Electricity Distribution in a Distributed Energy Future

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Energy Economics Summer School

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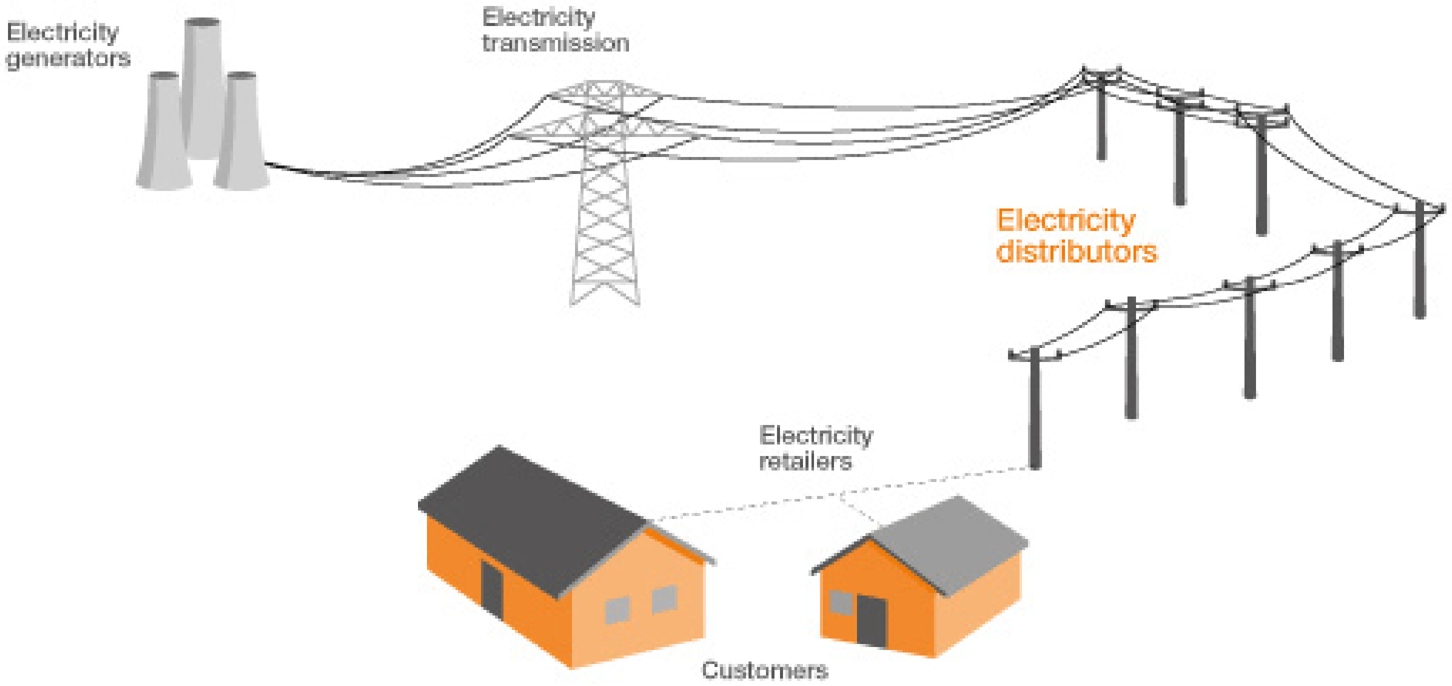
Objective

- Introduction to electricity distribution economics and
- Overview of the new trends that shape the future of electricity distribution

Not designed to be a monologue, please interrupt, ask, challenge

Disclaimer: All views expressed are solely my own and not Vector's

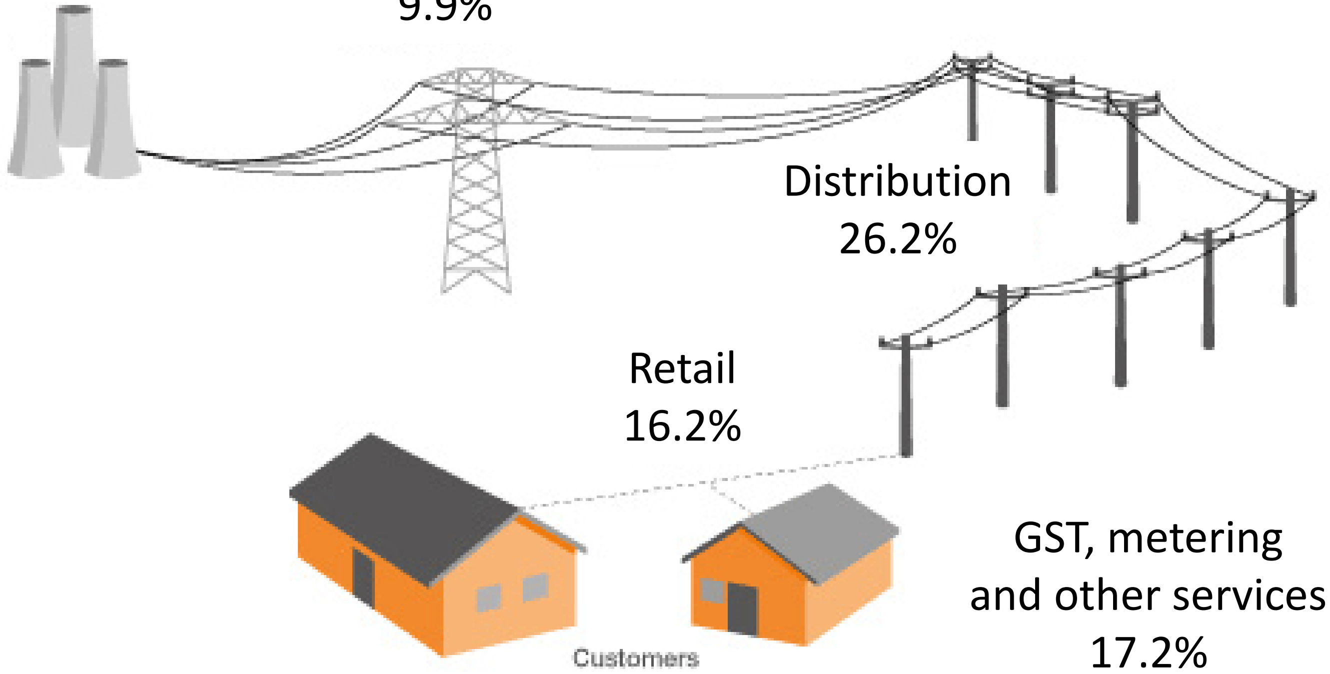
What is electricity distribution?



Distribution carries electricity from the transmission system to individual consumer (residential, commercial and some industrials)

Image source: Electricity Authority

What makes up a typical NZ electricity bill?



Generation
30.5%

Transmission
9.9%

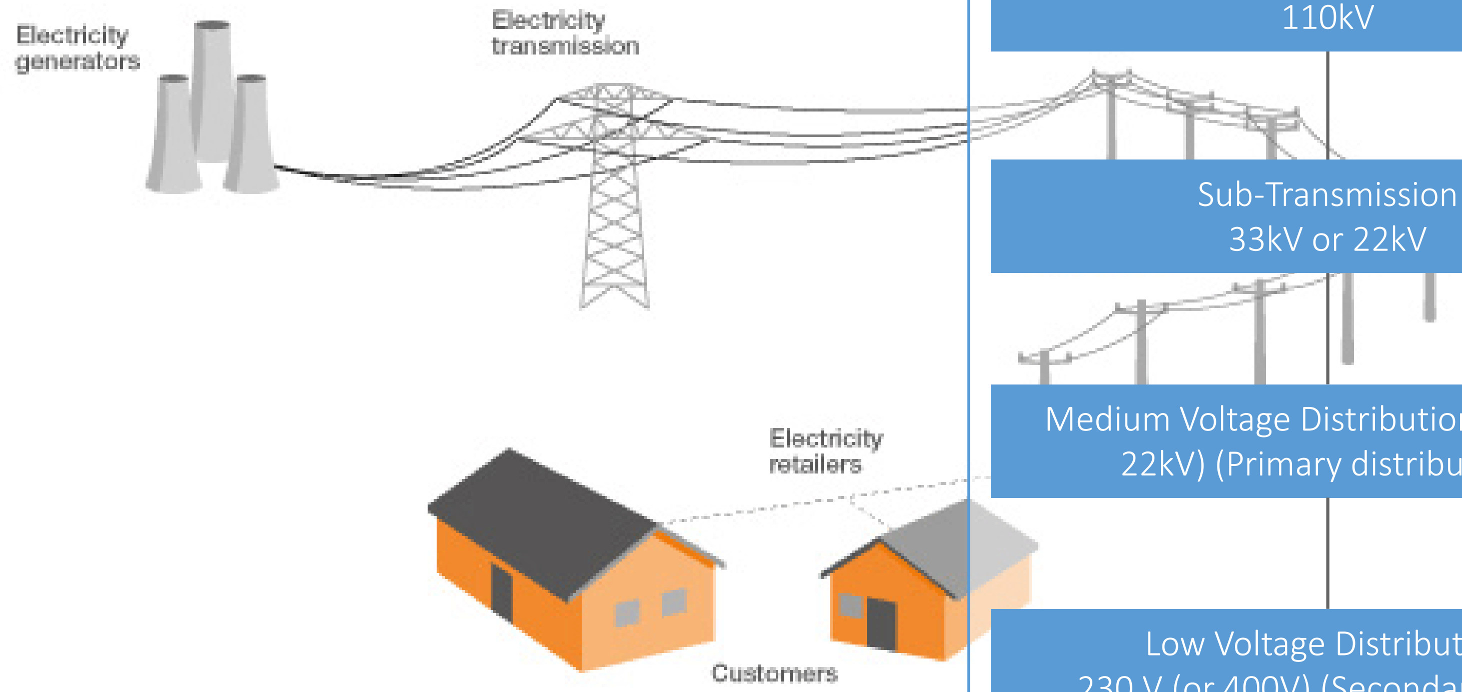
Distribution
26.2%

Retail
16.2%

GST, metering
and other services
17.2%

Source: Electricity Authority

What is electricity distribution?



Vector's distribution assets

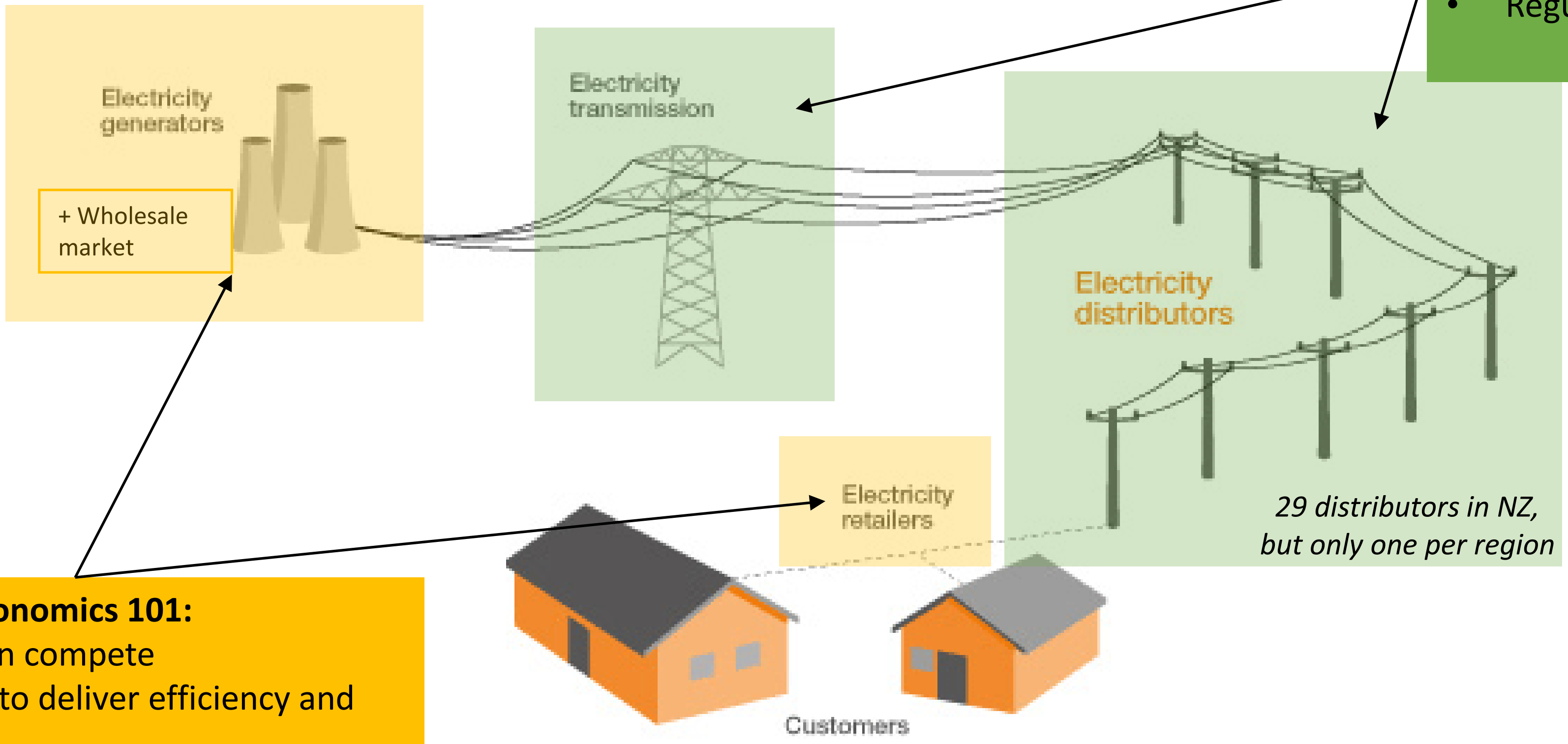
Sub-Transmission 110kV	74km	>40kV
Sub-Transmission 33kV or 22kV	969km	33kV/22kV
Medium Voltage Distribution 11kV (or 22kV) (Primary distribution)	7'366km	6.6kV-11kV
Low Voltage Distribution 230 V (or 400V) (Secondary distr.)	10'047km	1<kV

Distribution carries electricity from the transmission system to individual consumer (residential, commercial and some industrials)

Image source: Electricity Authority

Electricity Market Organisation: competitive and regulated markets

Economics 101:
- Natural monopoly
  more efficient to have only 1 company
- Regulation to ensure efficiency
  → Social optimum



Economics 101:
Multiple firms can compete
- Competition to deliver efficiency and innovation

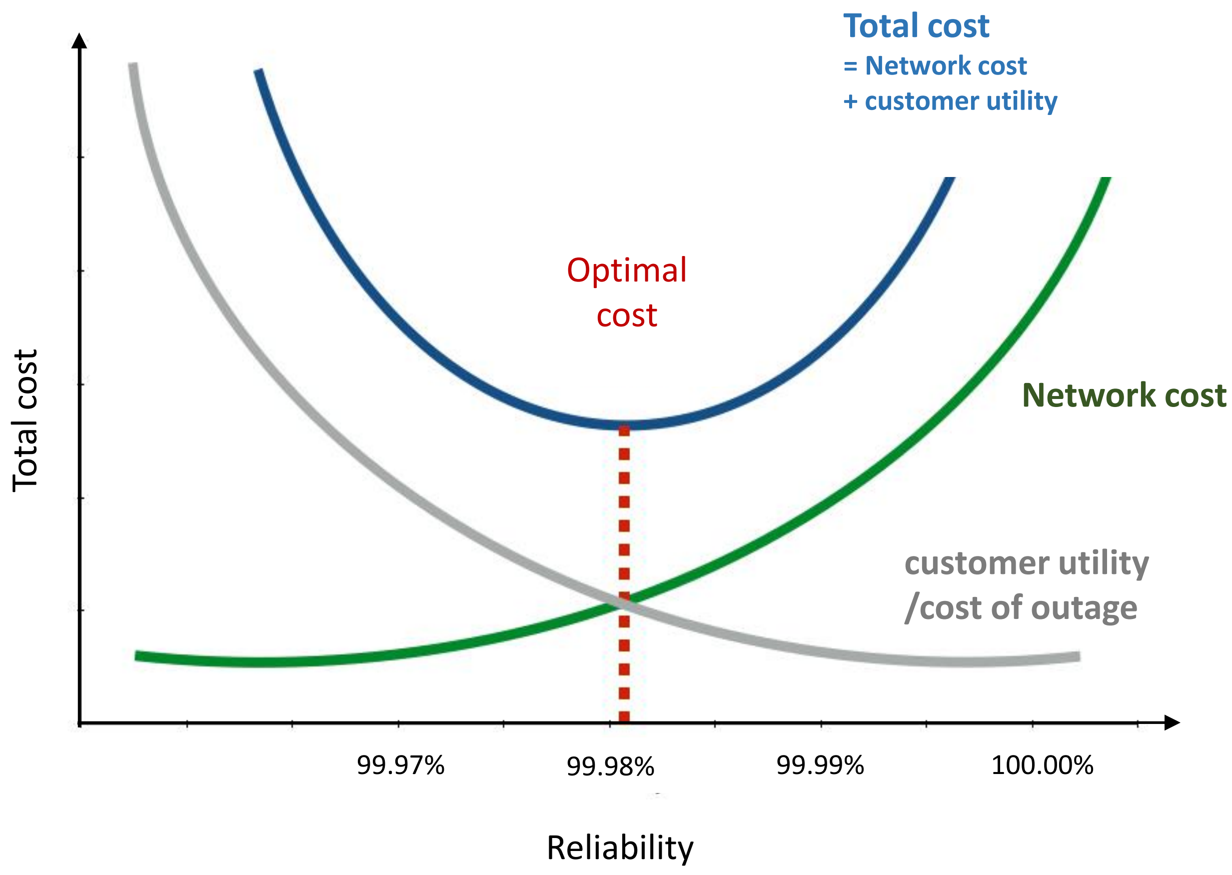
→ Social optimum

Image source: Electricity Authority

Electricity distribution regulation in NZ

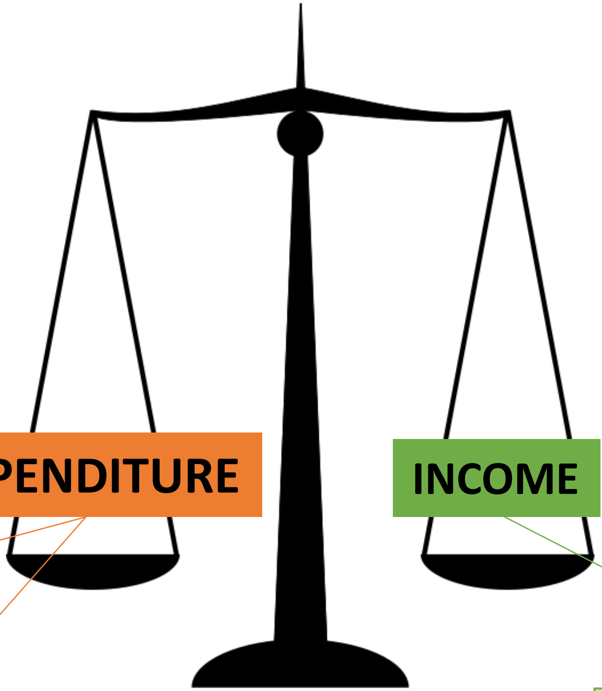
- What?
  - Ensure regulated business earns sufficiently but limit the ability of suppliers to earn excessive profits
  - Ensure that consumer demands on service quality are met.
- Who?
  - Commerce Commission
- How?
  - Price-quality regulation that defines
    - Maximum prices/revenues
    - Minimum service quality standard (i.e reliability)

Socially optimal reliability level is set by trade-off between infrastructure cost and customer utility



The reliability of the electricity infrastructure is extremely high, given that cost of outages affect all customers and lead high economic losses

What does a electricity distribution business do?



EXPENDITURE

INCOME

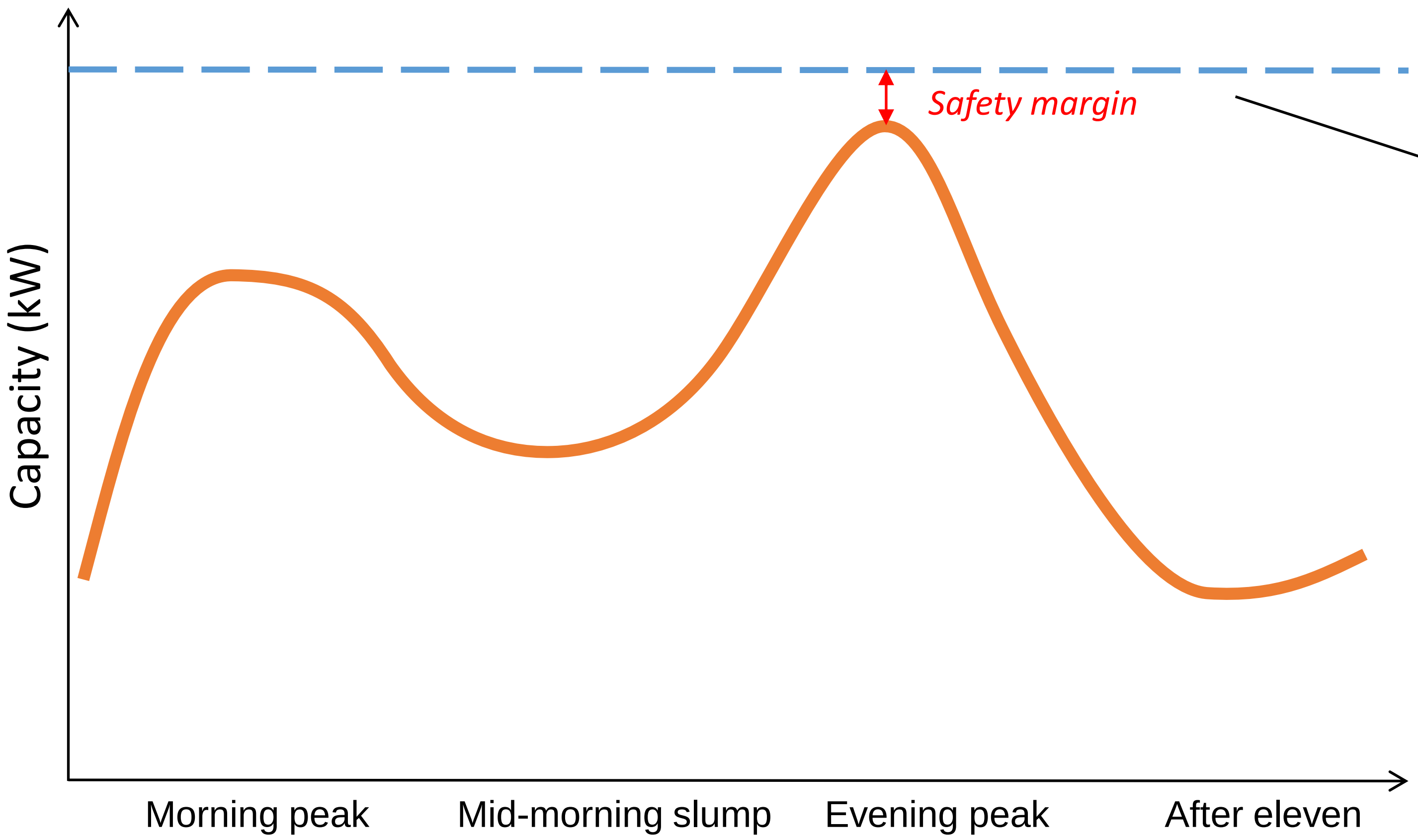
Planning
- Plans network
- Invests in infrastructure

Operation
- Connect new customers
- Repair faults (Storms!)
- Improve and maintain existing network

Distribution rates

from customer bill based on connection size and energy used

Electricity network investment and peak load

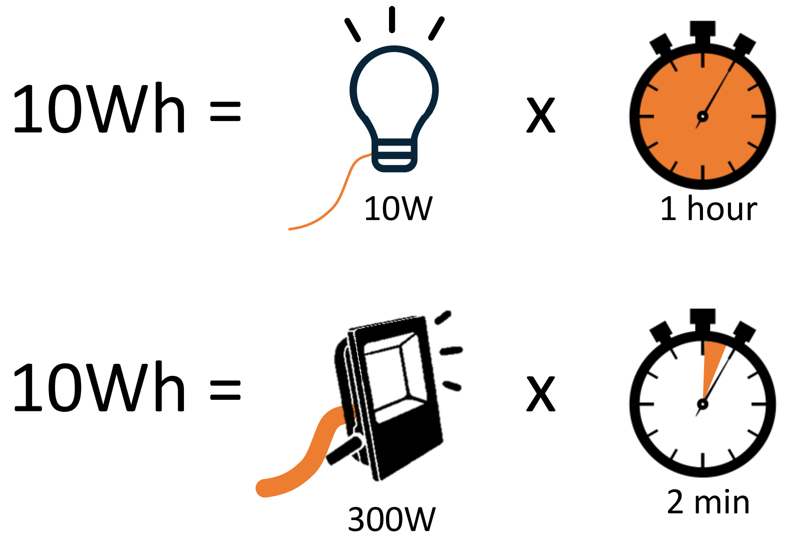


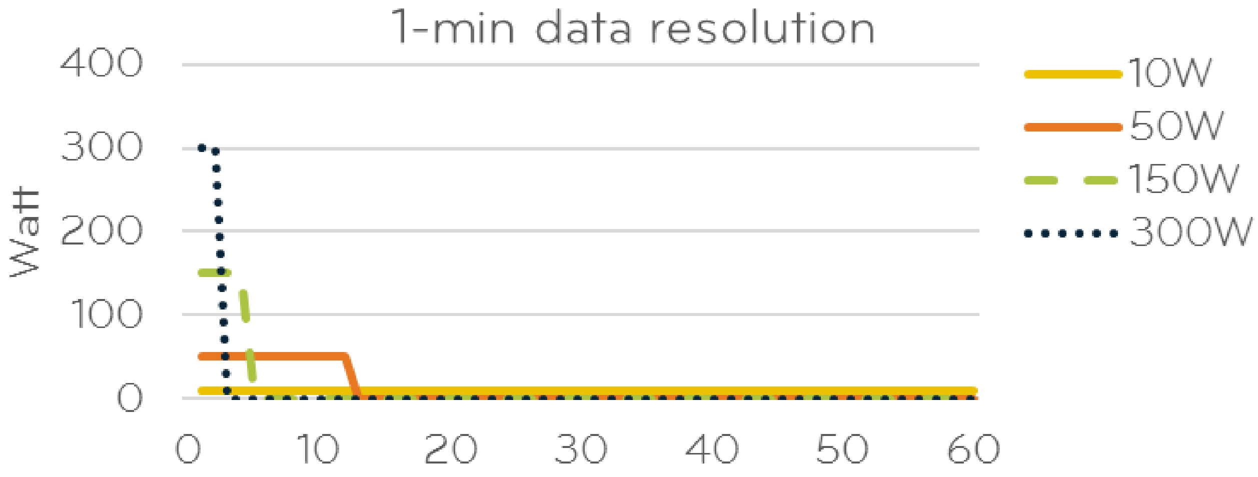
Design network to meet peak load

Investment driven by
peak load (instantaneous)
not energy consumption

Peak demand drives network investments

Energy = Capacity x Time





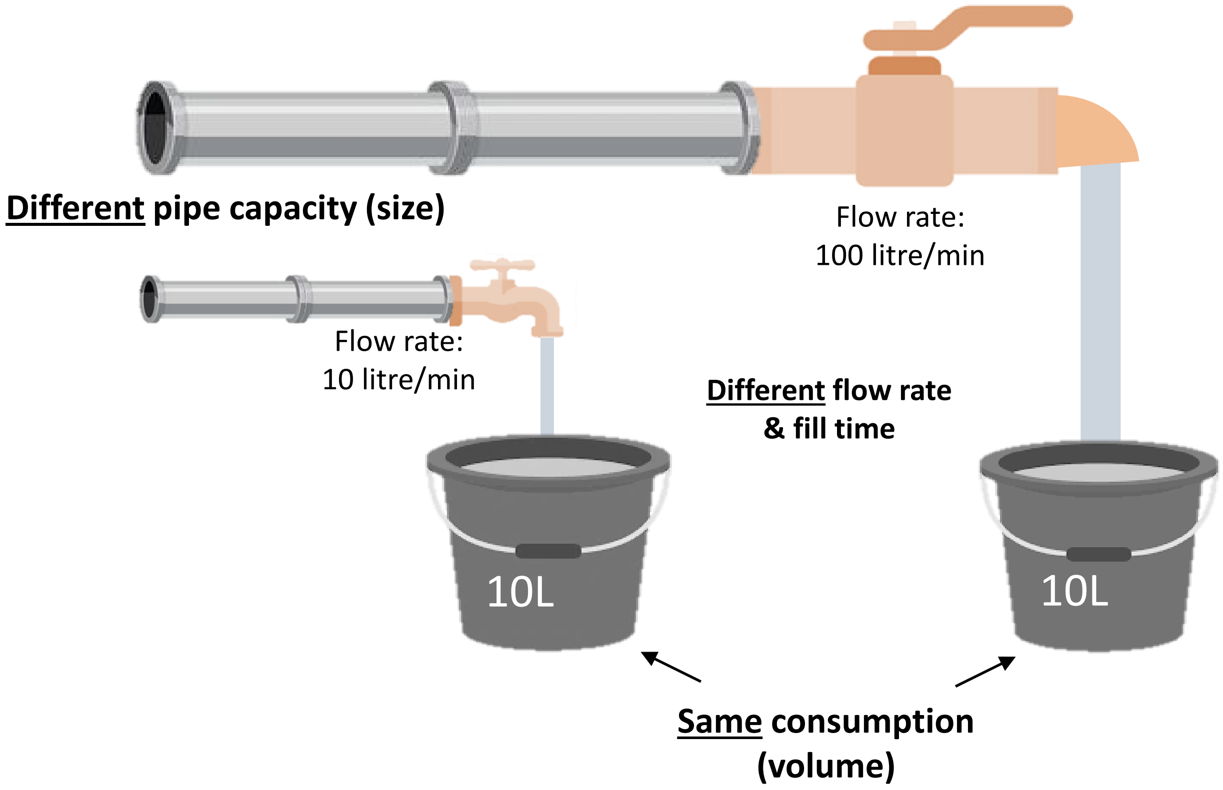
Peak capacity [W] not energy consumption [kW]) defines network sizing and investments

Analogy to filing a bucket with water

Energy consumption → volume of bucket

Capacity → pipe size

Current → Water flow rater

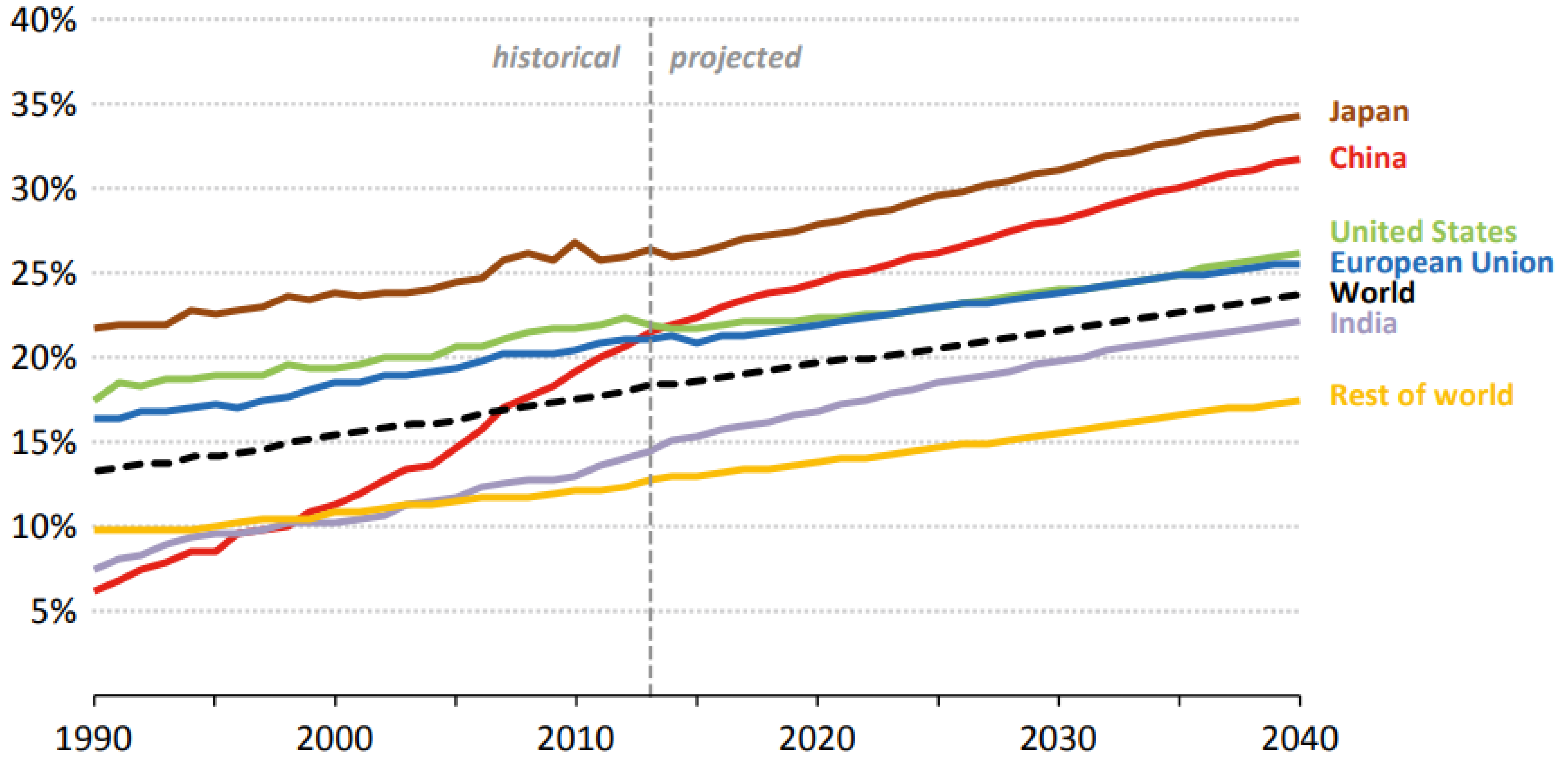


Pipe size (i.e. peak capacity [W]) not volume of bucket (i.e. energy consumption [kW]) defines network sizing and investments

(R)Evolution – New trends

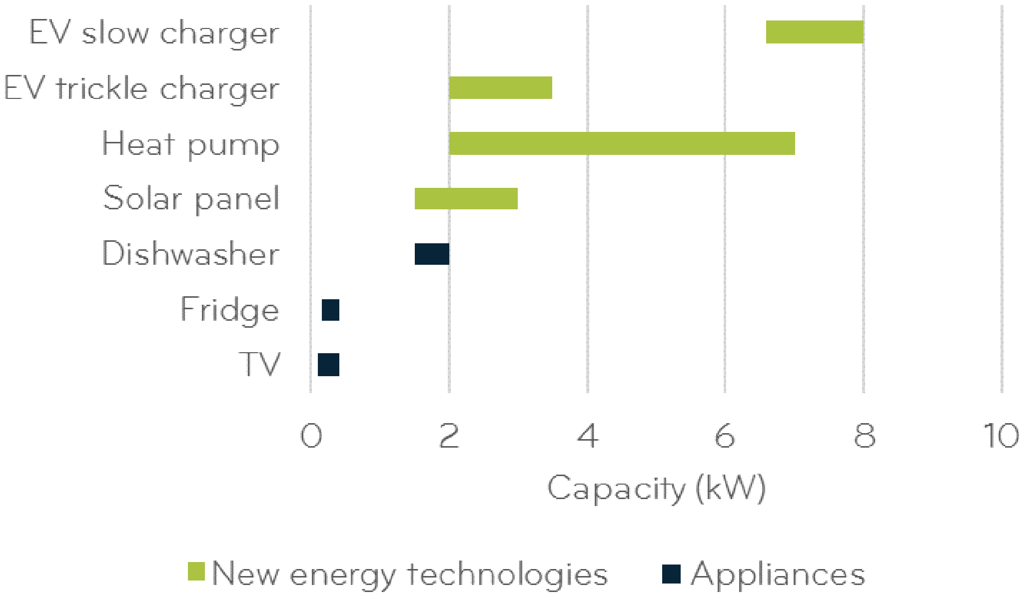
Electrification of the energy sector

Figure 8.2 ▷ Share of electricity in total final consumption by region in the New Policies Scenario

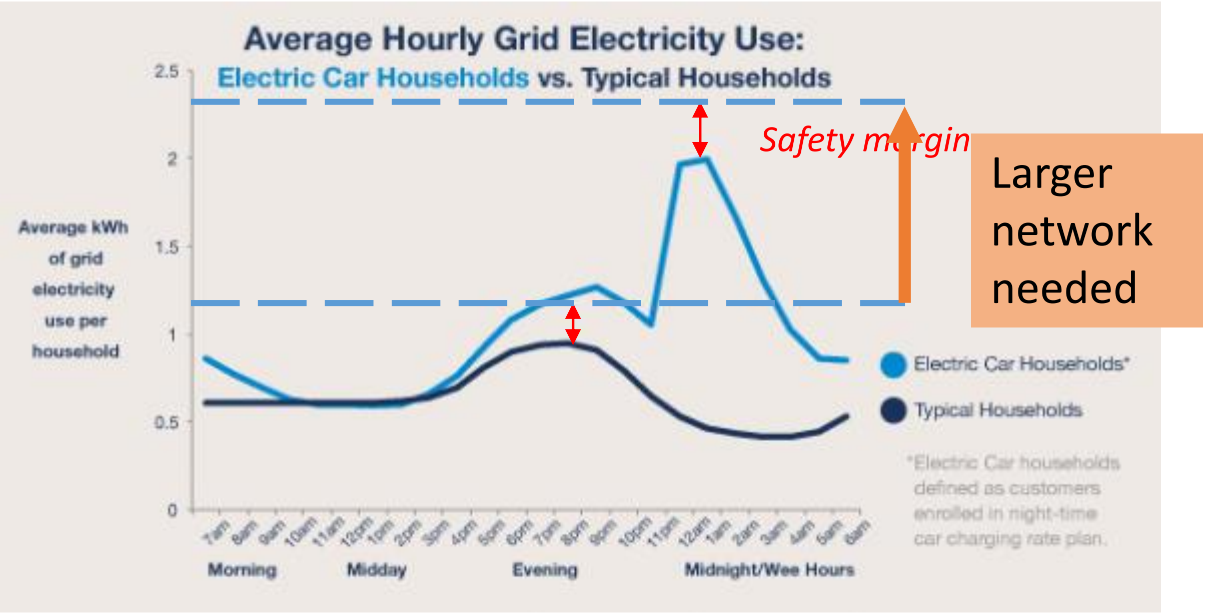


Source: IEA, World Energy Outlook 2016

Electrification of the demand-side

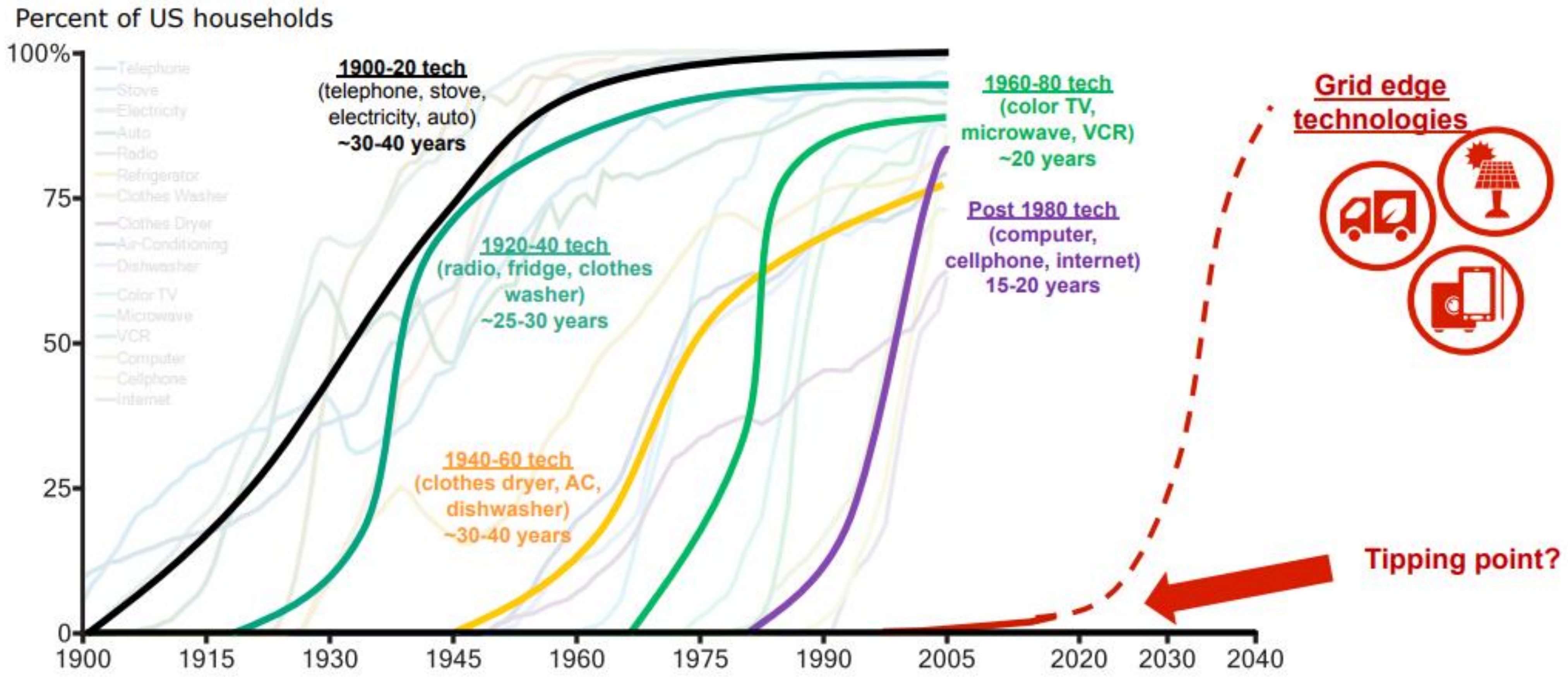


New energy technologies have higher loads than electric appliances



un-friendly network charging of electric vehicles could lead to significant investment requirements

Disruption: the pace of technology adoption is accelerating

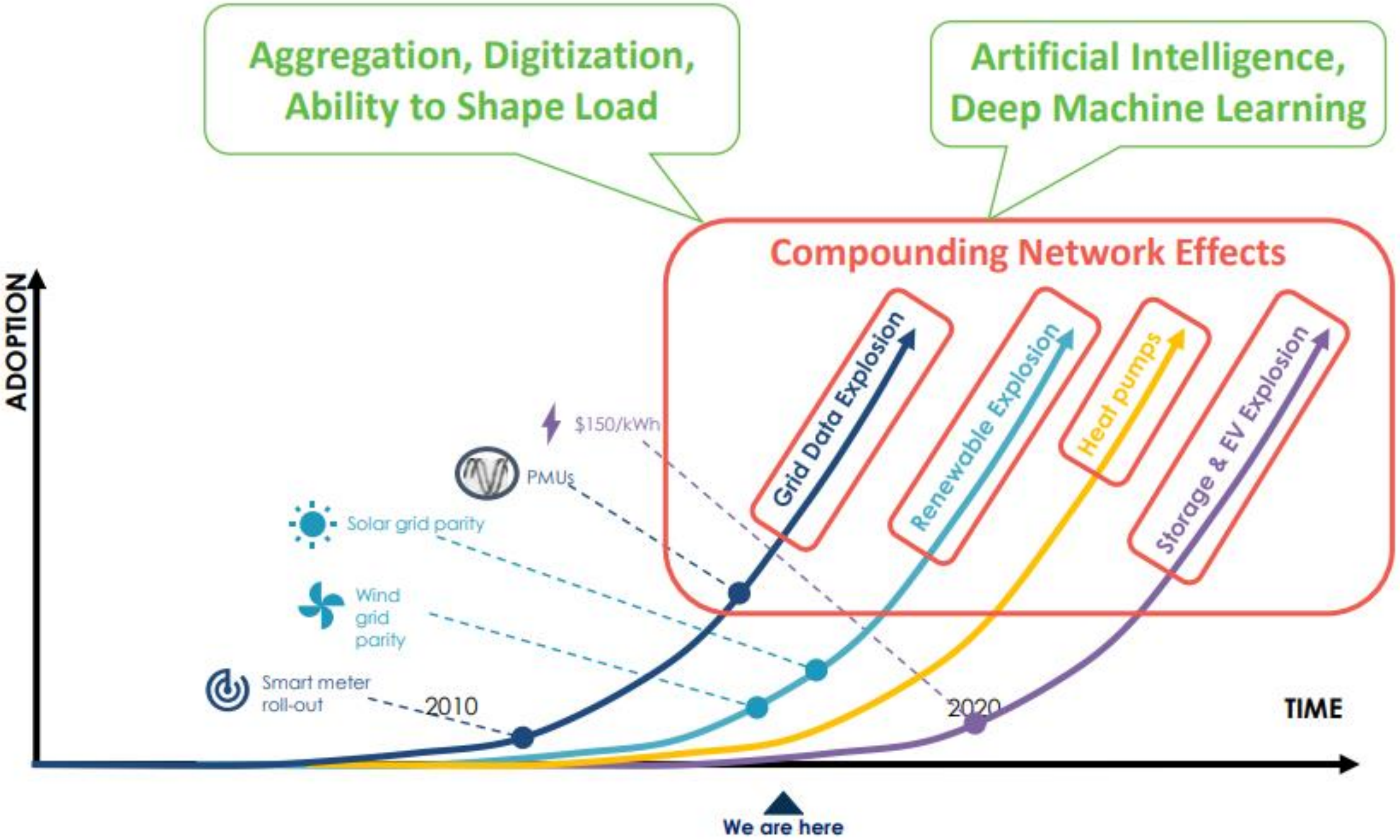


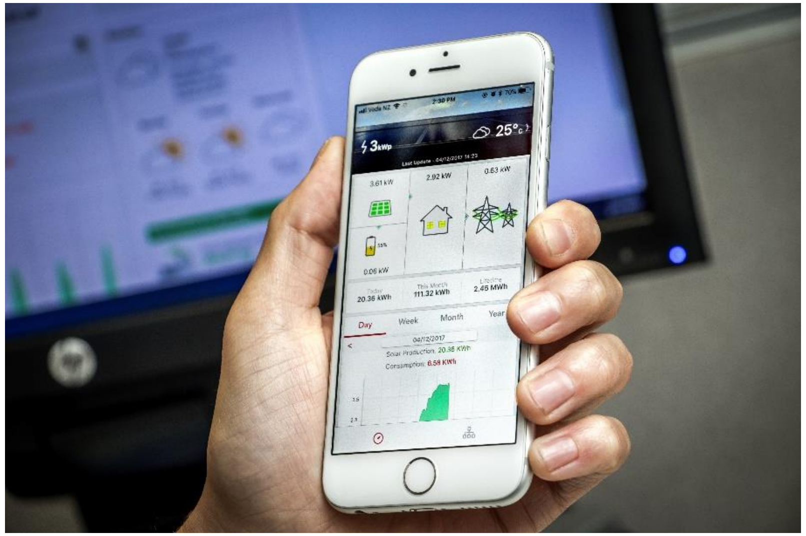
Compared to new consumer technology adoption, networks take time to build and have lifetimes of about 40 years

Today's infrastructure needs to be able to meet expectation of Aucklanders in 40 years

Source: World Economic Forum (2017)

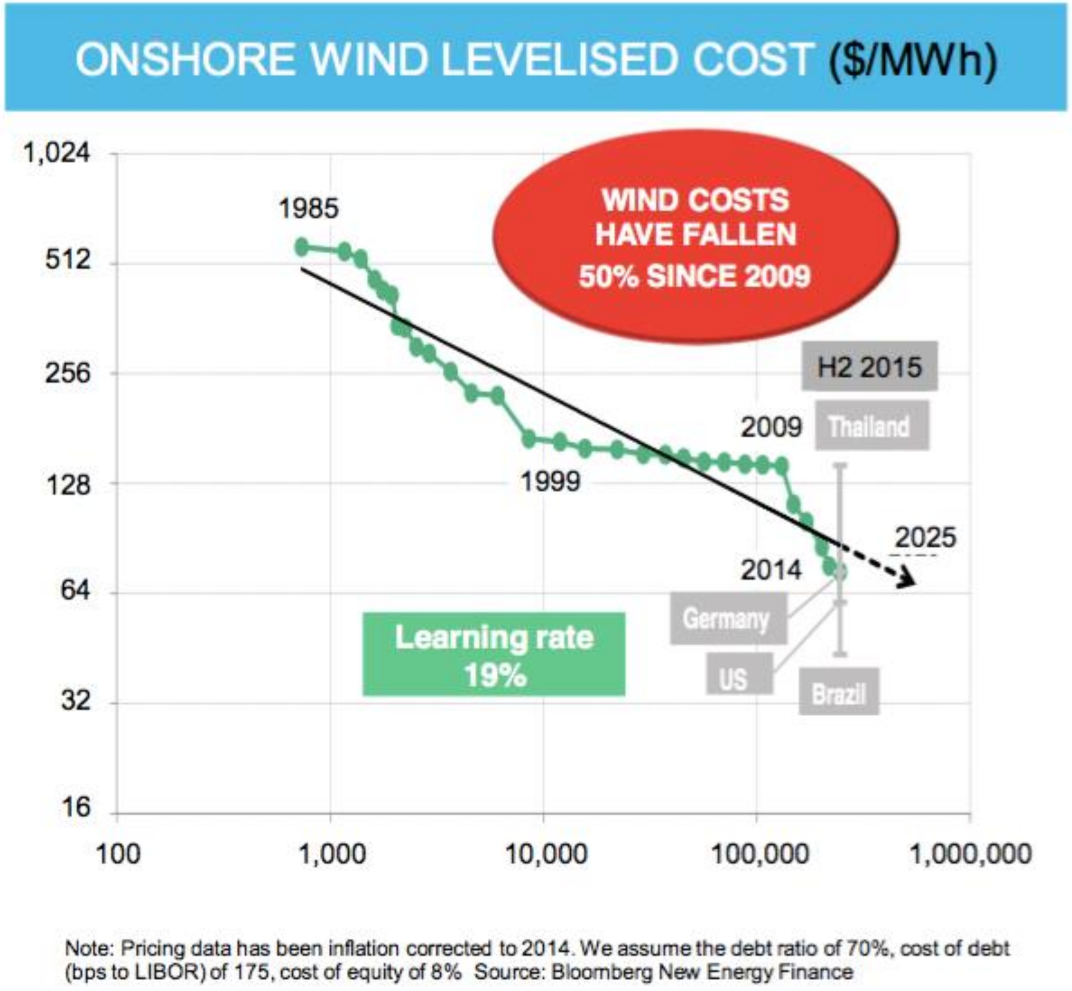
Cross-pollination from non- other sectors, in particular digital sector

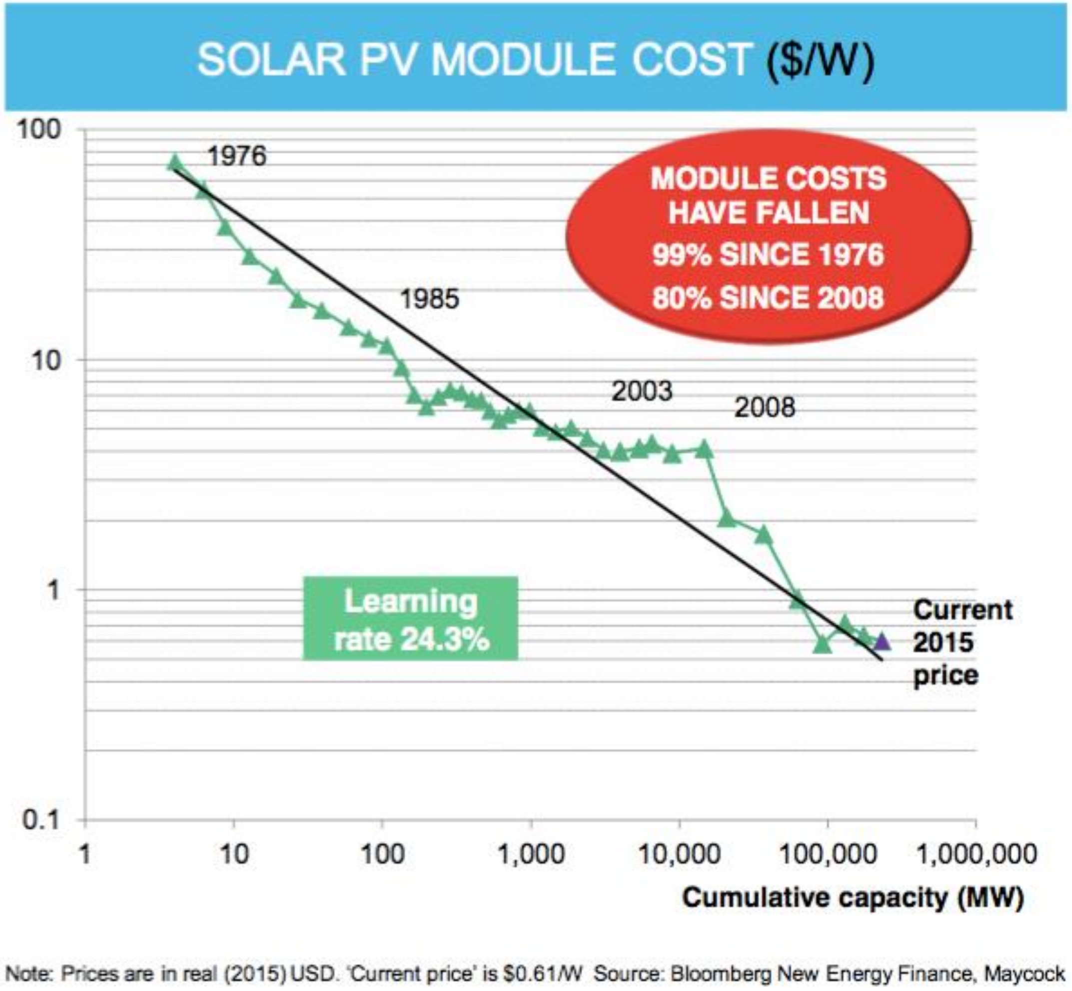




Advanced data analytics, control and an active customer is a opportunity for the sector to make sure we build infrastructure that is flexible and can adapt to society's requirements

Decreasing cost of wind and solar





Source: Michael Lieberich , Bloomberg New Energy Finance Summit

Decarbonisation: Unsubsidised solar and wind world records

Solar PV

- Country: Mexico
- Bidder: FRV
- Signed: October 2016
- Construction: 2019
- Price: US$ 2.69 c/kWh

Onshore Wind

- Country: Morocco
- Bidder: Enel Green Power
- Signed: January 2016
- Construction: 2018
- Price: US$ 3.0 c/kWh

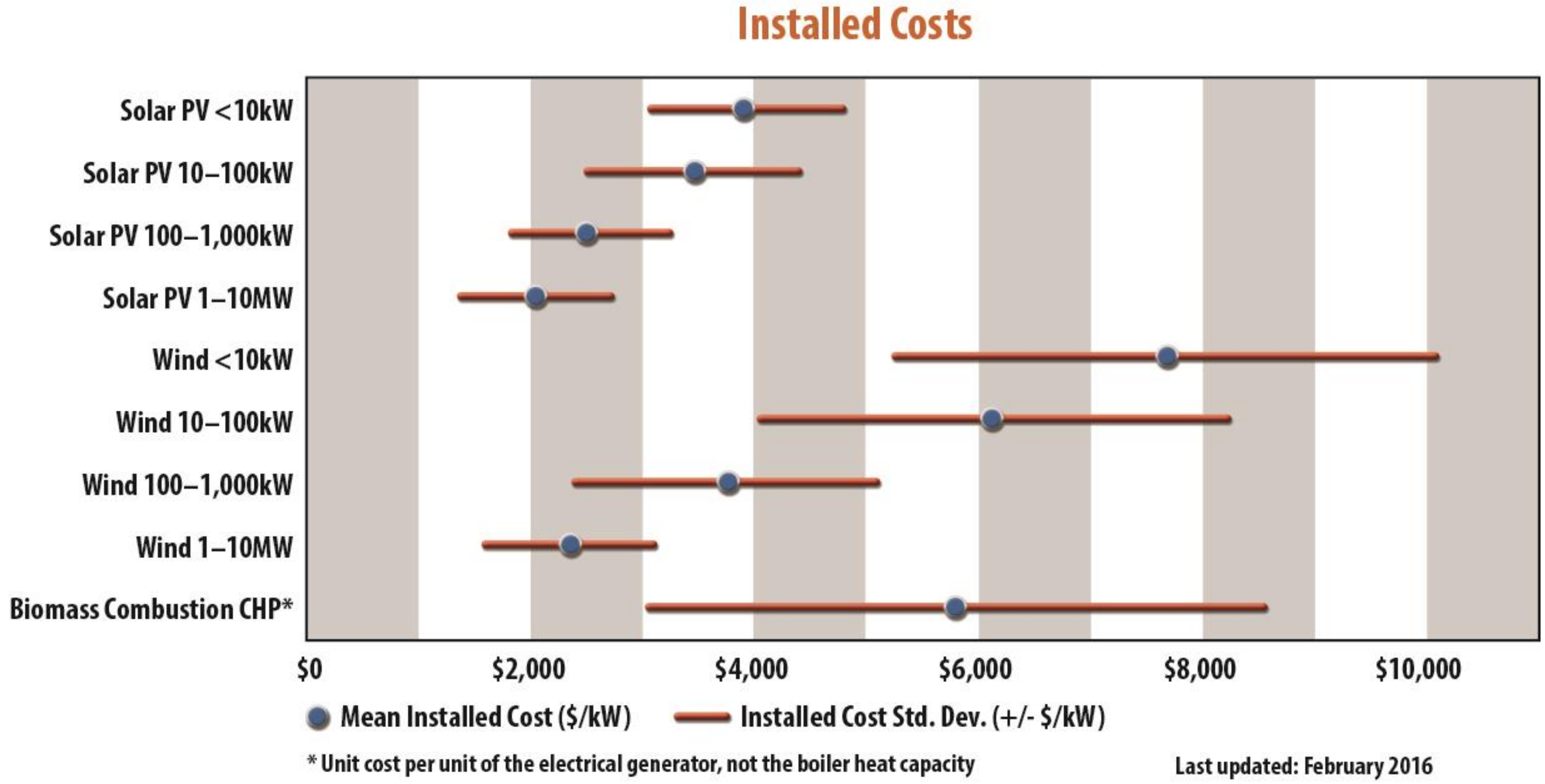
Offshore Wind

- Country: Germany
- Bidder: DONG/EnBW
- Signed: April 2017
- Construction: 2024
- Merchant price: US$ 4.9 c/kWh

*Note: The offshore wind merchant price is estimated based on project LCOE in real 2016 terms

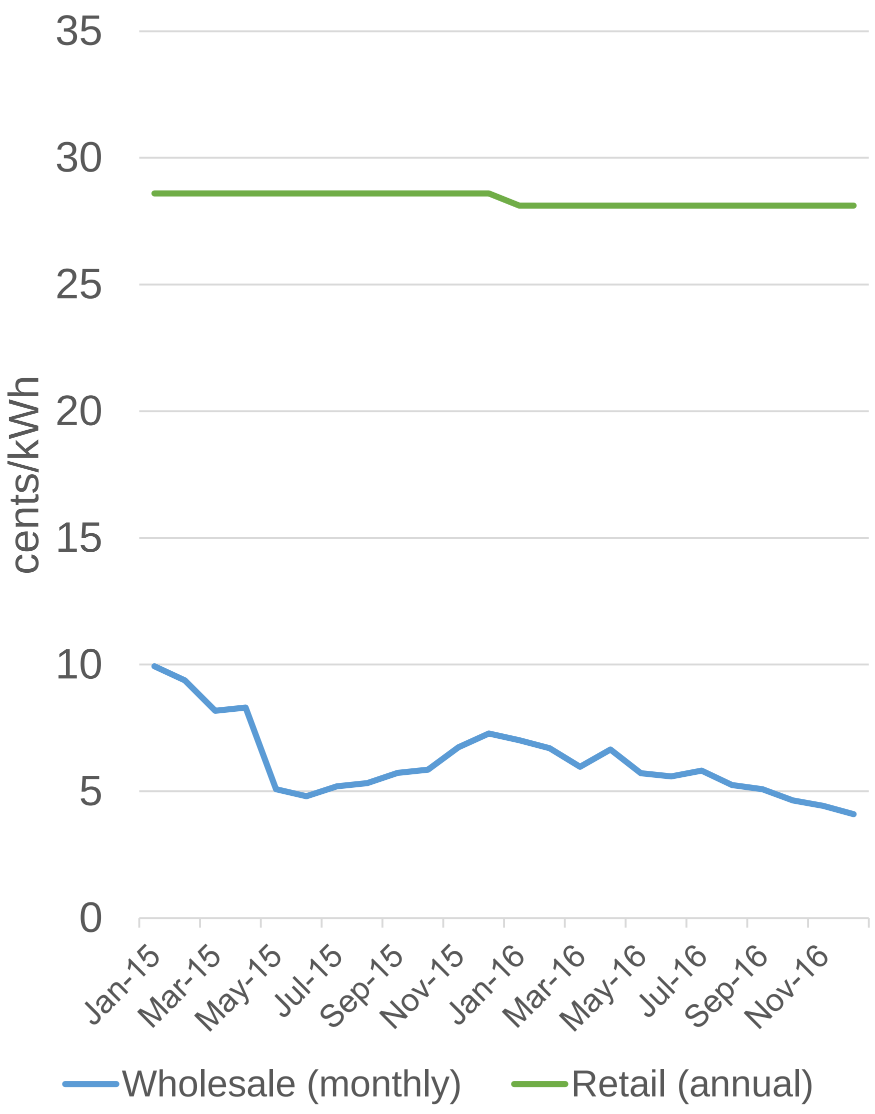
Source: Bloomberg New Energy Finance

Economies of scale remain



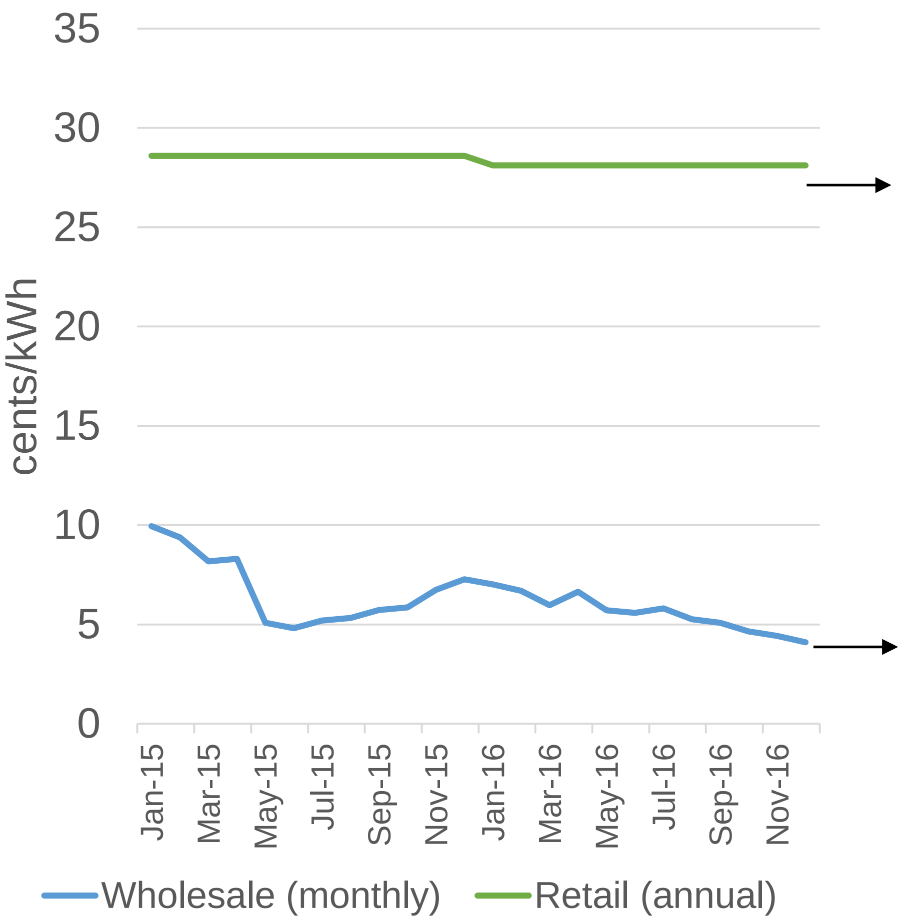
Source: NREL, www.nrel.gov/analysis/tech_cost_dg.html

Retail vs. wholesale electricity price



Source: Transpower & Ministry of Business, Innovation and Employment

Economics of solar look best against retail price, even if generation cost are higher



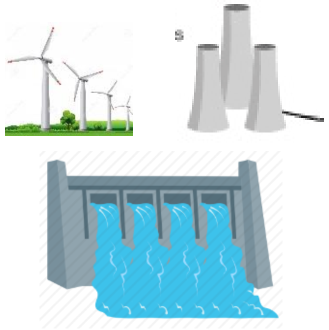
solar PV

VS.

Retail electricity

solar PV

VS.



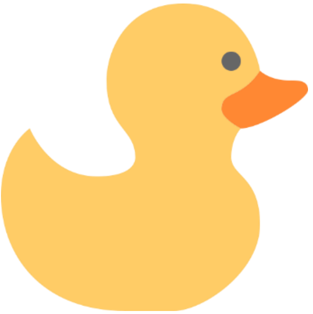
Electricity market

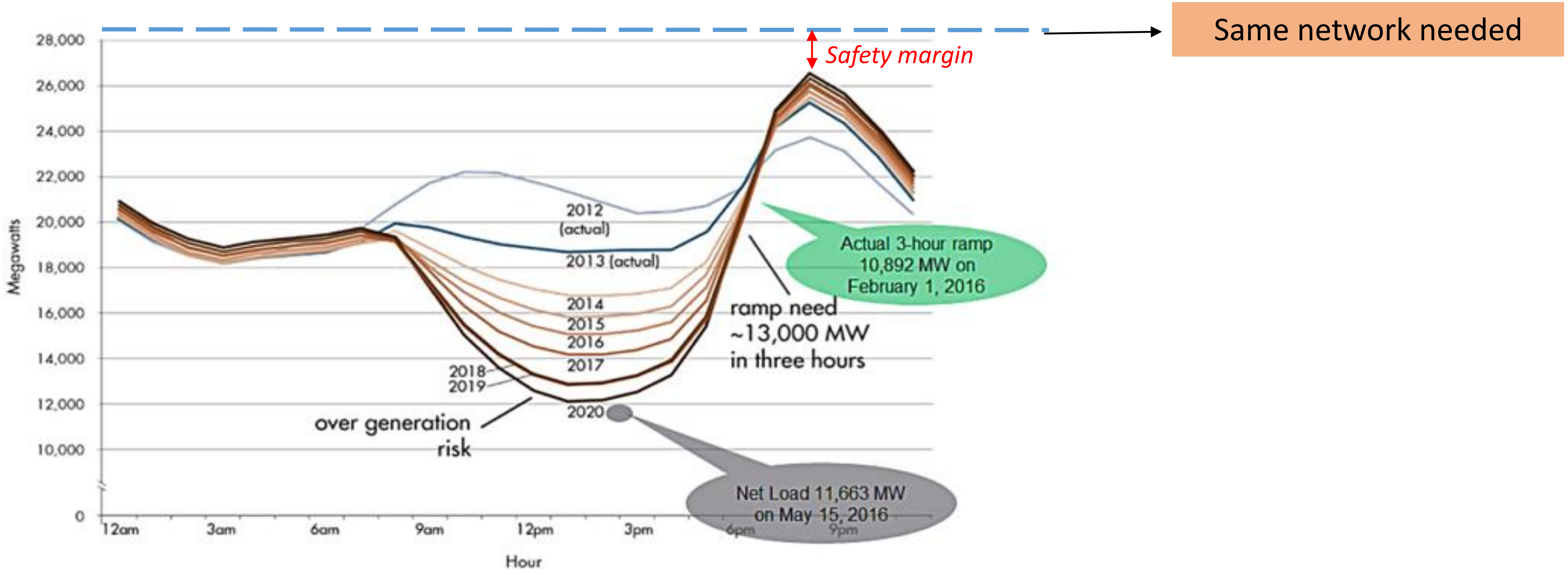
The trends shaping the future of electricity distribution

Fossil fuels	→	Decarbonised /renewable
Slow innovation	→	Disruptive change
Centralised generation	→	Decentralised generation
Passive customer with one-directional energy flows	→	Active customer with bi-directional energy flows
Analog/mechanical	→	Digital

System integration

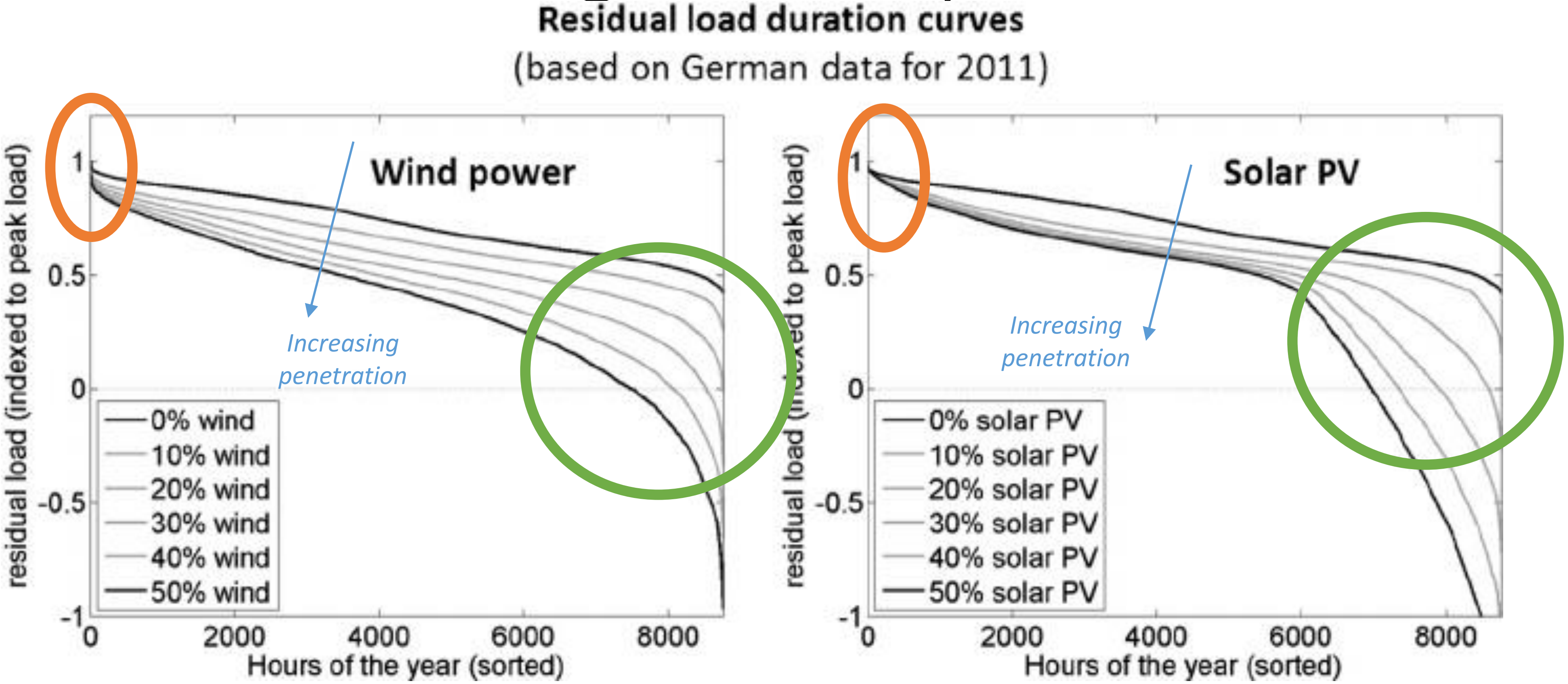
Duck curve





Solar generation tends to not contribute much during peak demand given that during that time sunshine is very low

Contribution during annual peak is low

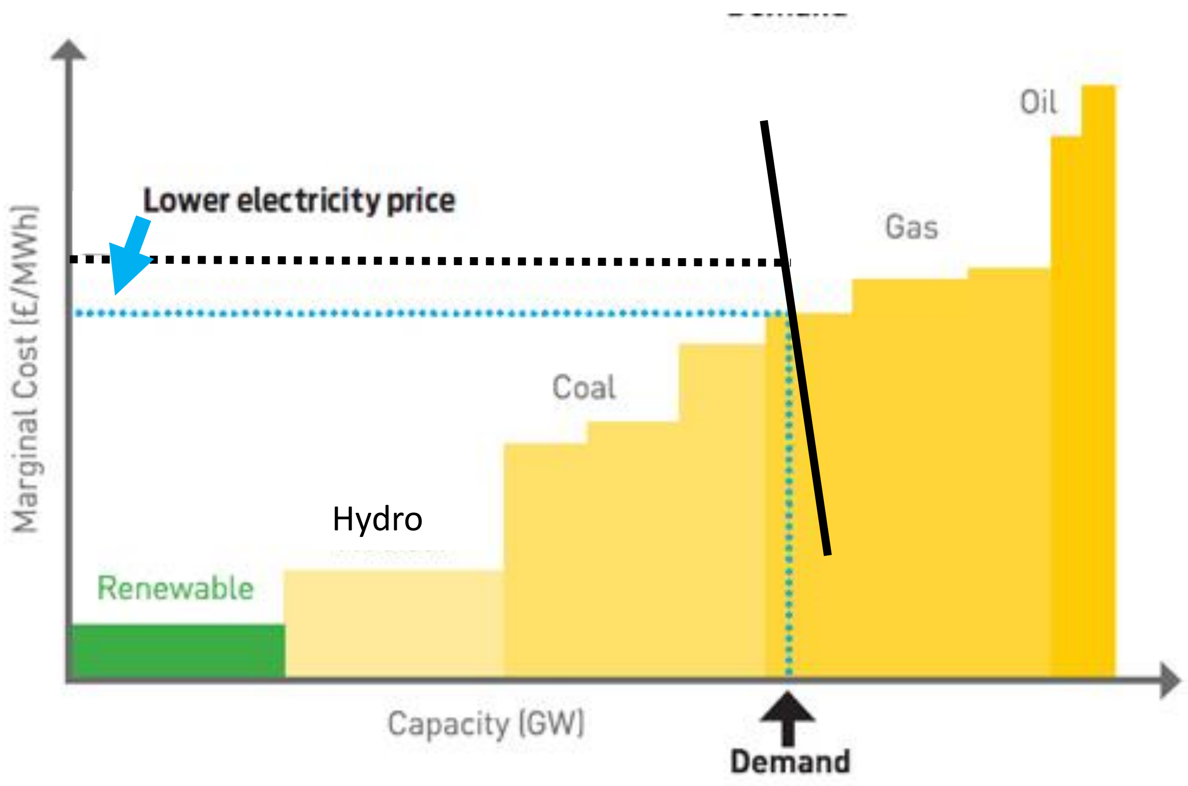


Wind and solar provide a lot of energy over the year

Wind and solar contribute little during peak demand

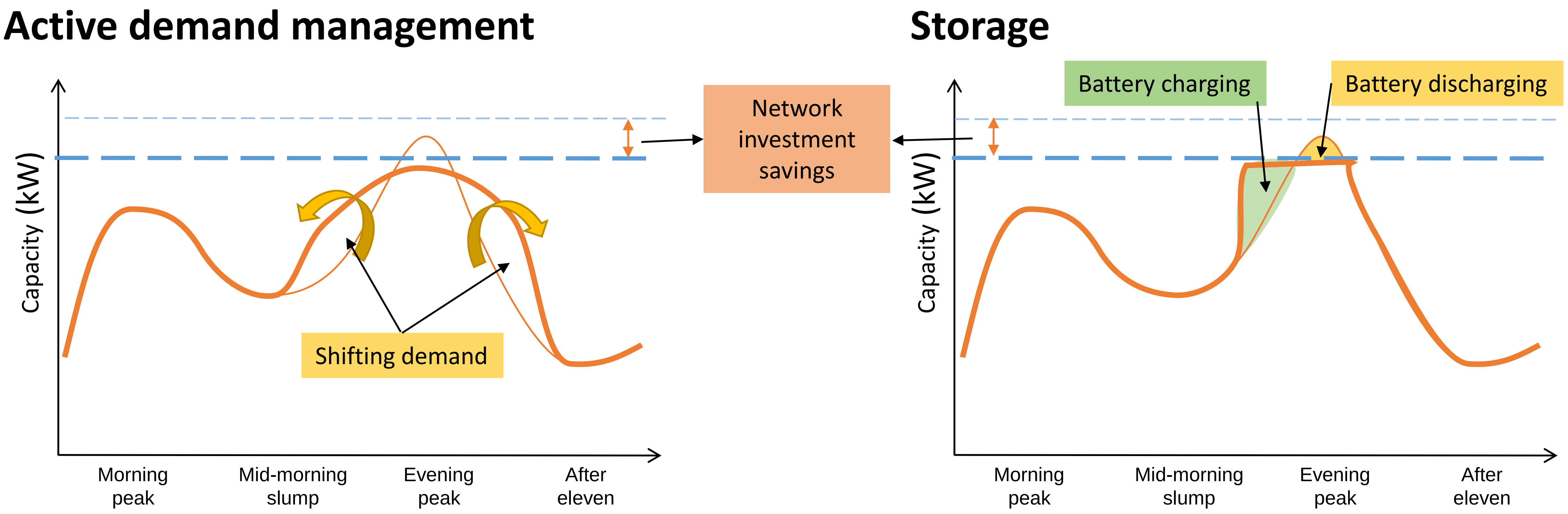
Need network infrastructure to be designed to meet peak load

Electricity market price – impact of wind and solar

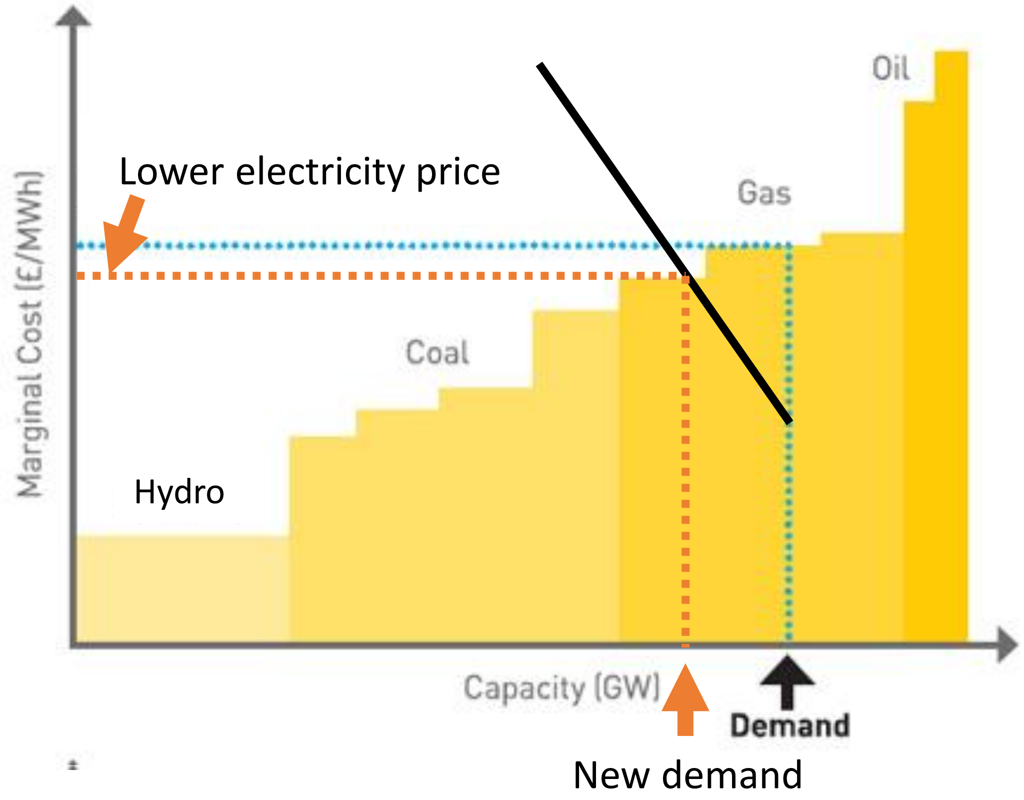


Wind and solar generation decreases electricity market price

Reshaping the load curve



Electricity market price – impact of active demand



Active demand side can decrease market price

Auckland project examples

Demand management at Vector
Hot water load control

- Electricity demand for hot water in homes with electric hot water heaters can be shifted if required, as the water cylinders can store hot water
- Vector has been using hot water load control since the 1950s to manage peak load
- Control mainly used in winter evening periods (5-8pm, June-August) when the distribution network is stressed, but also to support transmission in other parts of the year
- October 2015: Fire at Penrose substation took out 85 000 customers, but hot water control helped to contain number of outages

BUSINESS

Auckland powercut: Why the hot water cut out

9 Oct, 2014 5:00am

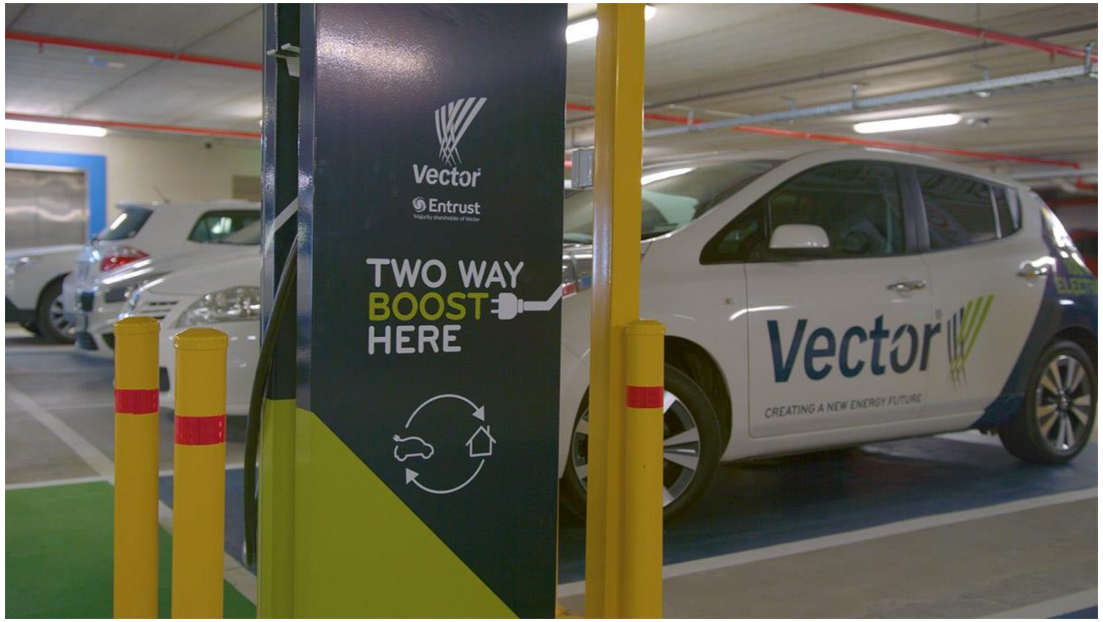
4 minutes to read

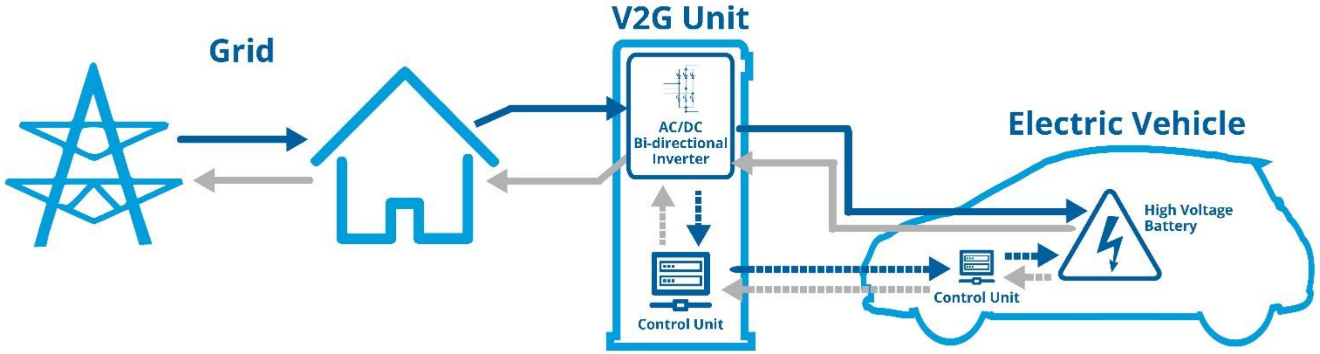
The outage led to thousands losing their hot water. Picture / Dean Purcell

NZ Herald

Demand management at Vector Vehicle to Grid EV charging

- A vehicle to grid (V2G) charger turns an electric vehicle can power homes and neighbourhoods by feeding into the network
- A Nissan Leaf G2 for example with a 30kWh battery could power the average household for 10 hours.



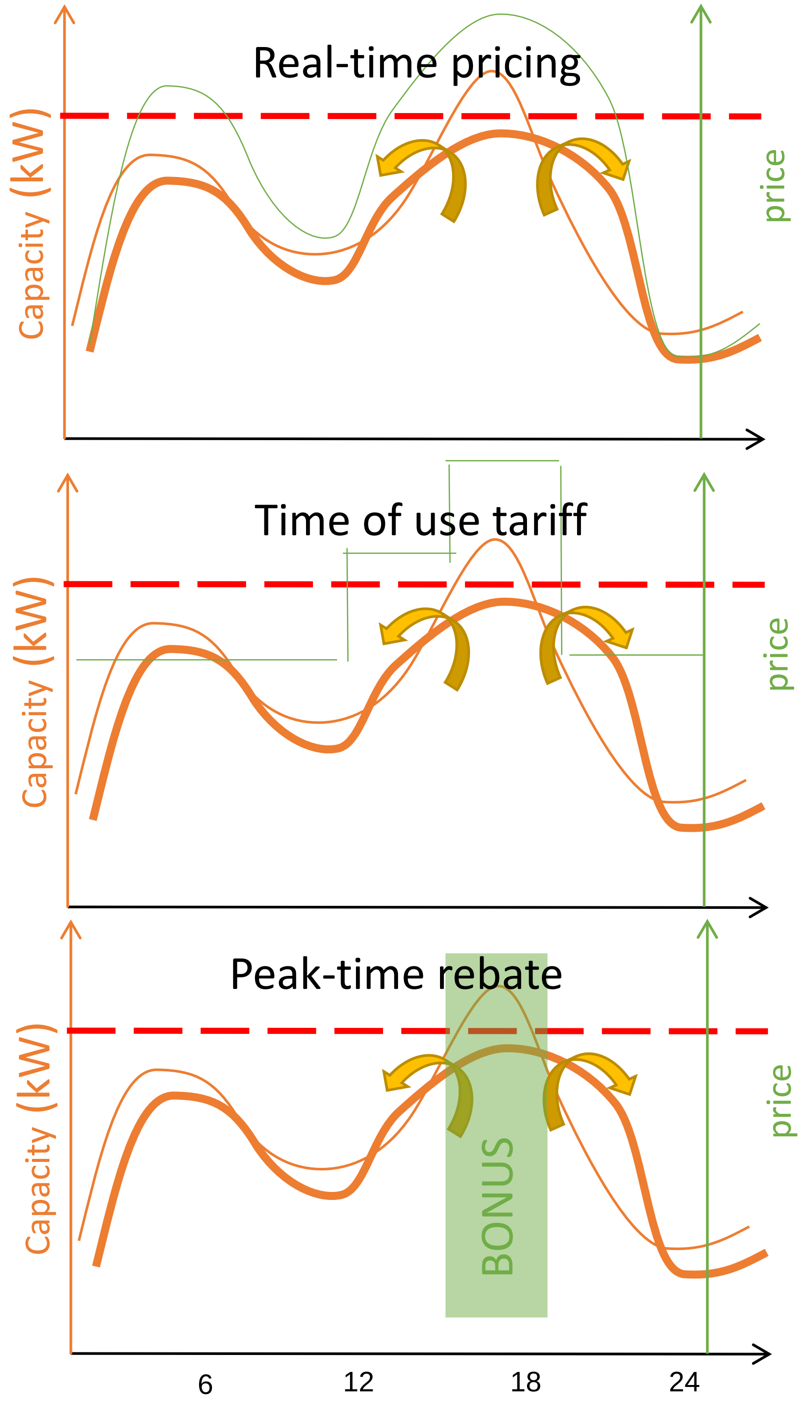


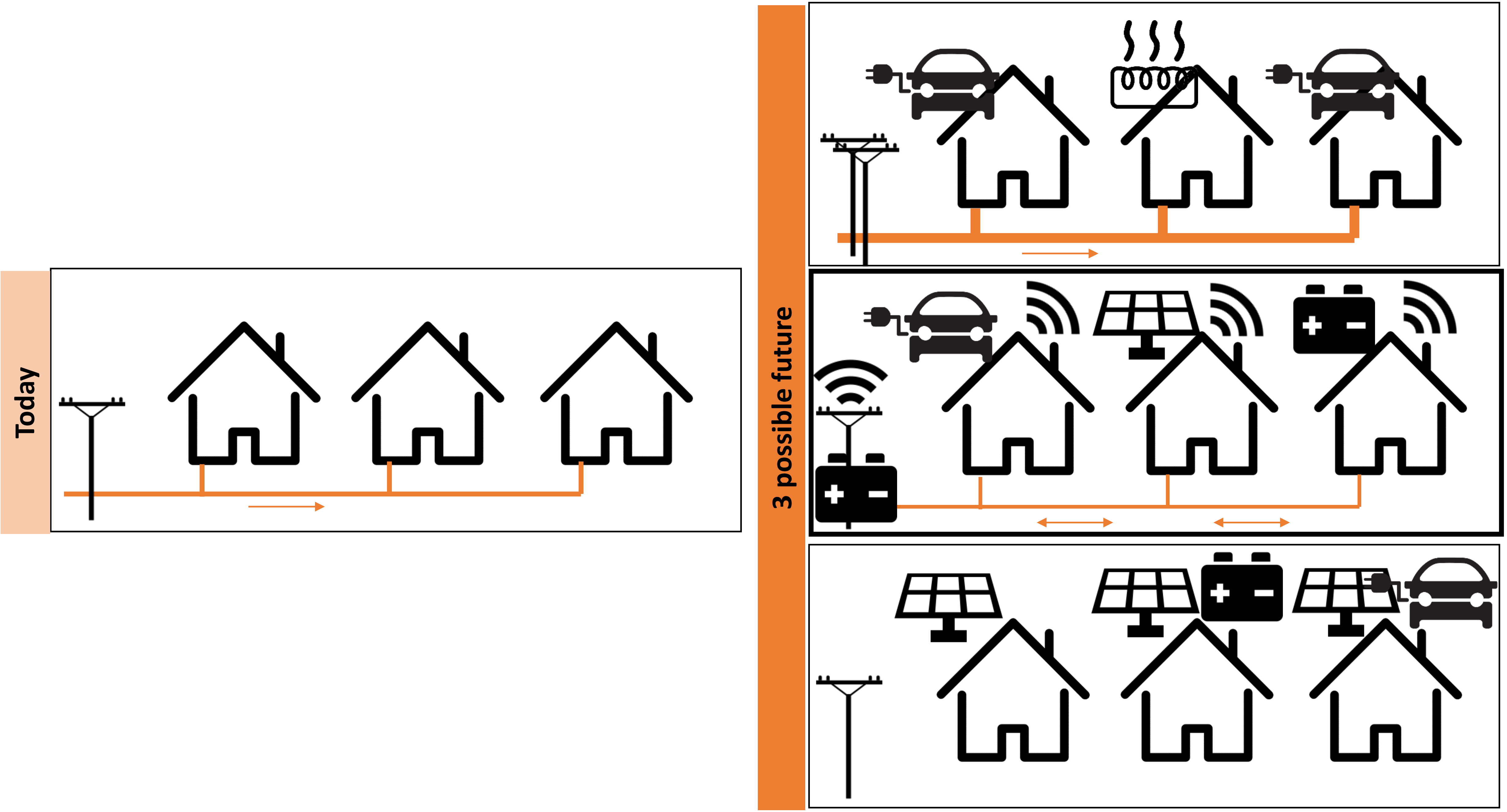
Energy storage at Vector: Glenn Innes Battery

- Load growth in Auckland suburb Glenn Innes means that network capacity started being insufficient
- Oct 2016: Largest battery in Asia Pacific Inaugurated in Glenn Innes (1MW/2.3MWh) (Oct 2017: new record set in Australia)
- In the first 6 months alone, the Glen Innes Substation clipped peak demand for well over 90 days

Cost-reflective pricing

- Pricing today is flat
- Network pricing should increasingly encourage/incentivise customers to reduce load
- Cost-reflective pricing is an umbrella terms and reflect a continuum of pricing opinion such as:
  - Real-time pricing
  - Time of use tariff with different time periods throughout the day such as peak, shoulder and off-peak
  - Peak-time rebate does reward customer with extra payment if they reduce their load during a specific peak event




Today
3 possible future

Discussion and questions?

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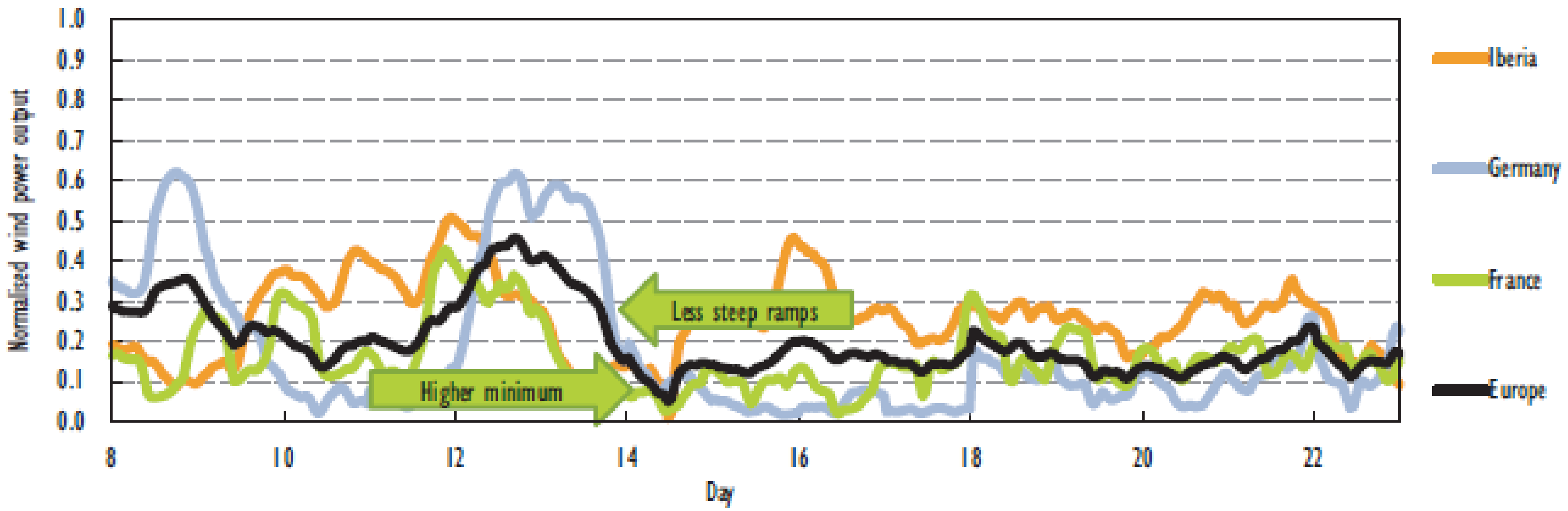
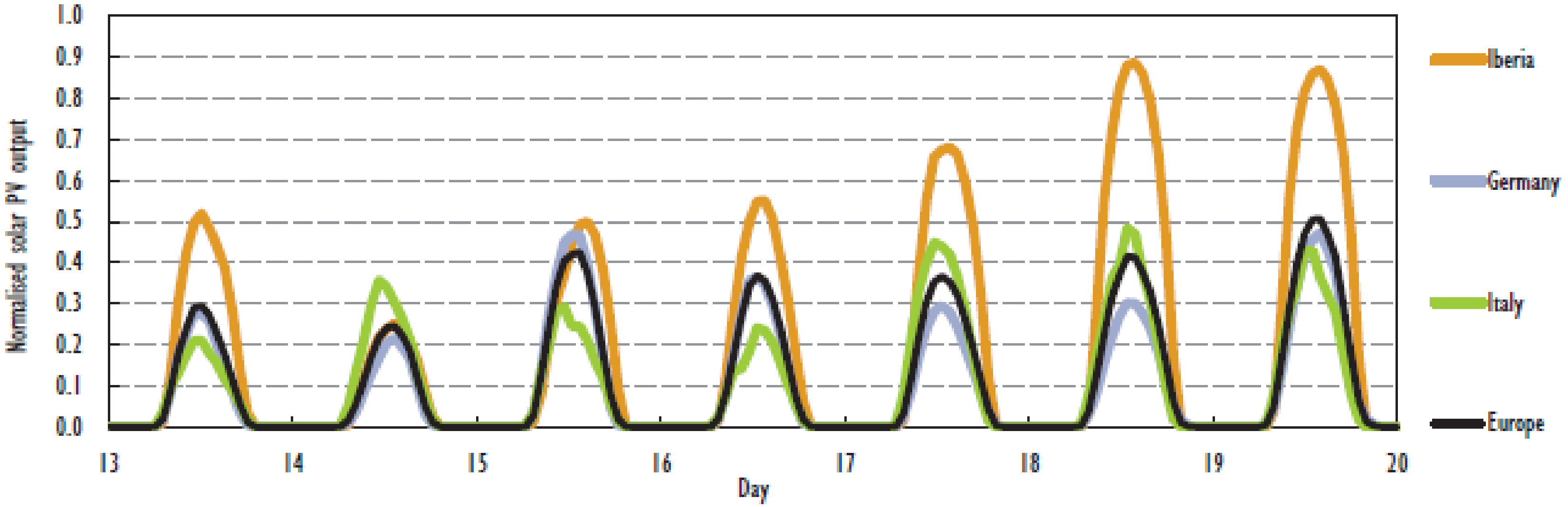
Appendix



Wind

-harder to predict



Solar PV

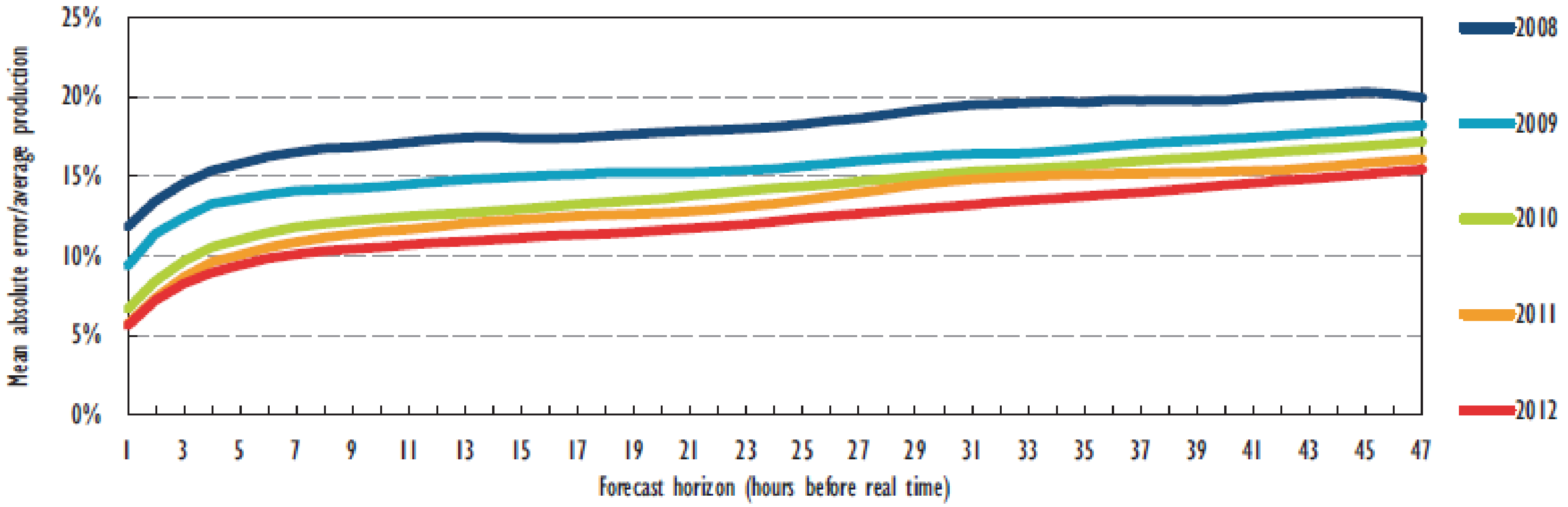
-easier to predict

Notes: Europe = all European case study countries. Generation data for April (top) and March (bottom) 2011. Output normalised to installed capacity.

Source: unless otherwise indicated, all tables and figures in this chapter derive from IEA data and analysis.

…but innovation in forecasts is important

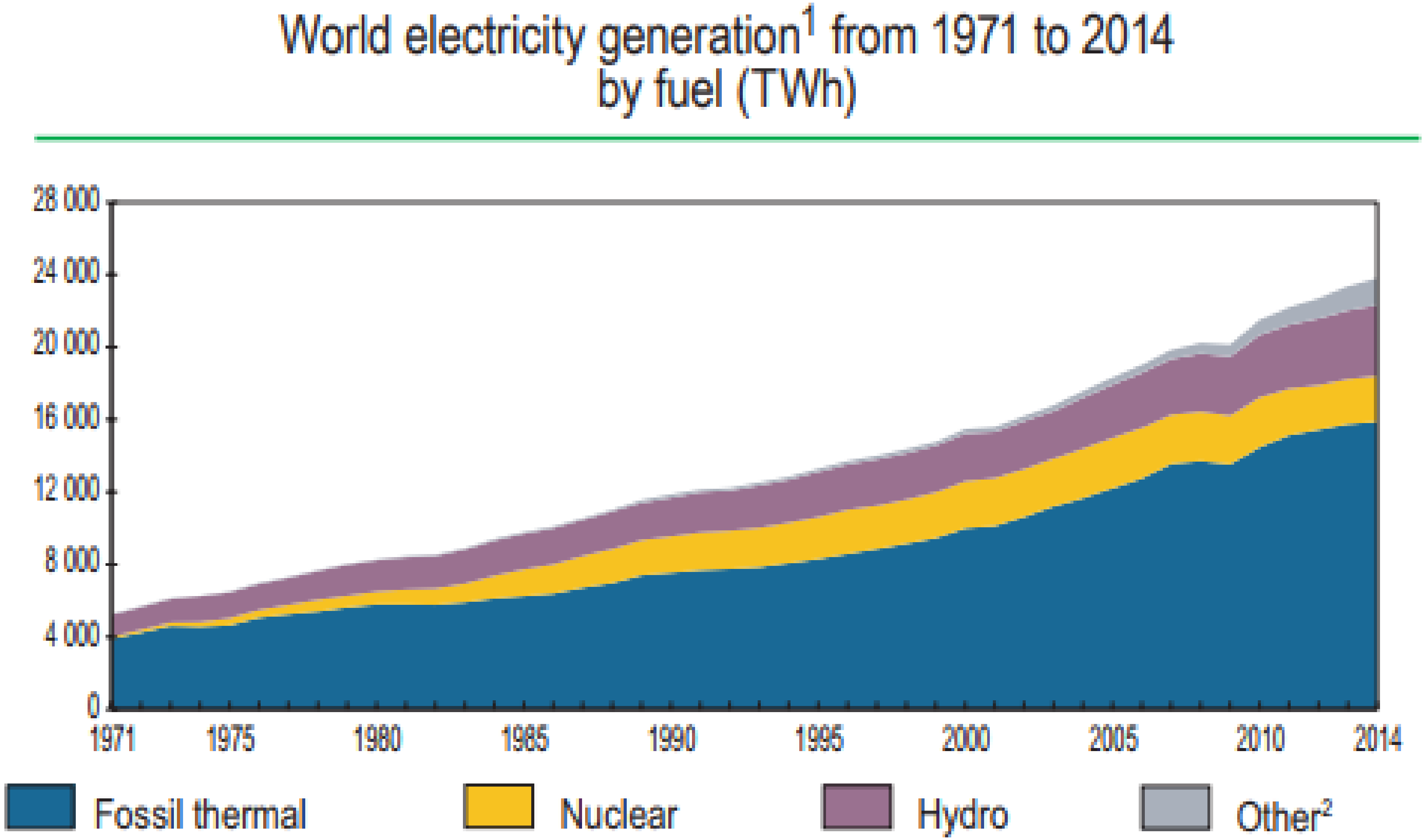
Figure 2.9 • Improvement in wind power forecasts in Spain, 2008-12



Source: based on data from Red Eléctrica de España.

Key point • Wind power forecasts have improved over recent years. Forecasts looking ahead only a few hours are more accurate than day-ahead forecasts.

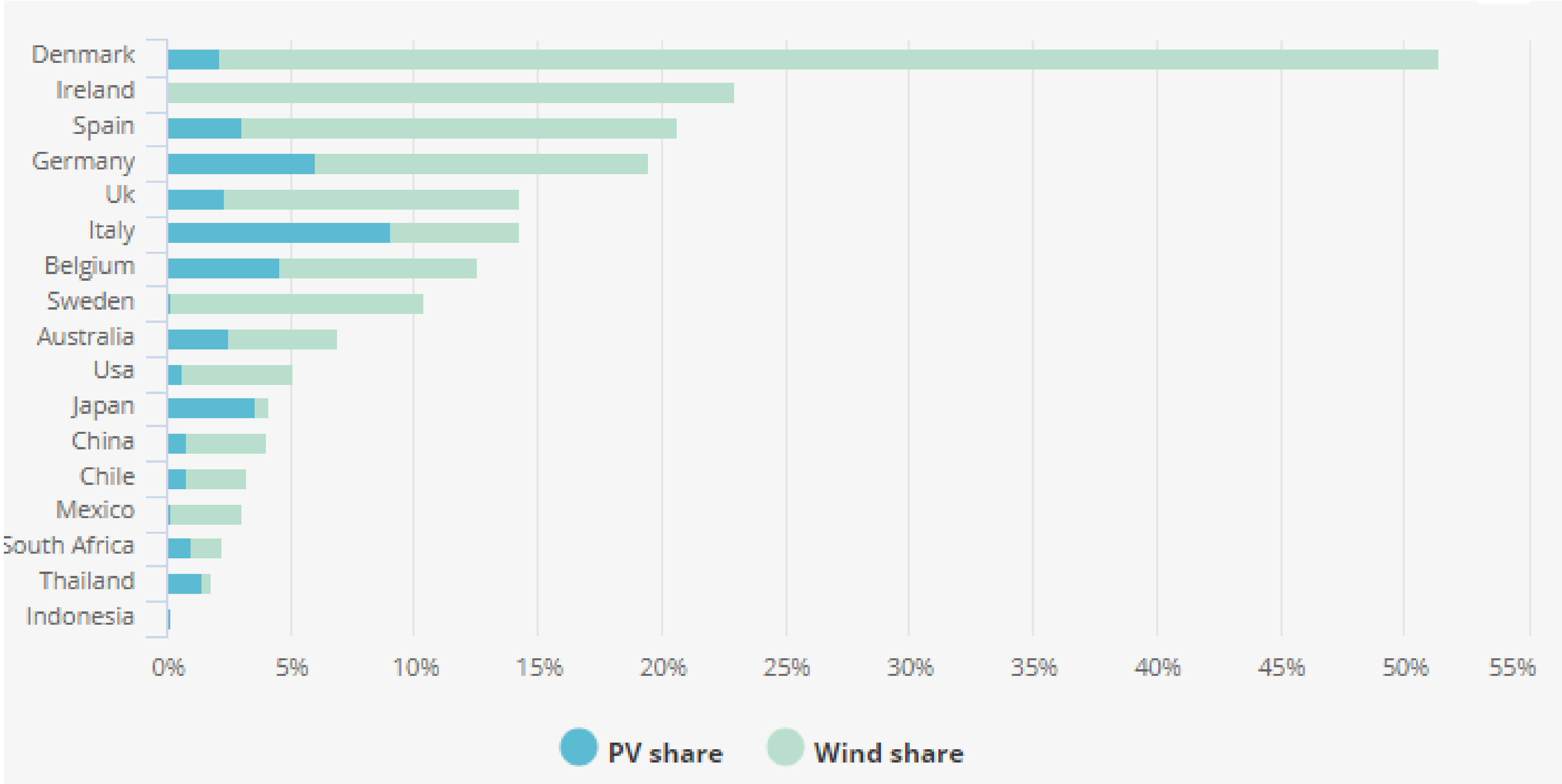
Share of wind and solar is still small globally



International Energy Agency (IEA), Key Energy Statistics 2016

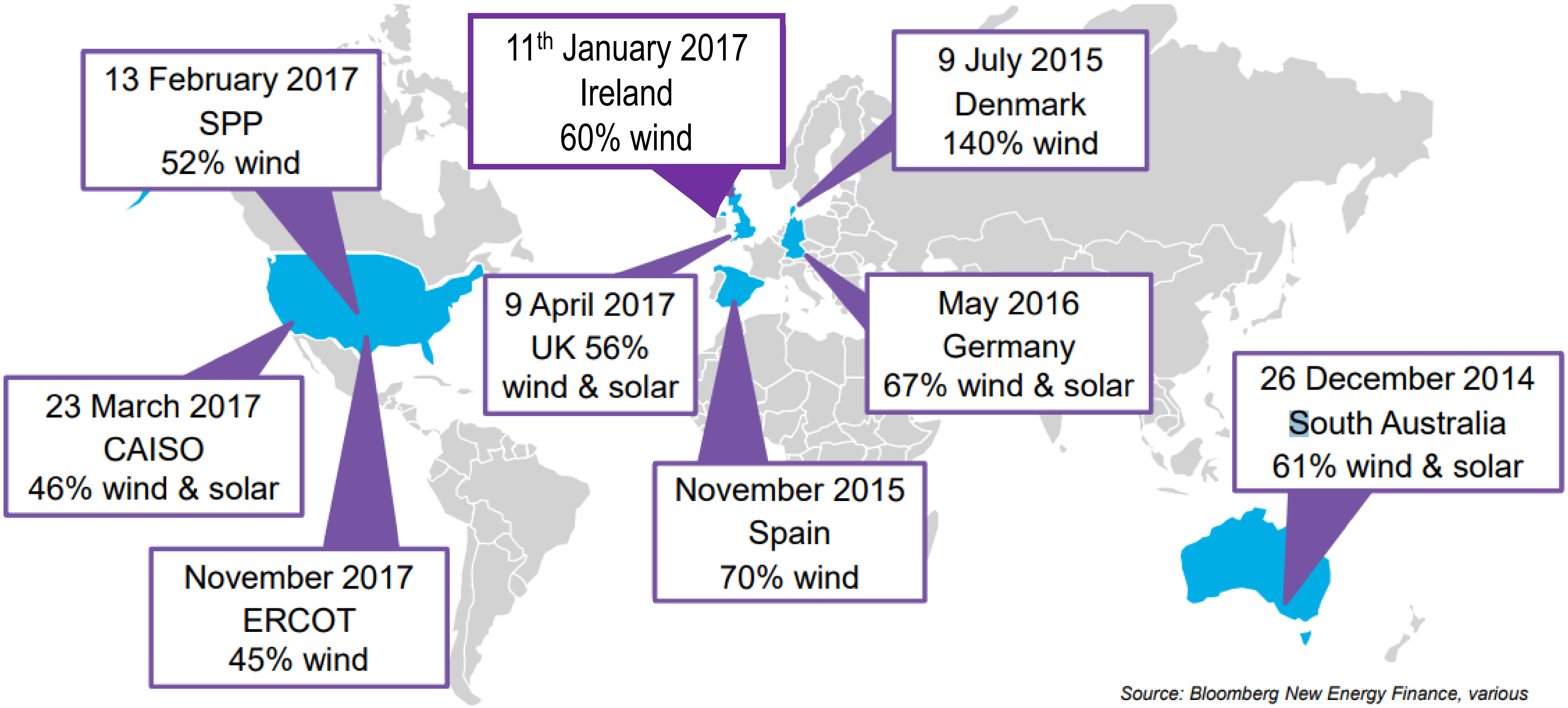
Other Includes geothermal, solar, wind,

But considerable in certain countries



Data for 2015; Source: IEA.org

And high in certain moments



SPP: Southwest Power Pool; CAISO: California ISO; ERCOT: Electric Reliability Council of Texas