ZERO-EMISSION PEAKER FROM HEAVY-DUTY VEHICLE FUEL CELLS AND SALT CAVERN STORAGE

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Overview

As we decarbonize, we will have to address one key challenge of the energy transition: peak power supply. Today, these periods of peak power demand are typically served by "peakers", assets like hydro or fossil fuel fired plants which can quickly be dispatched to meet sudden changes in demand. However, in a power system that is increasingly based in clean but variable renewables, the grid will increasingly require firm zero-emission resources to serve periods of high electricity demand and/or low renewable supply. While the costs of batteries have fallen significantly over the past few years, they remain better suited for short-term storage durations; for long-term storage durations, other zero-carbon solutions are needed (ARPA-E 2020). This need has only been underscored by the increasing frequency of extreme weather events, drought conditions and operating reserve shortfalls.

Our proposal to this challenge is a peaker based on automotive - specifically, heavy-duty vehicle (HDV) - fuel cells paired with salt cavern hydrogen storage. Together, they could form a peaker at $500-600/kW-peak, a fraction of the cost of alternatives; furthermore, such a peaker would emission-free, in contrast to hydrogen and/or biofuel combustion technologies which may not emit carbon, but do emit NOx - a precursor to ozone formation.

Methods

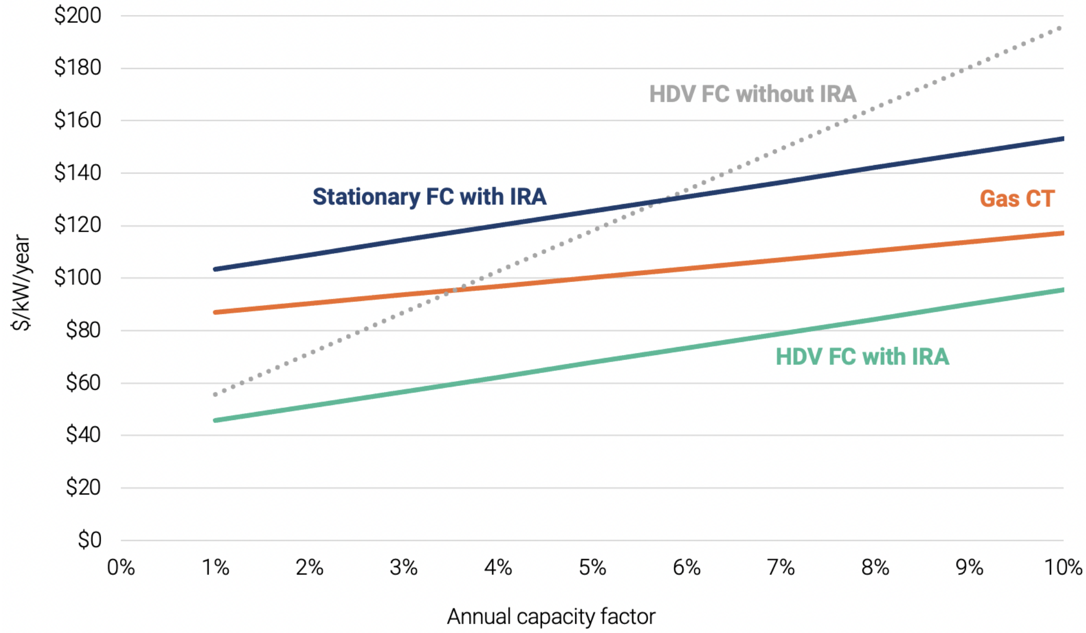
While such a pairing has been explored before, namely by Hunter et al. in 2021 in the context of flexible long-duration storage solutions for grids with high-variable renewable generation as well as tested in a demonstration project at NREL, the literature remains limited on the costs and applications; we aim to fill this gap by performing a techno-economic analysis of the peaker. We explore the current and projected costs as well as the supply chain availability of fuel cells, then analyze the costs of the whole plant (complete with hydrogen production and storage).

Results

From a cost perspective, the lower required lifetime and durability of auto fuel cells (FCs) makes them significantly less expensive than their stationary counterparts (DOE 2019, DOE 2021, Papageorgopoulos 2021). The infrequency of peak power demand events and the corresponding low annual capacity factor of peaker plants does not require the high durability ratings of stationary FCs and supports the use of auto FCs as an attractive, low-cost peaker. Similarly, the geologic storage of hydrogen and natural gas in salt caverns is a proven and mature technology with significantly lower costs than alternative hydrogen storage solutions, like liquified hydrogen or pressurized tanks. If the salt caverns are in close proximity to abundant renewables and existing power transmission infrastructure, the trifecta of conditions for a auto fuel cell peaker is met. In the future, falling costs of hydrogen storage also in rock caverns could expand their reach as well.

To understand the value of a peaker based on auto fuel cells paired with salt cavern hydrogen storage co-located with hydrogen production, we compare the technology to a conventional peaker plant, i.e., a gas-fired combustion turbine. With stacked incentives from the Inflation Reduction Act (IRA) for renewable electricity production, hydrogen production, and the fuel cell investment tax credit levelized over a system lifetime of 30 years, such a peaker proves cost-efficient compared to a natural gas peaker as seen in Figure 1.

Figure 1. Cost comparison of an HDV FC peaker with a gas combustion turbine peaker.



We calculate the cost of hydrogen to be $9.93/MMBtu ($1.34/kg H2) and assume a natural gas price of $3.42/MMBtu, the EIA-reported 2022 average (EIA 2022). Meanwhile, when manufactured at scale, we calculate the capex of a HDV FC peaker to be approximately $500-600/kW. We also perform a sensitivity analysis to explore the effect of differing input variables of resulting annualized costs; the magnitude of the electrolyzer capital cost has the largest impact on the annualized cost of the HDV FC peaker. Importantly, these costs are predicted to fall significantly in the coming years to around $481/kW for the stack, BOP and EPC by 2030 (BNEF 2022).

Conclusions

Looking forward, peakers based on heavy-duty vehicle fuel cells have the potential to be deployed around the US and abroad. In other work, we have explored the feasibility of deploying such a peaker at the Intermountain site in Utah to serve the LA basin. However, auto FC peakers also have significant potential to be deployed in ERCOT as well as northwest Europe, where we are currently analyzing the potential. Both locations currently store hydrogen and natural gas in existing salt caverns.

The proposed solution, a peaker based on relatively inexpensive and less durable HDV fuel cells paired with salt cavern hydrogen storage, would be capable of providing dispatchable firm power to help meet high seasonal demands over multi-day periods. Incentives from the Inflation Reduction Act bring down the capital and operating expenses for such a peaker, making it cost-competitive with natural gas peakers. Such a peaker would not only help us achieve net zero within the set timeframes, but also create a more resilient and sustainable energy system.

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