Where do we currently stand with energy storage development?

Jan Stempien

24th May 2018

THE LANTAU GROUP

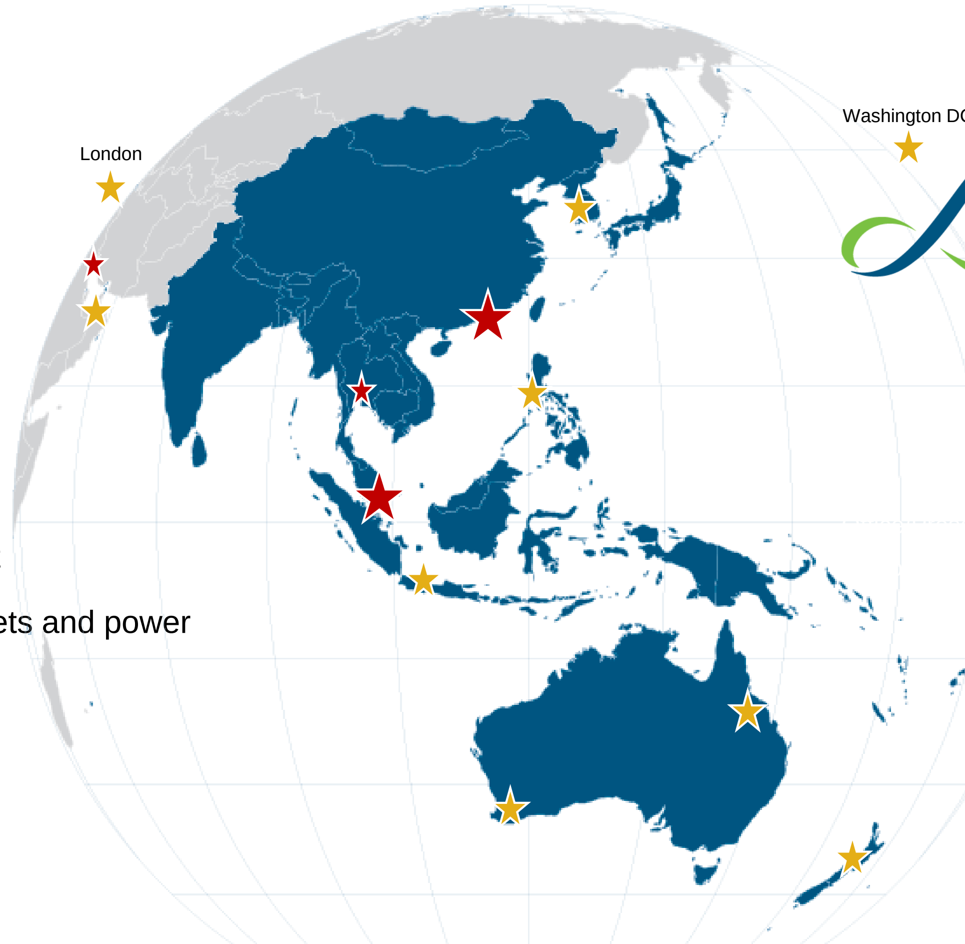
About The Lantau Group

Consultants to the Energy Sector

- Competition, Markets, Regulation, Policy
- Decisions Support Analysis
- Disputes
- Market Analysis
- Asset Valuation
- Strategy and Advanced Analytics

Offerings:

- Strategic, commercial, and regulatory support
- Ability to connect the dots between fuel markets and power
- Analysis-based recommendations
- Highly relevant international experience
- Accessible experts focussed on the region
- Pricing, trends, drivers, risks



Languages:

Arabic*
Cantonese
Mandarin
English
Bahasa Indonesia
Bahasa Malaysia
Bengali
French
German
Hindi
Japanese
Korean
Swedish
Tagalog*
Thai*
Vietnamese*

*External Advisors

Unrivalled experience across the power and gas value chain (examples)

Vietnam
- Gas and LNG demand supply
- Analysis of coal versus gas competition
- Gas master plan assistance (NOC)
- LNG infrastructure

Malaysia
- Single Buyer market design
- Post PPA expiry valuation / PPA disputes
- Incentive-based regulation (IBR)
- Cost of service / Tariff Design
- Load forecasting enhancement

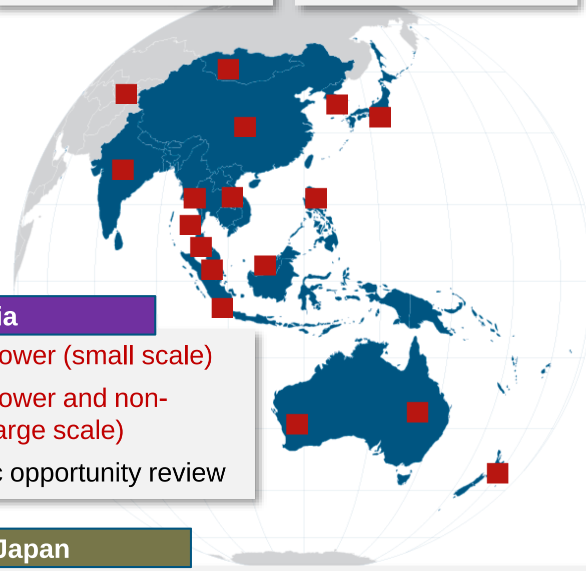
Singapore
- Market design / Structure/ regulation
- Market Power / Vesting Contracts
- Fuel Mix
- Tariff benchmarking
- Market price projections
- Gas network cost recovery

Philippines
- IPPA Design/Execution
- Ancillary services opportunities and regulation
- LNG entry strategy and economics
- Natural Gas Masterplan
- Distribution cooperatives support
- Most of the major renewable, gas, coal, geothermal, and hydro project market transactions

India
- Wholesale market modelling for IPP developer
- Fuel switching study
- End user pricing / invoice tracking

Mongolia
- Fuel switching study

Uzbekistan
- CNG Vehicle Market



Indonesia
- Gas to power (small scale)
- Gas to power and non-power (large scale)
- Strategic opportunity review

Japan
- Solar Entry Strategy
- End user pricing of gas and electricity

New Zealand
- Transmission cost recovery and evaluation
- Market design and regulation
- Hydro development cost-benefit analysis
- Gas market development

China
- Curtailment study in Gansu, Jilin and West Inner Mongolia
- Transmission system review
- Multiple studies on small-hydro power opportunities
- Coal-fired power generation and carbon policy in Zhejiang
- Coal-fired power investment opportunity in Chongqing
- Assessment of gas-fired CHP opportunities in Guangdong
- Strategic assessment of opportunities in Guangxi Province

Korea
- Korean "CBP" market review (KEPCO)
- Korean Nuclear Sector Review (KEEI)
- Vesting Contract Design (KEPCO)
- Gas and coal IPP opportunities

Australia
- Capacity market design
- Contract dispute
- Market design and policy
- Energy Market Review
- Demand response economics
- Renewable energy opportunities and regulation/policy
- Market analysis / modelling
- Market design and regulation
- Network regulation and cost recovery
- Gas market development

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Extensive experience serving Asia's energy leaders since 1997

Large **Users**

Oil & Gas companies

International Aid Agencies

Leading **Utilities**

Financial Institutions

Market and System Operators

Government Ministries

Regulatory Agencies

Independent **Power Producers**

Agenda

Introduction

Disrupting the energy value chain

Advancements in energy storage technologies & deployments worldwide

Economics of energy storage

Summary

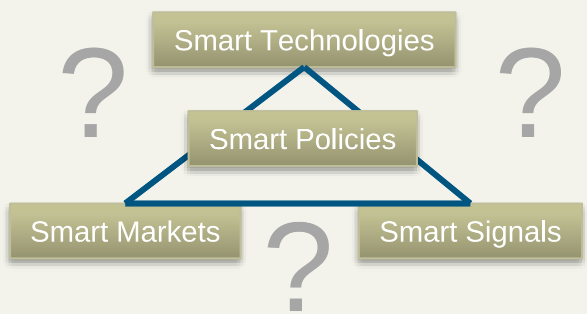
How we see it – Three Megatrends

Shifting the fuel and generation mix

- Strong focus globally on renewable energy, and improvement in price/performance points
- 2ºC goal is estimated to require:
  - Full decarbonisation of the power sector by 2050. If this is met by the renewables, annual growth rates in the range 25% - 30% are needed.
  - Half of the light-duty vehicles need to be electric by 2050
- 1.5ºC goal is estimated to require:
  - All vehicles must be electric by 2050
  - No more combustion engine vehicles sold post-2035.
  - Further gains in the buildings sector.

Changing the way we price energy usage

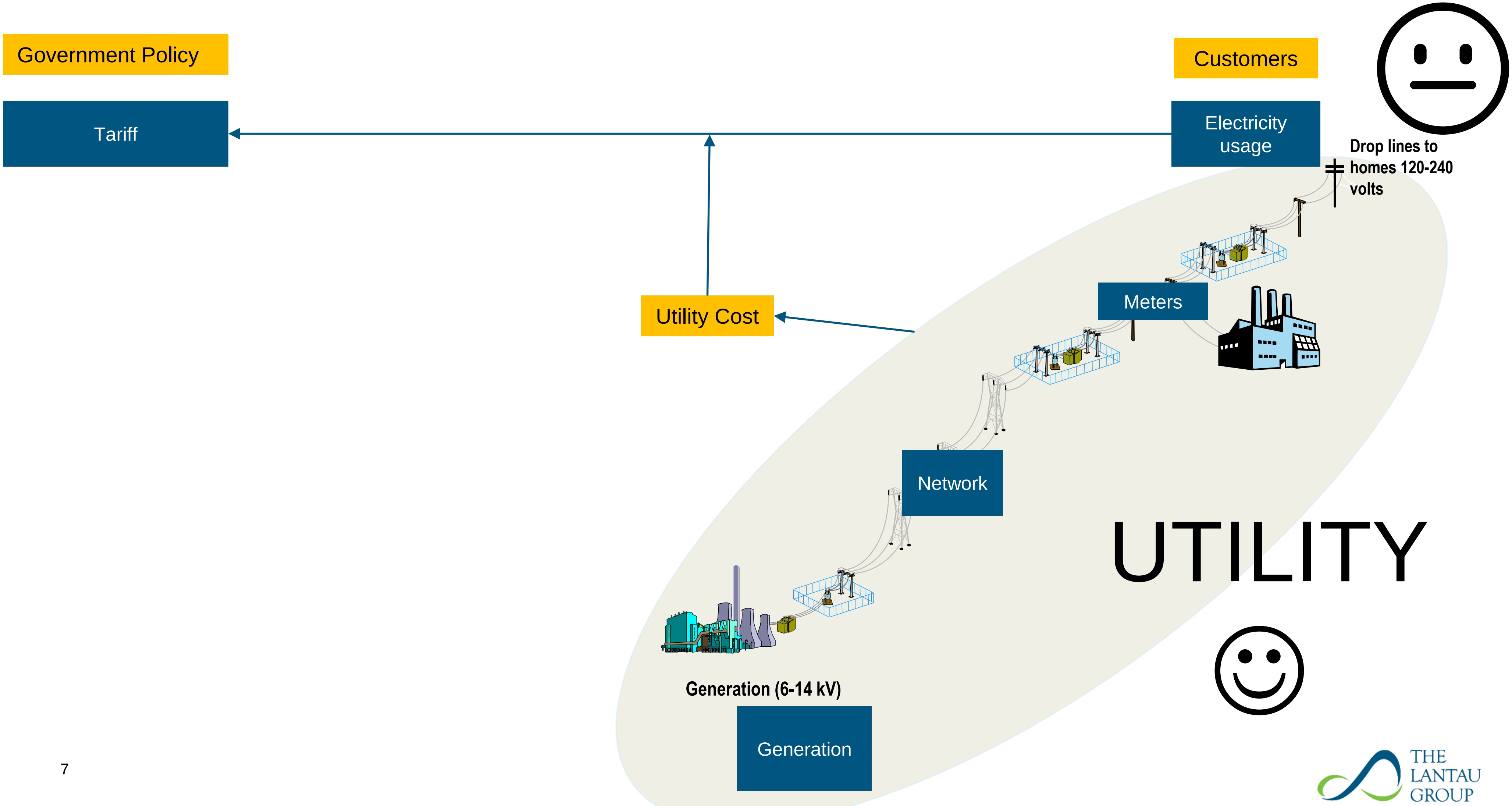
- Pricing influences incentives and behaviours, which can in turn shift costs from one group to another
- Speed of change in technology and adoption rates outpaces adaptability of regulation and policies
- How to signal and support the right overall mix of resource capabilities and responses?
- Smart usage requires smart meters and smart pricing, but few customers have these



Aligning incentives on both sides of the meter

- Increasingly the world of the ”grid” and the world “behind the meter” are becoming disconnected, with implications for cost and equity (who pays)
- Deployment of distributed energy sources proceeds in an ad hoc, opportunistic, and often imbalanced and cost-shifting way given rigidity in current tariff structures
- Energy storage becomes more valuable as various constraints and distortions increase due to less integration between economics of energy, environment, and security of supply objectives
- New challenges for grid operators to manage system security (keep the lights on)

Once upon a time, a utility's (and customer's) life was simple



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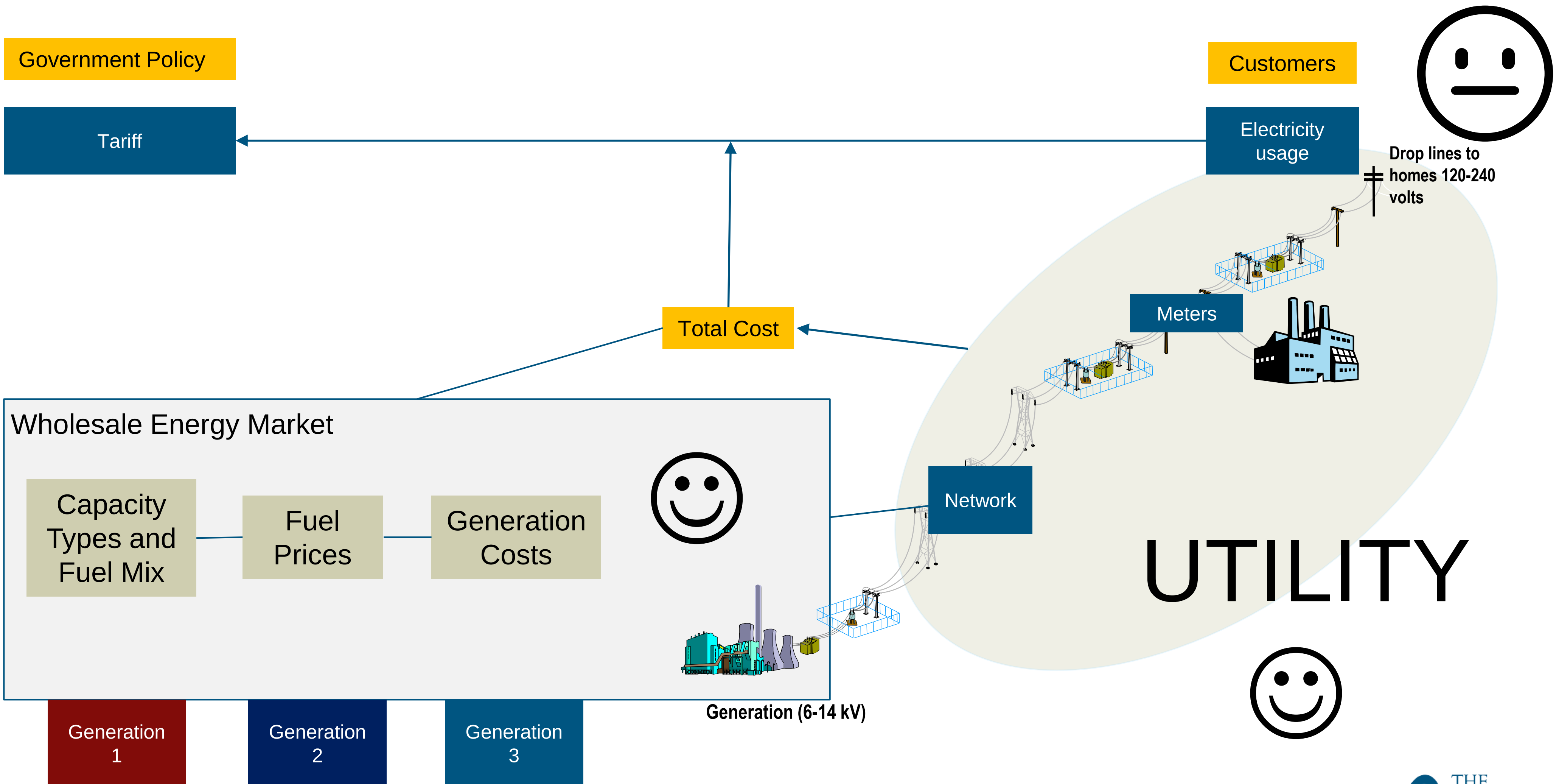
Many countries introduced “IPPs” and/or “Electricity Wholesale Markets”



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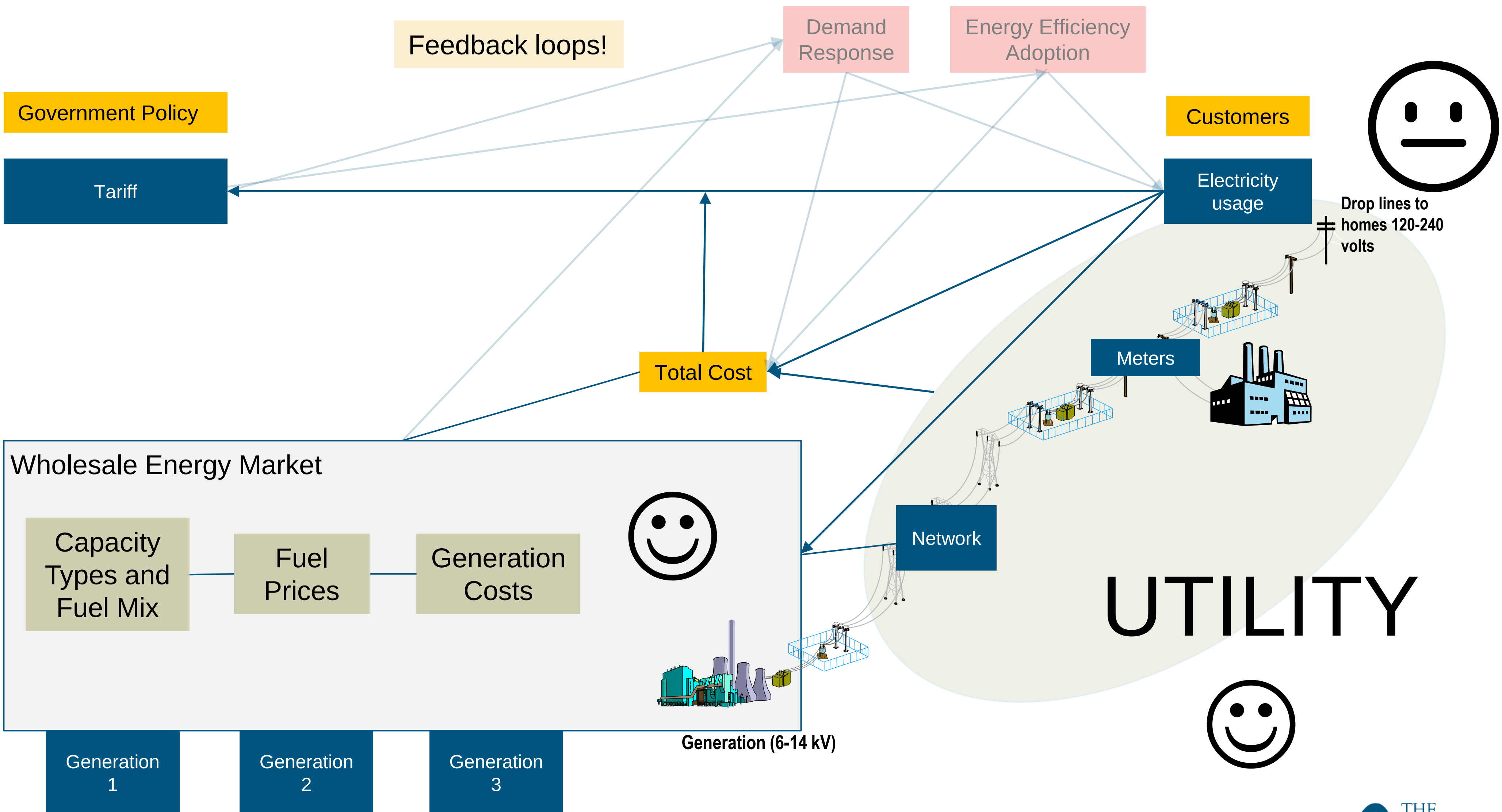
Demand response and energy efficiency were amongst the first "complications", but were relatively modest in their initial impact in most markets….



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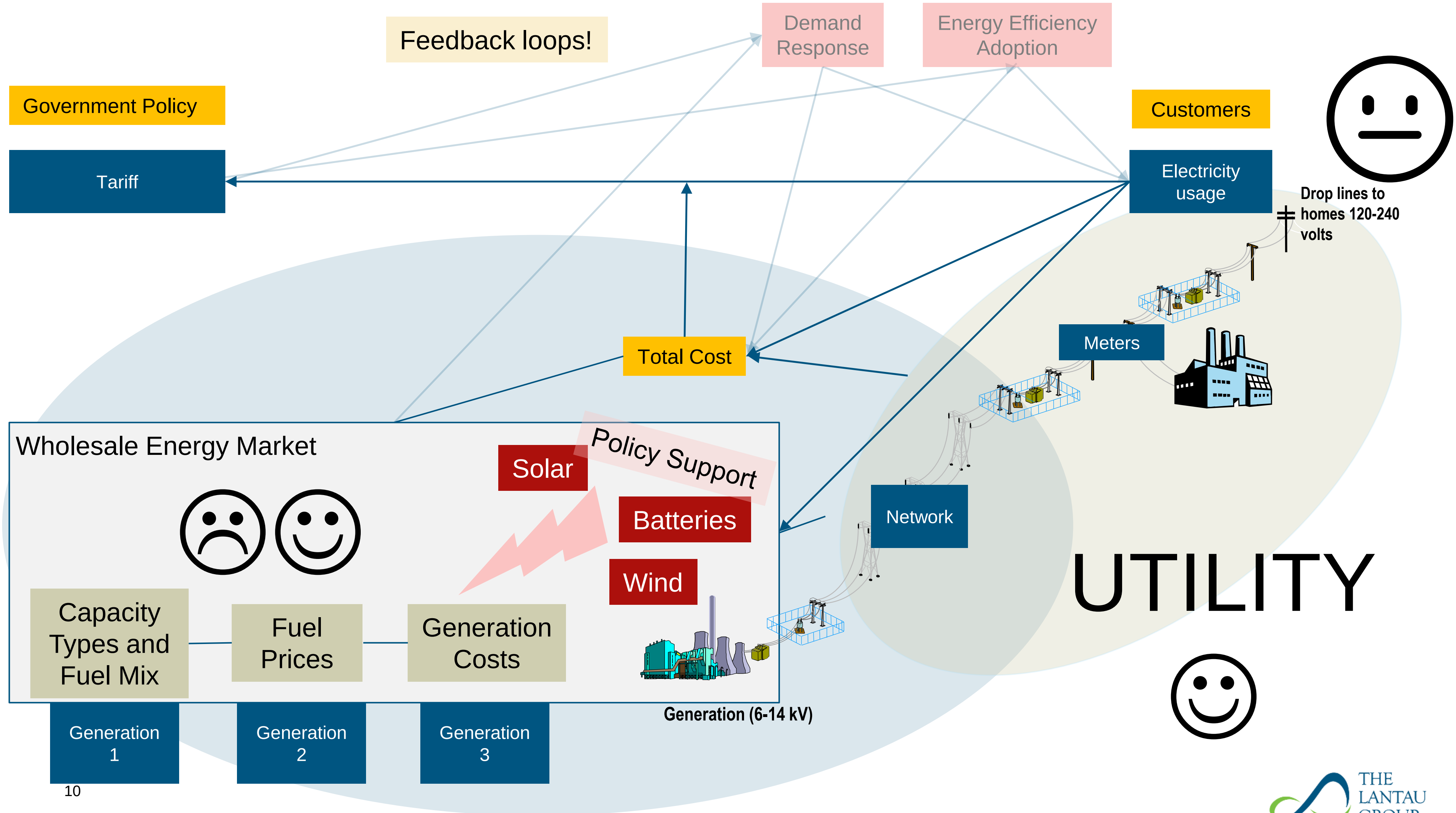
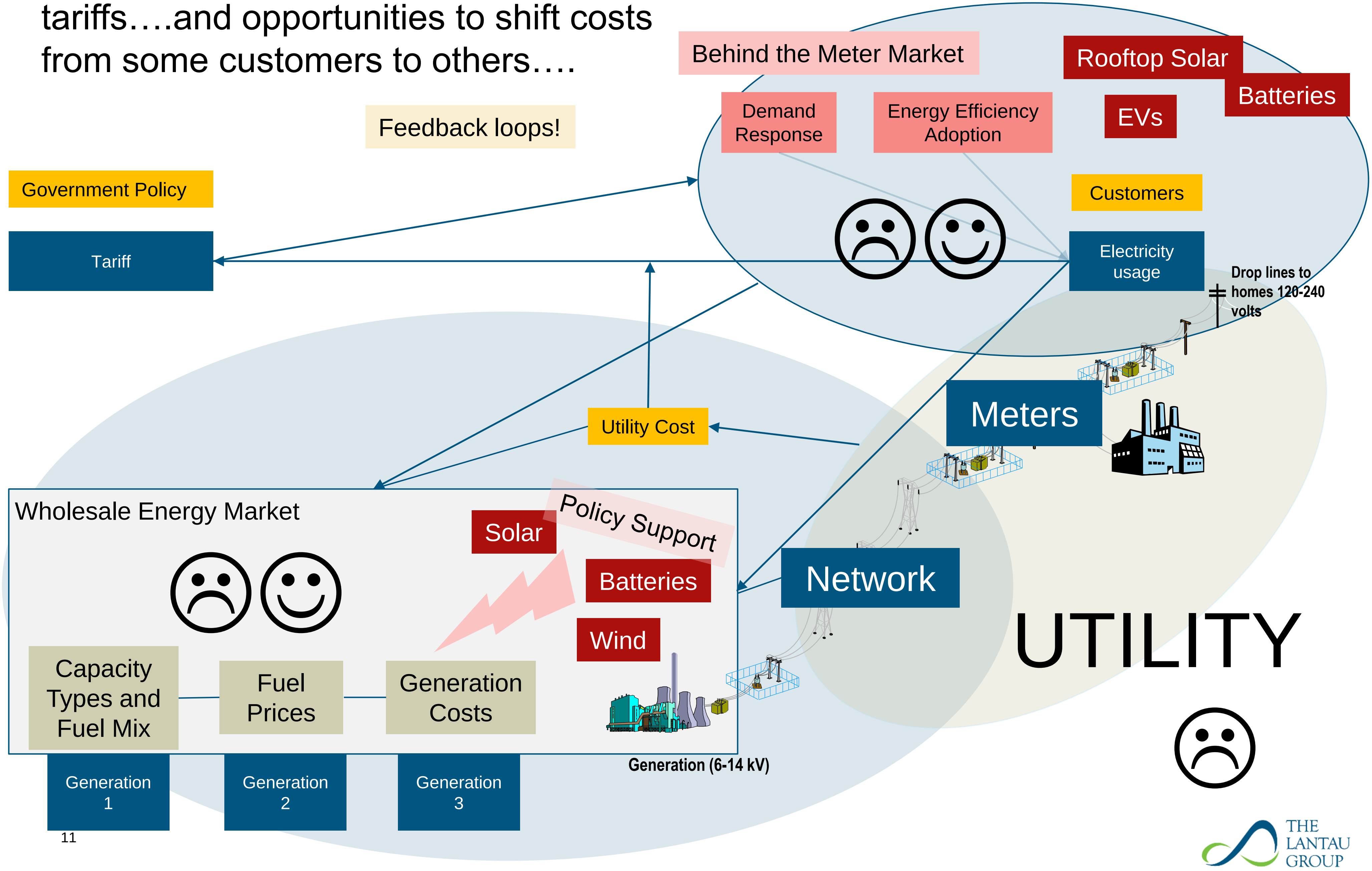
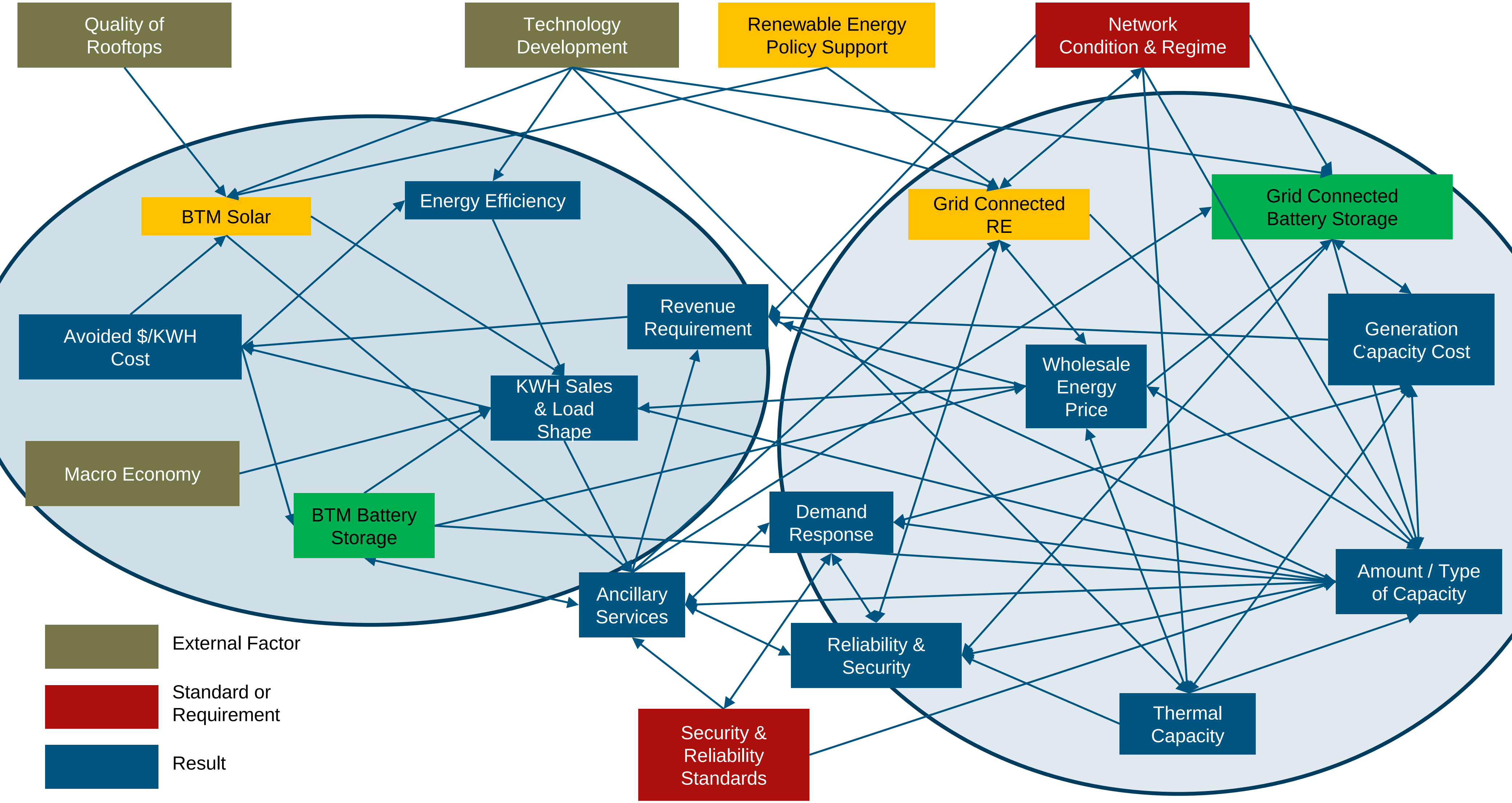
Policy support for grid-connected renewable energy (feed-in-tariffs and other mechanisms) pushed many wholesale energy markets out-of-balance



The "behind the meter" market is taking off in many countries, driven by rising tariffs….and opportunities to shift costs from some customers to others….



Storage can ease some of the constraints, but the benefits should not be taken for granted

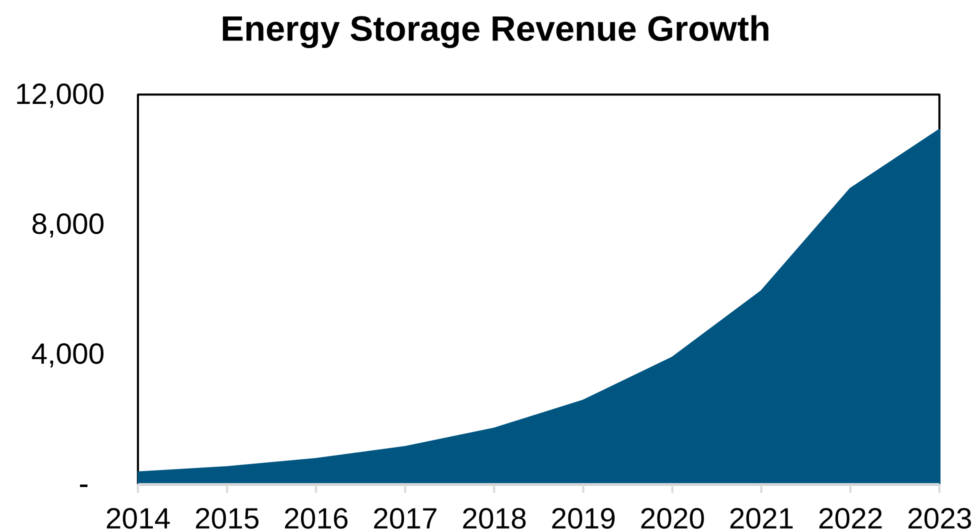


So what is exactly happening with storage?

Industry analysts see storage as a growing part of the sector

Energy storage growth has been tremendous – and it's expected to continue

- Annual installation size of 6 gigawatts (GW) in 2017 and over 40 GW by 2022 — from an initial base of only 0.34 GW installed in 2012 and 2013
- Annual revenue for all applications is expected to increase from USD 220 million in 2014 to USD 18 billion in 2023
- Battery storage capacity will rise from 360 MW to 14 GW over the same period.



Sources: Lux Research

However, this is still the initial stage of segment development and the future is unclear
But there are a lot of trials going on

Early reports on storage continue making headlines…

BRIEF

South Australia's grid service costs slashed 90% by Tesla battery

BUSINESS NEWS FEBRUARY 16, 2018 / 2:14 AM / 6 DAYS AGO

U.S. regulator moves to clear market barriers for energy storage technology

The Energy Revolution Of 2018: Electricity Storage

Bain Insights, CONTRIBUTOR
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Battery storage leaves fossil fuels and regulators in state of inertia

Coal beaten out as gas, battery storage and DSR are winners in UK's Capacity Market

Storage Might Solve Some Big Grid Problems, but Not the Ones You Think

A new wholesale market participation model for energy storage may help other inverter-based or distributed energy resources.

MARK AHLSTROM | MAY 15, 2018

However, currently in the Philippines most projects are delayed or only in proposal stage

- 10 MW Masinloc energy storage project (AES) – stand alone (ERC approval delayed)
- 40 MW Kabankalan energy storage project (AES) – stand alone (delayed)
- 30 MW Negros energy storage project (Silay Global Energy Solutions) – solar colocation (proposed)
- 8 MWh Mindoro micro-grid storage (Solar Philippines) – solar colocation (off-grid)
- 50 MWh Tarlac energy storage project (Solar Philippines) – solar colocation (proposed)
- 50 – 80 MW behind-the-meter energy storage (Sonnen + Natural Solar) – distributed storage (potential)

Source: Press releases

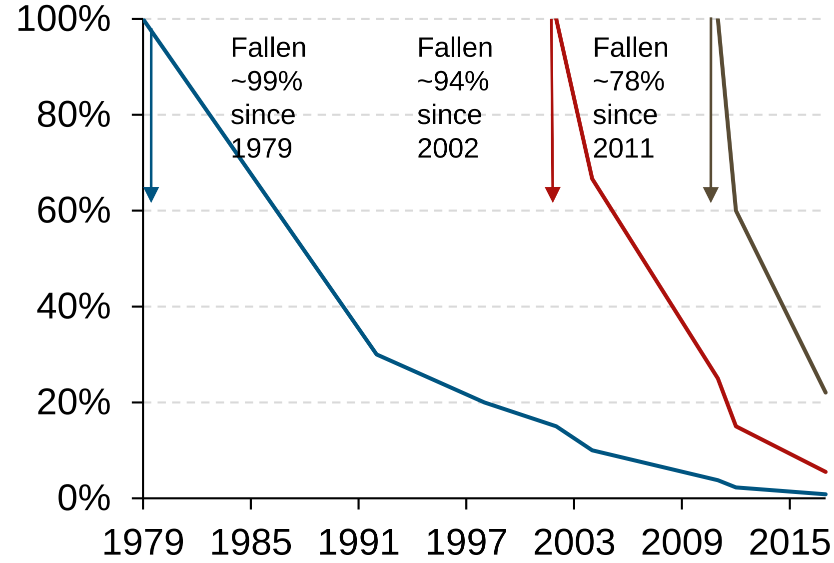
Storage deployment is concentrated in the US and Europe

Source: www.energystorageexchange.org

Many believe solar PV was the main enabler of battery storage

- Renewable energy policies are providing value-support to solar PV and other RE
  - Renewable Energy Credits
  - Renewable Portfolio Standards
  - Limitations / constraints on coal
- And then came the batteries
  - Can be charged with excess RE that would otherwise be curtailed
  - Can be combined with RE to emulate baseload generation (at a higher cost, but not as high as it used to be)
  - RE intermittency creates need for more ancillary services, including ramping at end of day

Indexed PV Module Prices 1979-2017

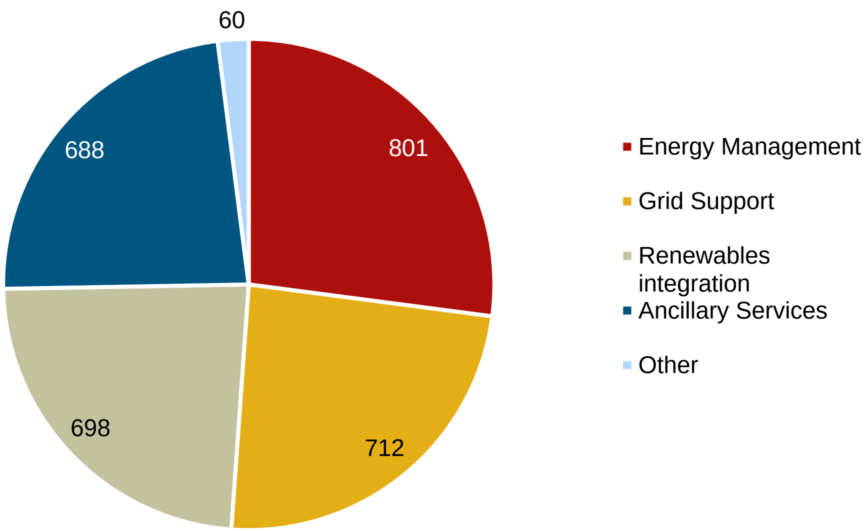


* $ price reflects Asian modules not exported to EU as reported on EU pvXchange platform. Other platforms show lower prices.

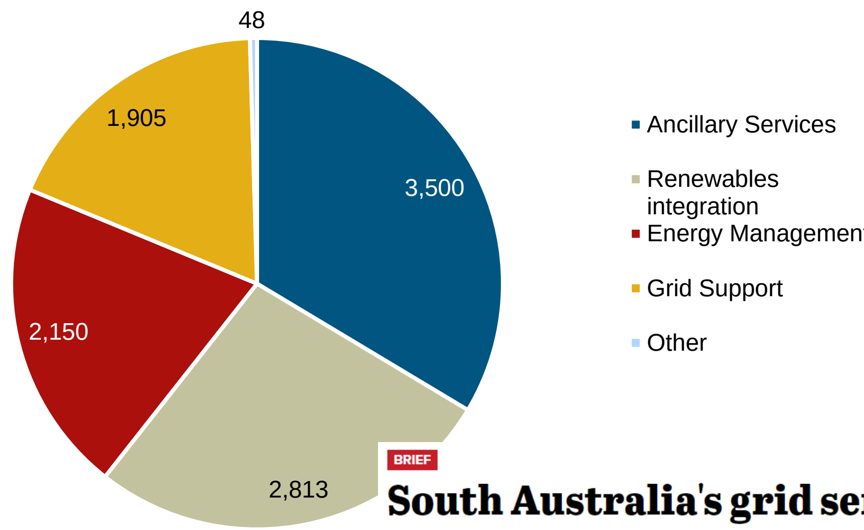
A symbiotic relationship?

But it's the ancillary services where storage makes the biggest impact

Number of storage plants by use case



Reported capacity of storage by use case (MW)

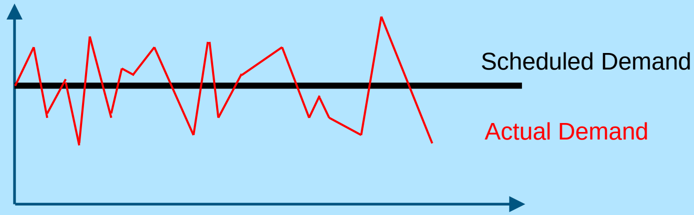


BRIEF

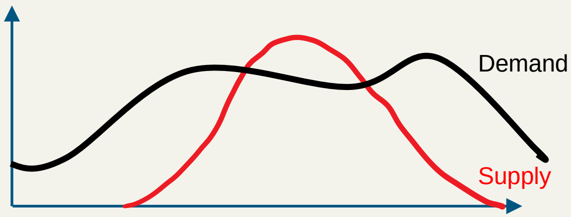
South Australia's grid service costs slashed 90% by Tesla battery

Ancillary services, followed by renewables integration and energy management are the major applications for storage

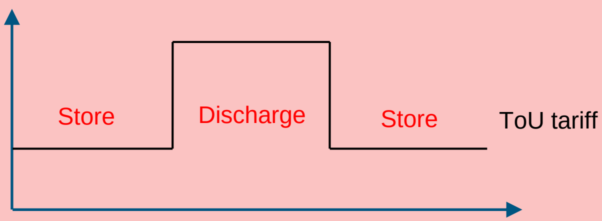
In deed, there are only limited number of value streams available for storage



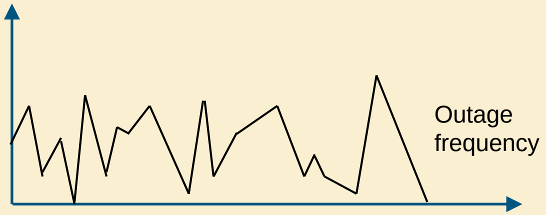
Many jurisdictions allow storage for Ancillary Services. Characteristics of storage allow it to be particularly responsive for frequency regulation – matching very short term fluctuations in supply and demand



Storage can be used to firm up the output from VRE, however the same can be done with traditional capacity



If price signals are available to end-user to adjust his consumption battery storage may be used for effective arbitrage of price signals (the classic use of pumped-storage, but behind the meter)
E.g. Time of use tariff or tariff with high demand charges



In off-grid areas, battery storage may provide significant improvement to the power quality at competitive cost to other small-scale solutions (such as diesel) or to firm up renewables

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Notwithstanding, storage can provide multiple services from a single facility, however regulations often do not allow such operations

Generation
- Load shifting
- Output firming
- Capacity addition

Transmission
- Ancillary Services
- Infrastructure expansion

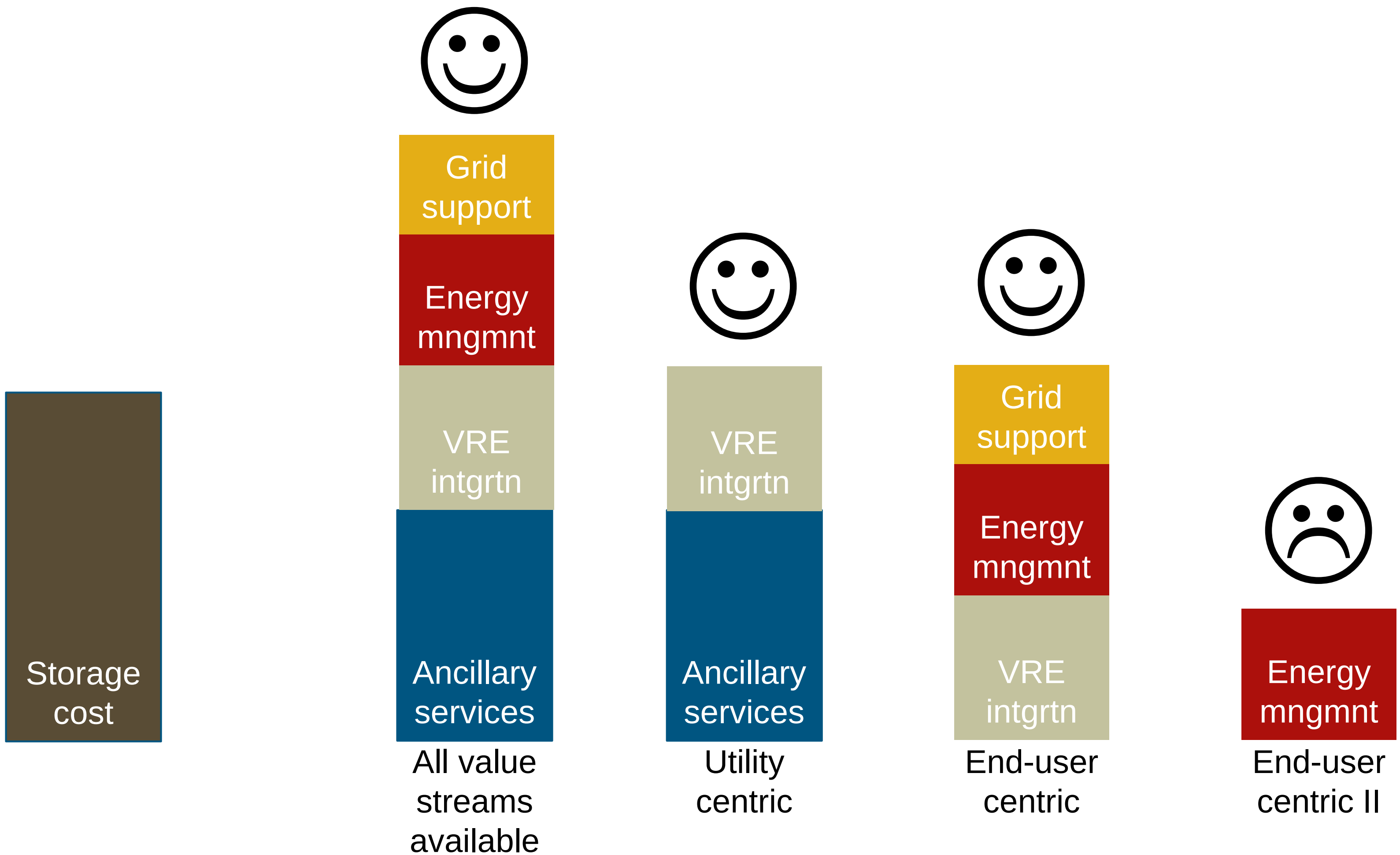
Distribution
- Infrastructure expansion
- Distributed supply/demand balancing

Retail/End-use
- Price arbitrage
- Behind-the-meter generation firming

- In theory, storage can provide multiple services at once
- However, reliability requirements and provisions enacted to set-up power market may require physical unbundling of services provided by a single facility
- Locational demand for some services may be the technical reason for such limitation

Regulatory developments hint that utility-scale storage facilities may be required to provide single service only – but the jury is still out

“STACKABILITY” of energy storage

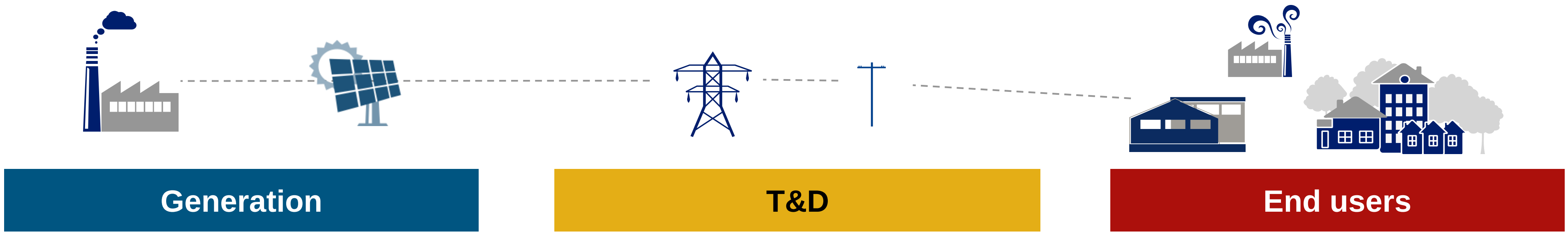


Maximizing the realizable value of energy storage requires finding “use cases” where multiple value sources are compatible

Example: Economics of BTM storage

- The economics of a battery storage depends on a wide range of factors
- Each application performs a different function in a different environment
- Understanding a specific application and economics in an actual deployment are crucial
- We will discuss a behind the meter application in detail to give and example

BTM – Description of application

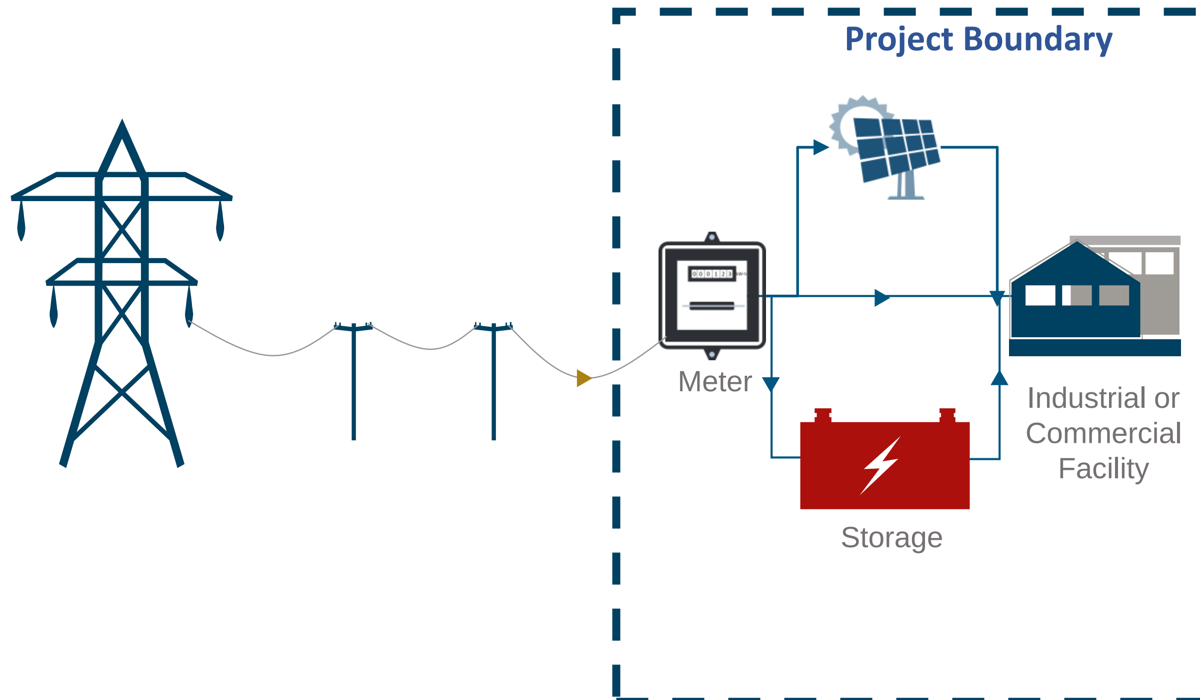


Case 1

- Storage is used to reduce the demand charges
- Batteries are charged in off-peak and discharged in peak periods

Case 2

- Storage and solar are used to reduce energy charges
- Batteries are charged with the excess renewable energy and discharged to supplant grid



Case 1: Using storage BTM to reduce peak demand charges

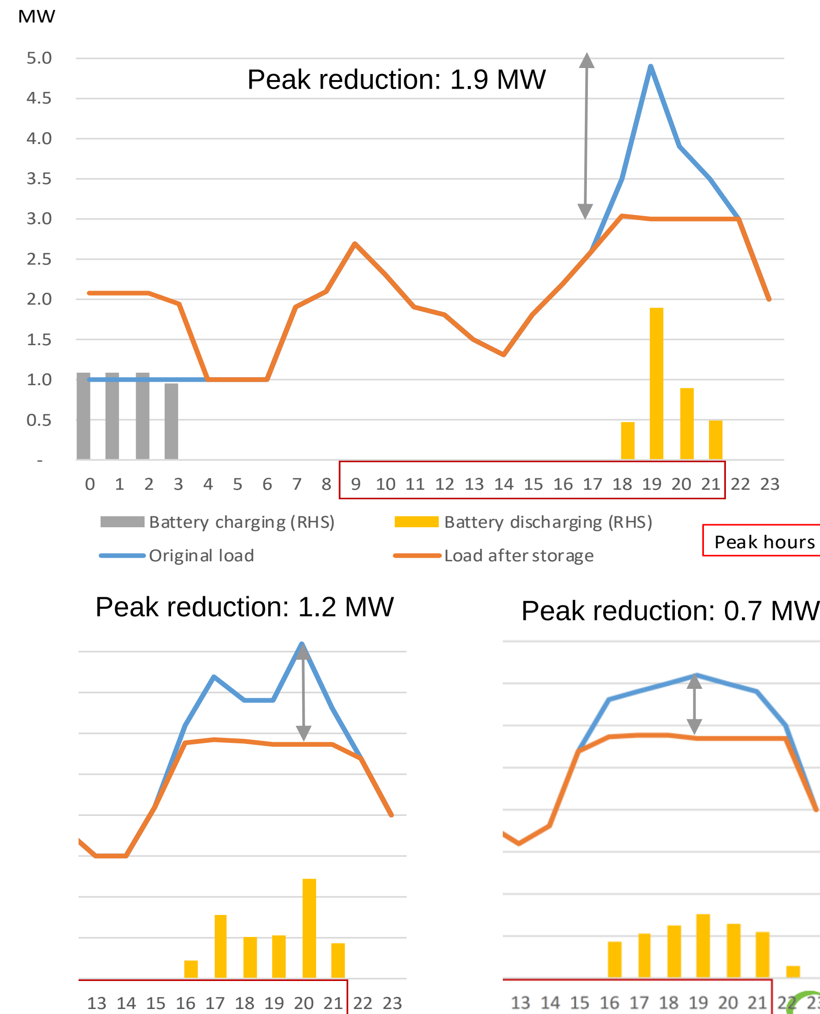
The key drivers of behind the meter returns are:

1. Structure and price of demand charge
2. Spread between peak and off peak electricity cost
3. Shape and predictability of load curve

Some key lessons:

- Feasibility is highly dependent on load curve characteristics. A flatter load curve or multiple peaks dulls the impact of storage in reducing demand charges
- This can be mitigated by reducing the size of the battery
- Combination with solar PV may improve returns

Three examples of peak reduction show an equal volume of energy shifting (3.7MWH), but differential impact on peak demand for different load curves



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Case 1: BTM – Investment analysis

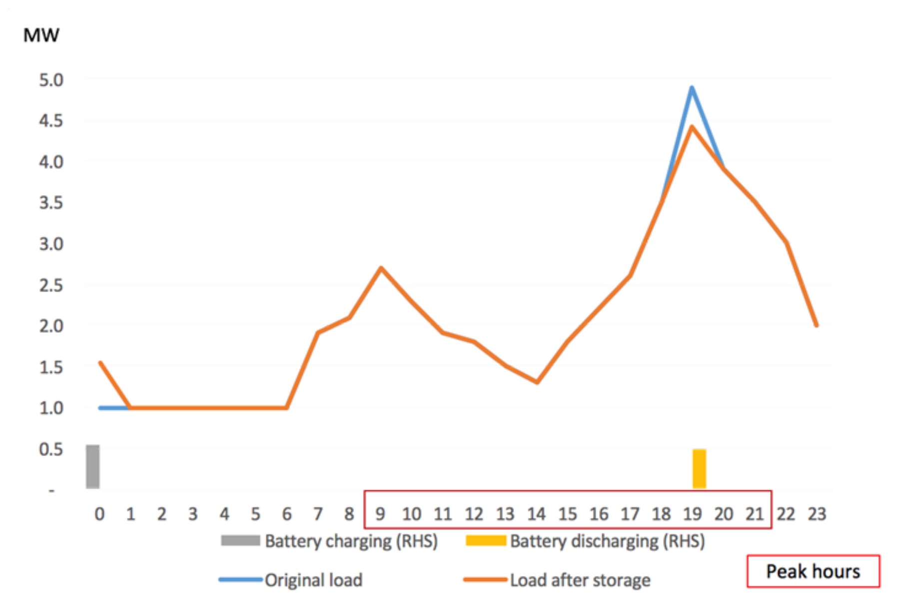
BTM could work in the Philippines now – in ideal cases

Inputs

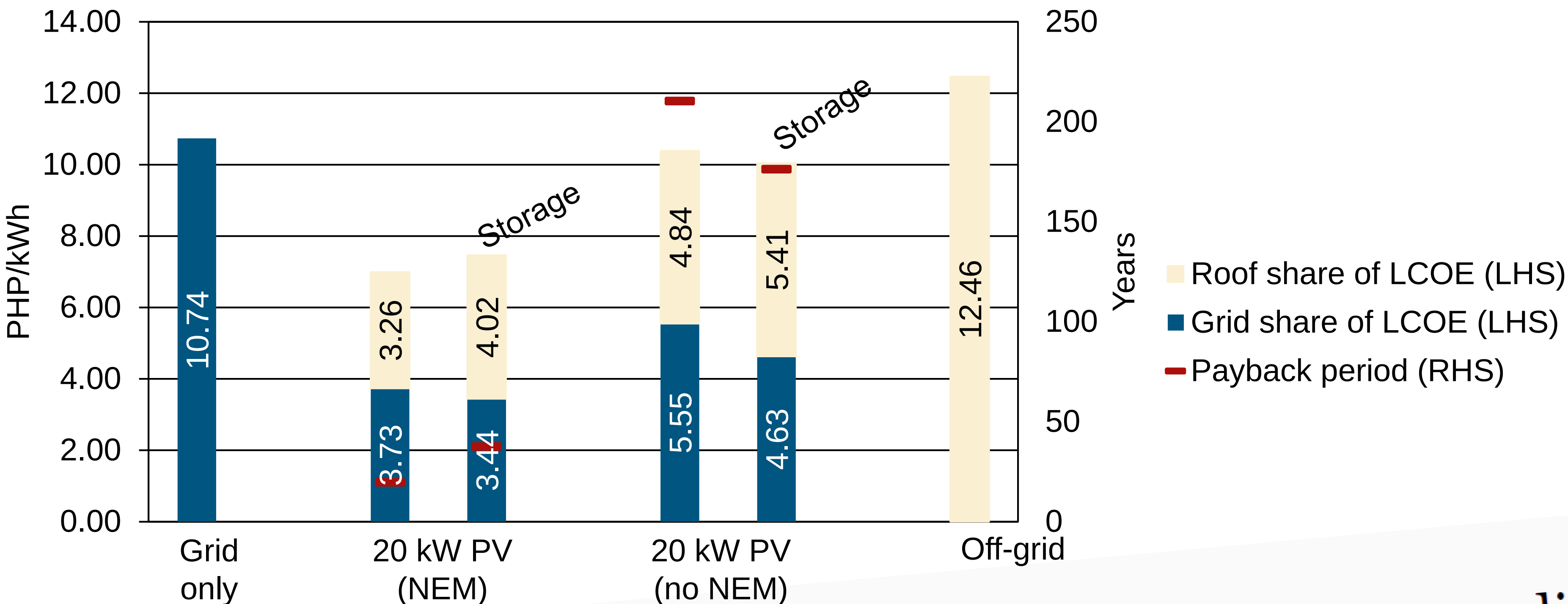
Battery system		
Power rating	0.60	MW
Storage duration	0.90	Hours
Storage capacity	0.54	MWh
Battery costs	0.50	$M/MWh
Balance of system	0.10	$M/MW
O&M costs	0.02	$M/MWh/yr
Electricity tariffs		
Country	Philippines	
Peak tariff	0.12	$/kWh
Off-peak tariff	0.08	$/kWh
Demand fee	10.00	$/kW/mth
Tariff escalation	2.0%	per year
General		
Load profile	Load 1	
Project life	10	years
Inflation	2.0%	
Discount rate	8.0%	

Summary Results

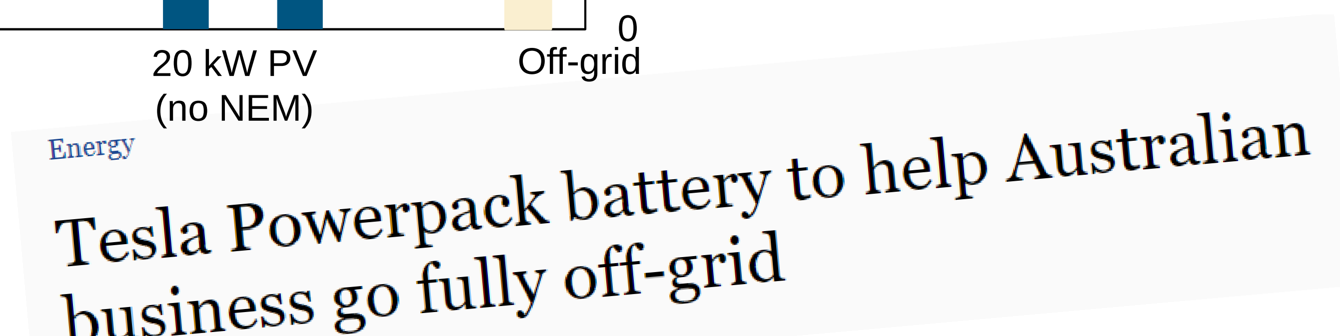
Returns		
IRR	8.8%	
NPV (discount rate)	12	$K
Investment		
Investment costs	0.33	$M
Total O&M costs	0.13	$M
Peak demand and charges		
Peak - Without storage	4.9	MW
Peak - With storage	4.4	MW
Charge - Without storage	0.59	$M/yr
Charge - With storage	0.53	$M/yr
Electricity charges		
Reduced demand charges	0.64	$M
Reduced usage charges	0.04	$M
Total O&M costs	(0.13)	$M
Total net savings	0.54	$M



Case 2: Economics of storage is also important



Source: TLG TFCF Model


Energy

Tesla Powerpack battery to help Australian business go fully off-grid

For tariffs without demand charges, limited business case exists for storage behind the meter

Based on Merlaco's GSA tariff, 5 kW peak and 1285 kWh/m consumption
850 $/kW PV and 200 $/kWh Storage, USD/PHP = 0.02
Assuming NEM credits

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Unique characteristics of Philippines market need to be incorporated

General settings

Project lifetime	25	Years
Discount rate	9.64%	%
Initial credit at every 24-month period	0	USD
Solar CF	13.7%	%
Maximum allowable LOLP	0.500%	%

Installed RE capacity, kW	2.41
Installed genset capacity, kW	0.00
Installed battery capacity, kWh	2.00
Peak demand, kW	2.35

Select your tariff	GSA

Copy load data | Find minimum size of RE (energy based) | Adjust battery capacity for LOLP

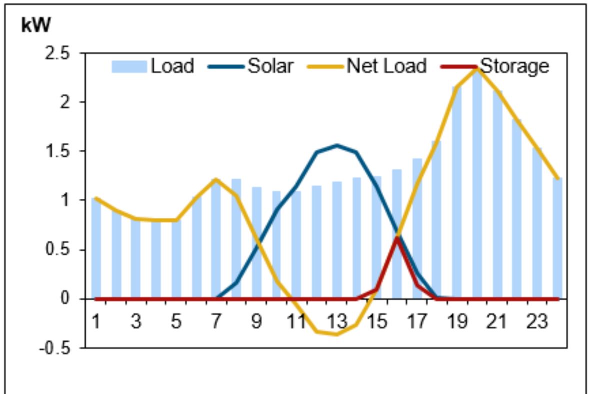
Results

LCOE embedded system share or offgrid	0.1000266	USD/kWh
LCOE grid share	0.2035354	USD/kWh
LCOE grid-tied	0.1790974	USD/kWh
LCOE no embedded system	0.2063647	USD/kWh

Payback period	4.35	Years
IRR	24.28%	%

Peak demand without solar	2	kW
Peak demand with solar	2	kW
Peak demand reduction	0%	%

Load-weighted grid LCOE	0.135	USD/kWh
Load-weighted PV LCOE	0.044	USD/kWh
Share of grid supply	75.3%	%
Share of PV supply	24.7%	%



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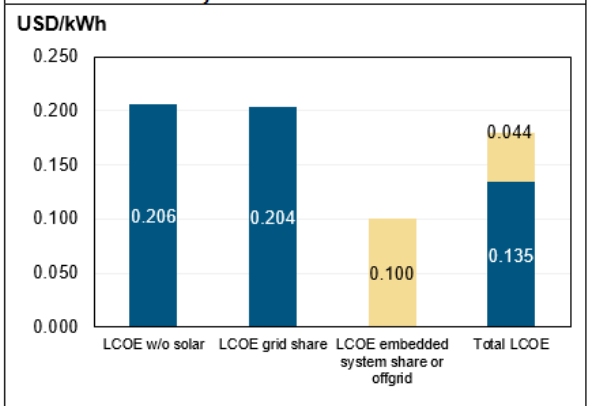


LCOE w/o solar	0.206	
LCOE grid share	0.204	
LCOE embedded system share or offgrid		0.100
Total LCOE	0.135	0.044

Philippines ESS Market Model was purpose build to analyse:

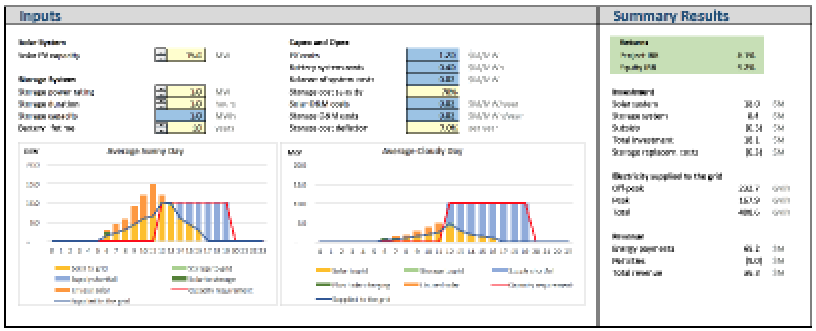
- Feasibility of distributed energy systems with renewable and conventional energy sources, as well as storage
- Feasibility of microgrids based on renewable, conventional and storage assets
- Tariff design in view of “behind-the-meter” generation
- Impact of “behind-the-meter” generation on the host utility revenue collection and cost of service
- Reliability of microgrids or off-grid systems
- Forecast market size for distributed energy technologies

Interested in how regulation and economics interplay in supporting storage?
Join us for the **TLG's Battery Storage Investment Workshop!**

Pragmatic, hands-on experience that simulates real-life analysis

The heart of the workshop is a skills session in which teams are given an Investment Case; a pre-loaded financial model; and supporting materials. They are then asked to conduct analysis of the cases and make investment recommendations. Participants leave with the knowledge, skills and confidence to perform basic energy storage investment analysis.

The Investment Cases are backed by bespoke financial models and are designed to replicate a real investment opportunities in the Philippines. The image below shows the Dashboard from one of the financial models participants will use in a group session. This is designed to replicate an actual investment analysis or project development preparation process

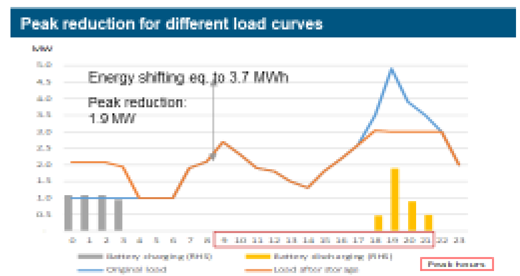


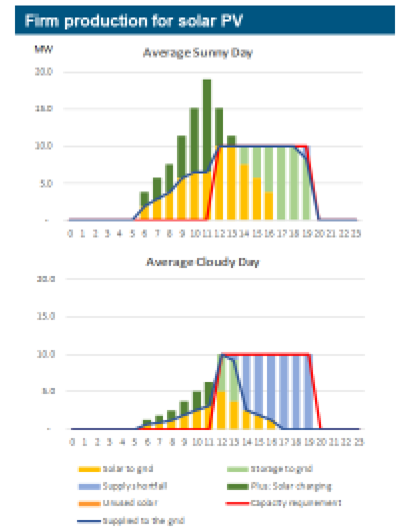
Welcome to the revolution of low-cost energy storage

Financial model supported by a sufficient level of engineering design

The ESS Project Financial Model can replicate the performance of batteries in range of storage applications with precise charge and discharge calculations over the 8,760 hours in a year to provide accurate performance data

This is supported by a full set of financial statements and complete economic and technical inputs to provide meaningful results for the Philippines in IRR and NPV terms – mimicking a real investment analysis process





In the ever changing regulatory regime, how to assess opportunities for storage across energy value chain?

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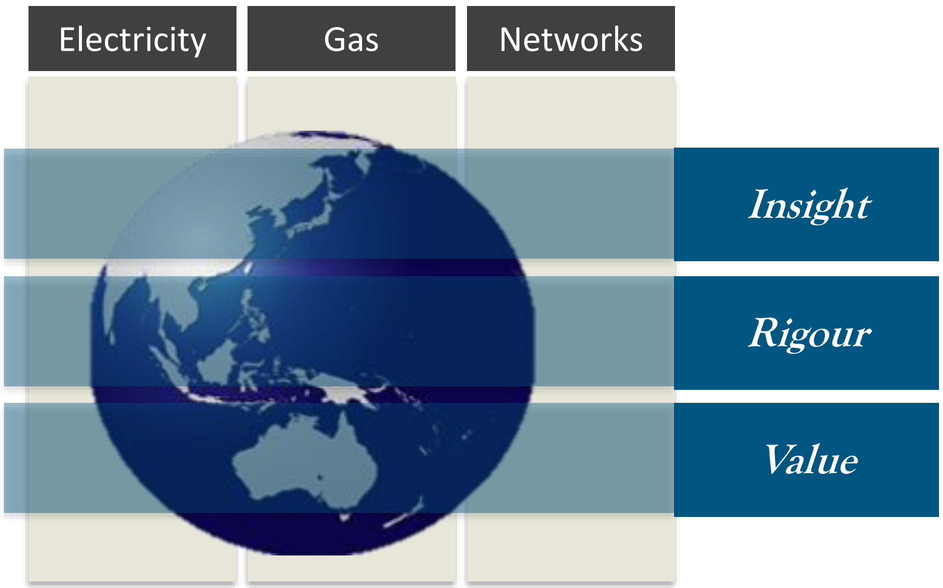

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