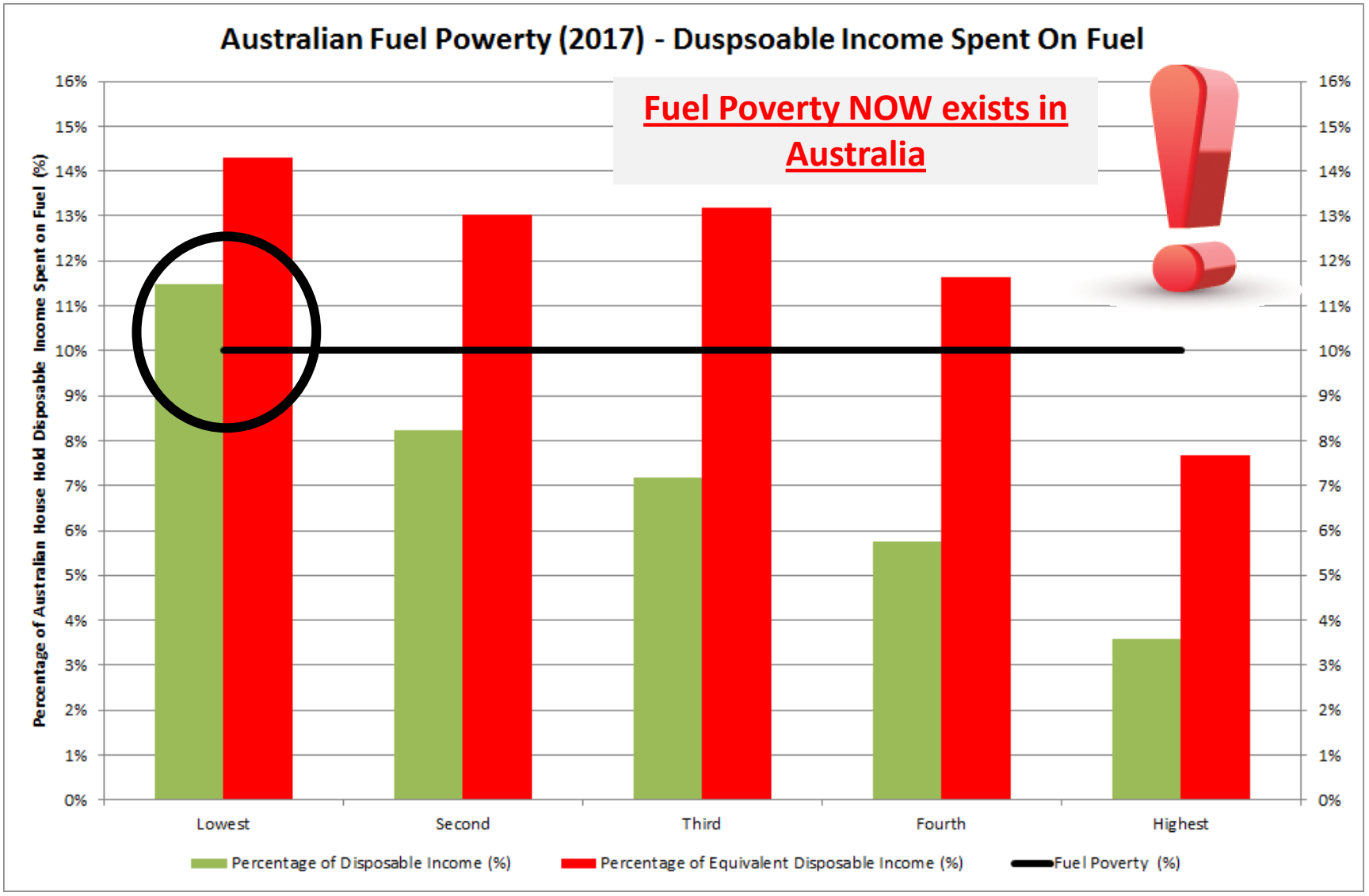
Taking the definition of Australian **Fuel Poverty** developed by Simshauser, P., *et al* (2011) and using their recommendation :

> “…
> Rather than estimating household expenditure given ambient temperature targets, this article utilizes actual energy consumption spending and real incomes to determine the proportion of household income spent on energy. As such, the measure of fuel poverty provided in this article could be argued to be more reflective. For a more comprehensive study on fuel poverty, expenditure on all forms of energy (including natural gas) would need to be incorporated.
> …”
>
> Simshauser, P., *et al* (2011), p. 66.

The Author has undertaken an update on Australian Fuel Poverty. The following Graph indicates an assessment of the current situation. A methodology all so follows.

Appendix ‘D’ – Fuel Poverty In Australia

Social Licence To Operate



Appendix 'D' – Fuel Poverty In Australia

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Fuel Poverty Methodology

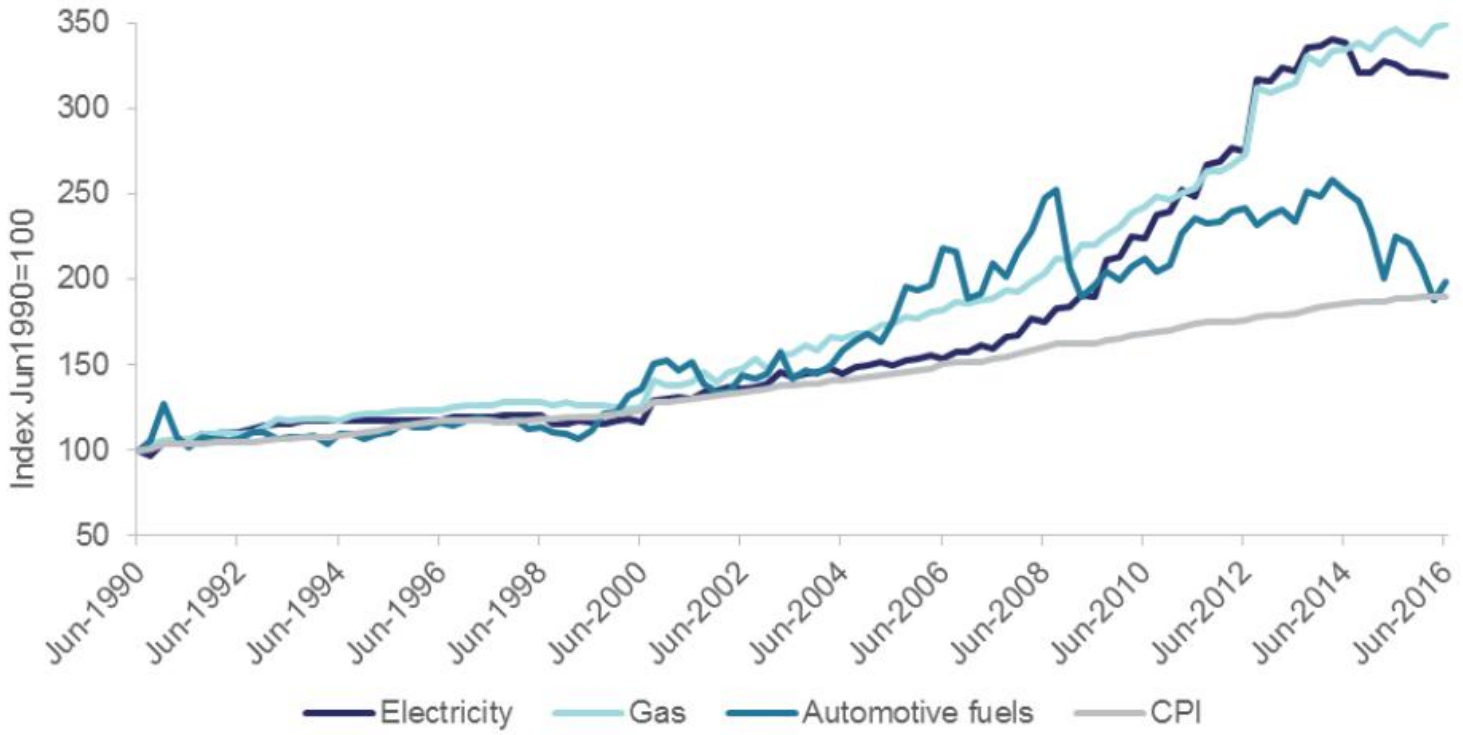
Energy Expenditure Data *Source* : ABS, 2013, "4670.0 - Household Energy Consumption Survey, 2012", Released at 11:30am (Canberra time) 24 September 2013
Table 4. GROSS HOUSEHOLD INCOME QUINTILE, Household energy expenditure and consumption estimates, at :
http://www.abs.gov.au/ausstats/abs@.nsf/Lookup/by%20Subject/4670.0~2012~Main%20Features~In%20this%20Issue~2
Australian Bureau of Statistics (ABS), Canberra, accessed 20 April 2018. Note : Whilst the Energy Expenditure Data used in this analysis is from 2012, it has been used as a benchmark against the data bases used in *Australian Chief Economist, 2016 "Australian Energy Update, 2016", October 2016, Commonwealth of Australia - Department of Industry, Innovation and Science (2016), Canberra, p. 12.* as a means of escalation to 2017 values. The 2012 Energy Expenditure Data was the latest that could be sourced from the ABS. Refer below for the Graph of "Australian Energy Update, 2016" data.

Appendix ‘D’ – Fuel Poverty In Australia

Social Licence To Operate

Fuel Poverty Methodology *con’t.*

Figure 3.4: Household energy price index



Source: Australian Bureau of Statistics (2016) *Consumer Price Index, Australia, June 2016*, 6401.1

Source : Australian Chief Economist, 2016 “Australian Energy Update, 2016”, October 2016, Commonwealth of Australia - Department of Industry, Innovation and Science (2016), Canberra, p. 12.

Appendix 'D' – Fuel Poverty In Australia

Social Licence To Operate

Fuel Poverty Methodology *con't.*

Household Income Data *Source* : ABS, 2017, "65230DO006_201516 Household Income and Wealth, Australia: Summary of Results, 2015–16", Released at 11:30 am (CANBERRA TIME) 8 December 2017, Table 6.1 INCOME DISTRIBUTION, Gross income quintiles, at : http://abs.gov.au/household-income
Australian Bureau of Statistics (ABS), Canberra, accessed 20 April 2018.

Commentary on Equivalent Disposable Income :

As household size increases, consumption needs also increase but there are economies of scale. An equivalence scale is used to adjust household incomes to take account of the economies that flow from sharing resources and enable more meaningful comparisons between different types of households.

Equivalentising factors are calculated based on the size and composition of the household, recognising that children typically have fewer needs than adults. The ABS uses the OECD-modified equivalence scale which assigns a value of 1 to the household head, 0.5 to each additional person 15 years or older and 0.3 to each child under 15 years.

For a lone person household, equivalised income is equal to actual income. For households comprising more than one person, it is the estimated income that a lone person household would need to enjoy the same standard of living as the household in question.

Source : ABS, 2017, "6523.0 - Household Income and Wealth, Australia, 2015-16 Quality Declaration LATEST ISSUE Released at 11:30 AM (CANBERRA TIME) 13/09/2017", at : http://abs.gov.au/AUSSTATS/abs@.nsf/Lookup/6523.0Explanatory%20Notes12015-16?OpenDocument Australian Bureau of Statistics (ABS), Canberra, accessed 20 April 2018.

End