The Impact of Energy Storage on Future Energy Landscapes:

How Research and Development of Proton Exchange Membrane Fuel Cells can Aid the Implementation of Intermittent Renewable Energy Sources.

Colin Carver
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Framing Question: To what degree can current prevalent methods of energy storage be paired with intermittent renewable energy sources?

Focus Questions: What advantages do proton exchange membrane fuel cells (PEMFCs) offer for the storage of intermittent renewable energy sources over other methods of energy storage? What aspects hinder the efficiency/cost of PEMFCs and how can these considerations be addressed?

Abstract—The utilization of renewable energy offers many advantages for mitigating climate change, energy security, reducing toxic pollutants, and promoting social equity, among other effects. However, much of future renewable energy will come from intermittent sources, and efficient methods of energy storage are needed to use this energy effectively. Proton exchange membrane fuel cells (PEMFC) offer distinct advantages to other energy storage methods as they are highly scalable and can be adapted to many uses, but are disadvantage by cost. Improving the performance and reducing the cost of the catalysts used in PEMFCs is the most promising approach for improving PEMFC and successful innovation in this regard will make this technology a highly viable option for intermittent renewable energy storage.

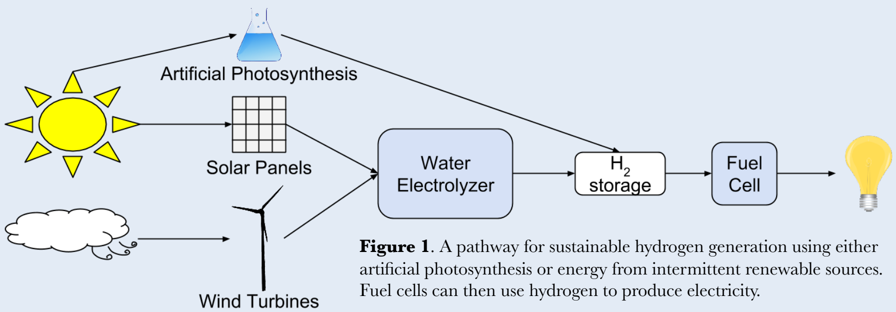

Figure 1. A pathway for sustainable hydrogen generation using either artificial photosynthesis or energy from intermittent renewable sources. Fuel cells can then use hydrogen to produce electricity.

Background—The increased use of intermittent renewable energy, an essential aspect of sustainable development, will require increased energy storage. The most common methods currently used to achieve this are batteries, thermal energy storage, mechanical flywheels, power to gas technology, and pumped-storage hydroelectric. Although these methods will likely play a role in future energy storage, PEMFC are better suited to small and medium scale applications for numerous reasons, but are currently economically uncompetitive. Future research can potentially drastically reduce the cost of PEMFC, making them an efficient way use energy storage from renewable generation. This can increase the use and prevalence of renewable energy in general, a process which will have profound impacts on future energy landscapes, and by effect on broader economic, political, and social behavior.

Method	Energy Density [Wh/kg]	Capacitance [MWh]	Discharge [MW/h]	Response time	Energy loss (per hour)	Cycle-life x 10^3	Round-trip Efficiency	Cost [$/MWh/cycle-life]	Scalability
Li-ion	100-200	20	16	ms	8%-20%	4-8	95%	150-200	High
Na-S	120-150	10^1	34	s	0%	4.3-6	85-90%	90-130	Medium
RFB	10-50	6-120	0.2-100	ms	0%	13	85%	70	High
TES	70	10	20	min	varies	10	-	500	Low
Flywheel	11-30	5	0.3	min	3%-20%	10-100	85%	25-200	High
P2G	-	-	-	days	-	-	42-58%	-	Low
Pumped Hydro	0.3	10^4	300	min	0%	20	70-85%	0.5-3	Medium
CAES	10-30	10^3	30-300	min	0%	30	60%	4-18	Low
PEMFC	800-1300	10	1	ms	0%	200	70%	200	High

Figure 2. The empirical parameters for lithium ion (Li-ion), sodium sulfur (Na-S), and redox flow batteries, along with thermal energy storage (TES), power to gas (P2G), pumped hydro, compressed air energy storage, and PEMFCs are compared. Key parameters for PEMFC included a large energy density, high scalability, and a comparable cost with other methods.

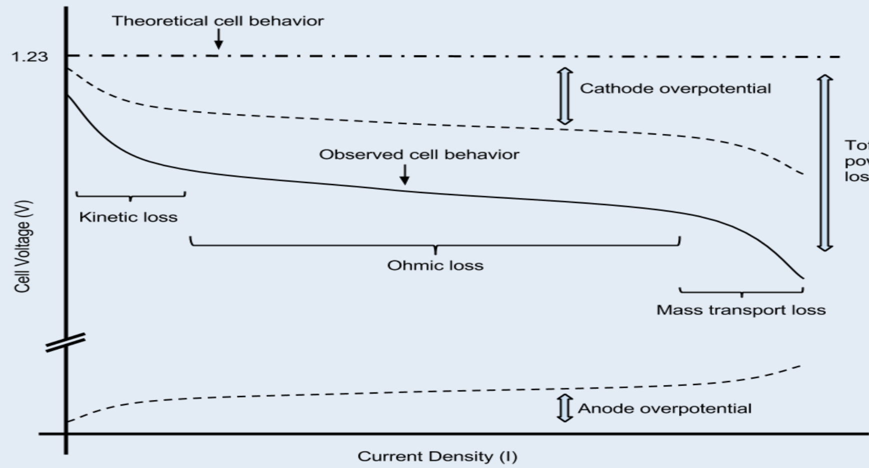

Figure 3. Theoretical and observed PEMFC behavior. Overpotentials are a result of more energy being required by a reaction than theoretical predicted. The overpotential at the cathode is typically two orders of magnitude greater than that of the anode; causing most of the power loss.

Discussion—Although PEMFCs can play a role in future energy landscapes, several key research goals must be met first. First, their cost must be reduced, either through minimal use of expensive the noble metal catalysts currently used or design of new catalyst using only earth abundant elements. Second, the durability must be improved, primarily by preventing the formation of reactive by-products during cell operation. Additionally, current levels of efficient should be either maintained or improved with these changes. With these advancements, PEMFC offer to make a substantial impact of the use of stored energy from intermittent renewable sources. Due to their high energy density and scalability, PEMFC are uniquely suited to small and medium scale applications. Applying PEMFC to these uses reduced pollutants and externalities as compared to fossil fuels.

Greater Impacts—Changing the way in which we generate and use energy will have intense, global impacts. The increased used of renewable sources of energy will lessen the emission of greenhouse gases, limit situated impacts of carbon emissions (such as smog), increase energy security and diversity, and make the generation of energy more geographical diffuse. These impacts stand to encourage equity among social classes and limit the future effects of anthropogenic climate change.

Resources

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