Electricity Distribution in a Distributed Energy Future

Dr Steve Heinen
Steve.Heinen@vector.co.nz

Energy Economics Summer School
21st February 2018
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?

Source: Electricity Authority
What is electricity distribution?

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:
- Multiple firms can compete
- Competition to deliver efficiency and innovation
  → Social optimum

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

29 distributors in NZ, but only one per region

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 to high economic losses.
What does a electricity distribution business do?

**EXPENDITURE**
- **Planning**
  - Plans network
  - Invests in infrastructure

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

**INCOME**
- Distribution rates
  from customer bill based on connection size and energy used
Electricity network investment and peak load

- Morning peak
- Mid-morning slump
- Evening peak
- After eleven

Capacity (kW)

Safety margin

Design network to meet peak load

Investment driven by peak load (instantaneous) not energy consumption
Peak demand drives network investments

Energy = Capacity \times Time

10Wh = 10W \times 1 \text{ hour}

10Wh = 300W \times 2 \text{ min}

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

New energy technologies have higher loads than electric appliances

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

Larger network needed
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.

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

Advanced data analytics, control and an active customer is an 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

**ONSHORE WIND LEVELISED COST ($/MWh)**

- Wind costs have fallen 50% since 2009
- Learning rate 19%

**SOLAR PV MODULE COST ($/W)**

- Module costs have fallen 99% since 1976, 80% since 2008
- Learning rate 24.3%

Note: Pricing data has been inflation corrected to 2014. We assume the debt ratio of 70%, cost of debt (bps to LIBOR) of 175, cost of equity of 8%. Source: Bloomberg New Energy Finance

Note: Prices are in real (2015) USD. Current price is $0.014/W. Source: Bloomberg New Energy Finance, Meycoo

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

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.
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
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

Active demand management

Storage

Network investment savings

Battery charging

Battery discharging

Shifting demand
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
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?

Dr Steve Heinen
Steve.Heinen@vector.co.nz
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*

![Graph showing improvement in wind power forecasts from 2008 to 2012.](image)

*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

- 13 February 2017, SPP, 52% wind
- 11th January 2017, Ireland, 60% wind
- 9 July 2015, Denmark, 140% wind
- 9 April 2017, UK, 56% wind & solar
- May 2016, Germany, 67% wind & solar
- November 2015, Spain, 70% wind
- November 2017, ERCOT, 45% wind
- 26 December 2014, South Australia, 61% wind & solar

Source: Bloomberg New Energy Finance, various

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