



New generating technologies

High-level overview for the Market Development Advisory Group

7 May 2019

COMPETITION • RELIABILITY • EFFICIENCY

Scope of this high-level overview

- Technology change is driving new and evolving forms of electricity generation
- Technologies summarised in this high-level overview are grid-scale technologies not in widespread use in NZ today, but which may be used at scale in the next 5-20 years
- Small-scale generation technologies within the meaning of distributed energy resources are not covered in this overview – refer to the Authority's *Enabling mass participation* project
- The Innovation and Participation Advisory Group (IPAG) has in its terms of reference the reduction of inefficient barriers to mass-market distributed energy resources and aggregators of these resources

Technologies covered in this overview

- Battery storage
- “Green” thermal generation
- Hydrogen generation, including stationary hydrogen fuel cells
- Pumped hydroelectric storage generation
- Solar generation (grid scale PV, concentrated photovoltaics, concentrated solar power)
- Tidal and wave energy

Battery storage

- Other than energy arbitrage, grid-scale batteries could provide—
 - capacity adequacy (peaking) role, competing with OCGTs
 - ancillary services (eg, reserves, frequency regulation, voltage support, black start)
- Total installed costs—
 - are cheaper on a per-unit of power capacity basis (i.e. \$ / MW) for batteries of shorter duration than for long-duration batteries
 - are cheaper on a per-unit of energy capacity basis (i.e. \$ / MWh) for long-duration batteries than for batteries of shorter duration
- Levelised cost of energy storage (2018): approx. \$305-\$705 / MWh (NZD 1 : USD 0.67)

Sources: Lazard 2018b, U.S. EIA 2018, Transpower 2017, Rocky Mountain Institute 2015

“Green” thermal generation

- Biomass-fuelled gas turbines
 - Perhaps more likely for OCGTs fulfilling peaking role, because of availability and cost of sufficient quality gas from biomass in NZ
- Hydrogen-fuelled gas turbines
 - See separate slide on hydrogen generation
- Carbon capture at source
 - Eg, Allam Cycle, where CO₂ flows over the blades of the turbine to make the rotor spin

Sources: Crolius 2019, Sapere 2018

Hydrogen generation

- Hydrogen created:
 - from water via electrolysis
 - from fossil fuels via gas reforming (with carbon capture and storage to reduce carbon footprint)
- Could replace natural gas as a fuel for generating plant
- Life cycle efficiency of electrolysis, storage and generation use = 25-35%
- Producing hydrogen from natural gas incurs an efficiency penalty of around 65-80%
- Production-only cost (2018): electrolysis: \$175-\$190 / MWh; steam methane reforming: \$70 / MWh with \$100 / tonne CO₂ carbon cost

Sources: Concept Consulting 2019, Committee on Climate Change 2018, Sapere 2018

Stationary fuel cells

- Electro-chemical reaction generates energy
- Fuel cells distinguished by operating temperature, catalyst, fuel types (eg, hydrogen, natural gas, biomass), hydrogen purity
- Fuel cell types include: polymer electrolyte membrane (also known as proton exchange membrane), solid oxide, molten carbonate, alkaline, phosphoric acid, direct methanol
- Relatively high thermal efficiency in converting energy (circa 50-60%)
- PEM fuel cell cost (2018): approx. \$350-\$430 / MWh on a levelised cost of electricity basis (1 NZD : 0.95 AUD)

Sources: Proctor 2019, CSIRO 2018, IEA 2017

Pumped hydroelectric storage (PHES) generation

- Two main types of PHES:
 - Pure, or off-stream PHES – uses only pumped water
 - Combined/hybrid PHES – uses pumped water and natural stream flow water
- Roundtrip efficiency of modern PHES circa 70-85%, although PHES still a net consumer of electricity
- Wind or solar power generation coupled with PHS is now being developed
- Flooded mine shafts, underground caves and oceans as reservoirs have been planned or are in operation
- Levelised cost of energy storage (2016): approx. \$225-\$295 / MWh (NZD 1 : USD 0.67)

Sources: Schmidt et al 2017, Lazard 2016, Luo et al 2014, Yang 2010, Chen et al 2009

Solar generation

- In 2017, 98 GW of solar generation installed globally vs. 70 GW of new fossil fuel generation built globally
- First time since industrial revolution that renewable energy form exceeded construction of conventional fossil fuel-powered electricity generation
- NZ has over 85 MW of distributed solar PV installed, almost half of which was installed over the past two years
- Levelised cost of energy for grid-scale (utility) solar PV (2018): approx. \$40-\$70 / MWh (NZD 1 : USD 0.67)
- Levelised cost of energy for concentrated solar power (CSP) (2018): approx. \$150 / MWh (NZD 1 : USD 0.67)

Sources: Transpower 2019, Lazard 2018a, Lilliestam et al 2018

Solar PV vs. concentrated solar power (CSP)

- Solar PV uses sunlight through the 'photovoltaic effect' to generate D.C in a direct electricity production process
 - Concentrator PV uses lenses or curved mirrors to focus sunlight onto small, highly efficient, multi-junction solar cells
- CSP uses mirrors to reflect and concentrate sunlight onto a single point where it is collected and used to heat fluid to a high temperature (eg, oil, molten salt), which is then used to make steam and drive an electricity turbine
- CSP technologies include parabolic trough, linear Fresnel reflector, power tower, and dish/engine systems
- CSP can provide dispatchable renewable power on a large scale

Sources: Lilliestam et al 2018, NREL 2019

Tidal energy

- Two types of tidal energy scheme:
 - Semi-permeable tidal barrages across estuaries allow tidal waters to fill an estuary via sluices and to empty through turbines
 - Harnessing offshore tidal streams using tidal turbines
- Tidal range of at least 3-7 metres required for economical operation and for sufficient head of water for the turbines
- Tidal energy schemes have low capacity factors – usually 25-30%
- Tidal power often misses peak demand times because of 12.5 hour cycle of the tides
- Levelised cost of energy (pre-commercialisation) (2015): approx. \$315-\$700 / MWh (NZD 1: USD 0.67)

Sources: Ocean Energy Council 2018, U.S. EIA 2018, Segura et al 2017, Ocean Energy Systems 2015

Wave energy

- Energy potential for waves greatest between 30° – 60° latitude in both hemispheres on west coasts due to global wind direction (NZ = 40° S)
- On average, waves in NZ have a power density of 40-60 kW / metre
- Overall, wave energy technologies in early stages of development – can be categorised as follows:
 - Turbine-type: eg, oscillating water column, overtopping wave energy converter
 - Buoy-type or point absorber: eg, float type, tube type
- Levelised cost of energy (pre-commercialisation) (2015): approx. \$315-\$1,000 / MWh (NZD 1: USD 0.67)

Sources: Ocean Energy Systems 2015, IRENA 2014, Muetze & Vining 2006, U.S. Dept of Energy 2006

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