Environmental Implications of Energy Storage Systems

Rebecca Macdonald and Birce Dikici (Advisor)

EMBRY-RIDDLE Aeronautical University

Introduction

With the continuously evolving energy markets and increasing efforts for climate change mitigation, research into emerging trends and future advancements in energy storage is becoming increasingly crucial.
This literature review was conducted to explore the various types of energy storage systems currently available and to investigate the ongoing advancements in energy storage technology.

Figure 1: Categories of Energy Storage Systems

Current Energy Storage Systems in the U.S.

Pumped Hydro

Energy is stored in the upper of the two different reservoir levels with the system cycling water through both using gravitational potential energy. *Application: Stabilize power grids. Challenge: Location of site requirements.*

Thermal

Energy is stored in either a solid, liquid, or air with heat/cold being captured and released (sometimes including a state change). *Application: Residential building, space heating and cooling. Challenge: Development of high temperature storage with turbine [2].*

Battery

A range of chemistries, all batteries storage is electrochemical with one (or more) cell(s) with a positive and negative terminals. Multiple batteries are connected in series or parallel for steady power. *Application: Electric vehicles. Challenge: Disposal/ end-of-life waste management.*

Compressed Air

Energy is stored by air compression in an underground cavern and then released to be heated and used with turbines to convert to kinetic energy. *Application: Microgrid systems. Challenge: Mechanical fatigue [2].*

Flywheel

Using a vacuum, energy storage is mechanical through kinetic energy of rotors spinning withing a cylinder on a stator with magnetic glide bearings. *Application: transportation (locomotive). Challenge: Long-term use causes low efficiency. [2]*

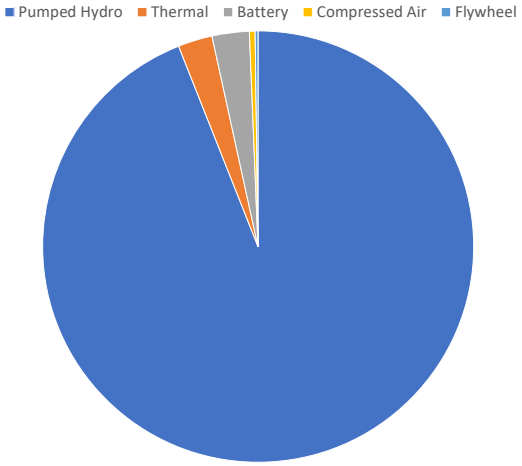

Figure 2: "Electricity Storage Capacity in the U.S. by Type of Storage Technology" [1]

Current Environmental Impacts

- Overall, the use of energy storage systems reduces carbon emissions significantly.
  - Reduced by having higher efficiency and life cycles, while having a long-life span.
  - Some applications, like pumped hydro, require large space reservoir site away from inhabited areas as to not negatively impact the environment.
  - In battery applications, the end-of-life disposal of the battery it critical as this can lead to many environmental negative impacts.

Table 1: Factors that Influence Selection of Energy Storage Systems [2] & [3]

	Energy Density	Efficiency	Life Cycle	Cost
Pump Hydro	3	2	2	5
Thermal	2	5	4	3
Battery	1	3	5	1
Comp. Air	5	4	3	4
Flywheel	4	1	1	2

Renewable Energy Sources

- Implementing more along with renewable energy sources will cause a more positive environmental impact. [3]

Flywheel Example:

- Integration with renewable energy source power plant system that has a 90% performance, longer life cycle, higher power, and higher energy density. [3]

Thermal Example:

- Integration with renewable energy sources, they can be used to mitigate the intermittency "by storing heat in water tanks, molten salts, or another material" [4].

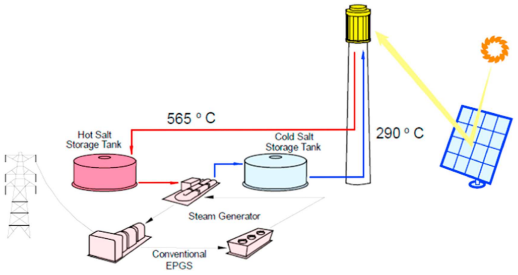

Figure 3: Example of Thermal Storage System pairing with Solar Tower and Molten Salts

Main Goals of the Future

- Need high efficiency and low cost in high demand times.[2]
- More research for new/update technology in energy storage to meet capacity needs.

References

[1] United States Environmental Protection Agency, "Electricity Storage," Energy and the Environment. Accessed: Mar. 26, 2024. [Online]. Available: https://www.epa.gov/energy/electricity-storage

[2] H. Ibrahim, A. Ilinca, and J. Perron, "Energy storage systems-Characteristics and comparisons," *Renewable and Sustainable Energy Reviews*, vol. 12, no. 5. pp. 1221–1250, Jun. 2008. doi: 10.1016/j.rser.2007.01.023.

[3] A. G. Olabi, C. Onumaegbu, T. Wilberforce, M. Ramadan, M. A. Abdelkareem, and A. H. Al – Alami, "Critical review of energy storage systems," *Energy*, vol. 214, Jan. 2021, doi: 10.1016/j.energy.2020.118987.

[4] S. Ould Amrouche, D. Rekioua, T. Rekioua, and S. Bacha, "Overview of energy storage in renewable energy systems," Int J Hydrogen Energy, vol. 41, no. 45, pp. 20914–20927, Dec. 2016, doi: 10.1016/j.ijhydene.2016.06.243.

[5] E. González-Roubaud, D. Pérez-Osorio, and C. Prieto, "Review of commercial thermal energy storage in concentrated solar power plants: Steam vs. molten salts," Renewable and Sustainable Energy Reviews, vol. 80. Elsevier Ltd, pp. 133–148, 2017. doi: 10.1016/j.rser.2017.05.084.