

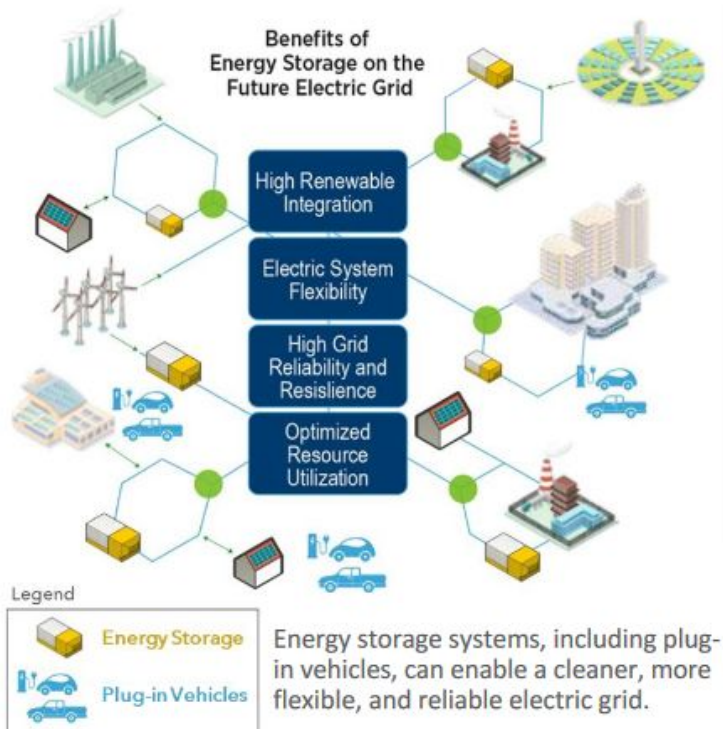


# **Renewable Energy & Sustainable Engineering Panel**

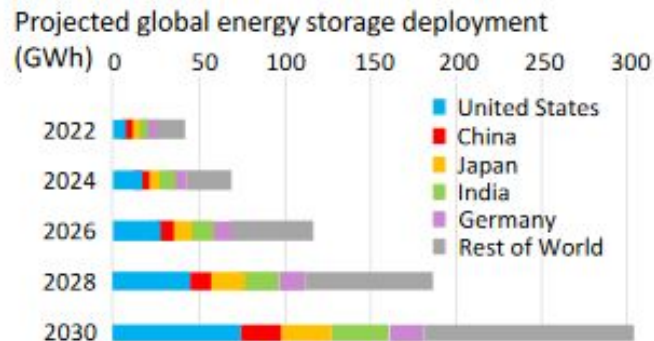
## **Energy Storage Technology**

Nadine Humphrey  
University of Pittsburgh  
2018 cohort

# Energy storage is a key component of expanding renewable technology

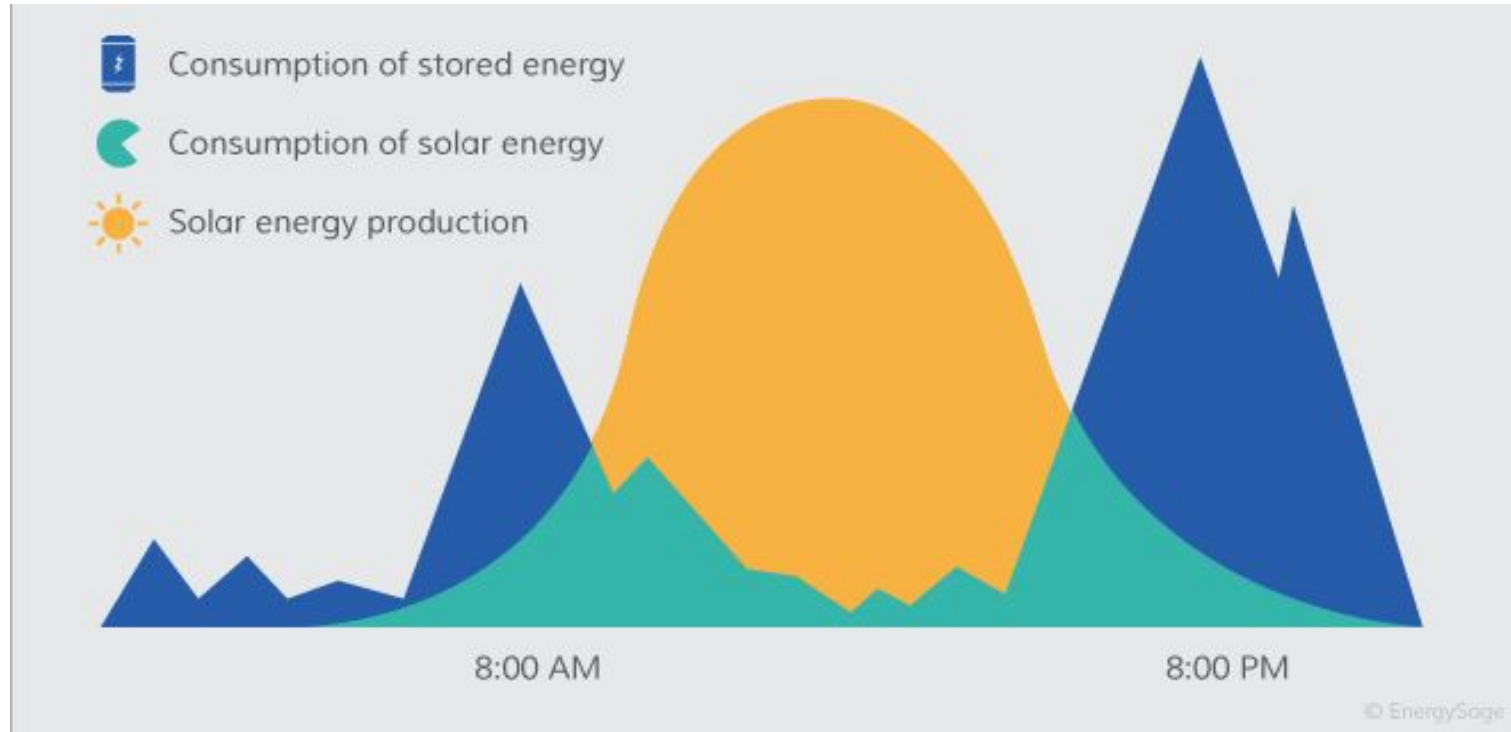


Storage technologies are becoming more efficient and economically viable. One study found that the economic value of energy storage in the U.S. is **\$228.4 billion** over a 10 year period.

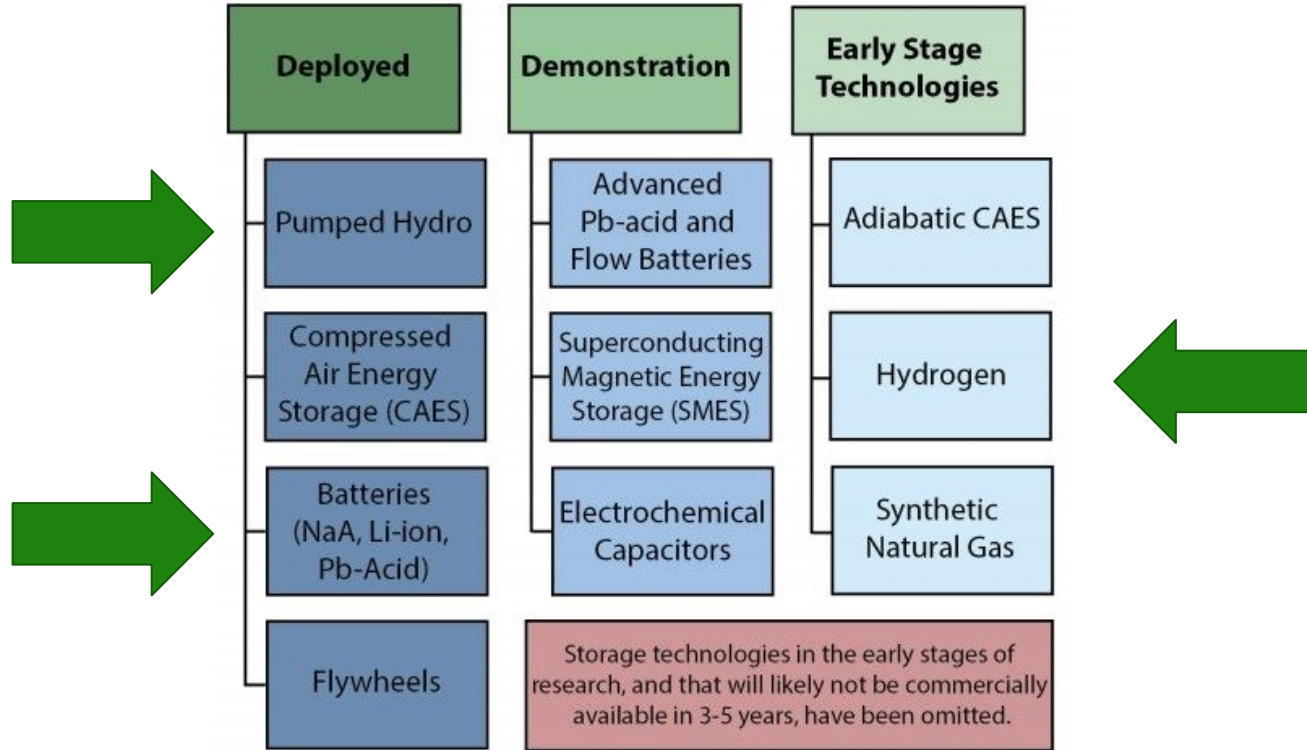


[Adapted from Bloomberg New Energy Finance 2017]

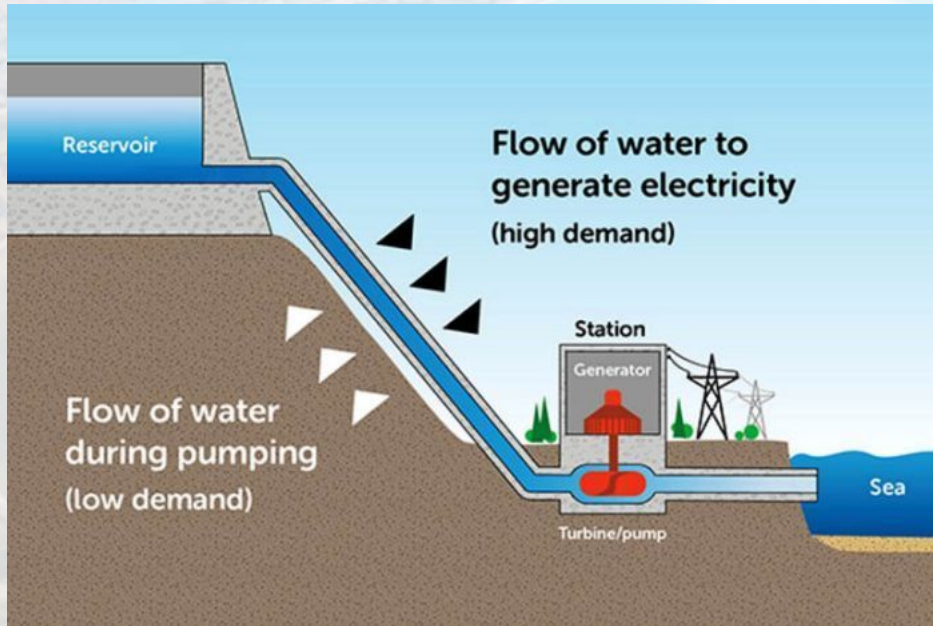
# Energy generation and consumption operate in opposite time zones



# Maturity and Range of Energy Storage Technologies



# Pumped hydroelectric storage systems are simple systems that store potential energy



## Pros

- Established technology
- Long lifetimes (50 - 60 years)
- High operational efficiencies (70 - 85%)
- Low storage costs



## Cons

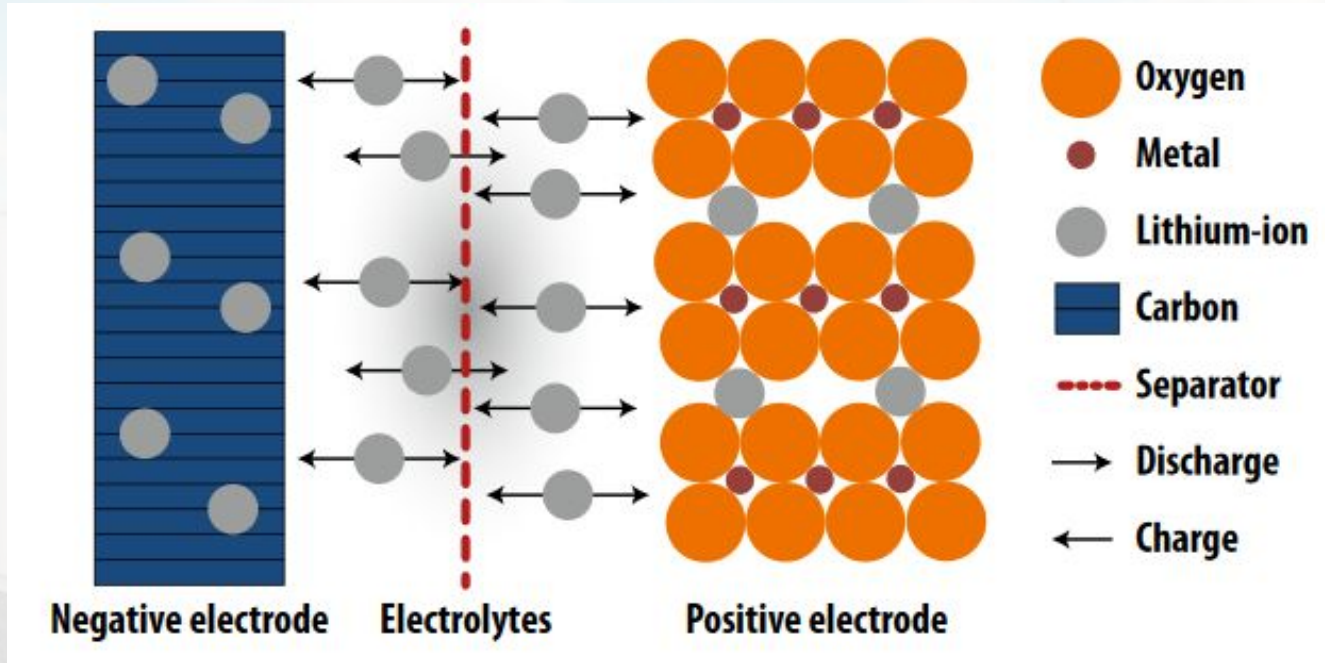
- Limited geographical applications
- High initial investment costs
- Permits and regulations ("red tape")
- Low energy density (large footprint)



# Gravity batteries are emerging alternatives to the pumped hydroelectric storage systems

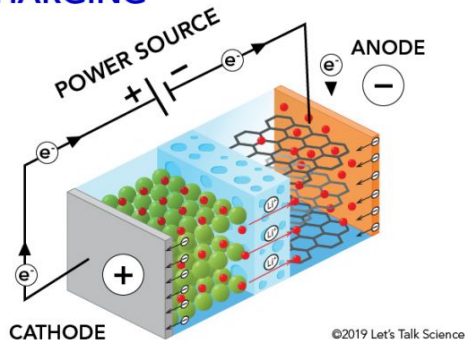


# Li-ion batteries use lithium metal oxide at the cathode and graphite at the anode to (dis)charge energy

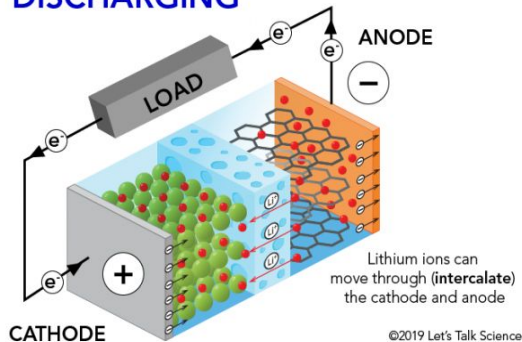


# Li-ion batteries have great advantages, but are still a developing technology

## CHARGING



## DISCHARGING



## Pros

- Rechargeable
- High energy and power density
- Self-discharge (1 min - 8 h)
- High operational efficiency (85 - 95%)



## Cons

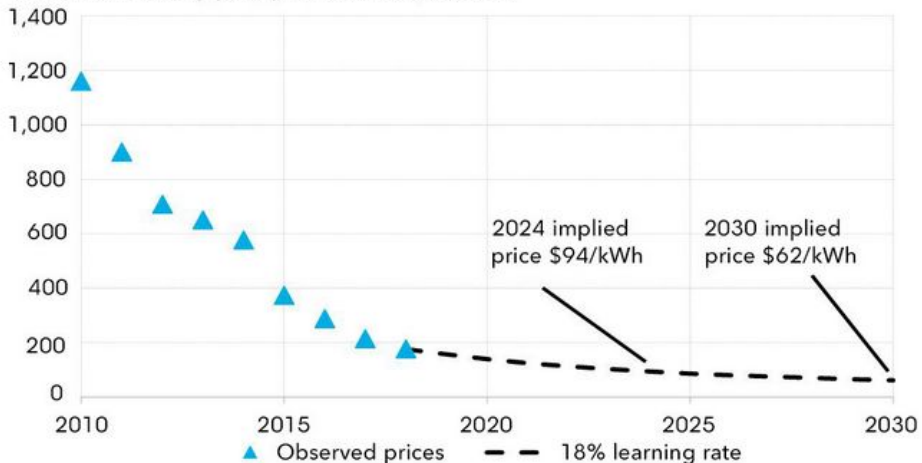
- Can cause battery fires (Samsung Note 7)
- Ageing (only able to last ~15 years)
- Transportation issues
- Cost (40% more than Nickel cadmium cells)



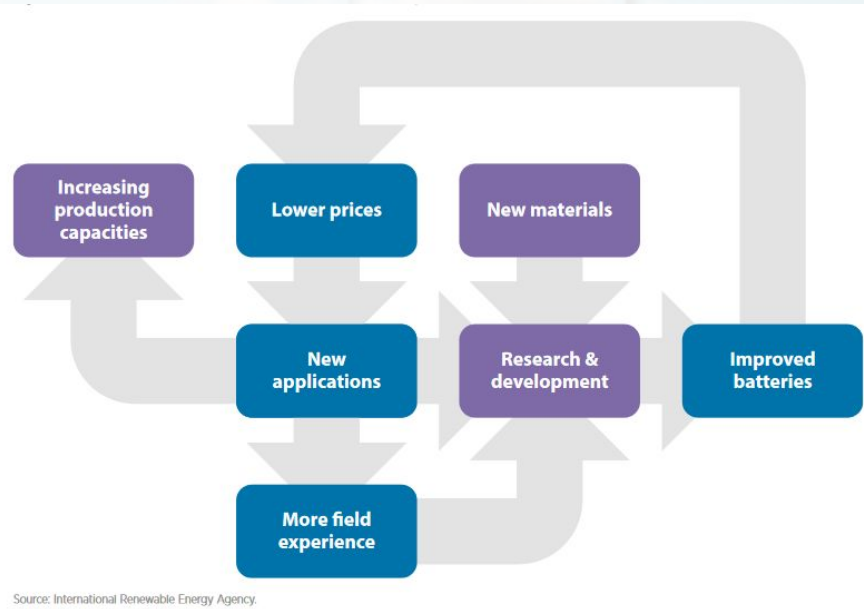
# Cost reduction strategies are working to make li-ion batteries more economical

Lithium-ion battery price outlook

Lithium-ion battery pack price (real 2018 \$/kWh)

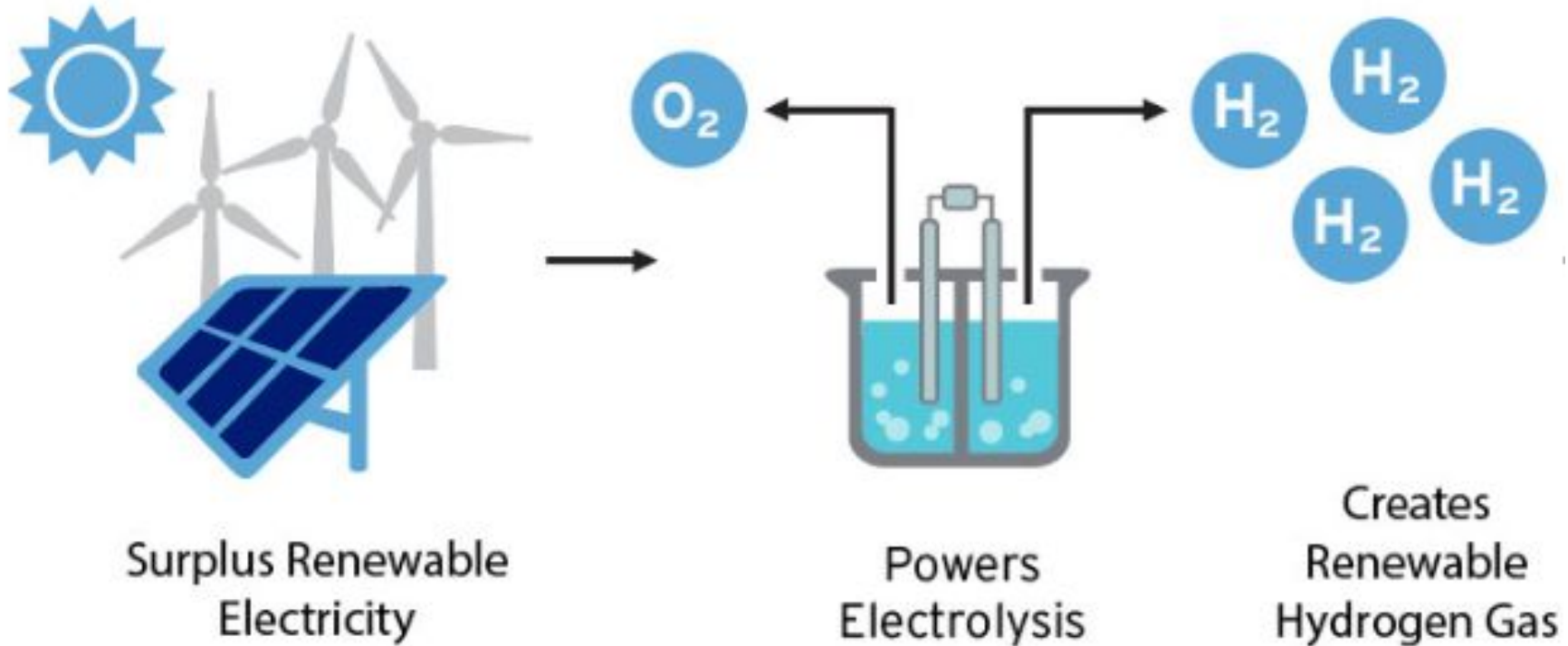


Source: BloombergNEF

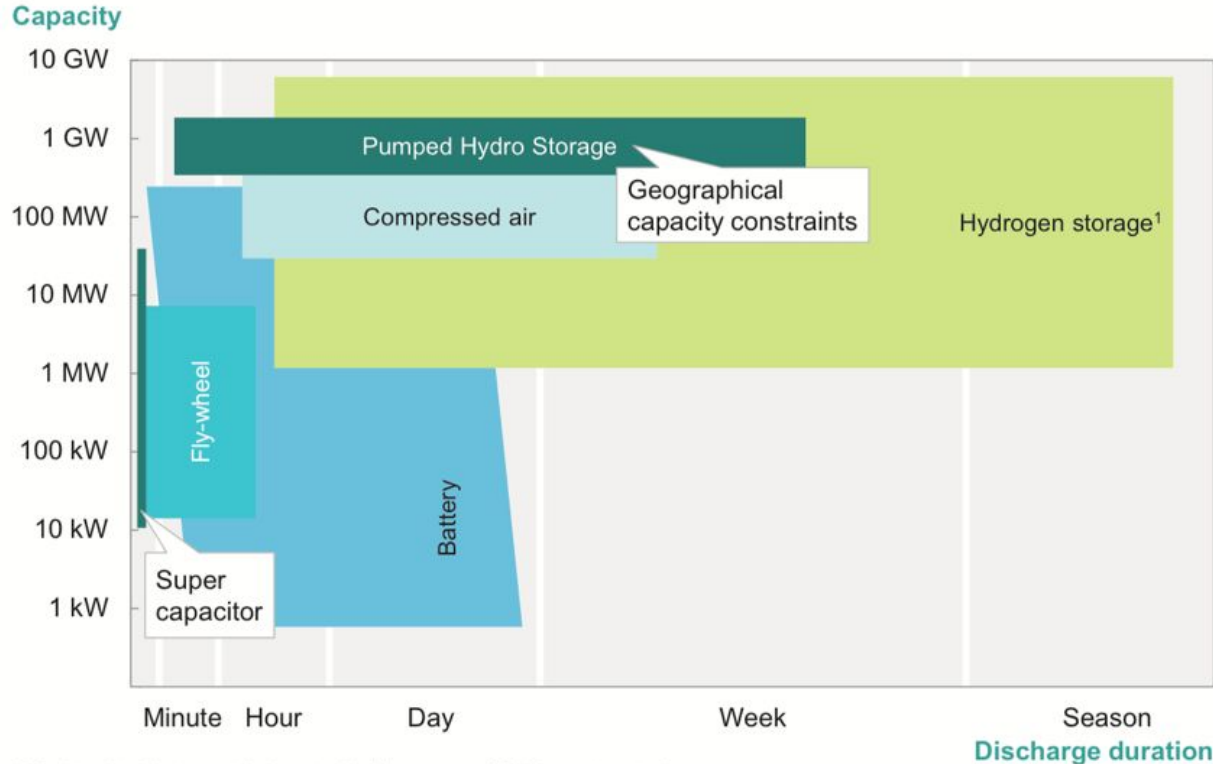


Source: International Renewable Energy Agency.

# Hydrogen electrolysis is a scalable, long-term solution to energy storage



# Hydrogen storage has the potential for seasonal energy storage, longer than anything currently available



<sup>1</sup> IEA data updated due to recent developments in building numerous 1MW hydrogen storage tanks

Source: IEA Energy Technology Roadmap Hydrogen and Fuel Cells, JRC Scientific and Policy Report 2013

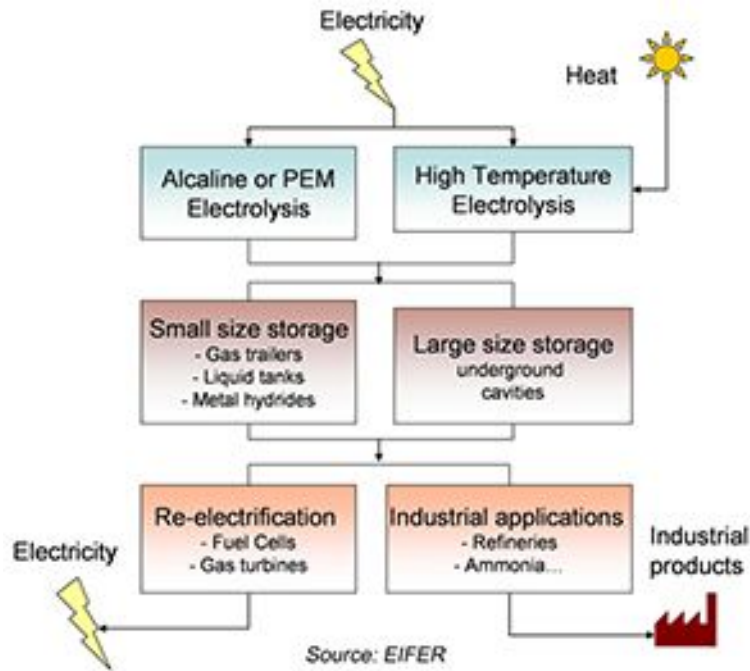


Sun



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# Hydrogen electrolysis storage scalability make it a great boon, but more research is needed



## Pros

- Environmentally-Friendly
- Fuel-Efficiency (65%~70%)
- Can be re-electrified in fuel cells (max 50% efficiency)



## Cons

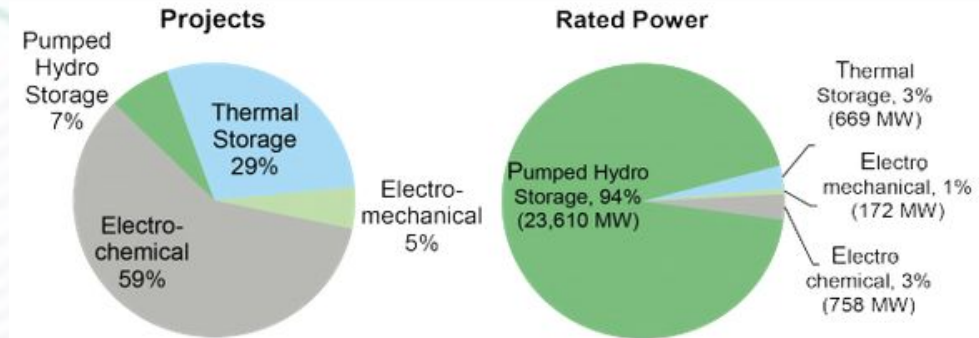
- Hard To Transport
- Very Flammable
- High cost (raw materials like Pt)
- Current grid not the ideal source of electricity for electrolysis



# Federal energy storage policies are promoting development of new technologies

**February 2018:** the Federal Energy Regulatory Commission (FERC) unanimously approved an order that will lead to greater market competition in the energy grid sector.

**May 2018:** the Department of Energy's Advanced Research Projects Agency (ARPA-E) committed up to \$30 million in funding for long-term energy storage innovation.



# Other Resources

- [http://css.umich.edu/sites/default/files/US%20Grid%20Energy%20Storage\\_CSS15-17\\_e2020.pdf](http://css.umich.edu/sites/default/files/US%20Grid%20Energy%20Storage_CSS15-17_e2020.pdf)
- <https://www.eesi.org/papers/view/energy-storage-2019>
- <https://www.forbes.com/sites/forbestechcouncil/2020/08/04/what-is-next-for-energy-storage-technology>
- <https://www.nrel.gov/news/features/2020/declining-renewable-costs-drive-focus-on-energy-storage.html>
- [https://www.worldenergy.org/assets/downloads/ESM\\_Final\\_Report\\_05-Nov-2019.pdf](https://www.worldenergy.org/assets/downloads/ESM_Final_Report_05-Nov-2019.pdf)
- [https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2017/Oct/IRENA\\_Electricity\\_Storage\\_Costs\\_2017.pdf](https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2017/Oct/IRENA_Electricity_Storage_Costs_2017.pdf)
- [https://www.energy.gov/sites/prod/files/2019/07/f65/Storage%20Cost%20and%20Performance%20Characterization%20Report\\_Final.pdf](https://www.energy.gov/sites/prod/files/2019/07/f65/Storage%20Cost%20and%20Performance%20Characterization%20Report_Final.pdf)
- [https://www.energy.gov/sites/prod/files/2018/09/f55/2018-08-23\\_Spotlight%20on%20Energy%20Storage%20-%20Brochure%20and%20Success%20Stories\\_0.pdf](https://www.energy.gov/sites/prod/files/2018/09/f55/2018-08-23_Spotlight%20on%20Energy%20Storage%20-%20Brochure%20and%20Success%20Stories_0.pdf)

Thank you for listening