Techno-economic Analysis of Balancing California's Power System on a Seasonal Basis with Hydrogen and Lithium-Ion Batteries

Emre Gençer* and Drake Hernandez
*Corresponding Author: egencer@mit.edu

MIT Technology & Policy Program

MIT Energy Initiative

Introduction

The electric power sector in the United States was responsible for 35% of the nation's CO_2 emissions in 2017. Non-emitting variable renewable energy resources (VREs) are needed on the power grid if the United States is to "deeply decarbonize" the power sector. The intermittent nature of these resources makes them difficult to integrate into the power system. Existing energy storage technologies, such as lithium-ion batteries, could be used to aid the integration of these resources, but these technologies are sized to produce power for hours at a time before needing to be charged again. While these energy storage technologies could address daily imbalances between supply and demand for electric power, they cannot address the seasonal nature of power production of certain VREs, such as hydropower generation. This seasonal imbalance is currently met by fast-ramping natural gas fired turbines whose operation yields emissions of greenhouse gases. This study analyzes the cost competitiveness of serving the load otherwise met by natural gas-fired gas turbines in California with a hydrogen-fired gas turbine (HFGT) relative to a lithium-ion battery system (LI).

Research Questions

- Evaluating the hydrogen value-chain, at what cost could electric power realistically be produced via an HFGT powered by green hydrogen?
- How lithium-ion batteries are necessary to replace the generation profiles of an existing natural gas-fired gas turbine in California?
- How do these technologies compare to one another on a cost basis? Are there instances in which an HFGT is more cost competitive than a LI based on estimates of today's costs?
- Which operating characteristics of the existing natural gas-fired turbine lead a technology to be more cost competitive than the other?
- How does the introduction of blue hydrogen affect the cost competitiveness of an HFGT?

Methodology

In order to compare the cost competitiveness of the two technologies, our analysis relied on the levelized cost of energy (LCOE) metric given the operating profile being replaced by the technologies did not change based on which technology was chosen. The variables used to calculate the LCOE for each technology were determined based on techno-economic assessments of each technology.

LCOE Calculation:

$$LCOE = \frac{\sum_{t=1}^{n} \frac{I_t + M_t + F_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{E_t}{(1+r)^t}}$$

HFGT:
The investment and operation and maintenance variables in each period were determined based on the size of the plant which the HFGT's load replaced. The fuel cost was calculated based on an internally constructed model which estimates the cost of green hydrogen produced via otherwise curtailed solar and the cost associated transportation and storage associated with moving the remotely produced hydrogen.

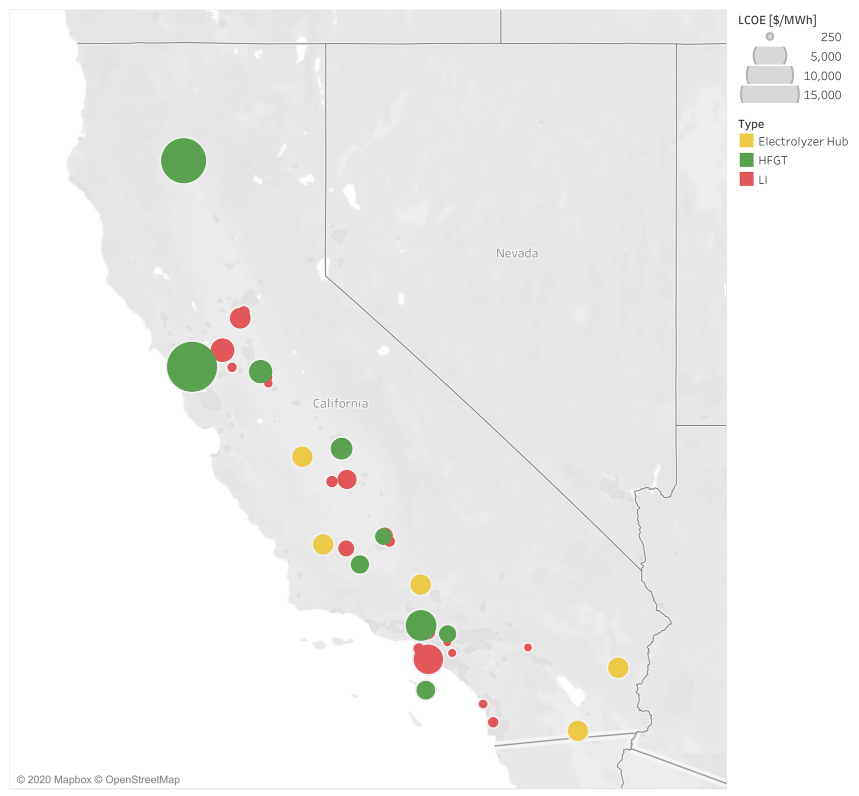
LI:
The investment and operation and maintenance variables for the LI technology are calculated via cost estimates found in Lazard (2019). However, the sizing of the system relied on the energy and power supply replaced. Our model assumed a 4 MWh/1 MW LI. The overall size of the system relies on either the power capacity of the plant it is replacing or the total energy the system would need to replace in order to meet the same generation profile as the existing natural gas-fired turbine. We assume the fuel cost for this technology to be equal to zero as the power would otherwise be curtailed.

Application:
Assessing the existing load for the existing natural-gas fired power plant as mentioned above and applying the LCOE calculation for each technology, we are able to determine which technology is more cost competitive for a given use case.

Taking the results from this analysis, we are able to run a regression and find which operating characteristics of the existing natural-gas fired gas turbine drive each technology's competitive advantage.

Key Results

- An HFGT fueled by with green hydrogen can be more cost effective than lithium-ion batteries based on operating profile of replaced power plant.
- The heat rate of the power plant replaced by either the HFGT or LI is the only significant driver of cost competitiveness between the technologies.
- The HFGT becomes more competitive technology if the replaced gas turbine's heat rate increases



Discussion and Future Work

- While we find there are instances in which an HFGT fueled by green hydrogen is a more cost competitive energy storage technology, one must confront the political and commercial realities around deploying such a quantity of green hydrogen in California.
- At this juncture, while there are power curtailments from VRE production in California, there is not nearly enough otherwise curtailed power to support a massive technology shift from natural gas-fired gas turbines to HFGTs. In order to ensure there is enough otherwise curtailed power, the state of California must continue to see dramatic growth in VRE capacity. However, as more VRE capacity is constructed, the value propositions for financiers may decrease – leading to suboptimal financing.
- Blue hydrogen could be used rather than green hydrogen. However, there are also concerns about supply of blue hydrogen and the lesser carbon benefit as compared to green hydrogen.