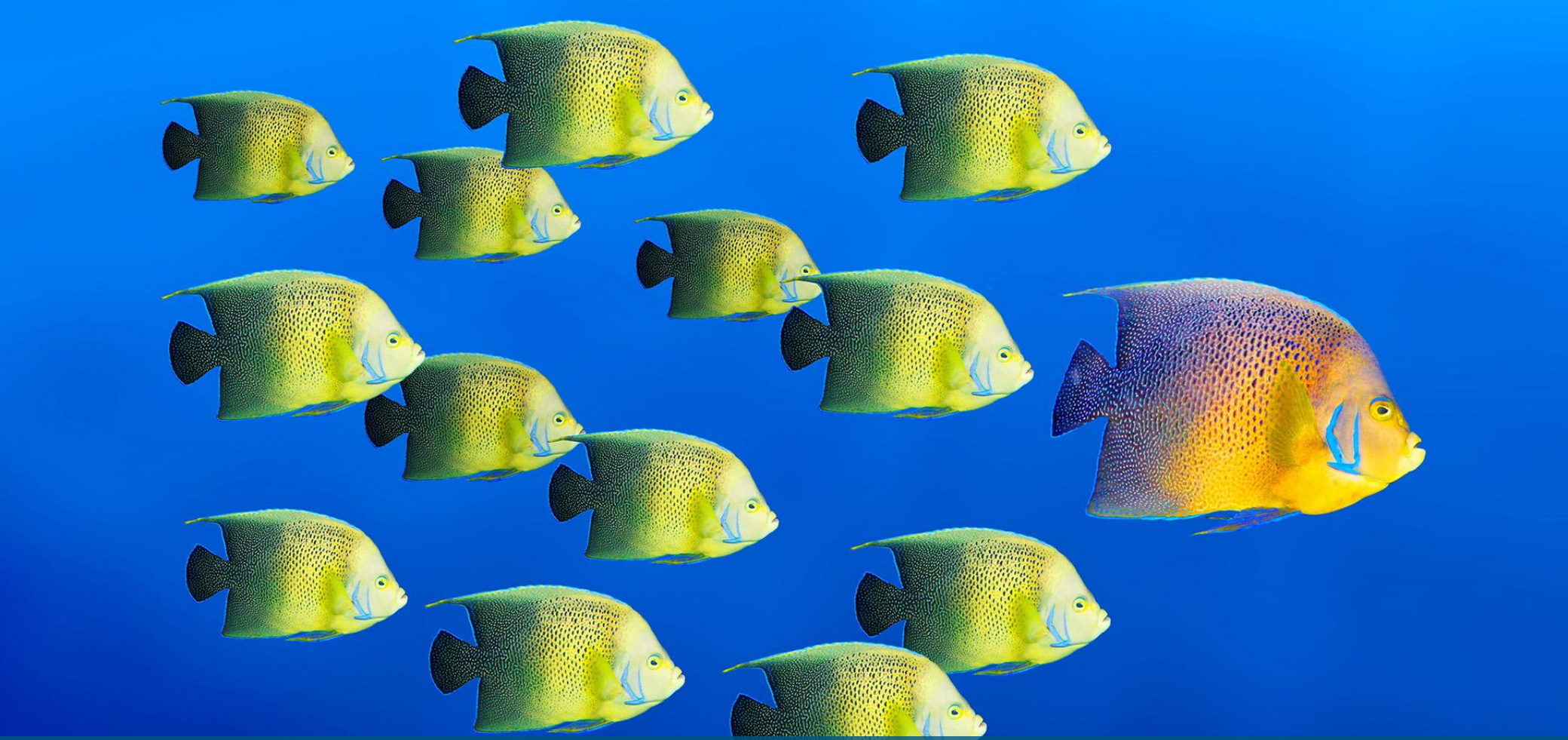

# Designing the Energy Transition Process: Should you Retrofit or Upgrade Existing Transmission & Distribution Infrastructure?

**Sarah Fairhurst**

28 November 2018

THE LANTAU GROUP

# Who are we?

Power and Gas, Markets & Regulation

Competition, Markets, Regulation, Policy

Decisions Support Analysis | Disputes

Market Analysis | Asset Valuation

Strategy and Advanced Analytics

**Offerings:**

- Deep analysis for strategy and valuation
- Experts in economic regulation
- Market design and evaluation
- Insightful analysis of the entire fuel-to-power value chain
- Unrivalled local expertise and knowledge
- Global experience and perspective


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Tagalog*
Thai*
Vietnamese*

*External Advisors

The analysis of power meets the power of analysis



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# Agenda

What is the role of the grid?

Grid expansion: views from China and Australia

Peek at the Sri Lankan energy transition – are there any lessons to apply?

# What is the role of the grid?



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# Before thinking about retrofitting or upgrading, let's look at the role of the grid

The grid is a:

- Highway to move energy from the place it is generated to the place it is consumed (energy flow)
- Way to share reserves across the system (back-up)
- Infrastructure that allows markets to develop (pre-requisite for trading) so that power can move from cheaper areas to more expensive areas (the value of trading)
- Way to keep the voltage and frequency stable so that electrical appliances are safe to use (ancillary services)

The cost of the grid is mainly fixed:

- Once built, operational costs are a minor component

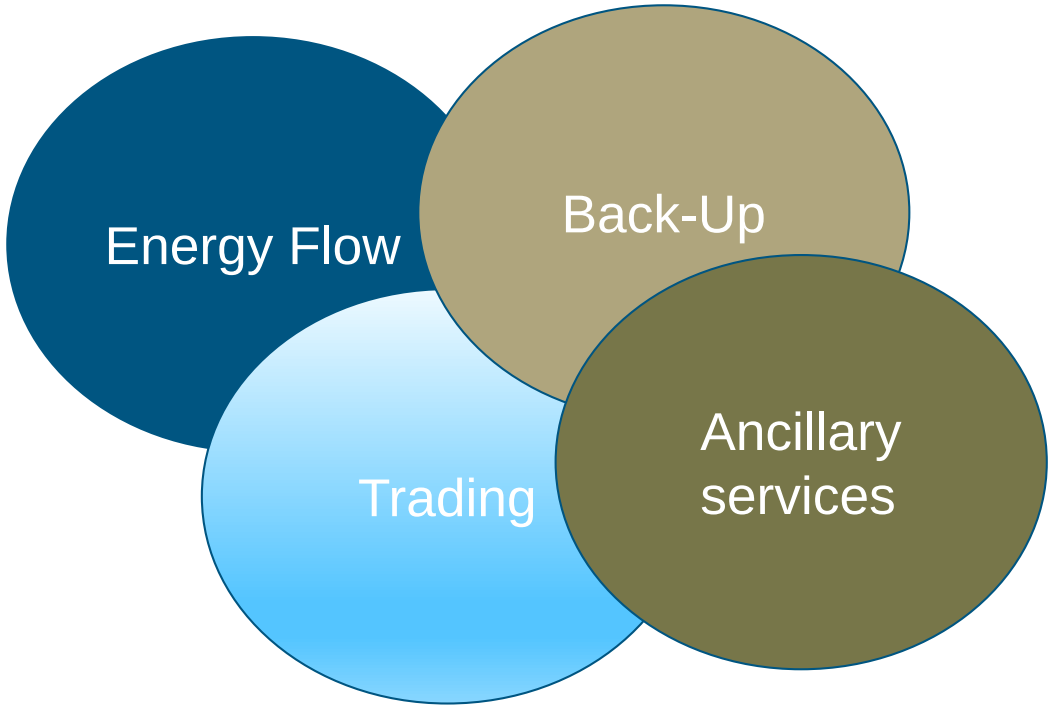
But in many places, the charging mechanism for the grid is variable:

- On a per kWh basis; or bundled with other charges

**Historically the role of the grid is taken for granted, the value poorly understood by consumers and the costs poorly aligned with revenue collection mechanisms**

# The value provided by the grid is hard to separate into component parts

- Considerable overlapping functions and value mean that separate prices for separate services have been slow to develop
- In an world where the grid just ”was” and nobody questioned the value of it, it was not necessary to justify the value nor enter into separate contracts for different services
- However, with changing technology, the world has changed



# Previously the grid was a natural monopoly; now there is competition

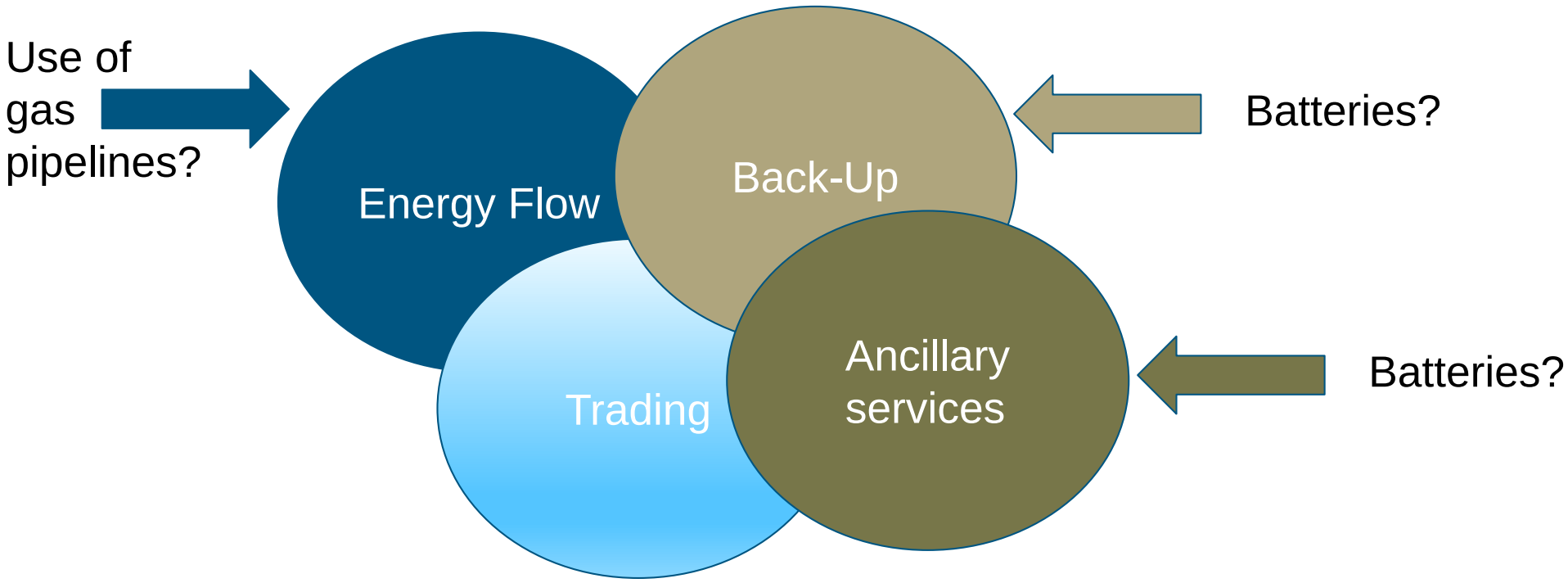
- Energy economics 101 used to say that large power stations are the most efficient and highest voltage lines have lowest losses
- Therefore the least cost solution was to build large power stations and then send power down smaller and smaller wires to the consumer

But that has now changed

- A gas fired power station made up of small gas engines is almost as efficient as a large CCGT
- A solar panel has much the same efficiency alone, in a small or in a large array – meaning that power stations of almost any size and location are possible
- Fuel cells may make home-generated power as cheap as “grid-generated power” – meaning that instead of power lines providing long distance energy transport, a gas grid may do this
- Battery storage can act as a “backup” in the home (“behind the meter batteries) and provide ancillary services (“grid scale battery storage”)

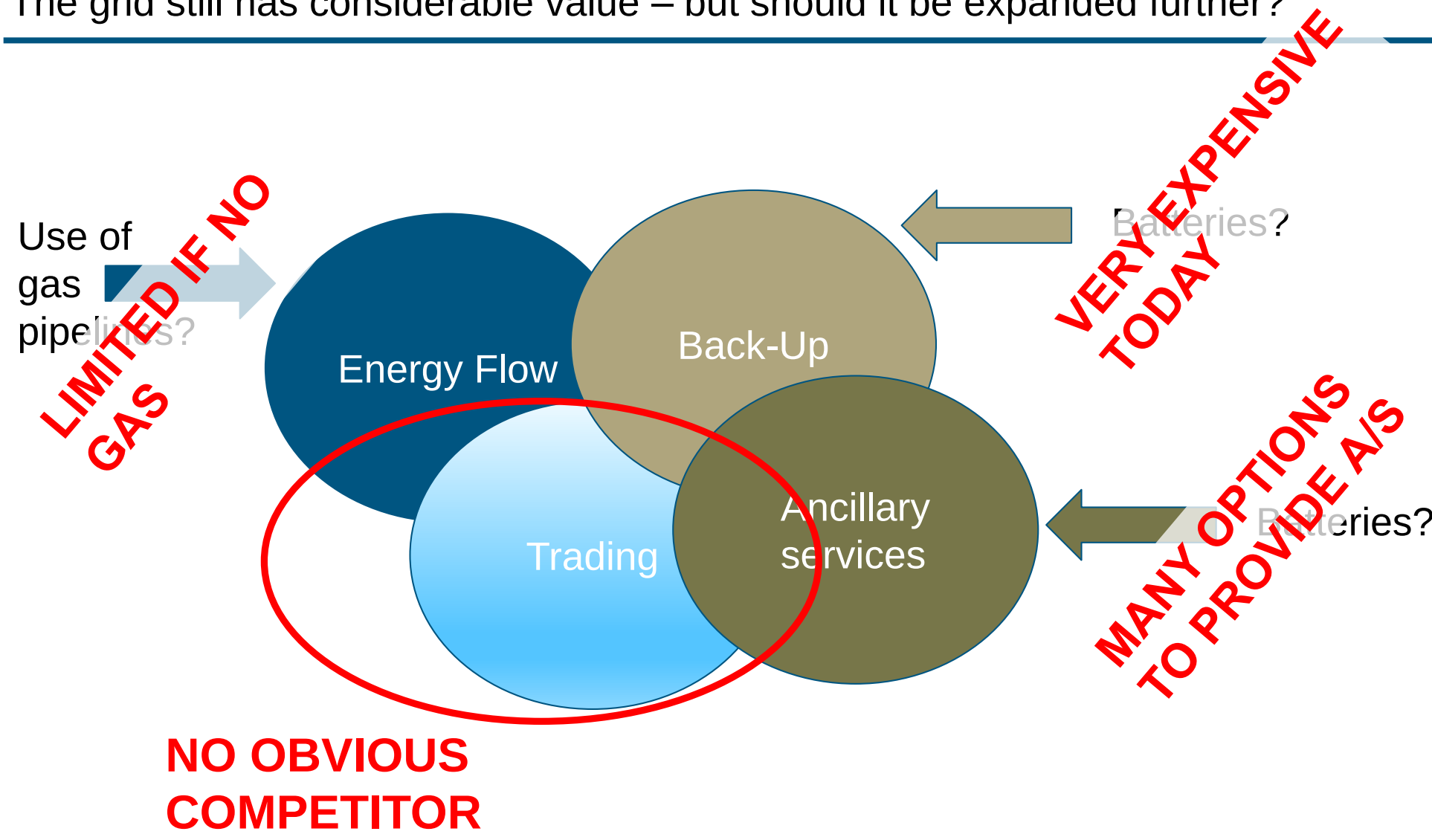
**Competition to the grid exists in some of it’s functions**

# Some of the functions of the grid can be provided in other ways




But this is a long way from a world where we do not need a grid

# The grid still has considerable value – but should it be expanded further?



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# Just because competition exists, does not mean the competition wins

- While a solar panel may be efficient stand-alone, the cost of installing it on a roof may be much more expensive than installing 1000 of them in a field
- While batteries can provide back-up and ancillary services, these are still more cheaply provided by using (for example) hydro power and a grid in most markets at the current time

**The fact is that transmission and distribution augmentation decisions are now more complicated – and need clearer insight and analysis to make good decisions**

- Decisions on network augmentation need a clear framework which takes into account the costs and benefits, the services that are provided, and whether the service is competitive – if someone else can provide it
- This may require updates to regulatory frameworks and the ability of networks to respond to competition like other services do, by offering competitive prices for some services
- It may also require consumers to better understand the value of networks and what services they are getting for the price they pay

# Grid expansion: views from China and Australia

Oversupply and curtailment of RE in China drives the grid expansion program

Power quality issues and security of supply drive grid retrofitting in Australia



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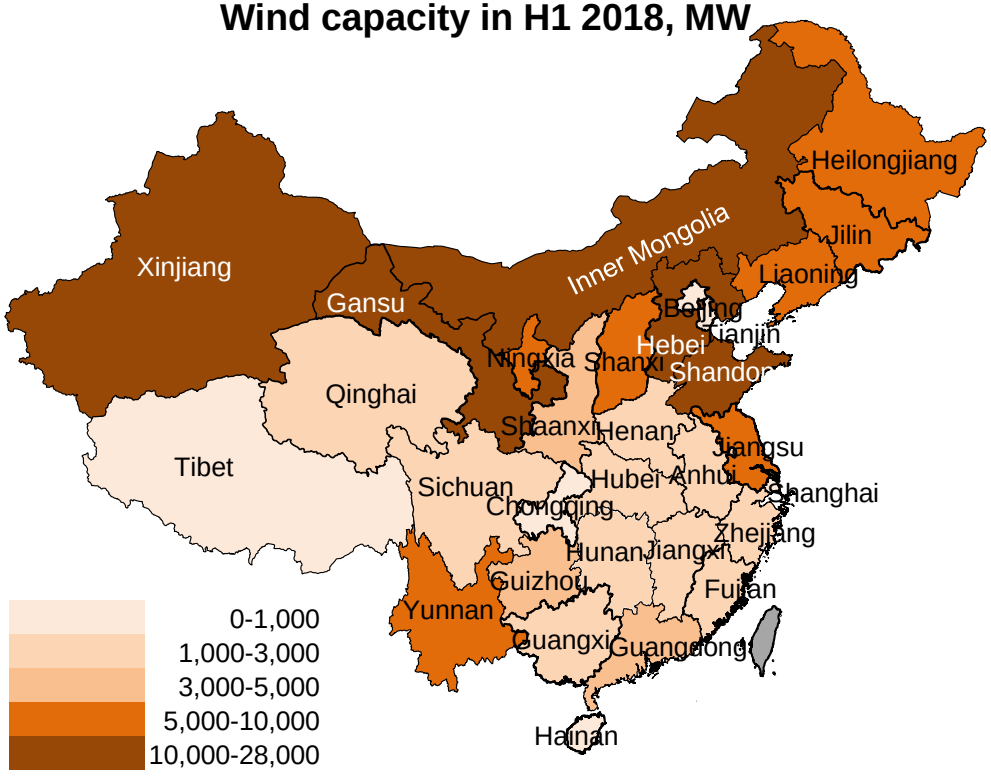
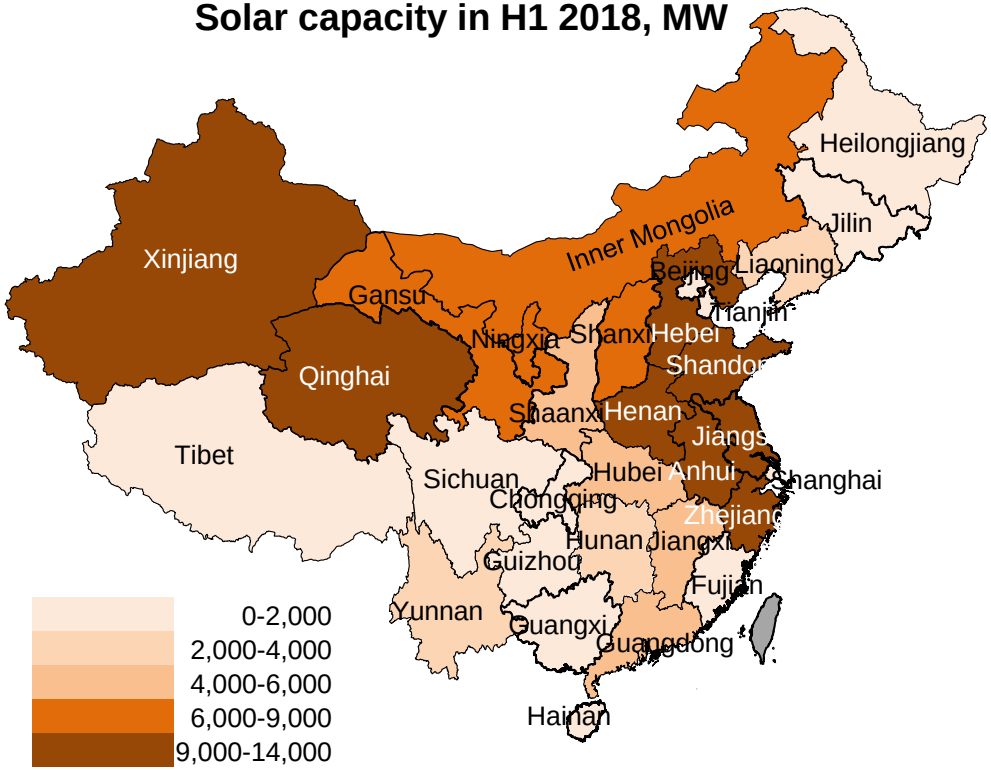
# China wind and solar capacity is mostly found in Northwest, North and Northeast and East regions where have good resources or high local demand

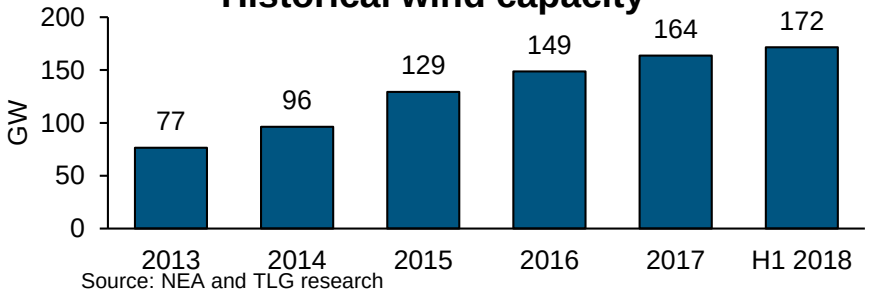
## Wind capacity in H1 2018, MW



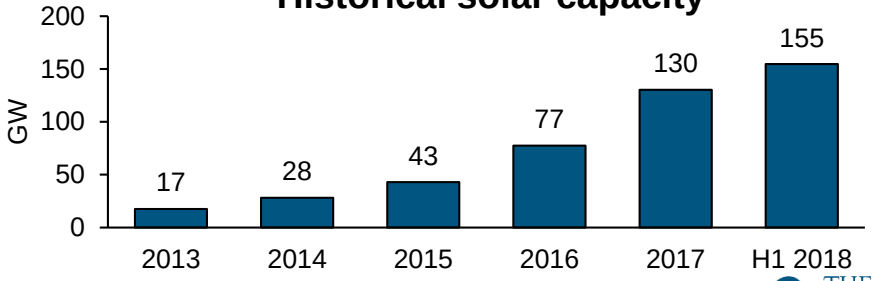

## Solar capacity in H1 2018, MW




## Historical wind capacity




## Historical solar capacity




Source: NEA and TLG research



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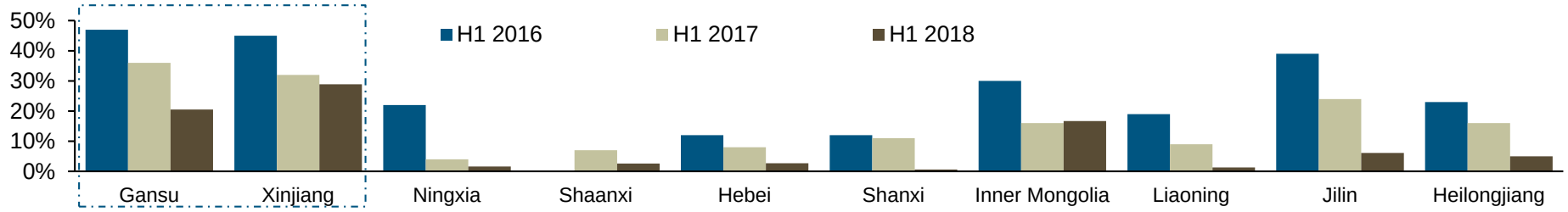
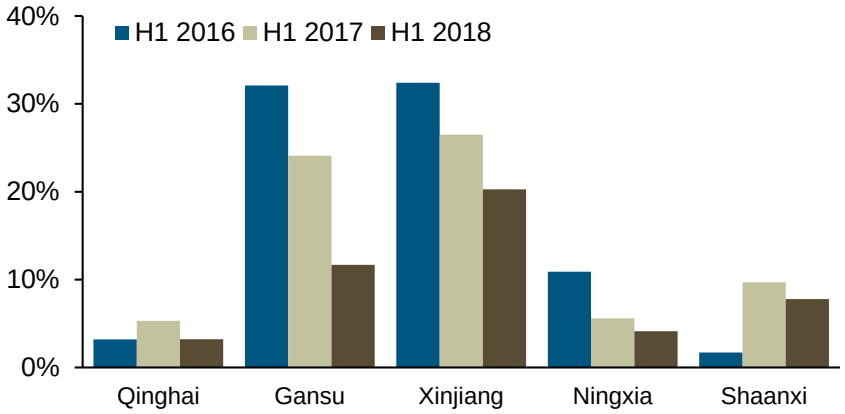
# However, much of the renewable generation has been “curtailed” because of insufficient ability to move the power where it is needed.

## Wind curtailment rates in 10 provinces




## Solar curtailment rates in 5 key provinces

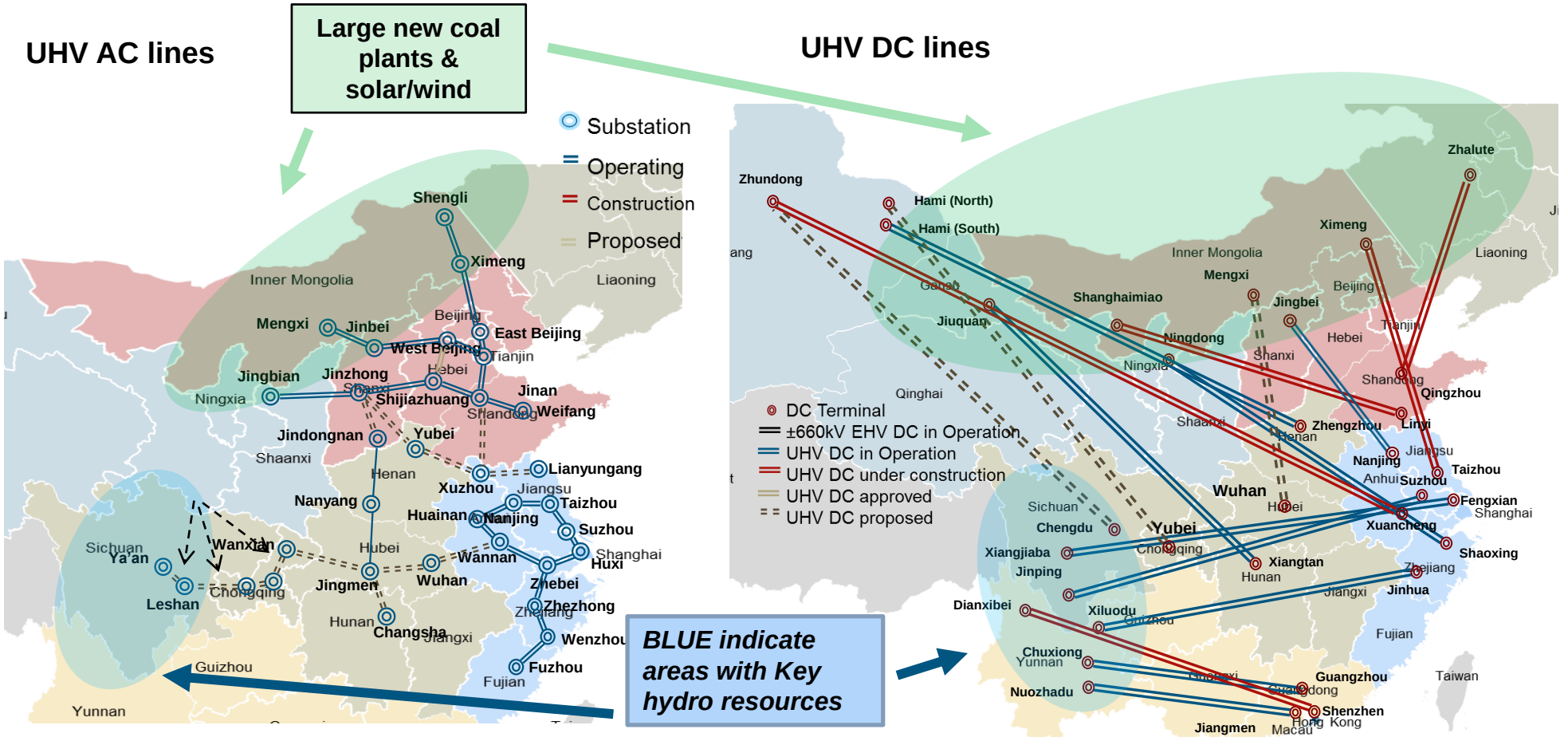



Transmission and curtailment rates have generally improved in H1 2018, although they are still high



Source: NEA, Northwest China Energy Regulatory Bureau and TLG research from news reports.

# UHV DC and AC lines expansions will enable power exports from the curtailed regions, but their utilization rates are likely to be relatively low at least in medium-term

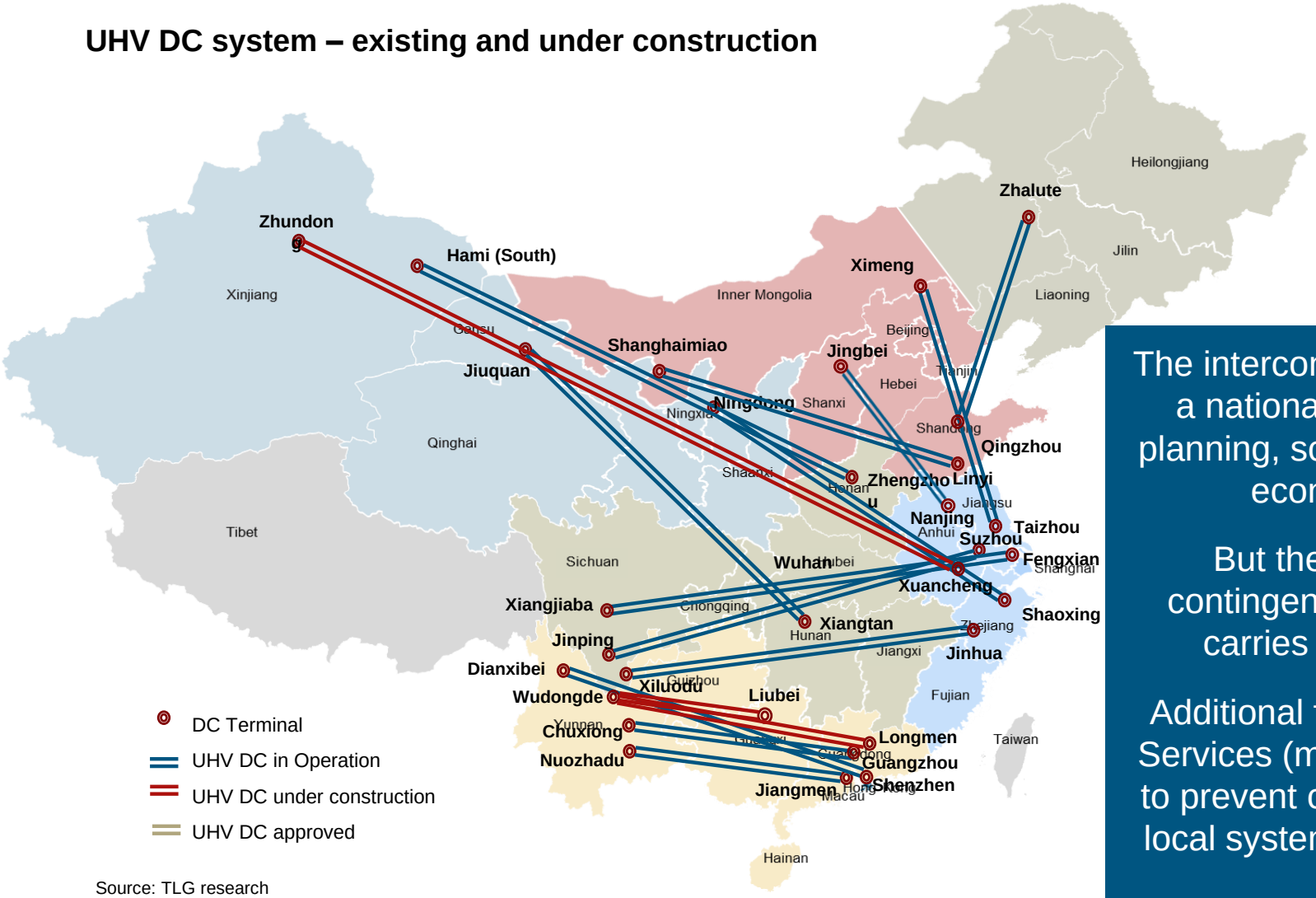



Source: TLG research and analysis

Building massive infrastructure on this scale is expensive and requires significant coordination between central and provincial authorities. It is unclear if the benefits of the grid expansion outweigh this cost because no cost-benefit analysis is undertaken

# Grid expansions may not be a solution – often it just moves them elsewhere – and the lines themselves become contingency events that must be managed

**UHV DC system – existing and under construction**




Source: TLG research

The interconnectors create close to a national electricity market in planning, scheduling, dispatch and economic efficiency.

But the DC lines are now contingency events given each carries 7-10 GW of power.

Additional fast response Ancillary Services (more costs) are required to prevent catastrophic collapse of local system frequency in such an event.

# Supply-side intervention (halting new built in highly curtailed regions and adding pumped storage plants) can mitigate RE curtailment if successfully implemented

## Proposed policies to mitigate curtailment

**Supply-side**

- **Slow-down approval** or halt new coal, solar and wind projects in highly curtailed regions will be very positive to reduce curtailment
- Several **Non-hydro RE targets** have been discussed in China, which incentive existing generators to continue to build new solar and wind capacity

**Flexible Generation**

- **More pumped storage plants:** Several provinces like Gansu and Jilin have plans to build new pumped storage plants
- **Increasing flexibility of the system:** This has been discussed, but it remains to be seen whether private players will invest in technologies (such as battery) that can improve the flexibility of the system

**Demand-side**

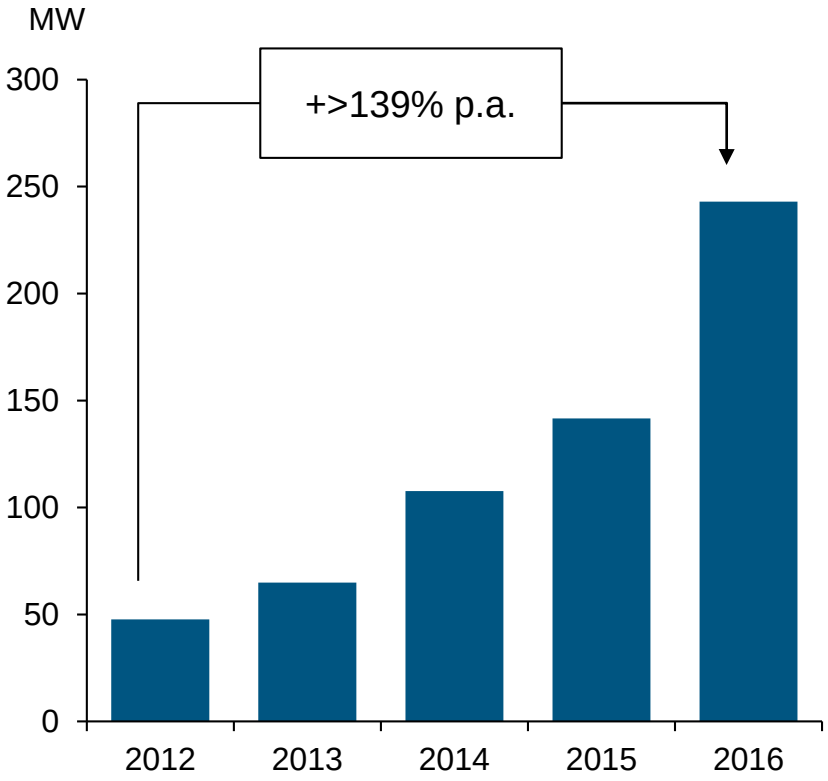
- **Wind/solar for heating:** This is still not commercially proven.
- Local governments with high wind and solar curtailment rates have been trying to attract energy intensive industries (like data centres) to move to their provinces

**Set-up of competitive spot electricity pool market**

- Eight provinces have been working to create competitive spot pool markets by end 2018. Mengxi in inner Mongolia and Gansu are among the eight
- If they are implemented in a similar way as international spot pool markets, curtailments are likely to be reduced because dispatch would be largely based on variable cost (solar and wind have zero variable cost)

# Development of battery storage can reduce curtailment, but it is yet to reach large-scale commercial deployment in China

**Installed capacity of battery storage**



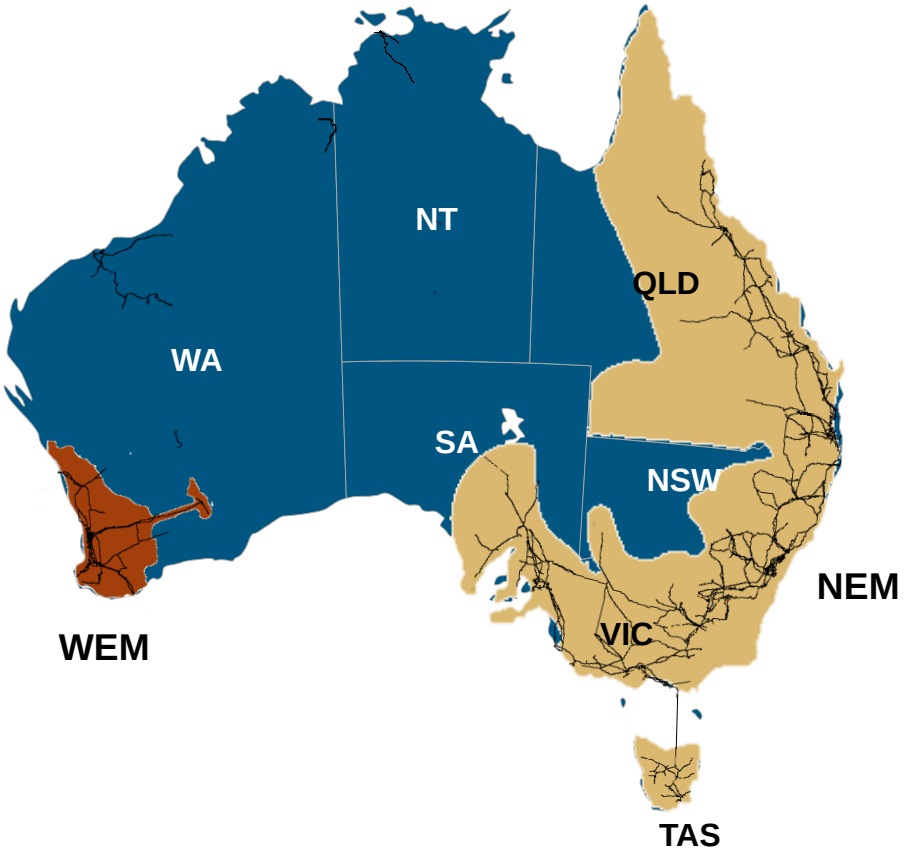

- Total installed capacity of battery storage is 243MW.
- 55% of new battery additions driven by the RE sector with most projects installed in northwest region with RE.
- In June 2016, NEA launched a pilot programme to implement a compensation scheme for ancillary services for battery storage in 'Three North' region with batteries r deployed with power plants or independently
- NEA drafted a guidance on *Improve Storage Technology and Industry Development* which is under
  - The overall target is to realize early stage of commercialization for storage industry before 2020 and gradually shift to large scale development before 2025.
  - Battery storage is encouraged with RE projects and smart grid.
  - Renewable energy plus battery is allowed to participate ancillary service market.
  - NEA proposed to introduce capacity payment mechanism for storage.

# Australia is also facing challenges of integrating RE and dealing with an aging grid

Australia has two disconnected power markets:

- QLD, NSW, VIC, TAS and SA are interconnected and trade electricity in the **National Electricity Market (NEM).** NEM is an energy-only market with energy and Ancillary Services being co-optimized. The market features 5-minute dispatch and 30-minute settlement.
- Western Australia, also has an electricity market, **Wholesale Electricity Market (WEM**), that operates over the South-West Interconnected System (SWIS), one of few interconnected systems in WA. WEM is an energy + capacity market with Ancillary Services contracted from the incumbent generator, Synergy. The market features 30-minute dispatch and 30-minute settlement.

**Coverage of Australia's electricity grids**



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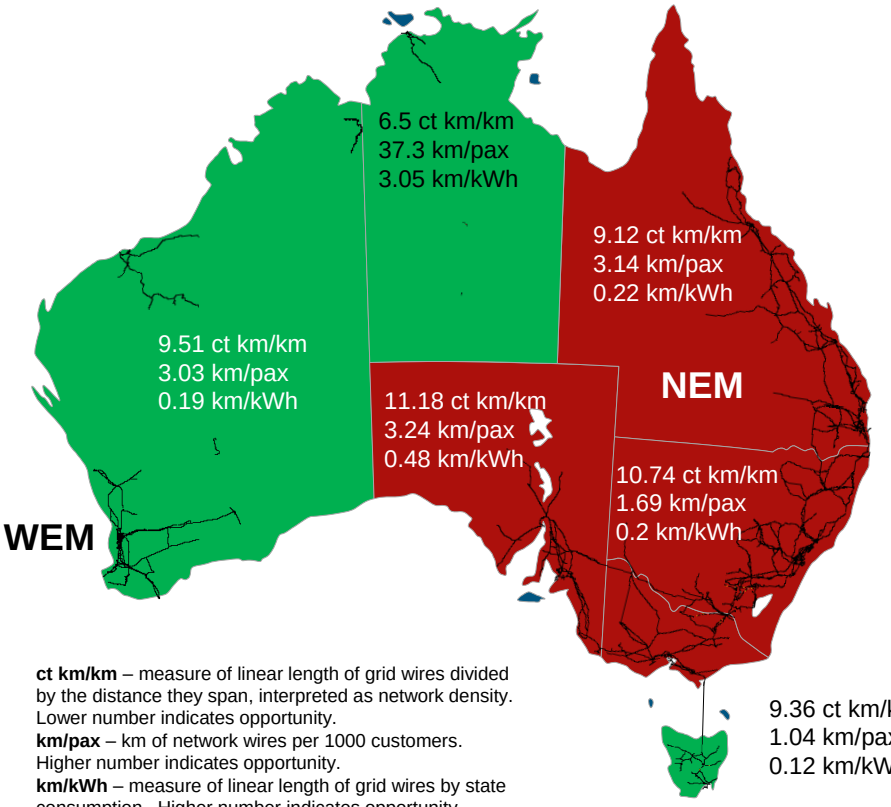
# Australia’s geography makes power systems very infrastructure intensive

A vast country with low population density, Australia is a challenging location for electricity grid development.

- The infrastructural requirement for the grid varies across Australia, with NT requiring 37 times the circuit km of network infrastructure per 1000 customers compared to VIC.
- The regulatory environment already requires network operators to compare network and non-network solutions
- There are significant grid interconnection projects planned but all only show benefits if the gas price remains high
- These infrastructure constraints combined with the requirement of the network operators to perform Investment Tests for grid expansion projects as well as asset replacement projects indicates a significant potential for battery storage

**Overview of Australia's grids**



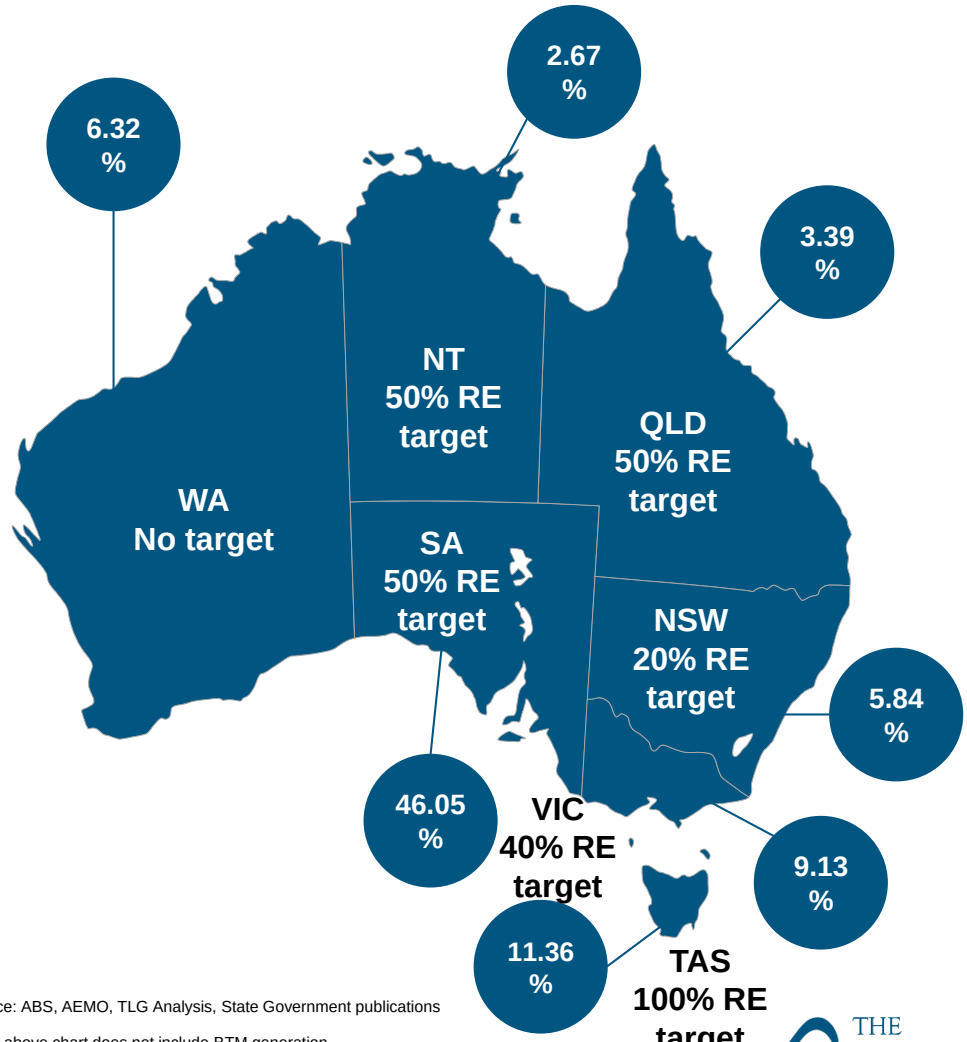

**ct km/km** – measure of linear length of grid wires divided by the distance they span, interpreted as network density. Lower number indicates opportunity.
**km/pax** – km of network wires per 1000 customers. Higher number indicates opportunity.
**km/kWh** – measure of linear length of grid wires by state consumption. Higher number indicates opportunity.

Source: Western Power, Power & Water Corportaion, ElectraNet, AusGrid, Sp AusNet, PowerLink, Transend

# High penetration of VRE and demanding geography may favour storage over grid expansion

- Sparse population centres and large distances between load centres can render network costs in Australia extremely high
- The combination of regulatory environment; economic drivers; positive social outlook; high penetration of renewables; low power quality; grid overloading in remote locations; and experience of catastrophic black-outs has led Australian citizens and business leaders to have highly positive outlook towards energy storage
- Multiple commercial and pilot projects are being tested in Australia covering most of the business models indicated in our previous reports
- Australia is the home to the currently world's largest energy storage system developed by Tesla and has a strong market for behind-the-meter (BTM) use of storage

**Share of VRE generation (2016) and RE targets**




Source: ABS, AEMO, TLG Analysis, State Government publications

Note: above chart does not include BTM generation,



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# Summary

- Both Australia and China saw significant uptake of Variable Renewable Energy.
- However, the countries took different approach to address the issues related to the uptake of VRE.
- Australia made significant efforts to implement highly localized storage projects developed around supplying various grid and market services.
- While China place its bets on the expansion of the UHV transmission lines able to transmit power across distant provinces.
- Both approaches are likely to alleviate the issues related to the uptake of VRE, while specific strategy to absorb significant amount of VRE depends on specific circumstances of a given country.

# So what does this mean for Sri Lanka?



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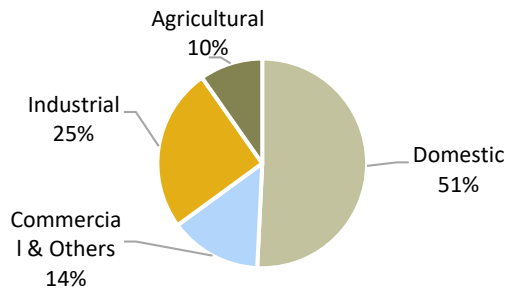
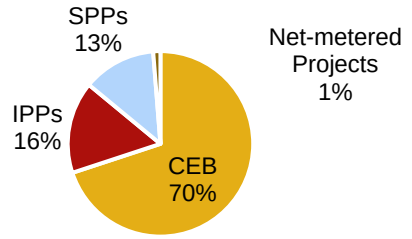
# A Snapshot at Sri Lanka's power sector in 2016

| | |
|---|---|
| **Installed capacity** | 4,013 MW |
| **Peak demand** | 2,453 MW |
| **Gross Generation** | 14,361 GWh |
| **Consumption per capita** | 684 kWh |
| **Private sector participation** | ~30% of installed capacity via IPPs/others |

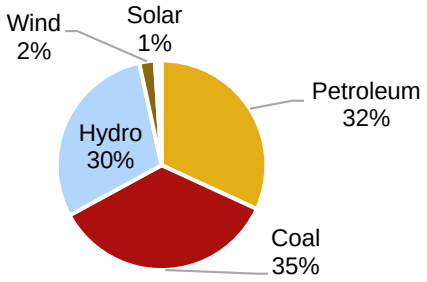
**Sri Lanka's Power Demand by Sector**



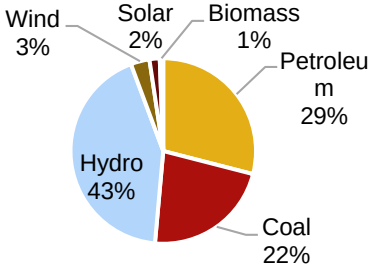

**Sri Lanka's Installed Power Capacity by Ownership**




**Sri Lanka's Power Generation by Fuel**




**Sri Lanka's Installed Power Capacity by Fuel**



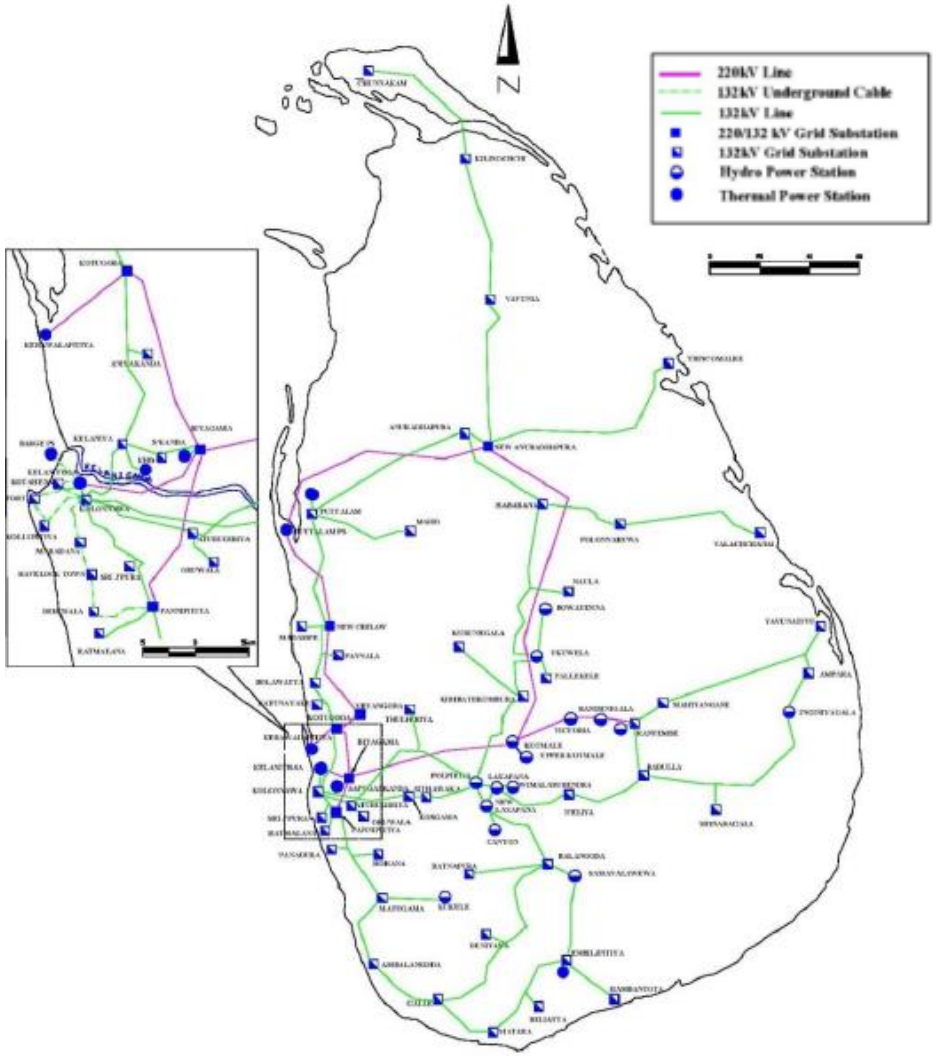




Source: CEB, SLSEA, IEA, TLG

# Electricity transmission network is solely owned by state-owned CEB

**Sri Lanka Transmission System (2017)**

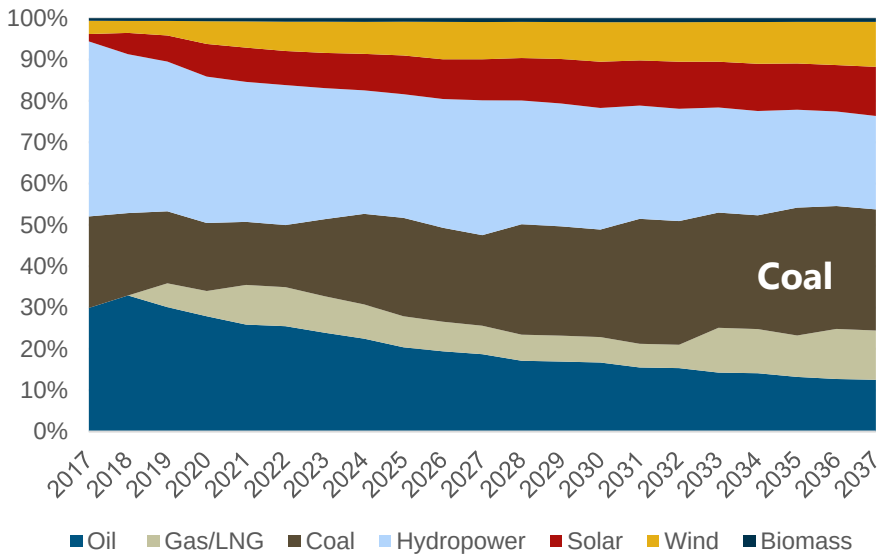



- CEB owns and operates the electricity grid; purchases power from generation licensees through Power Purchase Agreements (PPAs) and sells the power transmitted from generation stations to the distribution licensees.
- Meanwhile, grid access of renewable energy is regulated by SLSEA
- There are five major distribution licenses who purchase the power and distribute to the end consumers.
- Electricity distribution and sales come under the purview of CEB and LECO: CEB owns four distribution licenses for four distribution regions whilst LECO owns one distribution license.

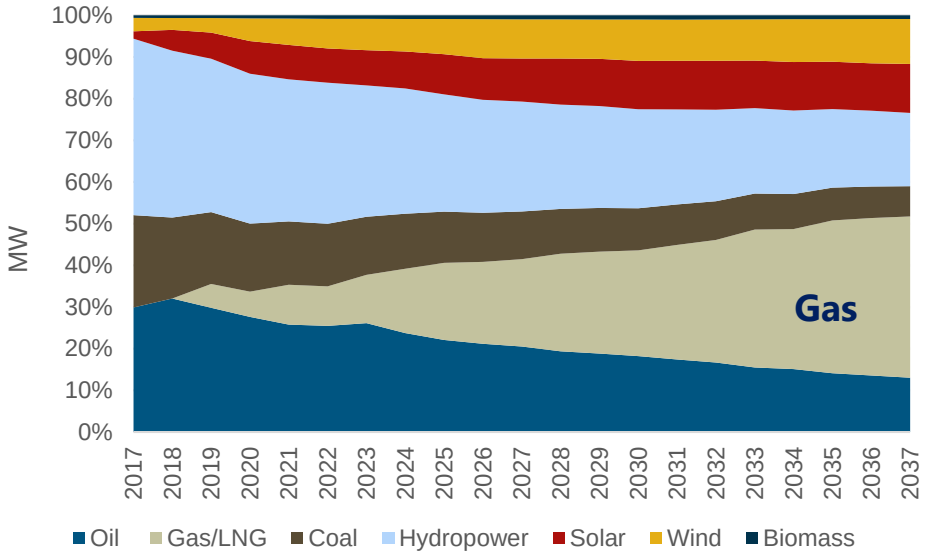
 Source: SLSEA

# There is some confusion as to the future direction of the electricity supply industry – coal, gas… where are the renewables?

## Projected Installed Power Capacity (2018-2037)




Source: CEB LTGEP 2018-2037




Source: Decision on Least Cost LTGEP 2018-2037, PUCSL

- Significant build-up of coal capacity was envisioned in the power development plan proposed by CEB in April 2017
- However, in the approved plan released in July 2017, the PUCSL overturned the decision to construct more new coal-fired power stations, with a plan heavily weighted towards gas and no new coal capacity additions
- While wind and solar feature in both plans, the quantities are not significant



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# Sri Lankan electricity grid experienced three instances of nationwide black outs in the last 3 years, with important lessons learned in the development of ancillary services for the robustness of system operation

| Date | Cause for backout | System Response | Implications |
|---|---|---|---|
| 13th March 2016 | Technical faults resulting from two break downs of a key transformer and a transmission line | Worst blackout in 20 years. Power was completely restored only after a day | Appointed a special committee to probe into all the incidents and prepare comprehensive report |
| 25th Feb 2016 | Lightning strike on a major transmission line causes tripping and technical fault | Power was restored after 3 hours | Disruption of a local grid resulted in a country wide blackout despite respective protection systems in place |
| 27th Sep 2015 | Tripping of a generating unit caused a total system failure in the grid | System was operating at low load, hence was vulnerable to over voltage. Load shedding and transformer tapper actions aggravated situation | A CEB commissioned study recommended specification of 'must run' units and addition of shunt reactors to mitigate such situations |

# Ancillary Services are the support services which are required for improving and enhancing the reliability and security of the electrical power system

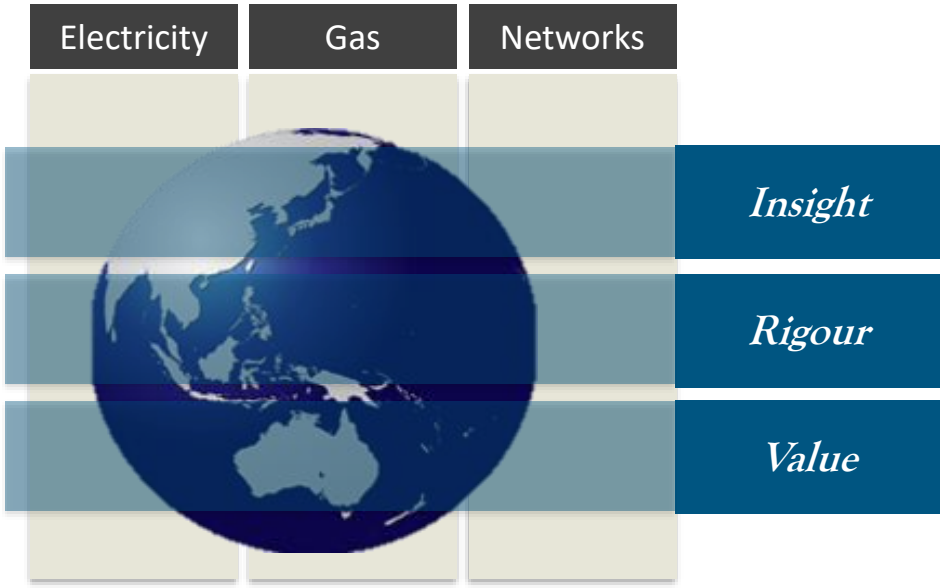
| | |
|---|---|
| Real power support service or load following frequency support ancillary services | • At present, there are no formal ancillary services. Grid frequency imbalance is dealt with by available hydro plants and oil based plants, but the system response is not optimal. As the grid grows, coupled with penetration of RE and reduction of oil use, a robust ancillary system will be needed |
| Voltage control or reactive power control ancillary services | • Voltage support involves the maintenance of reactive power to the grid to maintain system voltage in the optimal range.<br>• For the replacement of thermal capacity by renewables to be successful, Pump Storage Power Generation (PSPP) is going to be very important. |
| Black start ancillary services | •Nation wise electricity outage in Feb and March 2016 resulted in studies on the requirement of black start services. However, no service codes are currently being planned. Design of a properly sized system for black start support in close proximity to a large Power Stations is standard |
| Specification of 'Must Run" units and methodology | • CEB sponsored studies on the system outages have recommended specifying 'must run units' for voltage support, which is to keep a number of extra units running to support the power system recovery from a large disturbance to the normal operation |
| System reliability to supply shocks | •When a coal power plant's operation is halted, the repowering takes a day or more. In such instances of supply shocks due to equipment failures at the coal plant, the interconnected transmission capacity and systems should ensure "n-1" reliability at all times |

# Sri Lanka clearly needs a strong network to underpin economic growth

- With no gas network and significant hydro resources, using other forms of energy transport is not feasible
- Battery storage may be useful for certain services, but cannot replace the grid
- The small size of the country tend to drive a lower cost per customer (compared to the huge distances per head of population in Australia, for example) meaning that the grid is likely to remain relevant for a long time
- Integration of intermittent renewables into the Sri Lanka system will need a holistic energy policy which takes into account:
  - Impact of intermittency on the system;
  - Location of resources (both conventional and renewable);
  - Regulatory processes which allow fair competition between grid expansion and alternatives ways of achieving the same objective, such as location of generation closer to the load etc.
  - Flexibility in regulatory processes and tariff setting mechanisms which allow the network to compete

The best solution for consumers is for an efficient outcome which takes into account all technologies. A modern regulatory framework and enhanced decision making framework would enable this to take place

# Contact Us

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