Reuse Mining Assets for Pumped Hydro Storage (PHS) Projects

ACEF 2017 – CHARTING HE FUTURE OF CLEAN ENERGY IN ASIA
TECHNOLOGY INNOVATION: PART II

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EELO SOLUTIONS

Pumped Hydro Storage (PHS)

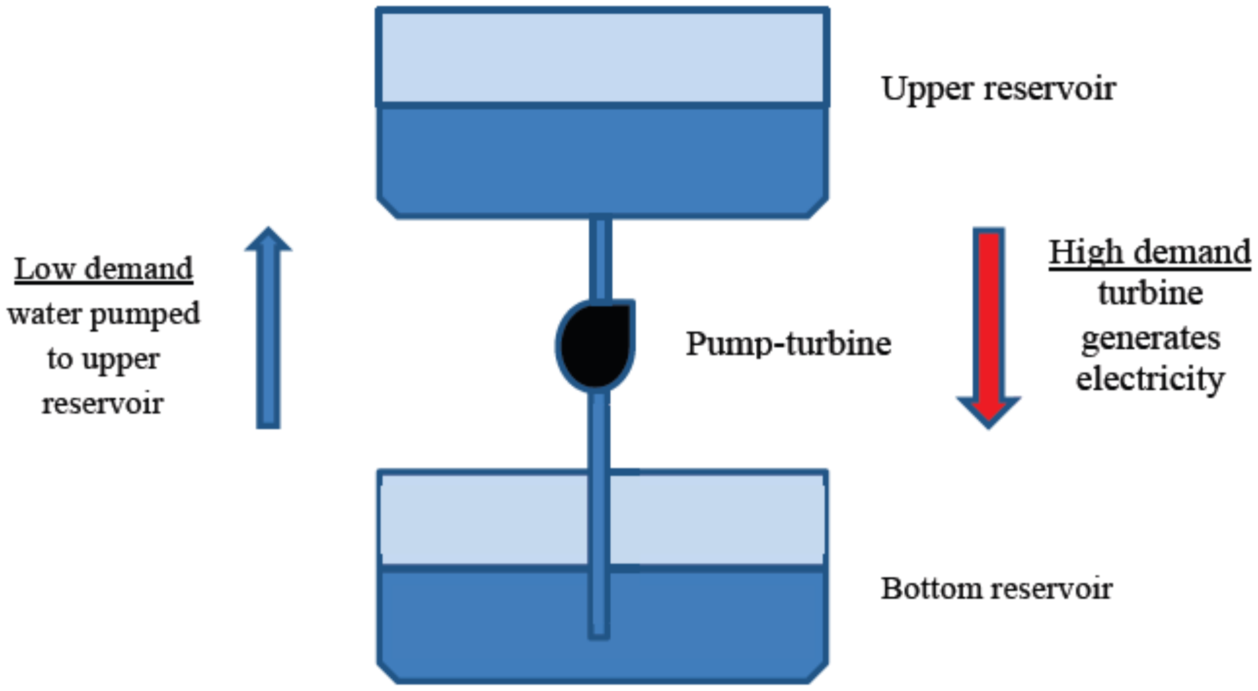
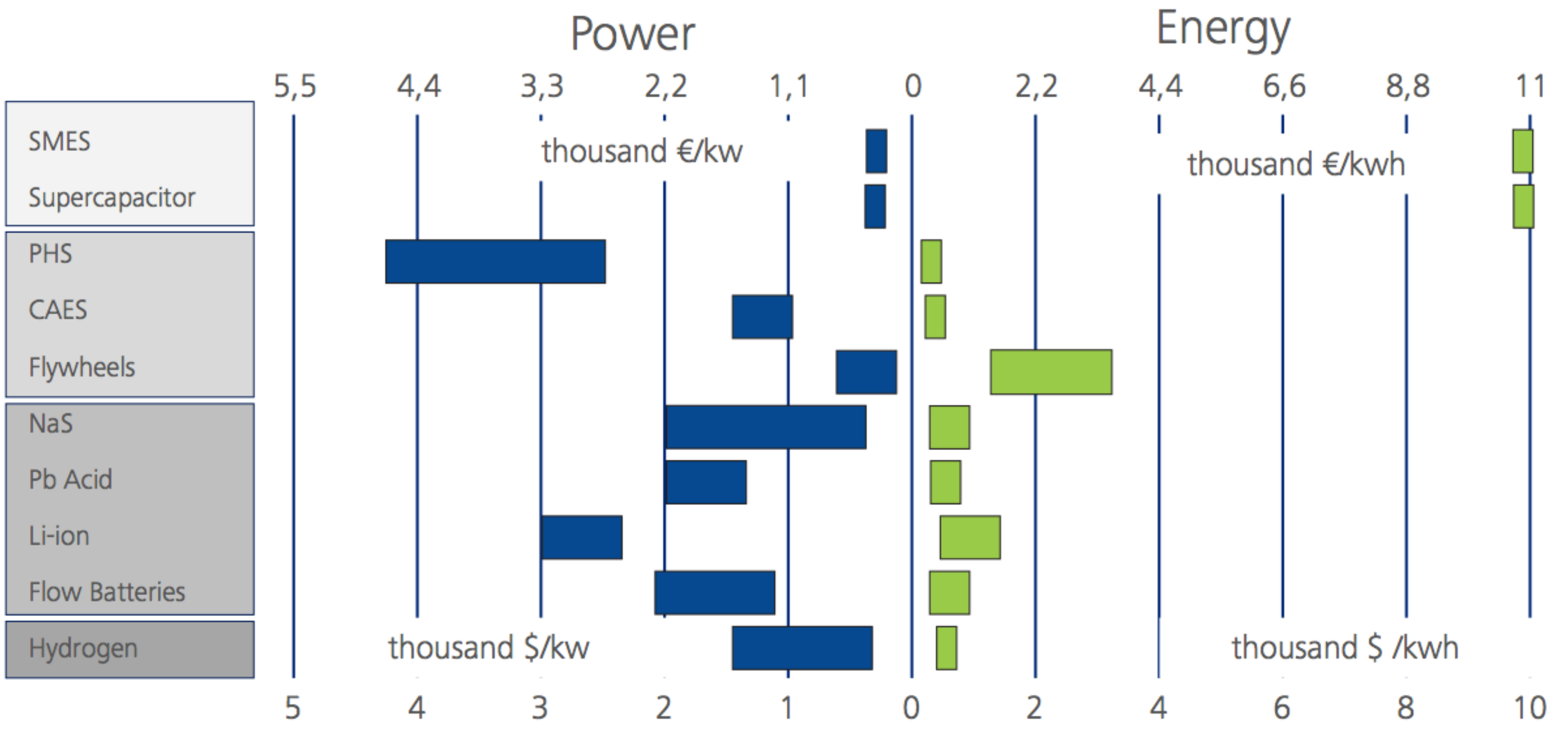


Figure 2 – Pumped storage hydroelectric station - basic principle of operation (Andrews, 2013, p. 342)

- The most mature energy storage system with 150GW storage worldwide
- Technology Basics:
  - Two reservoirs at different elevations
  - Generate power through gravity
  - Pump water back up with low cost or excess electricity
  - Low energy density
  - Large area and proper terrain required
- Benefits:
  - No capacity loss form charge and discharge cycles
  - Great for long discharge and frequent use

Economics of Energy Storage Systems

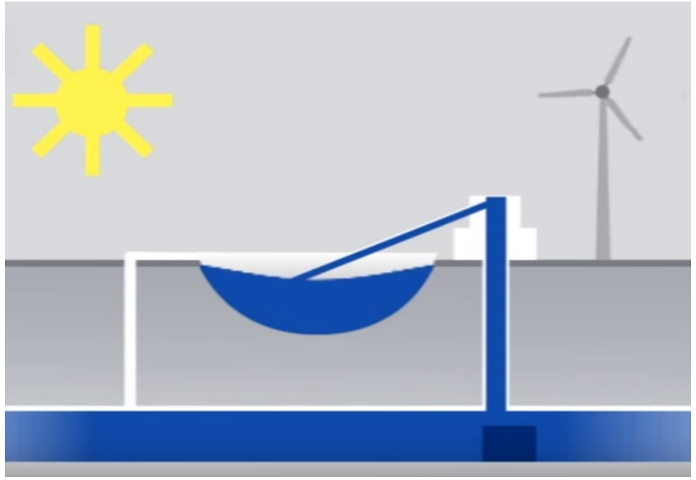


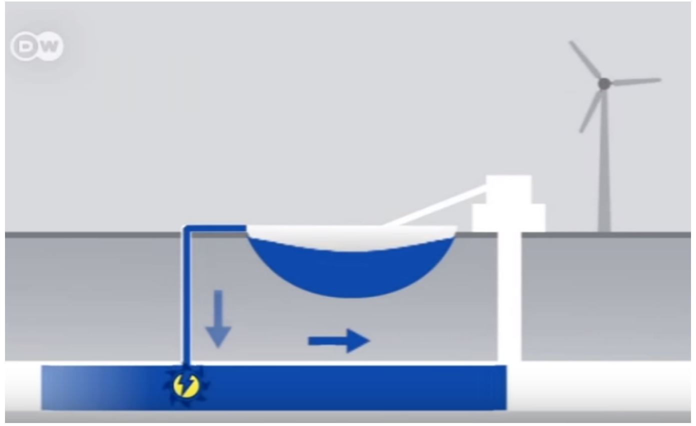
Levelized Cost of Energy (LCOE) for PHS systems is typically $150 – $200 per MWh

Source: Deloitte, 2016, Energy storage: Tracking the technologies that will transform the power sector

Decision Making Criteria

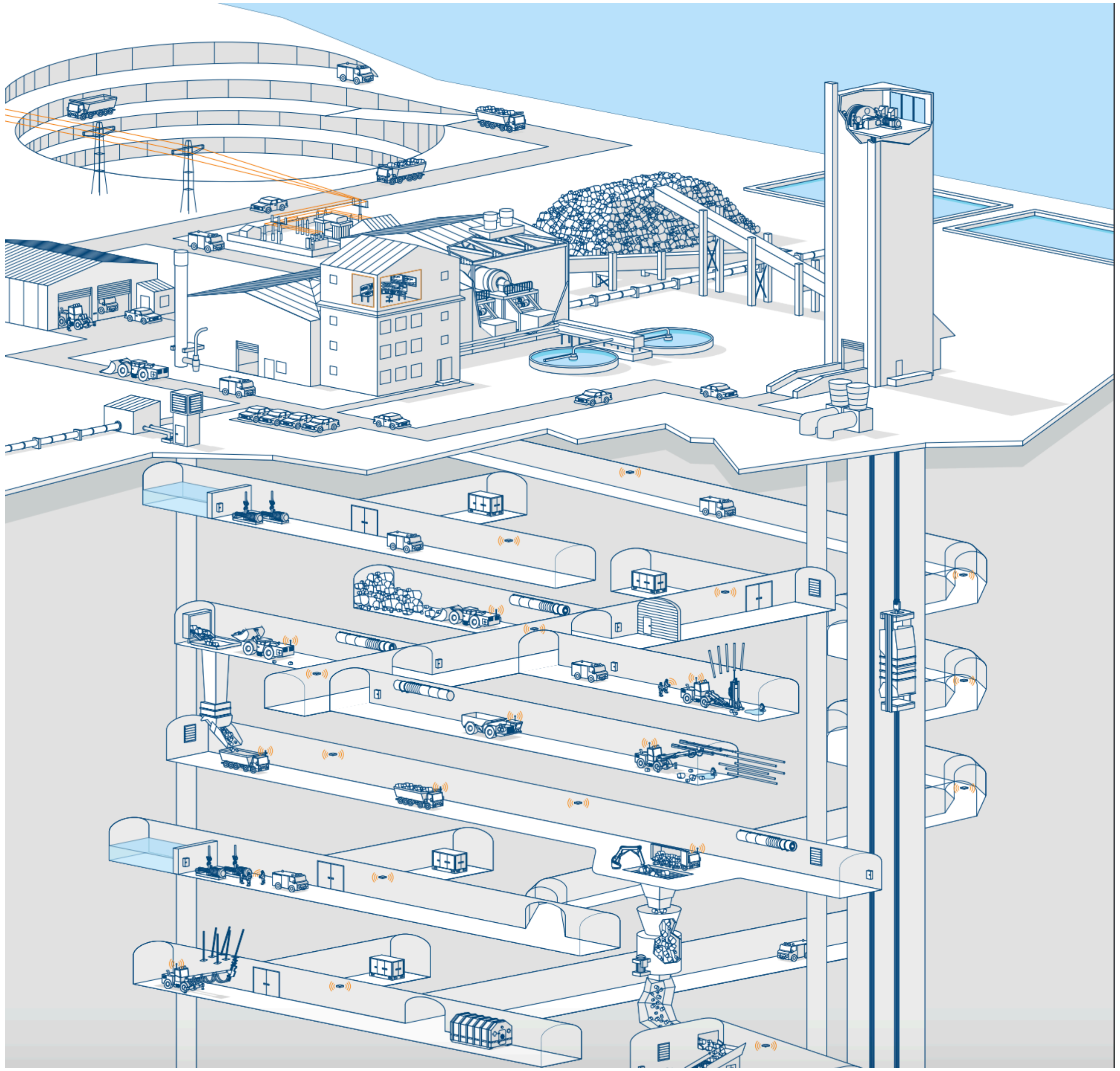
- Head availability
  - 100m+
- Storage Capacity
  - 4 – 10 hours storage
- Generation Capacity
  - 100MW +
- Water resources and quality
- Topography for reservoir to be constructed
- CAPEX/Financing
  - Construction of reservoir(s)
  - Power generation system
  - Transmission lines, roads, buildings, …etc





Source: Video extract from Deutsche Welle's YouTube: https://www.youtube.com/watch?v=L9cEwUTRvbI

Mining Operations



Source: ABB Illustration (https://library.e.abb.com/public/6029d76aadb0f2bac1257e030050cc43/abb-mining-illustration.pdf)

Kidston PHS Project (250MW)

History

- Gold producing mine shut down in 2001
- 250MW; 1,500MWh Capacity (6 hours)
- CAPEX of $1M/MW, ~25% of typical cost ($300M project)
- There will also be 320MW solar plants on site

Why this works?

- Minimize CAPEX by utilizing existing infrastructures:
  - Both reservoirs and the balance storage pit already exist
  - Existing transmission line & local distribution network
  - A large volume of good quality water already in the pits
  - Existing water pipe and water license from nearby dam
- Repurpose legacy assets from risk management to revenue generation
- Economic opportunities – bring new economic opportunities to communities that are remote and often dependent on resource projects
- Environmental upsides – no additional environmental impact comparing to constructing a new lower or higher reservoir

Source: Genex Power website (http://www.genexpower.com.au/)

Marmora PHS Project (400MW)

History

- Gold producing mine shut down in 1979
- 400MW; 2,000MWh (5 hours); 258m elevation
- CAPEX of $1.8M/MW, ~50% of typical cost ($700M project)

Why this works?

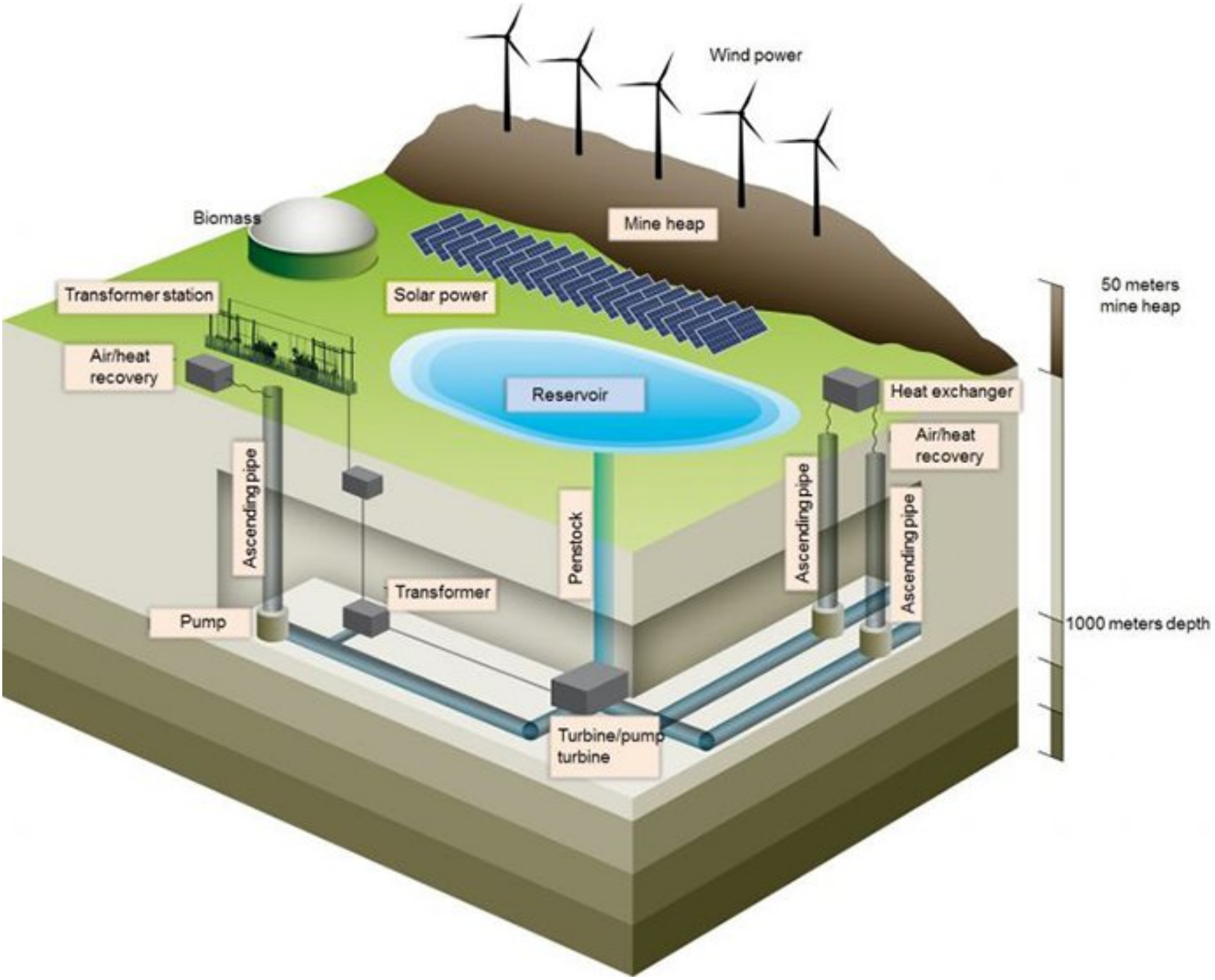
- Reduces CAPEX by utilizing existing infrastructures:
  - One reservoir already exist
  - Area available to construct a second reservoir
  - Near transmission line (8km)
  - A large volume of good quality water already in the pits
- Repurpose legacy assets
- Economic opportunities – bring new economic opportunities to local communities
- Environmental upsides – less additional environmental impact in a brown field project
- Community support – 13 communities

Challenges

- Cost is still too high to justify investment, especially in a jurisdiction with surplus energy

Source: Northland Power website (http://www.northlandpower.ca)

Prosper-Haniel coal mine PHS (200MW)



History

- Coal producing mine will shut down in 2018
- 200MW; 800MWh Capacity (4 hours)
- CAPEX unknown, but it will likely be much higher than the previous two projects

Why this works?

- Utilizing existing infrastructures:
  - Use underground mine areas as a lower reservoir
  - Existing transmission line & local distribution network
- Repurpose legacy assets from risk management to revenue generation
- Economic and environmental upsides similar to previous two projects

Challenges

- Prepare an underground reservoir is cost intensive to remove existing infrastructure and engineer an area that water does not leak
- Actual cost not yet determined (study underway)

Photo credit: University of Duisburg-Essen

Opportunities in Asia

- There are many near end-of-life and abandoned mines in Asia
- A closure sites is a liability to the mining company
- Re-purposing legacy assets from risk management to revenue generation is a win-win situation
- Mining assets can readily minimize the CAPEX of at least one reservoir
- Some mines have both surface and underground operations, which may be converted to the two reservoirs
- Take advantage of existing electrical infrastructure
- Sustain and create economic opportunities

Photo Credit: Freeport-McMoRan Indonesian mine (http://www.mining.com/the-worlds-top-10-gold-mines/)

Thank you

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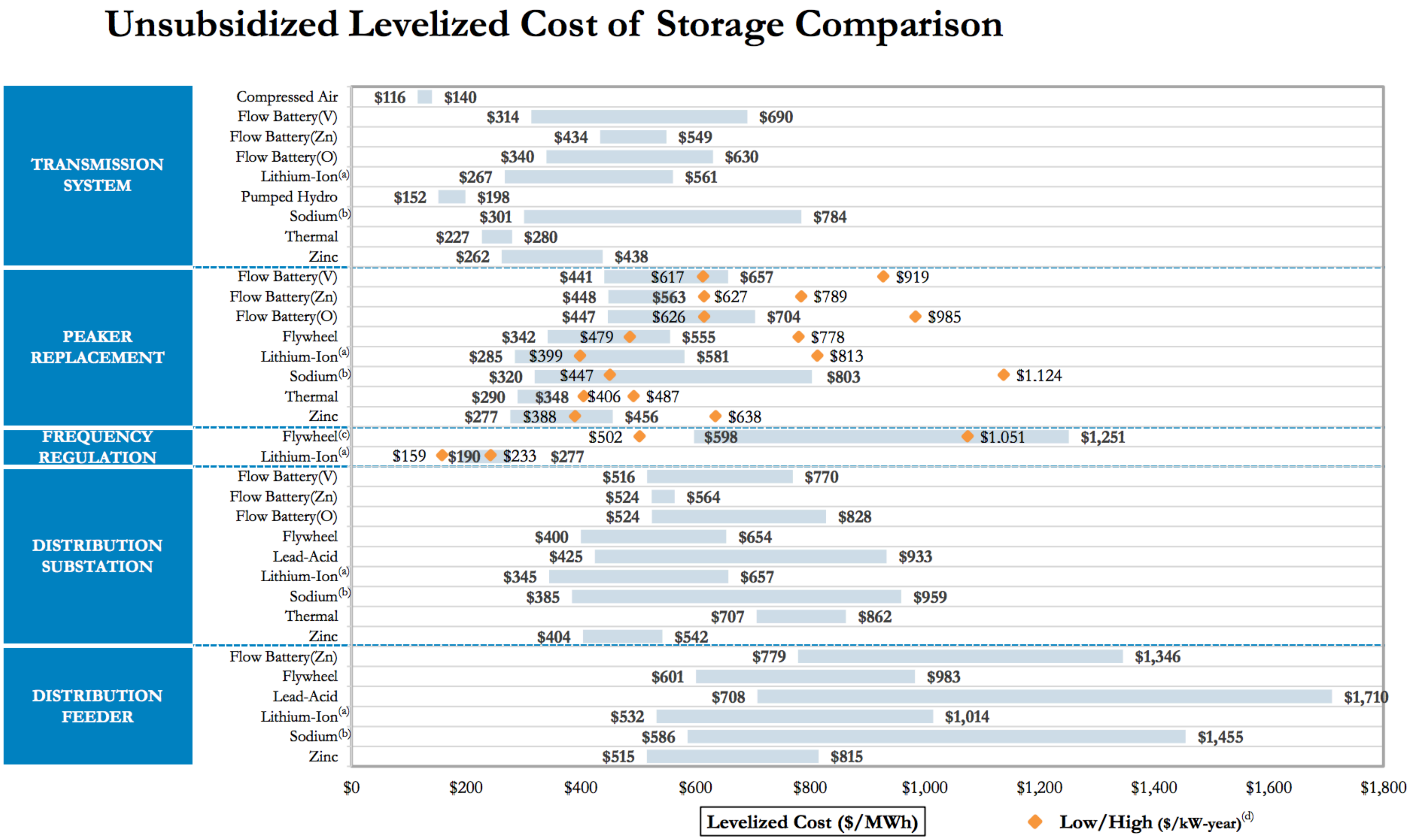
Characteristics of energy storage technologies

Technologies	Power rating (MW)	Storage duration (h)	Cycling or lifetime	Self-discharge (%)	Energy density (Wh/l)	Power density (W/l)	Efficiency (%)	Response time
Super-capacitor	0.01-1	ms-min	10,000-100,000	20-40	10-20	40,000-120,000	80-98	10-20ms
SMES	0.1-1	ms-min	100,000	10-15	~6	1000-4000	80-95	< 100ms
PHS	100-1,000	4-12h	30-60 years	~0	0.2-2	0.1-0.2	70-85	sec-min
CAES	10-1,000	2-30h	20-40 years	~0	2-6	0.2-0.6	40-75	sec-min
Flywheels	0.001-1	sec-hours	20,000-100,000	1.3-100	20-80	5,000	70-95	10-20ms
NaS battery	10-100	1min-8h	2,500-4,400	0.05-20	150-300	120-160	70-90	10-20ms
Li-ion battery	0.1-100	1min-8h	1,000-10,000	0.1-0.3	200-400	1,300-10,000	85-98	10-20ms
Flow battery	01-100	1-0h	12,000-14,000	0.2	20-70	0.5-2	60-85	10-20ms
Hydrogen	0.01-1.000	min-weeks	5-30 years	0-4	600 (200 bar)	0.2-20	25-45	sec-min
SNG	50-1.000	hours-weeks	30 years	negligible	1,800 (200 bar)	0.2-2	25-50	sec-min

Electrical   Mechanical   Electrochemical   Chemical

Source: Deloitte, 2016, Energy storage: Tracking the technologies that will transform the power sector

Levelized Cost of Energy Range



Project Parameters determined as a result of the Technical Feasibility Study process:

Kidston Project parameters

Parameter	Value
Installed Capacity	250MW
Storage Capacity	1,500MWh
Continuous Generation Duration	6 hours
Turbine Configuration	2 x 125MW Fixed Speed Turbines
Upper Reservoir Volume	2.8 Gigalitres or 2.8 Million m^3
Upper Reservoir FSL	579.0
Upper Reservoir MOL	571.0
Upper Reservoir Fluctuation	8.0m
Lower Reservoir FSL	376.6
Lower Reservoir MOL	349.0
Lower Reservoir Fluctuation	27.6m
Maximum Gross Head	230.0m
Minimum Gross Head	194.4m
Net Head Ratio	1.23
Time to Ramp Up to Full Generation Capacity	30 seconds

Source: Lazard LCOE v2.0, December 2016