DOE Hydrogen Program Record	
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Title: Hydrogen Fueling Stations Cost	
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Item

Capital equipment cost estimates[1] for 111 new fueling stations selected for award in California varied between approximately \$1,200 and \$3,000 per kilogram hydrogen dispensed per day (kg/day),[2] depending on daily fueling capacity and hydrogen delivery method.[3] The station capacity ranged from approximately 770 kg/day to 1,620 kg/day, and all stations were designed with 700-bar fueling capability for light-duty vehicles.[4,5]

Background

The development of hydrogen fueling station (HFS) infrastructure is critical to the growth of the FCEV industry. The U.S. currently has over 45 retail HFSs for FCEVs in operation, primarily in California [2]. The California Energy Commission has been funding the deployment of fueling stations for light-duty FCEVs for over a decade, in support of an initial goal to deploy 100 stations by 2024, which was expanded in 2018 to a goal of 200 stations by 2025 [3]. The stations have been designed to meet the SAE International J2601 fueling standard [4] to ensure the safe dispensing of hydrogen into fuel cell light-duty vehicles. Some of those stations could also safely fuel heavy-duty vehicles. Typically, HFSs are supplied with hydrogen via tube trailers, liquid hydrogen tankers, or onsite production. Hydrogen station designs typically include bulk storage, compression/pumping, high-pressure buffer storage, precooling unit, and dispensers, but vary depending on individual site design configuration. In California, HFSs are normally sited at existing gasoline stations. This record documents estimates for the equipment costs of newly developed hydrogen stations.

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[1] Combined total awarded grant and match funding (uninstalled capital cost) for 2020 California Energy Commission awards. These are estimated costs in the grant applications and may differ from final costs after installation but provide the best publicly available itemization to date.

[2] All costs in this record have been adjusted to \$2016 using Chemical Engineering Plant Cost Indices.

[3] Investigation of hydrogen fueling station installation and operational costs is strongly encouraged when selecting equipment for specific region.

[4] Of all stations awarded by the California Energy Commission in 2020, 1 contained onsite production and 3 were upgrades to existing stations. To improve the consistency of comparison with cost in prior awards, these two station types are not included in the present analysis.

[5] The stations can service 1,440 to 3,040 fuel cell electric vehicles (FCEVs), which equates to an average capital cost of \$640 to \$1,600 per FCEV over the lifetime of the stations. The number of vehicle calculations are based on 11,866 miles traveled per year and 61 miles per kg fuel economy [1], resulting in hydrogen fuel consumption of 0.533 kg per day per vehicle. These reported costs per vehicle assume a timeframe over the lifetime of the stations.

Data and Parameters

Data for this record have been compiled from a review of all funded proposals submitted to the California Grant Funding Opportunity (GFO)-19-602 for construction of hydrogen fueling stations [5]. Table 1 summarizes key cost and design characteristics of stations in funded proposals. Three different station developers were selected. On average, the capacity of the selected stations was significantly greater than the capacity of stations currently in operation. While stations from GFOs since 2012 have an average capacity of 480 kg/day, stations selected in GFO-19-602 ranged in fueling capacity from 770 kg/day to 1,620 kg/day. The larger daily capacity stations are supplied by liquid hydrogen tankers and have four fueling positions while the smaller daily capacity stations are supplied by gaseous tube trailers and have two fueling positions.

Table 1. Hydrogen fueling stations statistics for awarded stations in GFO-19-602

Hydrogen supply state		**24-hour fueling capacity (kg)[6]**		**Number of H70 fueling positions**	
Liquid state	Gaseous state	700–1,000	1,001–1,620	2	4
63	48	48	63	48	63

Cost attributes varied in detail and range, depending on the reporting company. In some cases, shipping, integration, infrastructure, and commissioning were included within the reported equipment cost. These inconsistencies resulted in a large range in the data set shown.

Findings and Summary

Across all 111 planned new hydrogen fueling stations, an average hydrogen station has capacity of 1,240 kg/day (median capacity of 1,500 kg/day) and requires approximately $1.9 million in capital (median capital cost of $1.9 million). Table 2 summarizes the costs of these stations, as total (combined total awarded grant and match funding) capital cost and capital cost normalized by station daily fueling capacity. The normalized capital cost varies between $1,200 and $3,000 per kg H_2/day ($300–$890/kg H_2/day per dispenser[7]). Differences in this cost data are largely due to differences in supply mode (i.e., gaseous vs. liquid), daily fueling capacity, and number of dispensers. It is also important to note that actual total costs may vary from those proposed.

Table 2. Capital hydrogen cost per daily capacity for hydrogen fueling stations based on delivery method

Delivery Method	**Daily Fueling Capacity (kg/day)**	**Total Capital Cost per Capacity ($/(kg/day H_2))**	**Total Capital Cost per Capacity per Dispenser ($/(kg/day H_2/dispenser))**	**Total Capital Cost ($'000)**
Gaseous tube trailers (GTT)[8]	770	1,800	890	1,400
Liquid hydrogen tankers (LHT)	1,400–1,620	1,200–3,000	300–740	1,900–4,200

[6] Station capacity was determined by applicants using the HySCapE model [7]. HySCapE is a mass balance model that predicts capacity based on the size of equipment at the station site. Reported daily capacities have been adjusted to capacities in submitted proposal based on HySCapE.
[7] Each dispenser reported in funding applications is assumed to represent one fueling position.
[8] All stations supplied by GTT were proposed by one company and were estimated to be of the same capital cost.

Compared to the costs of hydrogen fueling stations in California in prior years, the normalized cost of stations per dispenser has decreased between 77%–88% since 2012, likely due to the increase in station daily fueling capacity, along with reductions in fueling components cost (economies of scale). Equipment capital costs ($2016) through 2016 ranged from ~$1,300–$7,400/(kg/day) per dispenser and commonly had capacities in the range of 180–1,200 kg/day [6]. Historical hydrogen fueling station equipment unit costs, per unit of daily fueling capacity, per dispenser, are plotted in Figure 1.

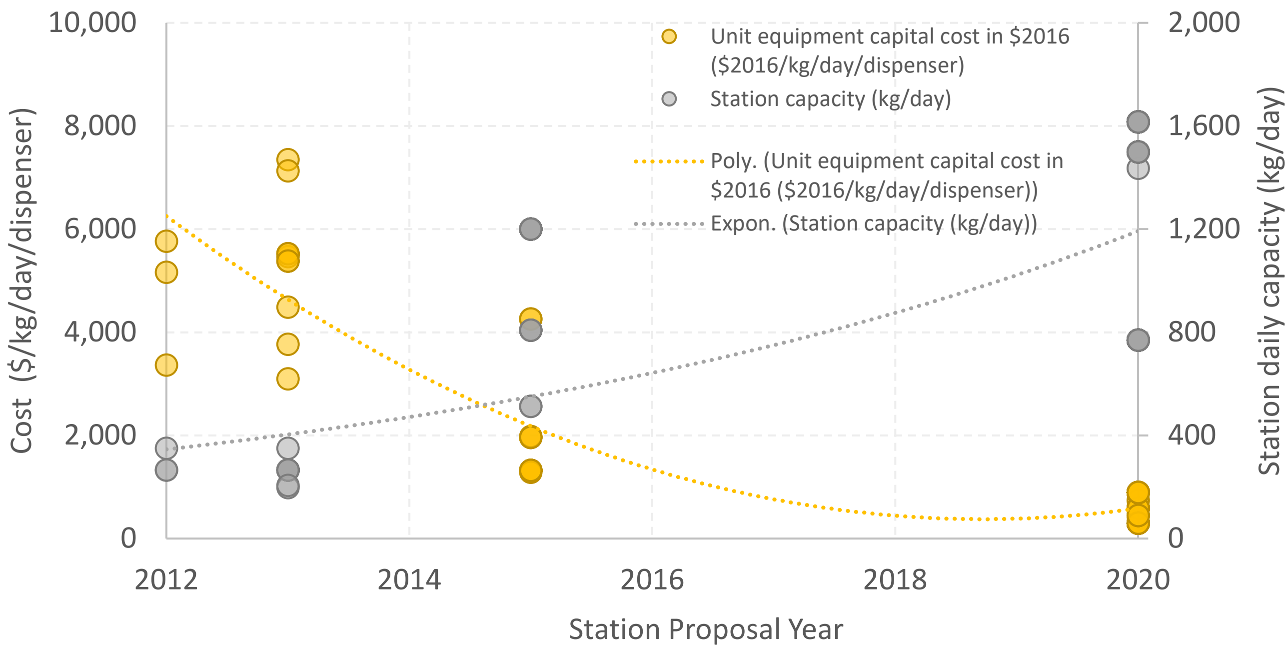

Figure 1. Hydrogen fueling stations equipment unit costs[9]

References

[1] U.S. Department of Energy, 2018, HFTO FY18 Inputs and Assumptions for Program Analysis, https://www.hydrogen.energy.gov/pdfs/18001_fcto_fy18_inputs_assumptions.pdf

[2] U.S. Department of Energy, 2020, Hydrogen Fueling Station Locations by State, https://afdc.energy.gov/data/10370

[3] California Air Resource Board, 2020, 2020 Annual Evaluation of Fuel Cell Electric Vehicle Deployment & Hydrogen Fuel Station Network Development, https://ww2.arb.ca.gov/sites/default/files/2020-09/ab8_report_2020.pdf

[9] Data represents costs supplied in funding proposals to the California Energy Commission. Outliers in early years were removed due to limited fidelity in cost estimates at the time. All data have been adjusted to $2016 using Chemical Engineering Plant Cost Indices.

[4] SAE International, 2020, *Fueling Protocols for Light Duty Gaseous Hydrogen Surface Vehicles*, https://www.sae.org/standards/content/j2601_202005/

[5] California Energy Commission, 2019, *GFO-19-602-Hydrogen Refueling Infrastructure*, https://www.energy.ca.gov/solicitations/2019-12/gfo-19-602-hydrogen-refueling-infrastructure

[6] California Energy Commission and California Air Resources Board, 2017, *Joint Agency Staff Report on Assembly Bill 8: 2017 Annual Assessment of Time and Cost Needed to Attain 100 Hydrogen Stations in California*, https://ww2.energy.ca.gov/2017publications/CEC-600-2017-011/CEC-600-2017-011.pdf

[7] Hydrogen Station Capacity Evaluation, 2020, https://openei.org/apps/hyscape/