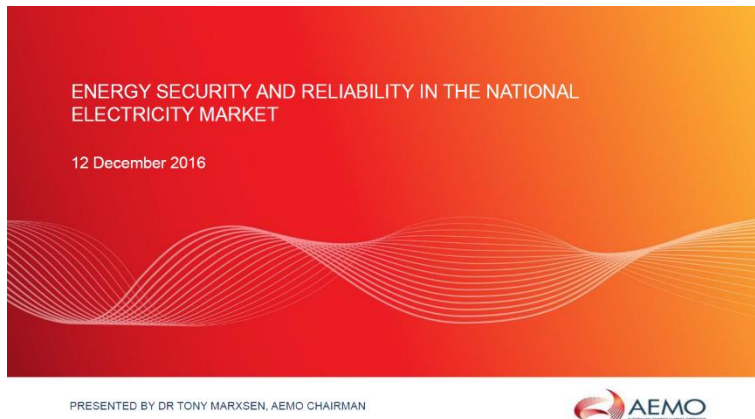


Good afternoon everyone and thank you for that introduction, Jeremy.

## Slide – Opening slide



Thanks for the opportunity to speak with you in what has been an intense couple of months.

Australia's national transmission grid was progressively built over nearly half a century between the commissioning of the very first interconnector linking NSW and Victoria via the Snowy Mountains Hydroelectricity Scheme in 1959, and the commissioning of Basslink in 2006.

We now have eight interconnectors linking the five National Electricity Market regions. These were built to carry power from large concentrated power stations near major fuel sources to major load centres some hundreds of kilometres away.

We can expect the grid 50 years from now must provide secure, reliable, affordable, zero-carbon supply in a profoundly different world:

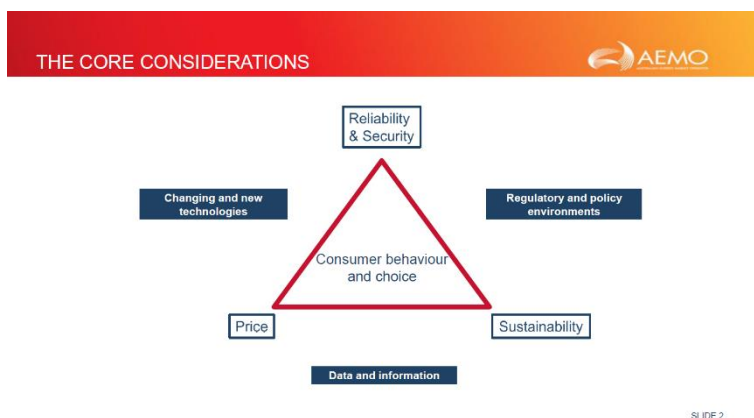
- A lot of power generation will be dispersed over wide areas, including urban areas.
- Many customers will use intelligent automated systems to manage their demand in response to price signals in their tariffs or even in real time.
- New forms of energy storage will operate at national grid, neighbourhood and microgrid scale and in individual premises.

- Every element of the grid and connected equipment will offer remote digital control.

In thinking today about electricity supply, we must bear in mind what sort of grid we will need for this new world. The grid we build today will still be there then.

Today we are dealing with a grid in transition. It demands innovative solutions from independent system operators like AEMO, from market participants, policy makers, consumers and communities alike.

### Slide – The core considerations we must keep front of mind



Designing the grid of the future must take into account three core goals: **affordability**, **reliability/security**, and Australia’s commitments to **emissions reduction**. No one element can be considered in isolation - the pathway forward must seek to balance all three.

The challenge of achieving this three-way balance has never been so clear or as daunting as it is today. I would like us all to keep these three crucial goals front of mind today as I share our preliminary recommendations from the SA Black System event in September, insights from our 2016 National Transmission Network Development Plan and finally, touch on what the grid may look like 50 years from now.

## Slide – SA Black System event - preliminary recommendations



### PRELIMINARY RECOMMENDATIONS



- Reduce the risk of islanding of the South Australian region.
- Increase the likelihood that, in the event of islanding, a stable electrical island can be sustained in South Australia.
- Improve performance of the system restart process.
- Improve market and system operation processes required during periods of market suspension.
- Address other technical issues highlighted by this investigation.

SLIDE 4

Today we have published our third report on the events that led to the state-wide blackout in South Australia. In summary, a severe storm came through the state on 28 September with tornadoes that destroyed transmission towers, resulting in a number of faults and related disturbances on the grid in just 87 seconds. Some generating units had embedded protection schemes, a previously unknown feature, which were set to ride through only a limited number of disturbances in a two minute interval. When the limit was reached, they cut their power output transferring load onto the Heywood Interconnector which tripped when it exceeded its safety limits. Loss of the generation plus loss of the import over the interconnector caused the state to go black.

A sequence of events such as this involving multiple failures or trips occurs very rarely and is classified as 'non-credible' in the National Electricity Market Rules.

Based on our initial static modelling, it seems likely that without a sustained reduction in generation the SA grid could have withstood the loss of all three power lines, and the fourth damaged after the black system occurred.

Static modelling looks at a possible scenario in a point in time. We may do further dynamic modelling, but we still cannot predict what additional events might have affected the SA power system beyond the time of the Black System as the storm front continued its progress through the state.

A review of history has revealed previous major SA supply disruptions with similar causes in 1999, 2004 and 2005. However, in those events, the generators that reduced output were coal and gas fired. This time it was wind turbines. September was truly a technology-neutral blackout.

In this third report, we outline where we believe we can take practical measures to:

- Reduce the risk of separation of the South Australian region from the NEM.
- Increase the likelihood that, if separation occurs, a stable electrical supply network can be sustained in SA.
- Improve performance of the system restart process should a Black System occur.
- Improve market and system operation during periods of market suspension.
- Address a range of other detailed technical and procedural issues highlighted by our investigation.

We present 15 preliminary recommendations in today's report. They are grouped against the structure of all our reports on this event: Pre-event, Event, Restoration, Market Suspension.

We will work in collaboration with network owners, industry groups, market institutions and the SA jurisdiction in seeking to implement recommendations.

Let me very quickly run through the primary goal of each group of preliminary recommendations.

Our 'pre-event' recommendations focus on improving our assessment and response to warnings of extreme weather and the management of consequential risks to electricity supply. In our next and final report, we will look at recommendations on the complex and vexed issue of generator performance standards, and improved information about the operation of embedded protection and control schemes.

Our 'event' recommendations will go beyond current world practice in protection schemes to find ways to minimise the chances of grid separation or, should it happen, maximise the chances of successful formation of a stable island system in South Australia. We will also explore the risks created when credible grid faults occur in close proximity to collections of decentralised generators such as wind turbines and solar plants.

Our recommendations on system restoration are particularly valuable. System restarts are very rare and pose extreme challenges to system operators. The last SA restoration from a Black System was 36 years ago in 1980 after someone inadvertently turned off the gas supply to Torrens Island Power Station. The most recent in New South Wales, Victoria and Tasmania were all more than fifty years ago. They are rare and they reward careful study.

Our preliminary recommendations on restoration aim to improve the speed of restoration of supply while still managing the risk of a second Black System – a risk that is always present during the delicate process of system restoration.

Suspension for more than a week of a regional market is unprecedented in the history of the NEM, so this again is a unique learning opportunity.

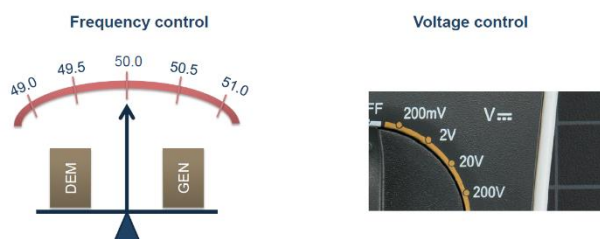
We found we needed better procedures to operate the power system during an extended Market Suspension. Manual approaches are fine for an hour or two, but can become almost unmanageable if used for days on end. Our preliminary recommendations will lead to

increased automation of some specific market processes as well as possible changes to the NEM Rules.

We expect that some of our findings will reveal the policy framework, market incentives and some other aspects of market operation which drive outcomes should also be addressed. We will actively contribute to the resolution of these matters, working in association with our stakeholders and in collaboration with the AEMC and Dr Alan Finkel's review.

We plan to release our final report into this event in March 2017. It will likely contain further recommendations on generator performance standards and the associated regulatory framework.

### Slide – Two key components of 'network grid health'



SLIDE 5

All grids rely on two vital functions to maintain safe, secure and reliable supply to consumers. Australia's national grid is no exception. These are frequency control and voltage control.

#### Frequency control

Frequency control is critical to power system security, and AEMO is responsible for enabling sufficient frequency control ancillary services (FCAS) to maintain frequency within prescribed standards. This task currently relies on services provided by synchronous generation, including an inherent inertial response to rapid frequency deviations that slows the rate of change of frequency (RoCoF).

A way of looking at this is that large grid connected generators spin at 3,000 rpm – about the same speed of rotation as a four-cylinder engine in a car on a 110kph motorway. In fact, the whole grid spins at exactly the same speed in lock-step. The powerlines are clearly not spinning physically, but they are spinning electrically. They are like long spinning shafts connecting all these spinning machines so everything on the grid spins as one – hence, the term synchronous. I know this sounds weird, but it is the most valid way of describing what some engineers have called the largest single machines on the planet – national power grids.

Grid frequency is simply the speed at which every synchronous machine connected to the grid spins as one.

It's very important that grid frequency stays very close to 50 Hertz. Large rotating generators and motors are designed to operate at a specific speed. If the frequency moves away from 50 Hertz their speed moves away from their design speed. If it moves too far, horrible things start to happen, like turbines or pumps exploding or heavy metal shafts breaking.

AEMO puts a lot of effort into keeping the grid frequency at 50 Hertz, and if we can't keep it close enough to 50 Hertz during an incident, we disconnect supply to avoid the risk of major long term damage to connected equipment. Working very closely and cooperatively with SA network service providers and generators, we got much of SA back on supply in hours. If the sort of damage I am talking about had occurred, it would have been days, weeks or months.

Before the SA event, we had already commenced an assessment of the suitability of current frequency control mechanisms to deliver the power system's needs over the longer term.

We have engaged international experts to provide input into these studies and will publish the outcomes of this work over the course of the next six months.

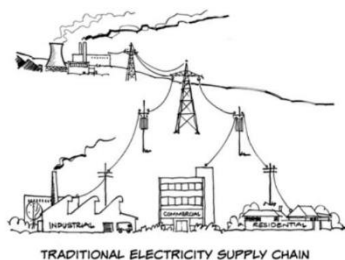
### **Voltage control**

Control of grid voltage within tight limits is necessary for the safety of all connected equipment and the safety of people who use that equipment – that means all of us.

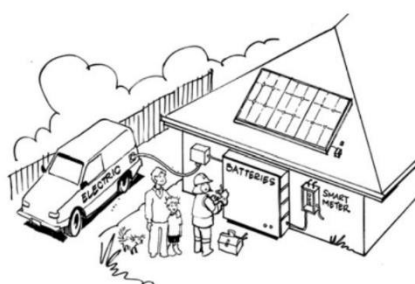
Grid voltage must also be managed carefully for the grid to remain stable. There are modes of grid instability that can occur when there is insufficient voltage support. These conditions are termed ‘voltage collapse’. This is one of AEMO’s tasks: to make sure voltages remain within limits even when things go wrong on the grid. Of course, there are limits to what we can do.

Now we know that we manage frequency and voltage to keep the grid healthy, let’s look at the power system of the future, both 20 years from now and stretching our vision, the features of Australia’s national power grid in 2066.

### Slide – Drivers impacting the NEM and the WEM



SLIDE 6



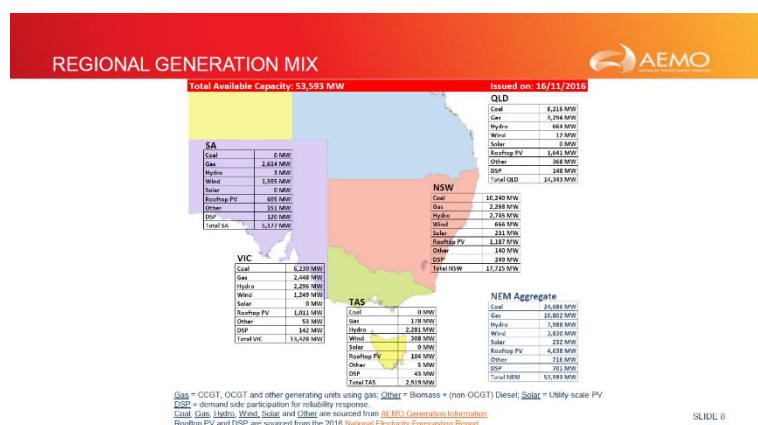
SLIDE 7

Over the last 10 years, there has been a lot of investment in intermittent generation such as large scale wind and solar PV. These are connected into the power system using inverter based technologies. This form of generation is not synchronous and it has a different

operating behaviour to traditional rotating machines. It required changes to how we manage power system security and very likely, how we operate the market in the future.

The Wholesale Electricity Market in WA is an isolated system that like SA (which is not an isolated system) has also seen this shift, with the take up of solar power growing at 10% per annum among households, and 25% for businesses. Minister Dr Mike Nahan recently stated the economics behind renewables meant WA could account for between 30 and 40 per cent of the state's future power supply. However, he noted the need to have a secure supply across the system regardless of the growing dependence on renewables. I will touch on this theme in more detail shortly.

### Slide – Regional generation mix

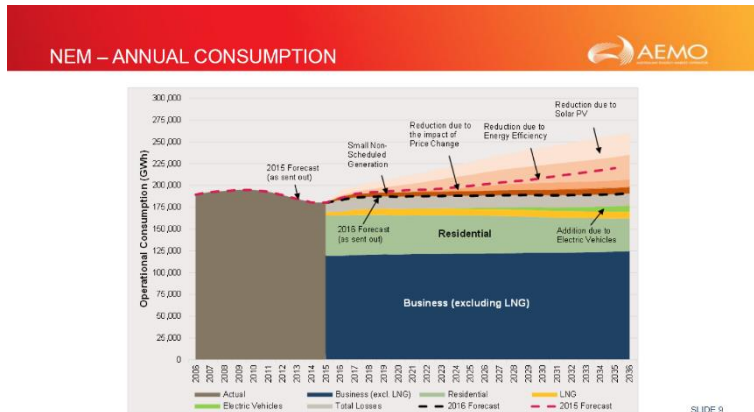


Focusing on the NEM for today's discussion, this diagram illustrates the break down via fuel source capacity of generation in the NEM. NEM-wide, coal and gas-fired generation makes up a large portion of the overall mix. However if we look at South Australia, wind capacity is now more than 30% of total capacity in the state, and if we add PV, renewables make up more than 45% of total capacity.

This dramatic change in supply mix has not happened over night, however it has happened over a relatively short space of time. From approximately 2010, installed wind generation capacity has doubled, and rooftop PV has gone from marginal, to a forecast 5000 MW

capacity by the end of this year. We are looking at a quantum shift in technology over a six year period.

### Slide – NEM Annual Consumption



Here is the holistic picture for the NEM's consumption outlook. You can clearly see the factors driving down consumption from the grid, such as Rooftop PV and uptake of more energy efficient appliances. What this illustrates is that customer demand is no longer the primary driver of network investment, instead investment in the future will be driven by those three considerations I outlined earlier – affordability / security and reliability / lower emissions.

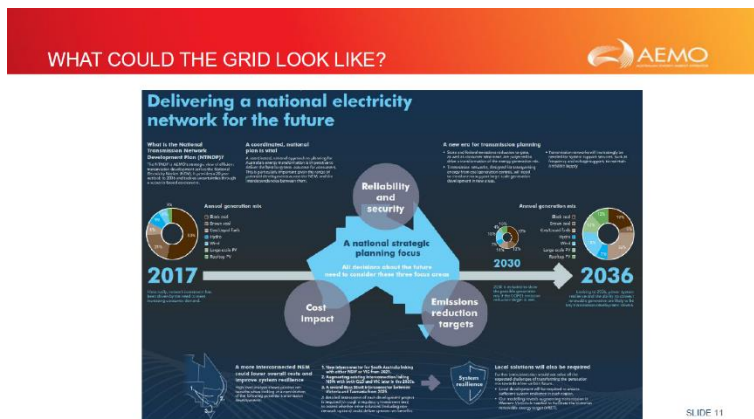
### Slide – The NEM in 20 years



We are already looking at a new era for transmission in the NEM. Network investment has historically been driven by the need to meet rising customer demand. Key investment drivers are now focusing more on power system security (such as the vital ability to maintain

frequency and voltage control as I have mentioned earlier) and the need to connect more than 20 gigawatts (GW) of new large scale renewable generation required to meet Australia's emission targets.

### Slide – What could the grid look like?



Our National Transmission Network Development Plan (NTNDP) published today suggests the next 20 years will be characterised by unprecedented transformation in the power industry as it transitions to a low carbon future.

### Slide – What could the grid look like (2)?

- 
- WHAT COULD THE GRID LOOK LIKE?**
- Transmission networks, historically designed for transporting energy from traditional coal and gas generation centres, will be asked to support large-scale renewable generation and be increasingly needed for system support services, such as frequency and voltage support to maintain a reliable supply.
  - AEMO's assessment finds potential value in developing a more interconnected National Electricity Market (NEM) over the next 20 years to:
    - remove network congestion
    - lower the overall cost of generation dispatched to consumers
    - improve the power system's resilience to unexpected events.
  - **Co-ordination and contestability can maximise the benefits of transmission investments across the NEM, and ultimately for consumers.**
- SLIDE 12

Sufficient inertia (that is, frequency resilience) is projected to be available over the next 20 years to maintain a secure and reliable supply only if the network remains interconnected during and following disturbances. Following a synchronous separation event, South Australia is at risk of widespread outages unless mitigation measures are put in place. System strength

(voltage resilience) is projected to materially decline across the NEM, particularly in areas of high inverter-connected generation such as much of South Australia, western Victoria, and Tasmania. There are also emerging local areas of poor network strength in New South Wales and Queensland, where high concentrations of renewables are anticipated by 2035–36.

To counteract the decline in system strength, improvements to either inverter-connected devices or addition of supporting plant will become essential for these systems to operate securely and reliably.

What is the future for transmission interconnectors in this new world?

AEMO's assessment of options for national transmission grid development finds potential value in developing a more interconnected National Electricity Market (NEM) over the next 20 years to remove network congestion, lower the overall cost of generation dispatched to consumers, and improve the power system's resilience to unexpected events.

While noting that there may be many different combinations of strategies to meet future balancing requirements, AEMO's NTNDP modelling reveals positive net benefits for potential transmission developments to help facilitate the diversity of the future generation mix and to improve system resilience.

Transmission networks, historically designed for transporting energy from traditional coal and gas generation centres, will be asked to support large-scale renewable generation and be increasingly needed for system support services, such as frequency and voltage support to maintain a reliable supply.

Co-ordination and contestability can maximise the benefits of transmission investments across the NEM and ultimately for consumers. Our modelling shows greater net benefits when multiple developments are combined, highlighting the benefits of a more interconnected NEM.

In short, we're projecting that a more decentralised grid must be a more interconnected grid.

The driver is not long-haul transport of energy alone, but energy transport combined with

transport of security support services. And we have to connect a lot of renewable power generation in new locations.

Geographic and technology diversity can smooth the impact of intermittency and reduce reliance on gas-powered generation. Greater interconnection maximises the value of this diversity and delivers cost savings to consumers.

Contestability in transmission could also be used to ensure development is more competitively priced, reducing the costs for consumers. Transmission contestability only applies in Victoria at present.

### **Slide – Interconnection alone will not secure the NEM**

#### INTERCONNECTION ALONE WILL NOT SECURE THE NEM

- A more interconnected NEM can improve system resilience, however it does not necessarily solve all challenges – local network and non-network options will also be required to maintain a reliable supply.
- Comprehensive RIT-T assessments will examine the full range of potential solutions, including a mix of smaller scale and non-network solutions:
  - Synchronous condensers, or similar technologies, will be required to provide local system strength and frequency control.
  - Energy storage and demand response technologies must also be explored.

SLIDE 13

A more interconnected NEM can improve system resilience. However, it will not solve all challenges – local (that is, intra-regional) network and non-network options will also be required to maintain a reliable supply:

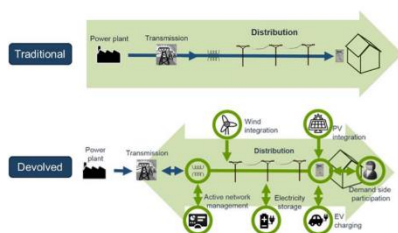
- Additional plant such as synchronous condensers or similar technologies, will be required to provide local system strength and frequency control.
- Our modelling reveals benefits from augmenting transmission in western Victoria to accommodate over 4,000 megawatts of projected new renewable generation capacity.

The modelling outlined in our NTNDP is complex with many assumptions, but we believe it is sufficiently robust to indicate opportunities for grid development that will save customers

money in the long term. The Regulatory Investment Test for Transmission (the RIT-T) is the prescribed process for fully detailed assessment of costs and benefits of particular projects. Our NTNDP indicates that RIT-Ts are warranted to further explore the interconnection and local network and non-network options I have mentioned earlier.

AEMO would also strongly recommend that a national approach that delivers contestability of all major transmission investments be adopted to promote competition and ensure the costs of grid investments to electricity customers are minimised.

### Slide – The need to look beyond transmission



SLIDE 14

We acknowledge transmission investment is costly and grid assets take time to plan and build, and we know that operational measures and alternatives such as distributed generation, energy storage and demand response technologies must have equal opportunity in the future grid. We expect their role to be major.

These Distributed Energy Resources (DER) can either shift time of use or reduce customer energy usage in total. The manner in which they are managed will shape the future of the electricity market, and fundamentally affects AEMO's core functions.

Some parts of the NEM have very high levels of DER by global standards. We are at the frontier of learning about the challenges of managing an interconnected power system with high levels of DER.

New DER markets are emerging, however they are still at an embryonic stage. The Power of Choice program is a major project for the industry. It is forcing traditional distribution network businesses to move from a regulated monopoly to a competitive environment. More options in the market should provide more ways to not only lower costs for customers, but also add cost-effective agile solutions to support the security of the broader grid.

### Slide – (separation slide) The NEM in 50 years



### Slide – The NEM in 50 years



The features of Australia's national grid in 2066 will include:

- Smarter faster control systems acting over longer distances.
- Greatly increased real-time data flows.
- New methods to manage grid frequency resilience.
- New methods to manage grid voltage resilience.

SLIDE 16

Fifty years is enough time for the world to change a lot. Some of us can remember what fifty years ago was like: we'd just adopted this newfangled decimal currency, Holden took the radical step of fitting seat belts as a standard feature, and the federal government finally killed off the infamous 'white Australia' policy. It was a very different world.

When we try to look forward 50 years, we expect the world will change just as much as it has in the last 50 - and the national grid must change with it.

The grid in 2066 will include:

- Smarter faster control systems acting over longer distances.
- Greatly increased real-time data flows to manage security.
- New methods to manage grid frequency resilience.
- New methods to manage grid voltage resilience.

Fifty years from now, grid control systems can be expected to change almost beyond recognition. They will be smarter, faster and extend over longer distances.

For a start, (and we are already working to put this in place for SA) there will be over-frequency-generation-shedding schemes. The assumption that every bad event leads to a shortage of supply is already outdated. If SA is exporting power to Victoria because local demand is low and wind generation is high (this happens on many weekends) and the interconnection to Victoria is suddenly lost, there will be a local excess of generation, not a deficit. To get frequency back to 50 Hertz, generation has to be shed to match demand, not the other way around.

In 50 years' time, it is entirely likely that AI software will be used to form fast, sophisticated judgements about the best action to take to preserve system security. It is impossible to predict what those algorithms might look like, but the likelihood of their emergence is plain to see when one looks back and compares today's practice with those of 50 years ago - and pulls out one's iPhone to ask Siri what will a future power grid look like (Try it – she offers a remarkably comprehensive range of information on this query!)

Grid operation relies on prediction of demand and supply a short time ahead so action can be taken to ensure balance and preservation of grid frequency close to 50 Hertz. Until now, customer demand could be predicted with confidence based on historical metering data flowing in from bulk supply points, possibly with adjustment for temperature predictions. Generators generally follow dispatch instructions pretty closely so we have some confidence

we know what will be needed five minutes, an hour, or even 24 hours ahead. We have time to prepare for changes in the balance of supply and demand.

The advent of renewable energy sources already challenges this approach. AEMO has invested millions now in wind and solar forecasting systems, but we still don't have all the data we need for these systems to achieve their goals. We have just given the go-ahead to a project to use satellite tracking of clouds to better predict local changes in solar output. We are also working to improve our access to data on the aggregate capacity of solar panels installed in any particular neighbourhood.

Residential battery storage will soon make our challenge even greater. The data required is not just capacity, location, and stored energy held in batteries (none of which we yet have) but also customer behaviour. We want customers to make choices that allow them to make most economic use of resources for their own financial benefit, but we don't yet have data that gives us confidence we can forecast their aggregated actions in order to preserve security of the grid while they are doing it.

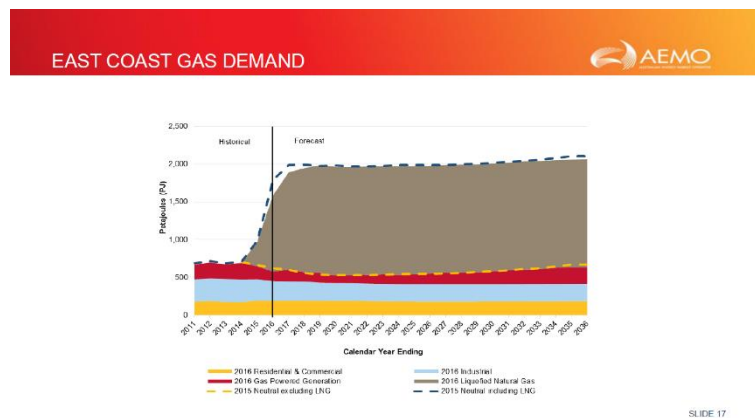
The rate of change of frequency in an event is critical. A high RoCoF leads to system black. A lower RoCoF is manageable and at least most of the lights stay on. RoCoF depends not only on supply/demand imbalance, it also depends on grid inertia. Inertia means frequency resilience. It cuts the rate of change of frequency when bad things happen.

The opportunity we have is to more directly manage frequency resilience like we directly manage supply/demand balance today. We expect to shortly see new markets that incentivise investors to build new inertia into the grid to replace that being lost as big coal generators retire. Such markets could even pay owners of old coal plants to keep their generators spinning and connected – just not producing power, so they don't need a boiler or a mine. Or investors might offer fast response battery storage or even super-fast response energy storage based on ultra-capacitors. Even wind farms and solar plants can use software to simulate inertia to some extent.

A market solution would be good and we are collaborating with the AEMC to see if we can set one in place. We want any arrangements we adopt to be technology neutral so different solutions compete on their merits and customers get supply security at the lowest possible cost.

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### Slide – East coast gas demand



Our National Gas Forecasting Report, published last week, examines a future pathway which projects new GPG capacity after 2030 of only 1.1 GW to meet maximum demand periods.

The report provides insights to the complex interactions between gas and electricity, and the need for coordinated, holistic approaches to cross industries and technologies.

Looking holistically at east coast gas demand, total gas consumption is set to double, driven by liquefied natural gas (LNG) exports and growth in gas-powered generation (GPG).

Excluding GPG, domestic gas use is projected to decline, with growth from a rising population offset by a gas-to-electric appliance switching trend, and declines in gas-intensive industry.

### Slide – The uncertainties with east coast gas

### UNCERTAINTIES IN EAST COAST GAS



- There are challenges and uncertainties complicating gas demand forecasts for interconnected gas markets over the next 20 years:
  - Link to volatile international oil and gas markets.
  - Transforming to a lower emission power system.
  - Changing domestic role of gas challenging supply and prices.
  - Changing economy, industry and consumer attitudes.
  - Planning challenges to cater for a range of future economic scenarios.

SLIDE 18

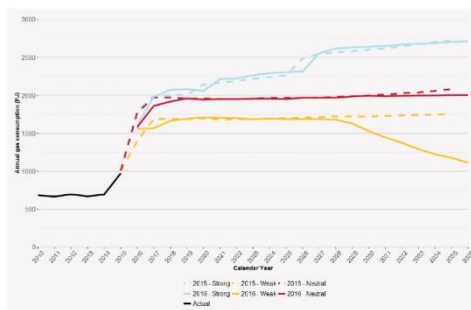
Similar to the electricity industry, the uncertainties in the gas industry outweigh the definitive. While the outlook continues to be dominated by export demand, catapulting Australia to the world's second largest LNG exporter and the major supplier for east Asian markets, the 2016 NGFR also forecasts growing demand for gas-powered generation (GPG).

This simply illustrates the reality that for at least most of the next two decades, if we want a secure reliable affordable supply of electricity, we need a secure, reliable affordable supply of gas.

With this outlook for gas demand comes great challenges for policy-makers, infrastructure planners, and asset operators.

### Slide – The uncertainties with east coast gas

#### THE UNCERTAINTIES WITH EAST COAST GAS DEMAND



SLIDE 19

This graph illustrates the great variances in our gas demand forecast scenarios – all six are potentially viable. Uncertainty rules! Our central forecast is called the neutral scenario, but we

have added two other scenarios to illustrate the range of variation realistically possible due to economic conditions. These are called the weak and strong scenarios.

The weak scenario assumes the closure of Australia's smelters and numerous other energy-intensive businesses, causing large falls in projected gas and electricity use. In this scenario, strong momentum for renewables plus continuing energy efficiency improvements are projected to flatten energy demand generally, making emission targets easier to achieve. In this Weak scenario the challenging global gas market is expected to drive LNG production down from 2030, so exhausted wells are not replaced and gas is supplied to export markets from elsewhere. It should not come as a surprise that forecast demand for the weak economic scenario in 2036 is nearly one thousand petajoules (PJ) below that in the neutral scenario.

The strong economic scenario assumes high international LNG prices, a robust economy, and a confident consumer. The strong case projects more coal generation retirements, LNG production from existing plants above name-plate capacity, with incremental supply developed from "debottlenecking" at the liquefaction plants, plus the construction of a seventh LNG supply train from 2027. Compared to the Neutral case, the Strong scenario adds 767 PJ to the neutral scenario's annual gas consumption in 2036 - most of which is attributable to LNG.

We have never before faced such a high level of uncertainty in our long term planning forecasts.

No matter where in Australia we live or what sort of energy we use, these are interesting and uncertain times.



## **Slide – Planning for the future**

PLANNING FOR THE FUTURE



- Resolving regional based limitations individually will potentially create excessive capacity, or potentially dismiss solutions by not considering benefits to other regions.
- Long term NEM wide solutions may include combinations of:
  - ✓ Operational measures
  - ✓ Regulatory changes
  - ✓ New technologies
  - ✓ Increase in regional interconnection.
- Industry wide engagement critical to ensure coordinated, national approach to the transition to a low carbon future.

SLIDE 20

There are many different possible futures for the NEM. From what we do know, resolving limitations individually region-by-region will potentially create excessive capacity, or potentially dismiss solutions that would benefit other regions. Energy and climate policy, consumer preferences, and new technology options are driving the need for long term NEM wide solutions.

Ideally, these solutions will be a combination of:

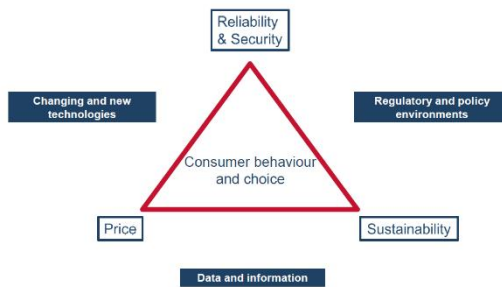
- Operational measures – such as ROCOF limitation in generator dispatch, national Under Frequency Standards, etc.
- Regulatory changes – such as the development of an inertia market or new fast FCAS procurement arrangements.
- Technology – exploration and fast tracking of potential energy storage solutions (both grid and local), high inertia synchronous condensers, new control settings on inverter based generation, and closer coordination of distributed energy resources.
- Transmission – as outlined in this presentation, the possible expansion of existing interconnector capacity and establishment of new ones, enabling sharing of energy and security services across the NEM.

All those here today, and all those involved in this wide industry, from network owners and operators, generators, customers, government leaders and policy makers, private investors,

consumer groups and media practitioners, we all have an opportunity to productively contribute to Australia’s long term energy security solution.

The most efficient strategy for NEM development will most likely mix technical and regulatory, centralised and decentralised, and network and non-network solutions. But only a coordinated, national approach to plan for the transformation will deliver the best outcome for Australians.

THE CORE CONSIDERATIONS 



SLIDE 21

**Slide – Thank you**