Fact Sheet:

Batteries

Background

Secondary cells or rechargeable batteries is a type of electrical battery that can be charged and discharged. Battery can be made using very different materials. The most produced battery in the recent years is the lithium-ion type. Batteries have loss of charge when not in use, this value depends strongly on their composition. Batteries answer to charge and discharge is very fast in comparison to other storage methods. The prices of batteries is linearly proportional to its storage capacity (50 MW cost roughly twice as much as 25 MW batteries).

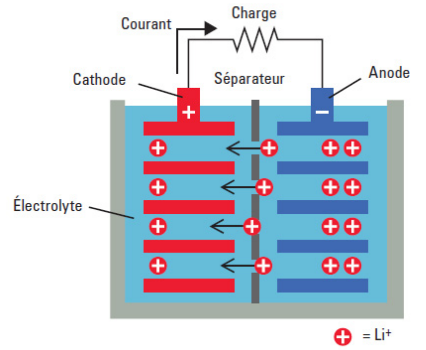

Figure 1: Schematic of Power to Gas system [1].

Example of applications:

LG Chem RESU house battery 5kW [2].

Alevo GridBank Li-ion battery 2MW [3]

Tesla Powerpack in South Australia with 100 MW of capacity [4].

Advantages

- Technology readiness level is high
- Efficient
- Very fast charge and discharge (useful for flexibility)
- Scaling up is fairly easy

Disadvantages

- Expensive
- Materials are mostly not very environmentally friendly
- Often limited in number of charge-discharge

Properties

Time:	Very fast answer (<0.2 second)
Efficiency:	Elec. → Battery (>90%), Battery → Elec. (>90%)
Cost:	~400$/kWh
Scale:	From Watt to 130 kW (in 2018)
Service life:	Very depending on type of Battery, usually 50'000 cycle (charge-discharge)
Energy density:	~450 kJ/kg or ~ 900 kJ/l

References

[1] M. Götz, *et. al.*, "Renewable Power-to-Gas: A technological and economic review," Renewable Energy, vol. 85, pp. 1371–1390, Jan. 2016

[2] LG Chem catalogue "Change your energy charge your life" (Aug 2017)

[3] Alevo GridBank www.postauto.ch (06.2018)

[4] BioCat Project Gas Grid Production (Denmark): http://biocat-project.com/ (06.2018)

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Fact Sheet:

Compressed Gas

Background

Compressed gas storage is a very similar technology than the pumped-storage hydrostorage. In the latter case, water is pumped to a higher elevation, in the compressed gas storage a gas, generally air, is pumped to a higher pressure. There are two type of storage: constant volume or constant pressure storage. Constant pressure storage has a higher efficiency of the turbomachinery whereas constant volume storage is often cheaper. Smaller application of energy storage using compressed air such as air-driven vehicle is as well developed (like the AIRPod 2.0 car developed by MDI [1].

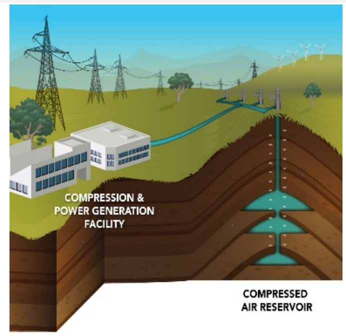
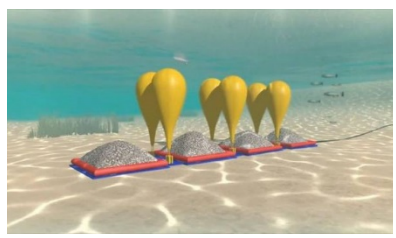


Figure 1: Schematic of system [2].

Example of applications:

Enairys' Hydro-Pneumatic Energy Storage, an air battery [3].



Hydrostor project: compressed air stored in underwater ballons [4]

Alacaes uses caverns in mountains to store gas [5]

Advantages

- Low-cost for large-scale
- Availability: using air as energy storage
- Storage in non-visible location possible
- Using natural components and easy to recycle metals
- Long duration storage without leak

Disadvantages

- Compressed gas has a low energy density
- Heat loss depending on the compression
- Disadvantage 3

Properties

Time:	XX s/Wh
Efficiency:	~70 %
Cost:	XX $ / kWh
Scale:	From XX W to XX kW
Service life:	XX years
Cost range:	XX $

References

[1] https://zeropollutionmotors.us/ (06.2018)
[2] www.technologybloggers.org (06.2018)
[3] http://www.enairys.com (06.2018)
[4] https://www.hydrostor.ca/ (06.2018)
[5] www.alacaes.com (06.2018)

Fact Sheet:

Flywheel

Background

Flywheel use the rotation of a cylindrical heavy piece of metal mounting on bearings to store mechanical energy. It can store and give energy extremely fast. Flywheel has been used in vehicle to store breaking energy or as a battery. A 20 tons flywheel is used at the EPFL in Lausanne to store grid electricity and then provide a powerful pulse of electricity to the TOKAMAK lasting only a few seconds. NASA also designed a Flywheel working under vacuum and a new company called Teraloop is creating a flywheel levitated on an electromagnetic field. Flywheel is a very interesting energy storage system for a short to medium period.

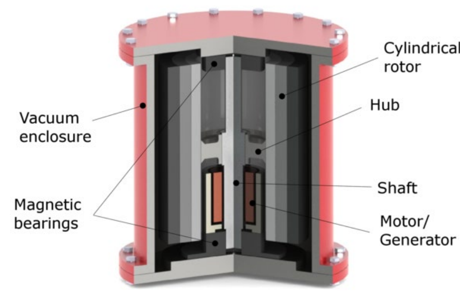
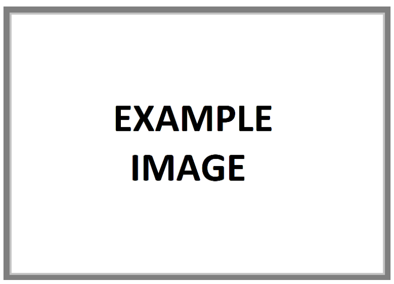
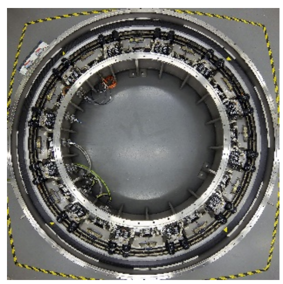


Figure 1: Schematic of system (CC).

Example of applications:



Flywheel in a car [2].



Teraloop [3]

EPFL 20 tons Flywheel [4]

Advantages

- Efficient
- Variable energy density
- Indefinite lifespan
- High energy storage capacity
- Can be made out of renewable material

Disadvantages

- Heavy and bulky
- Fixed square surface area and volume
- Energy loss due to friction

Properties

Time:	XX s/Wh
Efficiency:	XX %
Cost:	XX $ / kWh
Scale:	From XX W to XX kW
Service life:	XX years
Cost range:	XX $

References

[1] www.website1.com (date of visite)
[2] Reference 2
[3] https://www.teraloop.org/ (Jan 2019)
[4] https://actu.epfl.ch/news/the-motor-generator-is-spinning-its-web-again/ (Jan 2019)

Fact Sheet:

Name of technology

Background

Ice storage is using the latent internal energy of crystallization of water to store energy. Energy can be restored by melting the ice. The advantage of ice storage is the price and the availability of the water. The energy stored is usable at a constant temperature. Ice storage is mostly used in residential buildings. In practice it is either used with thermo-solar panel and heat pump in winter. But mostly ice storage is used in order to shift the electricity consumption of the air-conditioning system from peak to off-peak price period. Ice-storage is one of the best storage system for cooling of building.

Ice forming around the heat exchanger coils inside an ice storage [1].

Example of applications:

IceBrick™ [2].

IceBear 20:with a capacity of 28 kWh [3]

20 MW of CALMAC's IceBank for a School in South Flordia [4]

Advantages

- Water is cheap and easily obtainable
- Optimal temperature of melting for air conditioning usage
- Using latent heat increase the energy density

Disadvantages

- Heat loss with time
- Can only be use at 0°C
-

Properties

Time:	XX s/Wh
Efficiency:	XX %
Cost:	XX $ / kWh
Scale:	From XX W to XX kW
Service life:	XX years
Cost range:	XX $

References

[1] https://www.ice-energy.com/grid (Jan 2019)
[2] http://nostromo.energy/icebrick-2/ (Jan 2019)
[3] https://www.ice-energy.com/technology/ (Jan 2019)
[4] http://www.calmac.com/energy-storage-case-study-sarasota-school-district (Jan 2019)

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Fact Sheet:

Power-to-Gas

Background

The Power-to-Gas (PtG) process is the transformation of electric energy into storable methane or hydrogen via electrolysis and/or subsequent methanation [1].Different technologies exist for the two processes electrolysis and methanation, each with advantages and drawbacks. The efficiency of the two processes are around 70% and 80% respectively. Hydrogen as fuel has the main advantage of not producing CO_2 at the location of use but is a gas, which is extremely flammable and difficult to contain, whereas methane is a standard fuel and can be made CO_2 neutral. However, it is less efficient to produce methane. Power-to-gas could be the perfect system in symbiosis with the intermittent renewable energy production mix of the future.

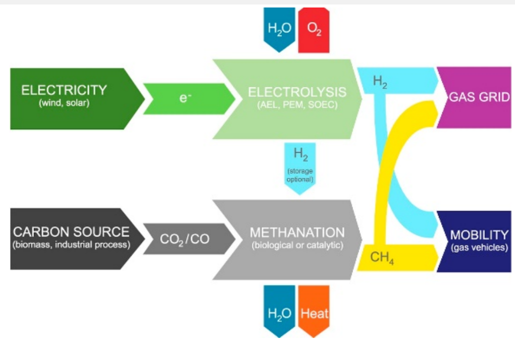

Figure 1: Schematic of Power to Gas system [1].

Example of applications:

Research project, H_2 production and underground storage [2].

H2 production used by fuel cell PostBus. Max. day production: 2500 nm³ [3]

1MW of electricity is used to generate methane for gas grid [4].

Advantages

- Environmental friendly storage for intermittent electrical sources
- Methane grid infrastructure is already there & long distance energy transport efficient
- Natural Gas (methane) can be made CO_2 neutral
- Gas storage is easy

Disadvantages

- Expensive
- Efficiency
- Storage for H_2 is difficult
- A lot of promising electrolysis technologies are still under development

Properties

Time:	XX s/Wh
Efficiency:	Elec. → H_2 (60-70%), Elec. → H_2 → CH_4 (50-60%). H_2 or CH_4 → Elec. (60%)
Cost:	Hydrogen, natural gas, biogas, methanol, ethanol
Scale:	XX Wh/m³ @ XX bar
Service life:	XX years
Cost range:	XX

References

[1] M. Götz, *et. al.*, "Renewable Power-to-Gas: A technological and economic review," Renewable Energy, vol. 85, pp. 1371–1390, Jan. 2016

[2] Underground Sun Storage Project (Austria): www.underground-sun-storage.at. (06.2018)

[3] Swiss PostAuto production and used of H2 for public transport. www.postauto.ch (06.2018)

[4] BioCat Project Gas Grid Production (Denmark): http://biocat-project.com/ (06.2018)

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Fact Sheet:

Pumped Storage Hydropower

Background

Pumped-storage hydroelectricity is a technology used since more than a hundred years. At first, it was used to compensate the difference between the constant production of nuclear power plant and the fluctuating consumer demand. Then the low price of petroleum leading to a low-price of electricity made the hydroelectricity too expensive. Nowadays, as most of the country move towards a higher production coming from renewable energy, hydroelectricity is a perfect technology to compensate the fluctuating nature of renewable production.

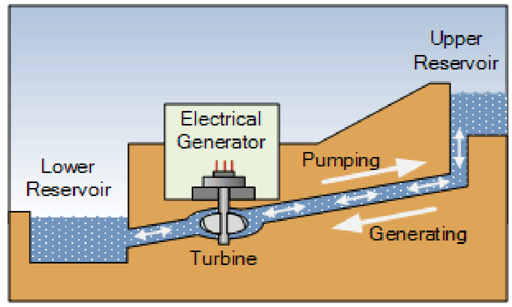

Figure 1: Schematic of system [1].

Example of applications:

Hongrin dam with a 480MW power capacity [2].

Linthal hydropowerplant of 1450MW [3]

Grande-Dixence: 2000MW dam where ~60% of its water is pumped [4]

Advantages

- Can store a high amount of energy
- New systems have quick answer time (a few minutes)
- Long live-time.
- Very-eco friendly (except concrete production)
- No leakage with time
- Long duration storage

Disadvantages

- Very high capex
- High surface footprint
- Cannot really be upgraded
- Very safe, but big problems have tremendous impact (flooding, etc.)
- Construction can have big impacts

Properties

Time:	few minutes
Efficiency:	El. → Pump → El. (~75%)
Cost:	XX $ / kWh
Scale:	From XX W to XX kW
Service life:	XX years
Cost range:	XX $

References

[1] www.alternative-energy-tutorials.com (06.2018)
[2] http://www.fmhl.ch/ (06.2018)
[3] International hydropower association, *Hydropower Status Report* (2017)
[4] www.grande-dixence.ch (06.2018)

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