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Phys/Envst 104

There's a Great Future in STORAGE

How would you like to spend your winters studying by candlelight in a cold and dark library? Well, this will be your future unless a proper system of energy storage is implemented. Imagine a day when we finally transition to renewable energy sources at Mount Holyoke College, yet we have no way to store it. In the summer solar panels will bring in all of the energy you could ask for and more, but come winter when the sun is scarce, generating sufficient energy will be a challenge. Next, imagine a scenario where there was a methane leak from natural gas storage and we were confronted with a full-fledged power outage on campus. These situations could be avoided if we implemented an effective storage method.

The Importance of Storage:

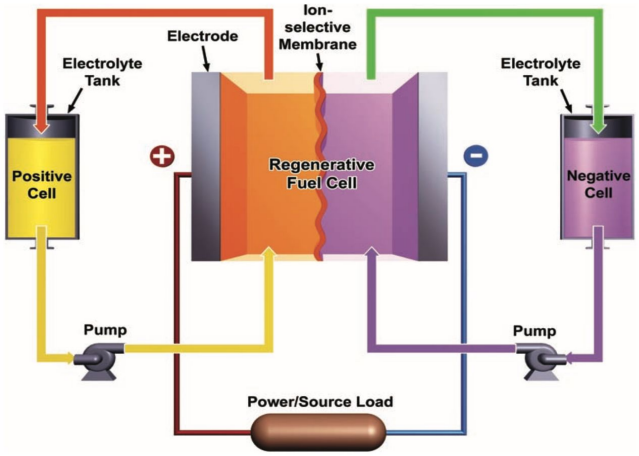
- Storage is already used with non-renewable sources of energy on the grid. For example, nuclear power plants continually generate the same amount of energy day and night, so storage is essential in order to utilize the energy generated at night when demand is low. (HE)
- Storage is critical for renewable sources of energy, such as wind and solar because they have variable energy generation and effective storage techniques are critical to develop to ensure that energy supply and demand match. As we transition to renewable sources of energy at Mount Holyoke College, we will need an effective method of storage to accommodate for the variability of electricity generation from wind and solar.[1] (HE)
- Not only can storage be useful for inconsistency in energy generation, but also for crisis management. For example, in the summer of 2016, there was a massive methane leak from a natural gas storage facility near Los Angeles, California. (HE)
- Faced with the prospect of a large-scale blackout throughout the heavily populated Southern California, the necessity for effective storage became understood as critical.[2] (HE)
- If we can develop an effective storage technique at Mount Holyoke, we will position ourselves well for a possible crisis in addition to complementing renewable energy generation. (HE)

Possible Storage Methods

Flow battery

Pros

- Design flexibility: for flow battery, the power is determined by the size of the electrodes and energy storage is determined by the size of the storage tanks. We can design for power or storage according to our need. (KY)[3]
- It can be recharged instantly by replacing the electrolyte liquid[4]. (KY)
- Longer life: lose only one percent of its capacity per 1000 cycles(charge and discharge)[5]. (KY)
- Fully recyclable electrolyte: more environmentally friendly.[6] (KY)



Cons

- The chemical leakage may cause serious contamination. (KY)
- Architectural disadvantage due to low energy density which will make it bulky.[7] (KY)
- Require more parts (such as pumps) compared with other types of batteries.[8] (KY)

Figure 1: Component for RFB (Redox flow batteries)(KY)[9]

How the flow battery works:

The flow battery consists of two tanks of liquid with two different type of chemical components, and a reaction part. During discharging, the liquids are pumped into the reaction part, and an electron will be released during the oxidation from a high chemical potential state. This electron will move through the external circuit and create a current. Then it will be accepted via a reduction reaction at a lower chemical potential state.[10] (KY)

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[1] Union of Concerned Scientists, "How Energy Storage Works" http://www.ucsusa.org/clean-energy/how-energy-storage-works#.WOpIIVKZOb8

[2] Scientific American, "Battery Storage Poised to Expand Rapidly" https://www.scientificamerican.com/article/battery-storage-poised-to-expand-rapidly/

[3] Energy Storage Association, "Redox flow batteries"

[4] Energy Storage Association, "Redox flow batteries"

[5] John A.Paulson "Long-lasting flow battery could run for more than a decade with minimum upkeep"

[6] Ke-Long Huanga, Xiao-gang Lia, Su-qin Liua, Ning Tana, Li-quan Chen(2007)"Research progress of vanadium redox flow battery for energy storage in China"

[7] Energy Storage Association, "Redox flow batteries"

[8] M. Skyllas-Kazacos, M. H. Chakrabarti, S. A. Hajimolana, F. S. Mjalli, and M. Saleem (2011) "Progress in Flow Battery Research and Development"

[9] Liyu Li,* Soowhan Kim (2011) " A Stable Vanadium Redox-Flow Battery with High Energy Density for Large-Scale Energy Storage"

[10] Clean Techinica "Flow Battery Vs. Tesla Battery Smackdown Looming"

Calculation: MHC's annual use is 30 million kWh for all energy, or roughly 100,000 kWh/day. The energy density for a typical VRB is 24Wh/L[11]. That means if we use solar cells for energy and there's a cloudy day, we will use 4*10^6L of flow battery to help us get through that day, which will occupy a volume of 4000m^3. (KY)

Since the flow battery is still being developed, what about the Lithium-ion battery as an alternative?

Lithium-ion battery:

Pros:

- Lighter in weight than other batteries of the same size, because electrodes are made of a lighter lithium and carbon[12] (LN)
- Can store a large amount of energy because Lithium is very reactive and its atomic bonds have a high energy storing capacity (high energy density) (LN)
- Most lithium-ion batteries can store 150 watt-hours of electricity per one kilogram of battery (LN)
- They are able to hold charge for a long period of time. A typical lithium-ion battery pack only loses about 5 percent of charge each month (in comparison to 20 percent loss per month of NiMH batteries) (LN)
- They do not have to be discharged completely before being recharged (LN)
- They are able to sustain several hundred cycles of charging and discharging (LN)

Cons:

- Once they are manufactured, they begin to age immediately, and last for two to three years after even if they are unused (LN)
- They are sensitive to higher temperatures which cause them to degrade more rapidly, therefore they would need to be housed in very specific conditions (LN)
- They are also sensitive to being discharged completely, and may be destroyed if this is done (LN)
- A computer component is needed in order to manage battery function, adding to cost (LN)
- They are generally expensive, however as new methods of production develop costs may decline (LN)
- Lithium-ion batteries, in rare cases may catch fire (LN)

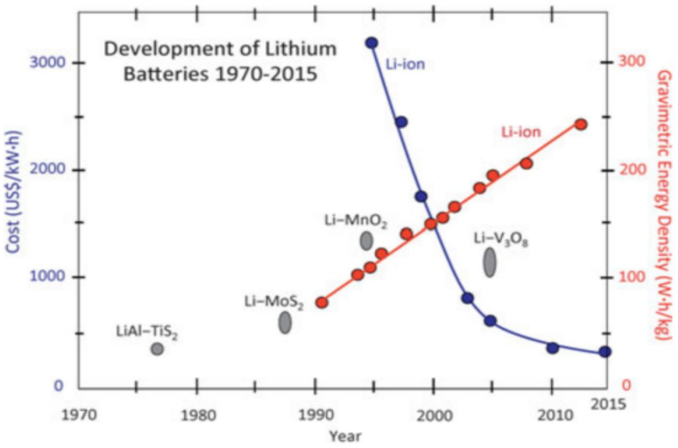

Figure 2: Development of lithium batteries from 1970–2015[13] (LN)

How Storage Could Work at Mount Holyoke:

- In May 2016, at College of Marin in California, Telsa installed five 480-kilowatt lithium-ion batteries located in 10-foot cabinets. These batteries were installed to complement the College's solar energy generation. (HE)
- These batteries could potentially save the College $10,000 dollars a month.[14] Mount Holyoke could use this model from the College of Marin after we install solar panels. (HE)
- Although Tesla paid for the battery installations at the College of Marin, the investment at Mount Holyoke would likely save us money in the future. (HE)
- If the price of installation was not feasible, there are opportunities for price deductions. For example, the state of Massachusetts is willing to provide 50% of the total project cost for institutions that "design, deploy, and prove out energy storage business models."[15] (HE)

Figure 3: The Lithium-ion storage at College of Marin[16] (HE)

Recommendations:

For Mount Holyoke, we would recommend the lithium-ion battery. The flow battery may be a good option for the school in the future, once the technology is more mature. AES Corp. is currently in the process of designing a large lithium-ion battery that would store energy collected from solar panels, to be used at times of peak energy consumption in Long Beach, CA.[17] If this project is successful, it could serve as a model for MHC.

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[11] Ke-Long Huanga, Xiao-gang Lia, Su-qin Liua, Ning Tana, Li-quan Chen(2007)"Research progress of vanadium redox flow battery for energy storage in China"

[12] Everyday-tech "How Lithium-ion Batteries Work" http://electronics.howstuffworks.com/everyday-tech/lithium-ion-battery.htm

[13] George Crabtree, Elizabeth Kocs, and Lynn Trahey (2015)"The energy-storage frontier: Lithium-ion batteries and beyond"

[14] Marinij, "College of Marin gets Tesla batteries for Solar Power Storage" http://www.marinij.com/article/NO/20160515/NEWS/160519871

[15] Massachusetts Clean Energy Center, Advancing Commonwealth Energy Storage (ACES) Program Request for Proposals http://files.masscec.com/Advancing%20Commonwealth%20Energy%20Storage%20%28ACES%29%20RFP%202017.pdf

[16] Marinij, "College of Marin gets Tesla batteries for Solar Power Storage"

[17] Scientific American " World's Largest Storage Battery Will Power Los Angeles" https://www.scientificamerican.com/article/world-s-largest-storage-battery-will-power-los-angeles/