DCFC + Hydrogen Station Design Optimization

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Agenda

- Project motivation and background
- Scenarios
- Assumptions
- Summary of Results
  - DCFC + Hydrogen station
  - Benefit of installing PV
  - Value of co-location with site load
  - 15-min versus 1-hr resolution
- Recommendations
- Future work

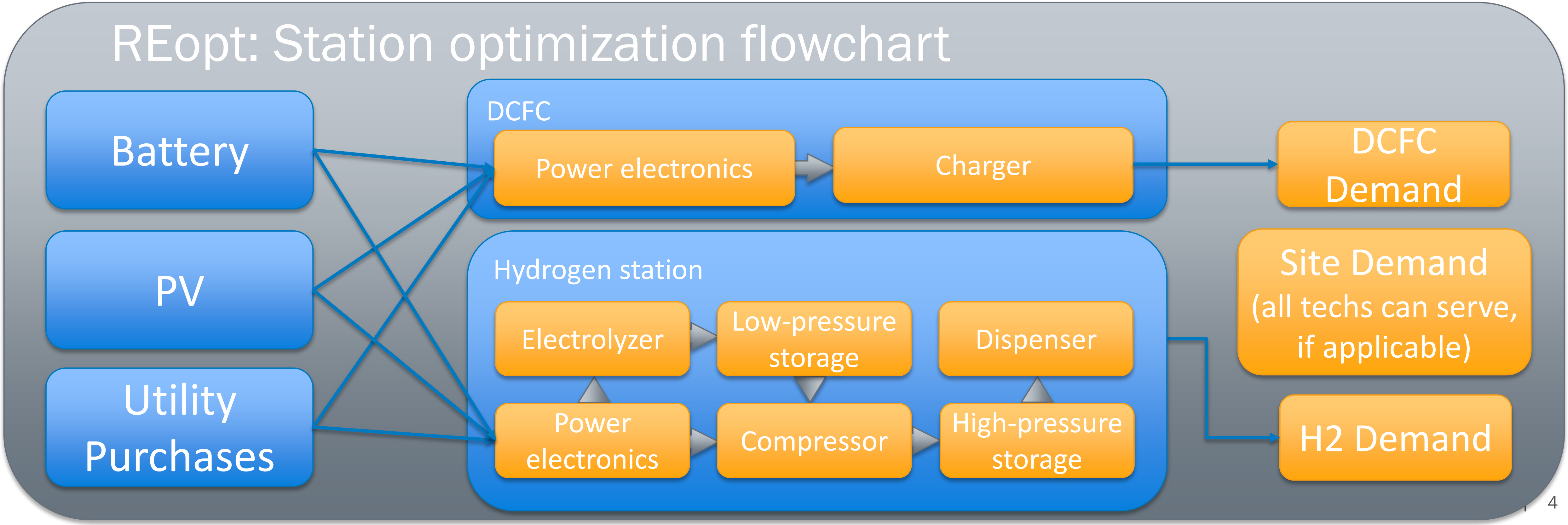
Motivation and background

- Both DCFC and Hydrogen stations are working to create successful long-term business models; however, analyses for DCFC and H_2 fueling infrastructure are almost always performed separately.
- Early work at UC Davis by Burke, et al. to integrate DCFC and H_2 stations shows that there is **potential to reduce the combined fueling/charging system costs**
  - https://ncst.ucdavis.edu/project/deployment-sustainable-fuelingcharging-systems-california-highway-safety-roadside-rest
- Building on the previous findings, this work provides a detailed exploration of the **benefit of integrating DCFC and hydrogen stations to lower the total system cost from load balancing and equipment cost sharing**.
- To achieve this we have adapted the REopt optimization framework† to simultaneously optimize the design and operation of integrated DCFC and H_2 fueling station.

† See the next slide for more information.

System configuration

- REopt is a techno-economic decision support platform used to optimize the sizing, siting and operation of energy systems. (more details can be found at https://reopt.nrel.gov/)



Scenarios

- We examine different configurations of DCFC and hydrogen stations.
- We allow batteries to be installed for each scenario (if cost-effective).
- The model is run for an entire year.
- Additionally, we preform several sensitivities:
  - Benefit of installing PV
  - Co-location with site load reflecting a supermarket
  - 15-min versus 1-hr resolution

Fueling station	Fueling details	
DCFC Only †	4 plug low utilization (150kW each w/ 2.36% load factor)	
	4 plug (150kW each with 13.7% load factor)	
	20 plug (150kW each with 20.7% load factor)	
Hydrogen Only ‡	1 position, low use (100kg/day, 54% load factor, 20-30 vehicles per day)	
	2 position, high use (400kg/day, 54% load factor, 80-115 vehicles per day)	
Combined DCFC + Hydrogen	4 plug DCFC (low utilization)	1 position, low use (H_2)
	4 plug DCFC	1 position, low use (H_2)
	20 plug DCFC	1 position, low use (H_2)
	4 plug DCFC (low utilization)	2 position, high use (H_2)
	4 plug DCFC	2 position, high use (H_2)
	20 plug DCFC	2 position, high use (H_2)

† Based on 2017 EVgo data for 50kW charging
‡ Based on data from NREL's National Fuel Cell Technology Evaluation Center

Assumptions

- Sites receive retail electricity service on Southern California Edison GS-TOU-1 option B (high energy charge, low demand charge) or Consolidated Edison SC-9 (low energy charge, high demand charge)
- DCFC [1] : $150,000/plug includes equipment and installation ← Doesn't include land or permitting
- Hydrogen [2,3,4,5,6]
  - Electrolyzer: $1,690/kW, $94/kW-yr, 54.6 kWh/kg, 20-year life
  - Compressor: $21,730-$35,600/kg-hr, 5.9 kWh/kg, 10-year life
  - Low pressure storage: $839/kg, 20-year life
  - High pressure storage: $1,547/kg, 20-year life
  - Vehicle dispenser: $50,000 (low scenario), $200,000 (high)

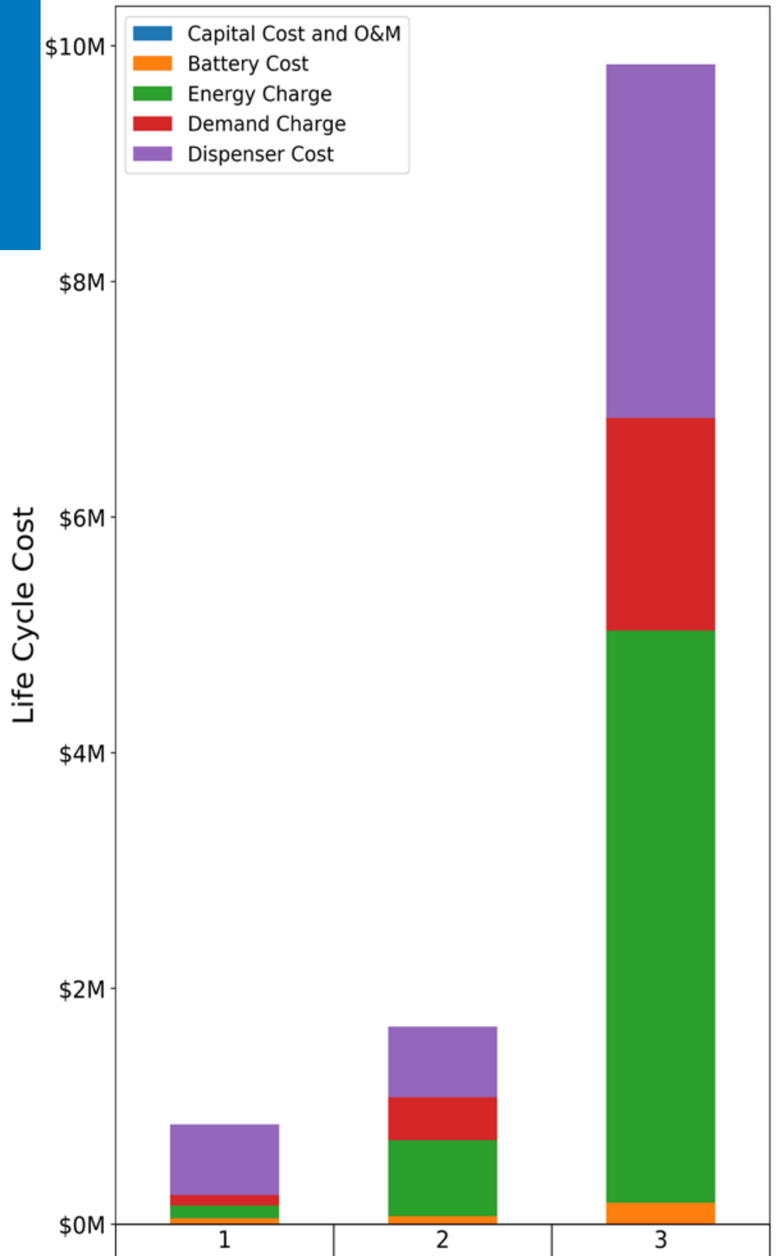
Includes land and permitting for electrolyzer, and only equipment costs for compressor, storage and dispenser

- Lithium-ion Battery [7] : $840/kW, $420/kWh, 10-year life
- Solar photovoltaic [7] : $1,600/kW, $16/kW-yr, 20-year life ← Doesn't include grid interconnection cost
- Financial [7]: 8.3% discount rate, 2.3% electricity cost escalation, and 25-year project lifetime

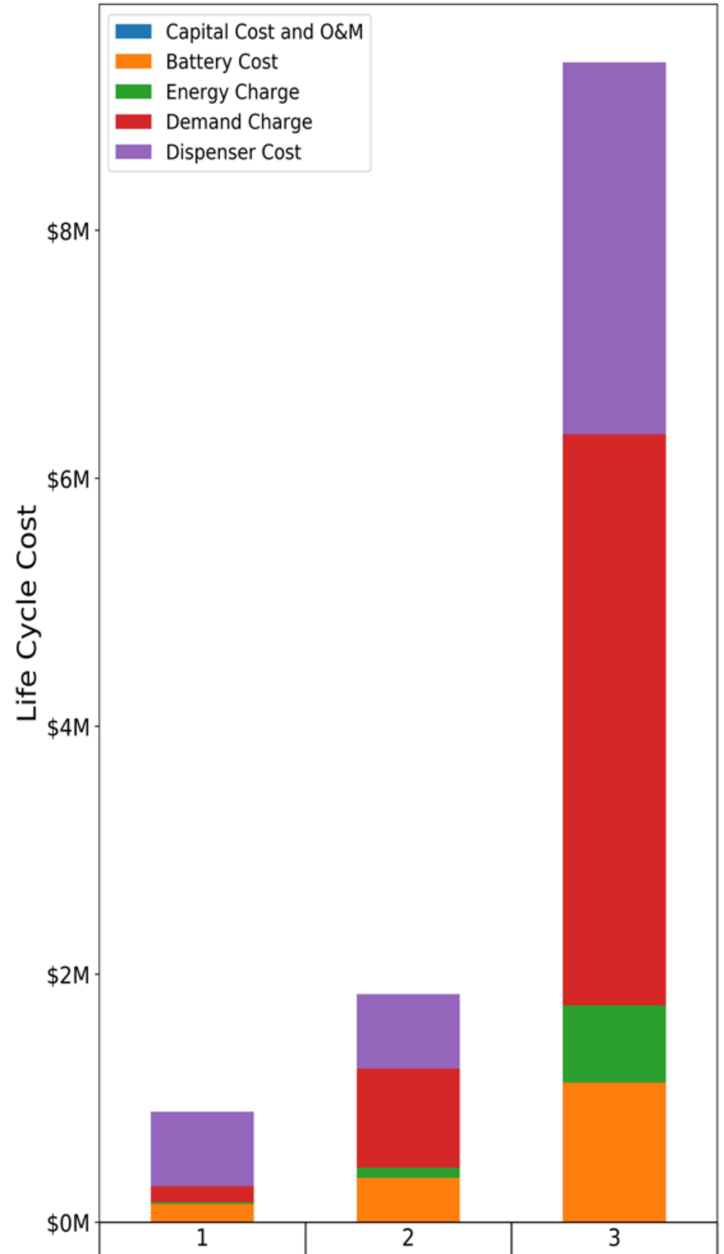
Sources:
1. forthcoming NREL-DOE report
2. H2A Current Forecourt Electrolyzer (https://www.nrel.gov/hydrogen/h2a-production-case-studies.html)
3. H2FIRST Reference Station Design Task (https://www.nrel.gov/docs/fy15osti/64107.pdf)
4. Hydrogen station technical status and costs (https://www.nrel.gov/docs/fy14osti/58564.pdf)
5. Hydrogen component validation (https://www.hydrogen.energy.gov/pdfs/review17/tv019_terlip_2017_p.pdf)
6. Estimate from NFCTEC data
7. REopt Defaults (https://reopt.nrel.gov/tool/REopt%20Lite%20Web%20Tool%20User%20Manual.pdf), leveraging NREL's 2019 Annual Technology Baseline, Lazard, and U.S. Energy Storage Monitor

Standalone DCFC

- Cost components are broken down for each scenario.
- The California rate has higher energy charges and lower demand charges, while the New York rate is the opposite.
- The cost of electricity is much greater than the capital cost.
- Because of the demand charge, larger battery storage is installed at the New York sites.



	1	2	3
Location	CA	CA	CA
Hydrogen	No	No	No
DCFC (Plugs)	4_lu	4	20
Storage	Yes	Yes	Yes
PV	No	No	No

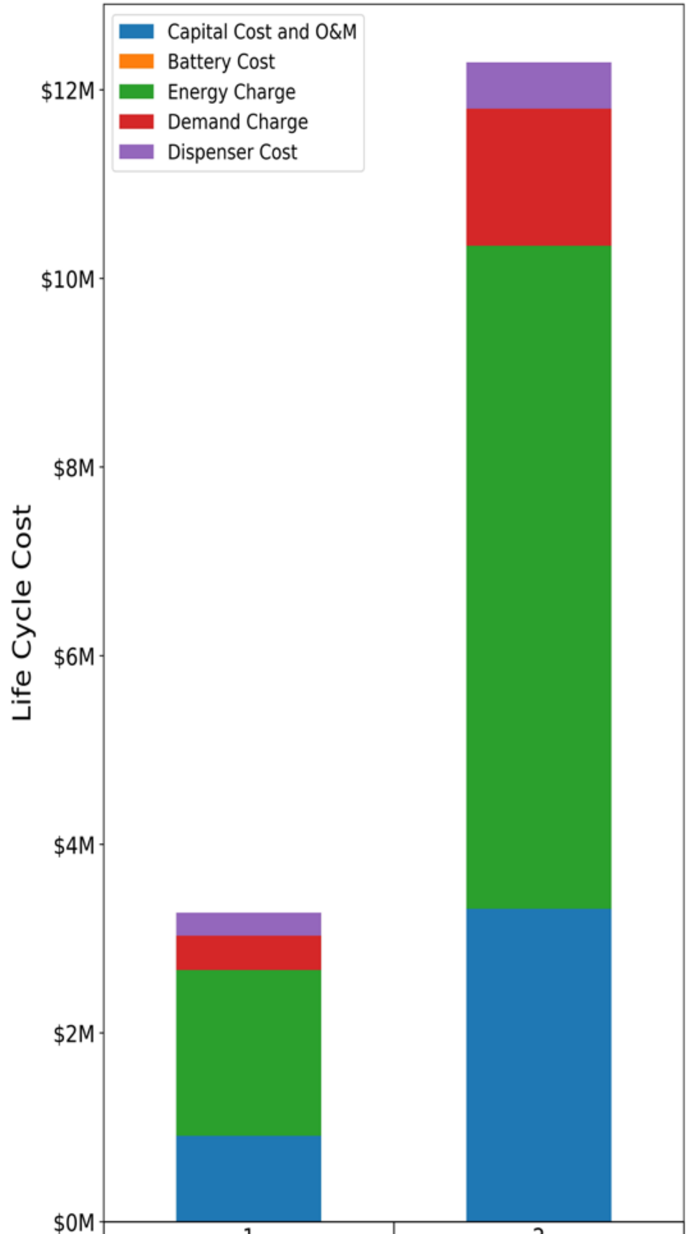


	1	2	3
Location	NY	NY	NY
Hydrogen	No	No	No
DCFC (Plugs)	4_lu	4	20
Storage	Yes	Yes	Yes
PV	No	No	No

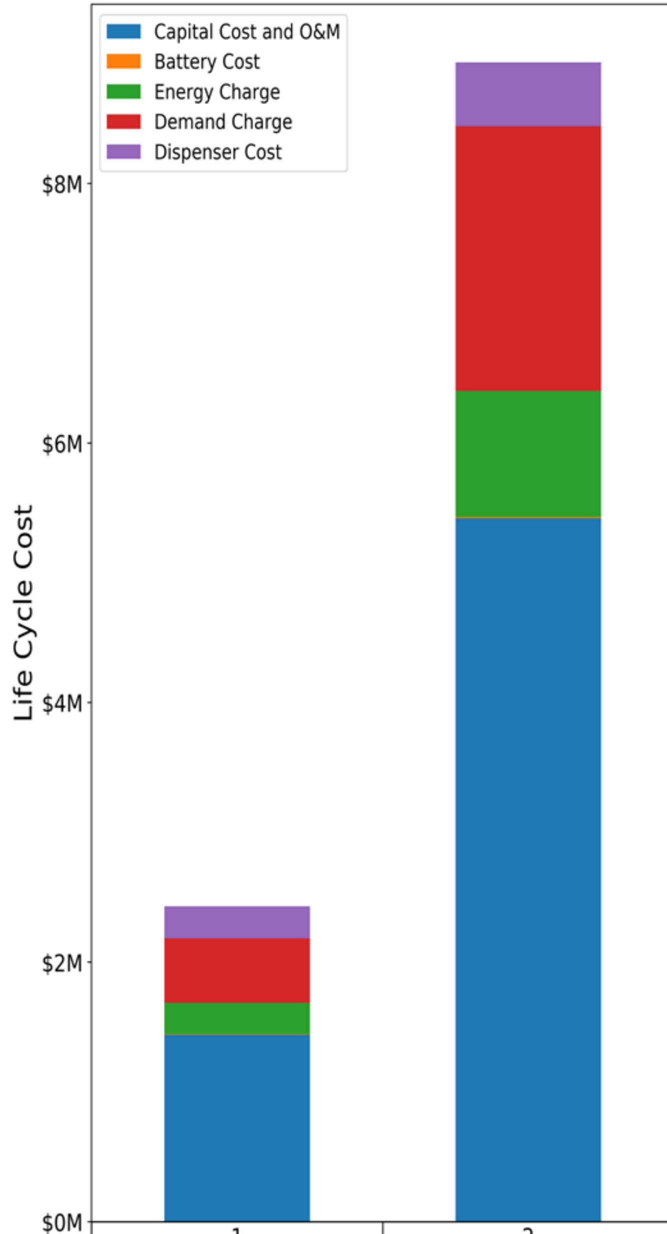
4_lu = 4 plugs, low utilization

Standalone Hydrogen

- Capital cost plays a more significant role for hydrogen fueling stations.
- Electrolyzer flexibility reduces the ratio of demand charges to energy charges.
- Because of the existing electrolyzer flexibility, batteries are not cost effective.



	1	2
Location	CA	CA
Hydrogen	Low	High
DCFC (Plugs)	No	No
Storage	Yes	Yes
PV	No	No



	1	2
Location	NY	NY
Hydrogen	Low	High
DCFC (Plugs)	No	No
Storage	Yes	Yes
PV	No	No

Comparison Methodology

Separated systems

(forms baseline by adding
results for separate station optimizations)

DCFC Only + H2 Only

vs.

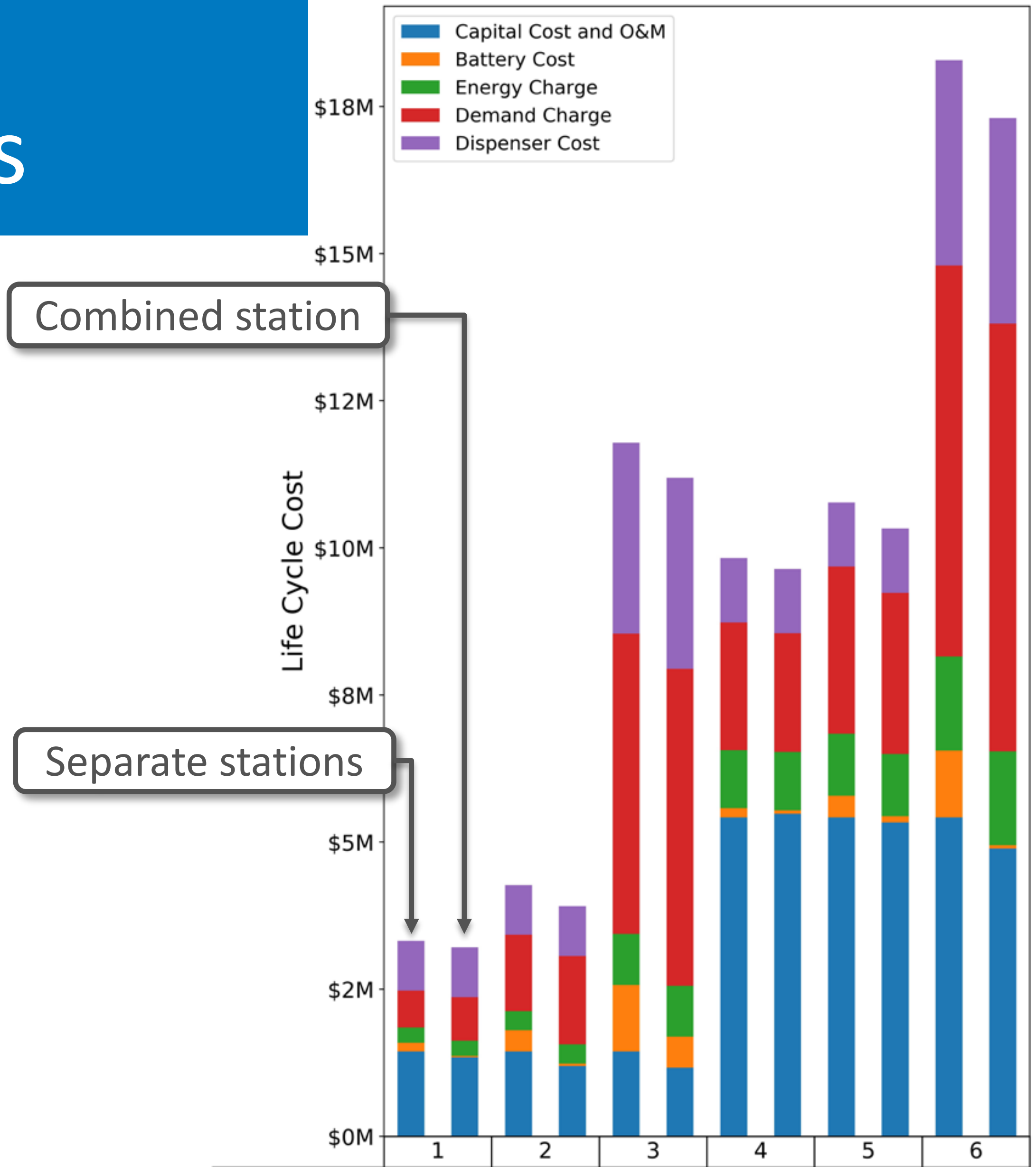
Optimized system

(Combine DCFC and hydrogen stations at the same site and optimize their operation)

Optimized DCFC and H2 Demand in model

Value of combining fueling/charging stations

- Combining DCFC and hydrogen stations results in a **savings of up to 8.7%** of the total life cycle costs.
- Combining hydrogen with DCFC **reduces the need for a battery**
- The savings is highly dependent on the fueling/charging needs; however, it appears that matching consumption between fueling and charging results in the greatest benefit (e.g., 4 plug DCFC and low hydrogen use; 20 plug and high hydrogen use).

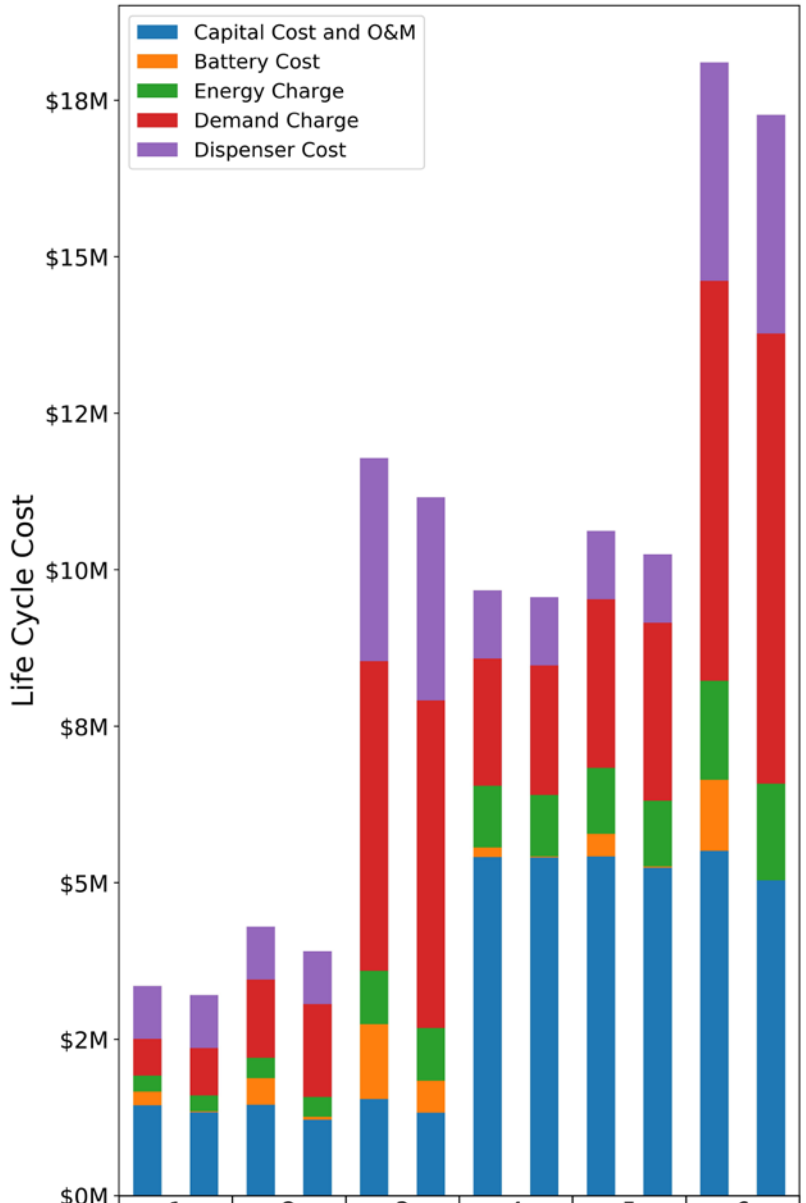


	1	2	3	4	5	6
% Savings	3.8	8.7	5.2	2.0	4.3	5.5
Location	NY	NY	NY	NY	NY	NY
Hydrogen	Low	Low	Low	High	High	High
DCFC (Plugs)	4_lu	4	20	4_lu	4	20
Storage	Yes	Yes	Yes	Yes	Yes	Yes
PV	No	No	No	No	No	No

4_lu = 4 plugs, low utilization

Value of Adding PV

- While all sites benefit from adding PV (reduced LCC), its relative % savings impact varies across sites
  - Note that CA sites always benefit from PV and more substantially so
- We recognize that land is not available at all fueling/charging stations; however, PV integration should be considered when possible.



	1	2	3	4	5	6
% Savings	6.4	11.7	7.5	1.5	4.1	5.9
Location	NY	NY	NY	NY	NY	NY
Hydrogen	Low	Low	Low	High	High	High
DCFC (Plugs)	4_lu	4	20	4_lu	4	20
Storage	Yes	Yes	Yes	Yes	Yes	Yes
PV	Yes	Yes	Yes	Yes	Yes	Yes

4_lu = 4 plugs, low utilization

Comparison Methodology: Site load

Separated Systems

(forms baseline by adding results for separate stations and site load only optimizations)

DCFC Only + H2 Only + Site Only

vs.

DCFC + Site

(this scenario adds site load to the DCFC system to understand the impact of co-location with site load)

DCFC + Site + H2 Only

vs.

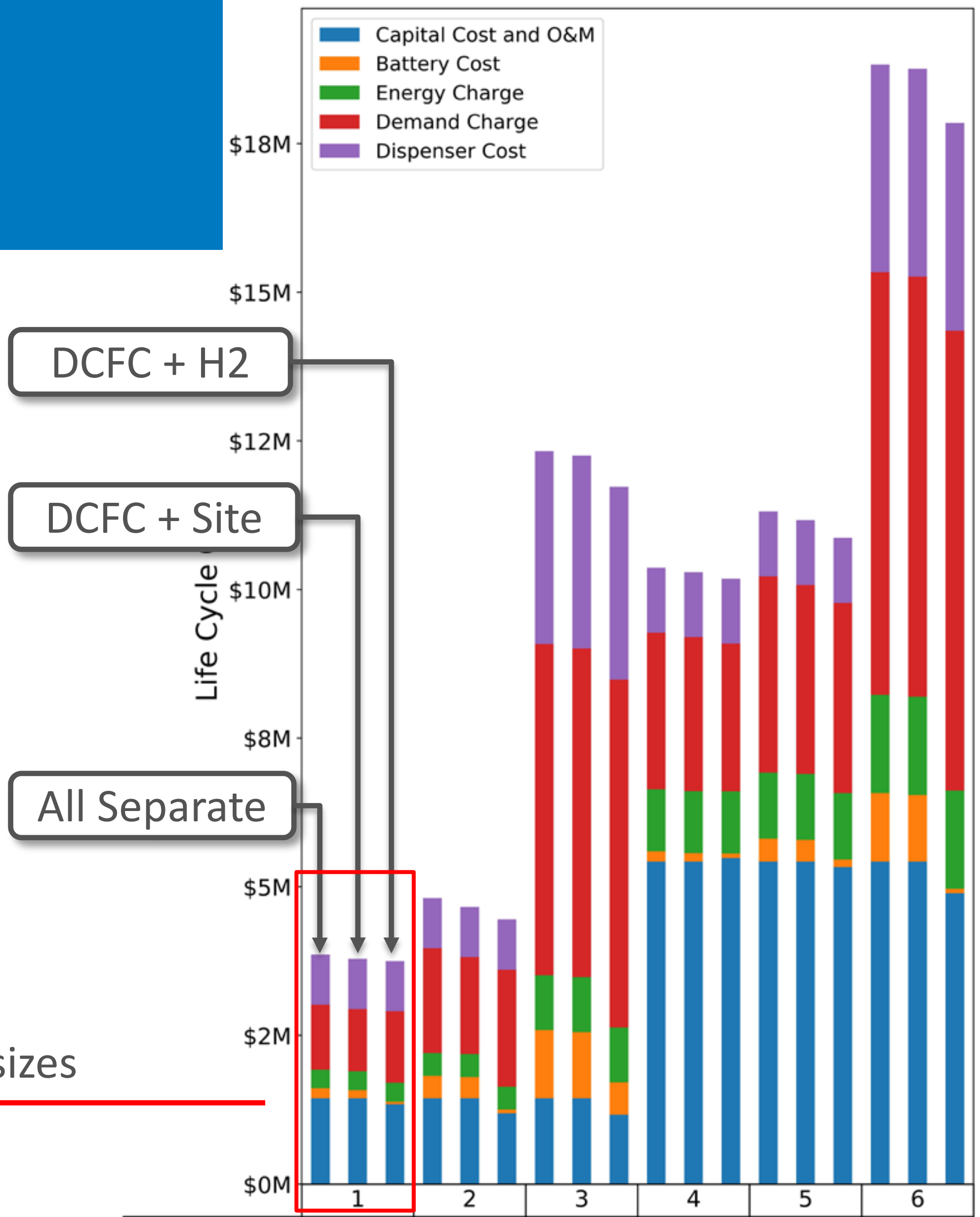
DCFC + H2

(this scenario considers a combined DCFC and H2 station and standalone site load to complete the scenarios necessary to analyze the impact of site load)

DCFC + H2 + Site Only

Impact of Co-location: NY

- Co-location with a supermarket load in NY can reduce DCFC system costs by 0.5-3.3%
- However, DCFC + hydrogen can reduce costs by 1.9-7.7%.
- Both battery and hydrogen system size decrease in the DCFC + H2 case, delivering larger savings and reduced upfront costs



	1	2	3	4	5	6
% Savings	2.3|3.3	3.4|7.7	0.7|5.0	0.9|1.9	1.4|4.1	0.5|5.3
Location	NY	NY	NY	NY	NY	NY
Hydrogen	Low	Low	Low	High	High	High
DCFC (Plugs)	4_lu	4	20	4_lu	4	20
Storage	Yes	Yes	Yes	Yes	Yes	Yes
PV	No	No	No	No	No	No

System component sizes

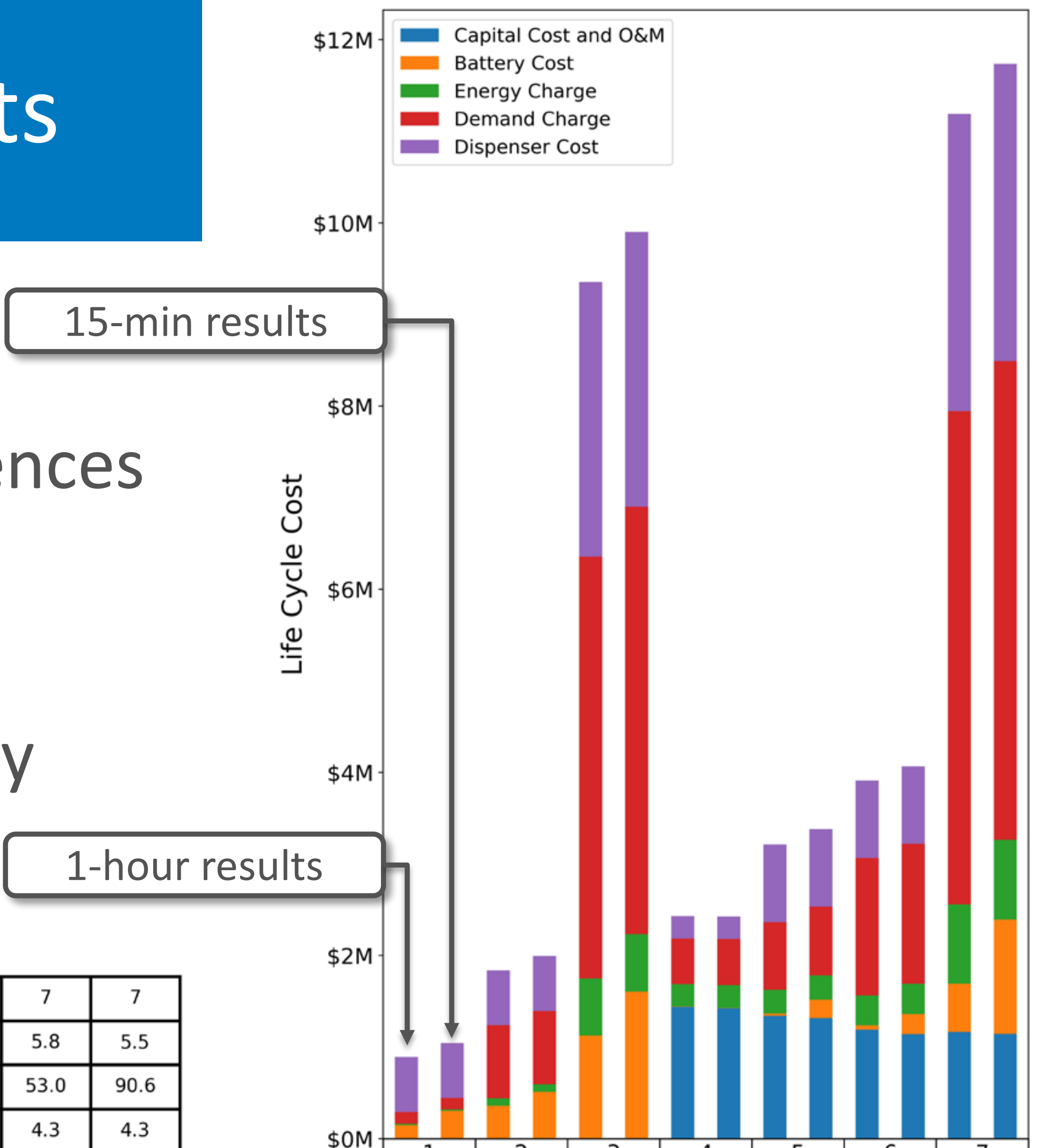
Electrolyzer (kg/hr)	7.2	7.2	6.6
Low Pressure Storage (kg)	177.0	177.0	141.7
Compressor (kg/hr)	4.4	4.4	4.4
High Pressure Storage (kg)	70.5	70.5	75.6
Battery (kWh)	233.6	183.1	60.3
Inverter (kW)	103.4	89.2	28.5
Solar PV (kW)	0.0	0.0	0.0

4_lu = 4 plugs, low utilization

Evaluating 15-min Impacts

- Comparing absolute LCC values
- Similar LCC values with highest differences coming with 4 plug, low utilization
- Battery inverter capacities increase significantly, energy capacity stays very similar

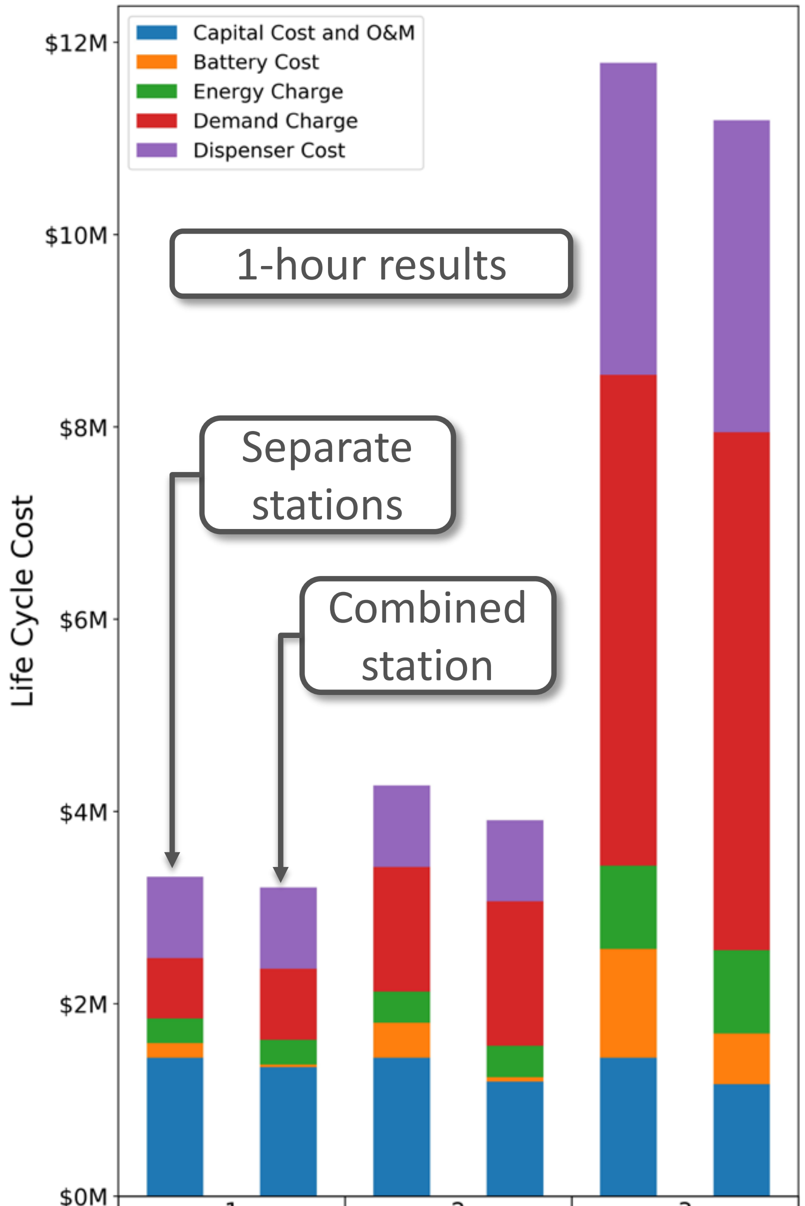
	1	1	2	2	3	3	4	4	5	5	6	6	7	7
Electrolyzer (kg/hr)	0.0	0.0	0.0	0.0	0.0	0.0	7.2	7.1	6.6	6.5	5.8	5.5	5.8	5.5
Low Pressure Storage (kg)	0.0	0.0	0.0	0.0	0.0	0.0	177.0	174.5	141.7	140.4	95.3	89.7	53.0	90.6
Compressor (kg/hr)	0.0	0.0	0.0	0.0	0.0	0.0	4.4	4.3	4.4	4.3	4.4	4.3	4.3	4.3
High Pressure Storage (kg)	0.0	0.0	0.0	0.0	0.0	0.0	70.5	69.1	75.6	70.4	72.2	69.3	71.0	69.0
Battery (kWh)	196.3	217.3	592.6	610.9	1,996.6	2,009.6	3.9	8.3	26.9	97.9	47.4	107.6	744.6	1,255.5
Inverter (kW)	92.3	286.4	166.7	354.8	458.7	1,073.7	3.0	2.2	20.4	213.1	36.0	229.5	310.1	984.6
Solar PV (kW)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0



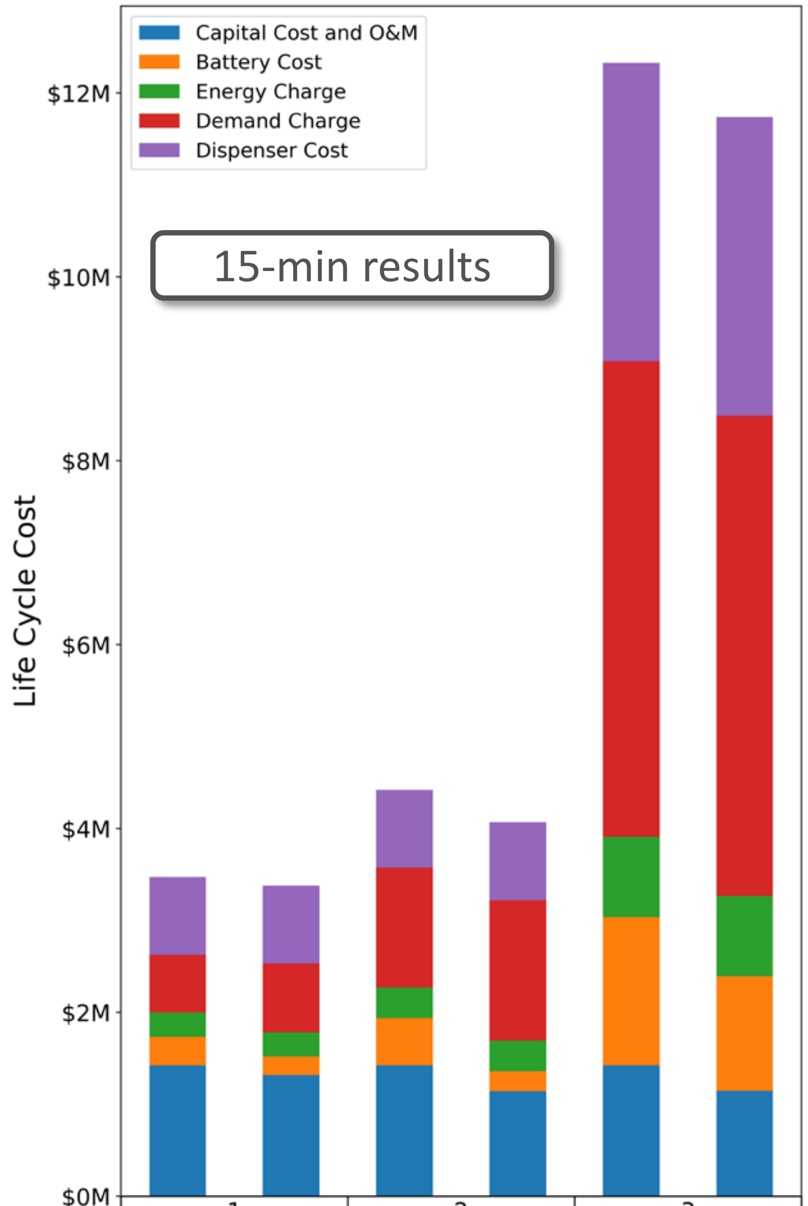
	1	2	3	4	5	6	7
% Increase	16.9	8.3	5.8	0.0	5.2	4.0	4.9
Location	NY	NY	NY	NY	NY	NY	NY
Hydrogen	No	No	No	Low	Low	Low	Low
DCFC (Plugs)	4_lu	4	20	No	4_lu	4	20
Storage	Yes	Yes	Yes	Yes	Yes	Yes	Yes
PV	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Evaluating 15-min Impacts

- Comparing % savings moving from 1-hour to 15-min resolution
- Greater savings with 15min analysis

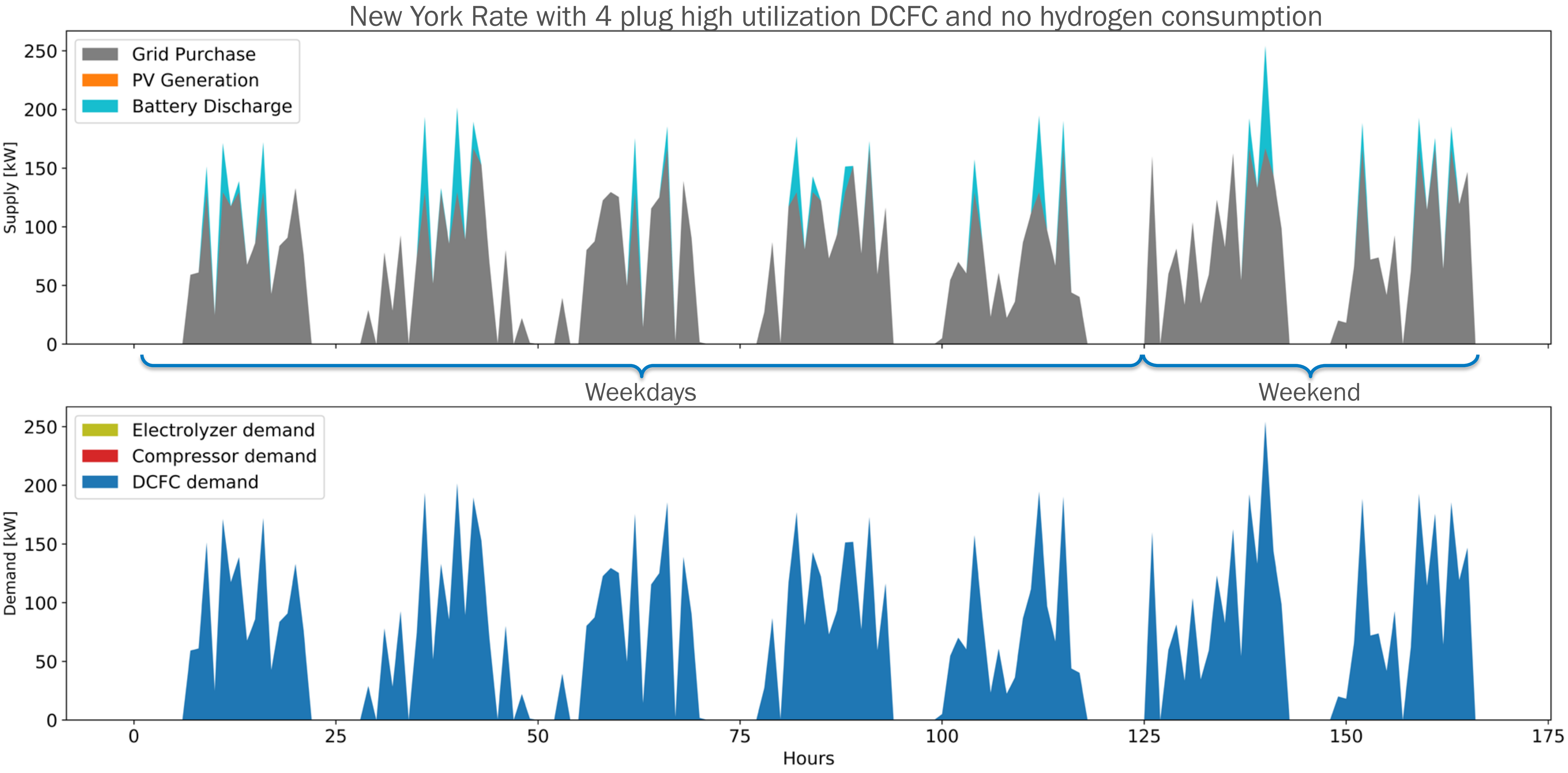


	1	2	3
% Savings	3.8	8.7	5.2
Location	NY	NY	NY
Hydrogen	Low	Low	Low
DCFC (Plugs)	4_lu	4	20
Storage	Yes	Yes	Yes
PV	No	No	No

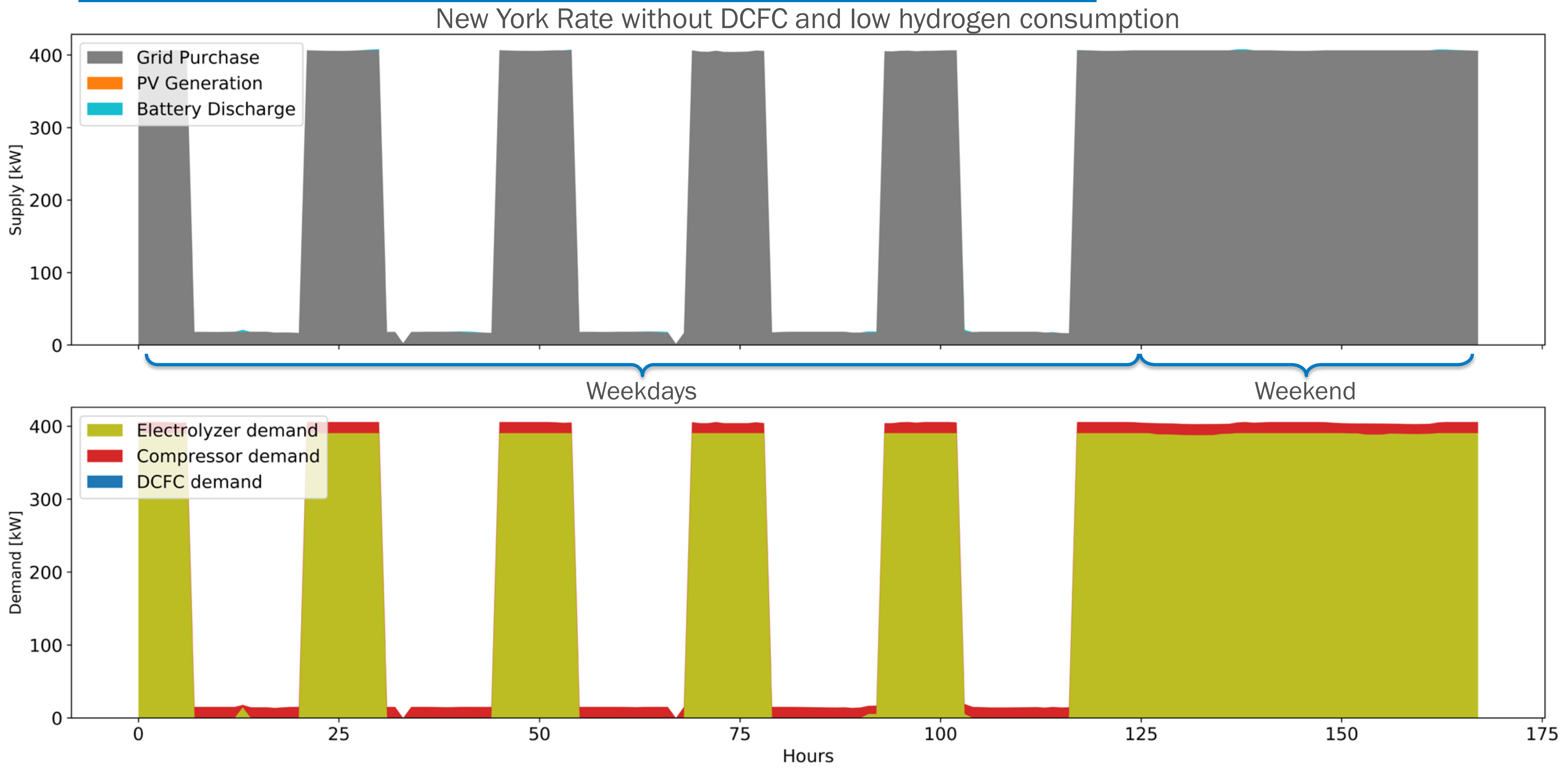


	1	2	3
% Savings	4.1	10.3	6.7
Location	NY	NY	NY
Hydrogen	Low	Low	Low
DCFC (Plugs)	4_lu	4	20
Storage	Yes	Yes	Yes
PV	No	No	No

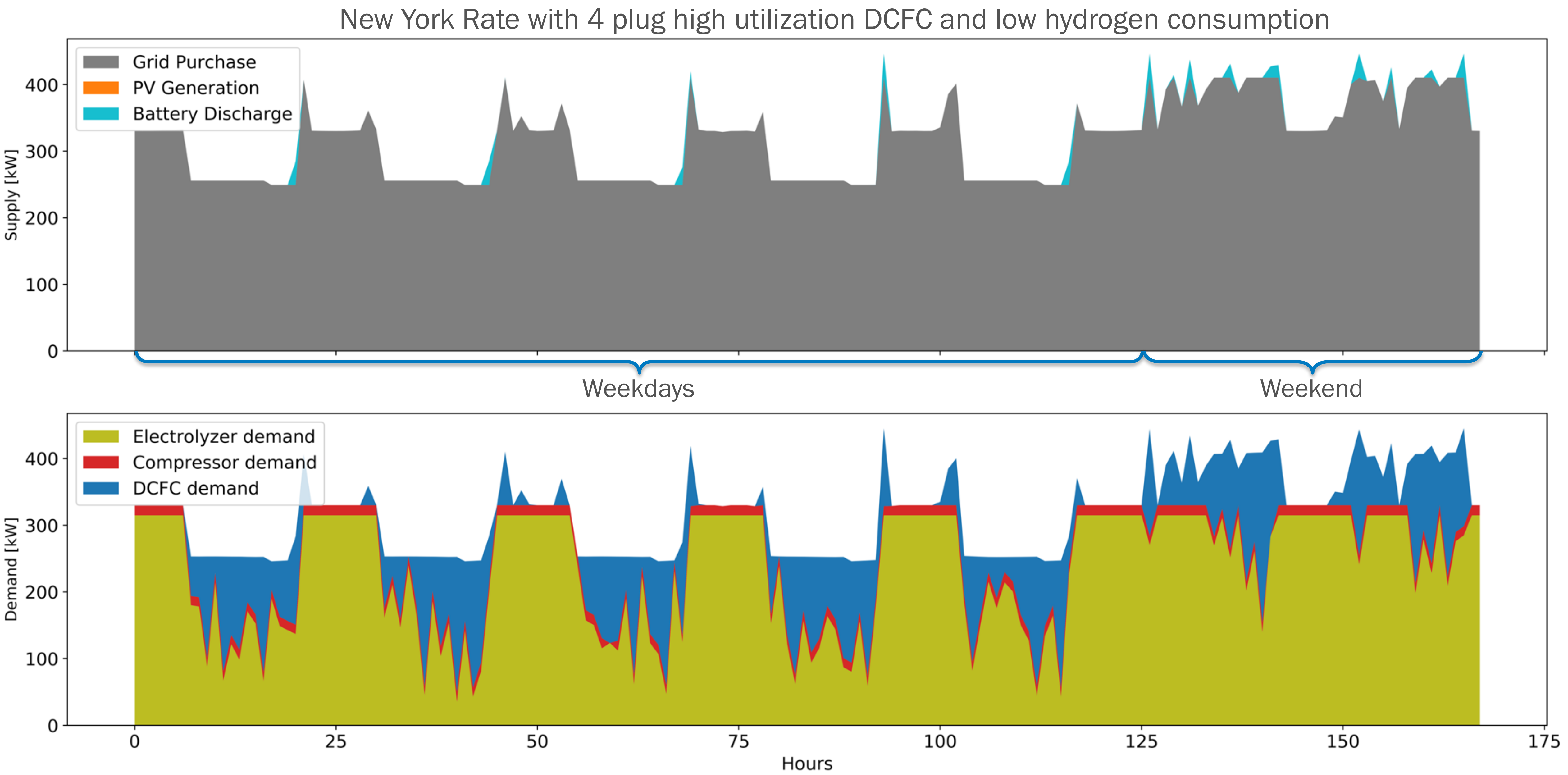
A closer look: DCFC only



A closer look: Hydrogen only



A closer look: Combined



Caveats

What this study does:

- Compares the benefits for combining fueling/charging technologies with a variety of sensitivities.

What this study does not do:

- Predicts changes in fueling/charging demand over the lifetime of the equipment.
- Estimates site installation and utility interconnection upgrade costs.
- Considers flexibility opportunities in the DCFC demand.

Summary of findings

- **Combining hydrogen fueling and DCFC stations can significantly reduce lifetime costs** compared to separated stations.
- **Co-location** with additional site load **reduces DCFC costs, however, integration of DCFC with hydrogen provides an even greater cost reduction.**
- **Adding PV** to combined stations **further reduces the lifetime station cost**.
- **Capital investments** in station combination today **can help reduce the cost of operating** DCFC tomorrow.
- **Product diversification** acts as a **hedge against variability** and enables a **more dynamic response to market changes**.

Future work

- Expand concept to include heavy-duty BEV charging and FCEV fueling.

- Perform a hardware-in-the-loop evaluation of DCFC + Hydrogen station designs based on the results of this work
  - Funded by DOE Hydrogen and Fuel Cell Technology Office
  - To be completed this year
  - We are interested in stakeholder feedback so please contact us to learn how you can get involved.

Thank you

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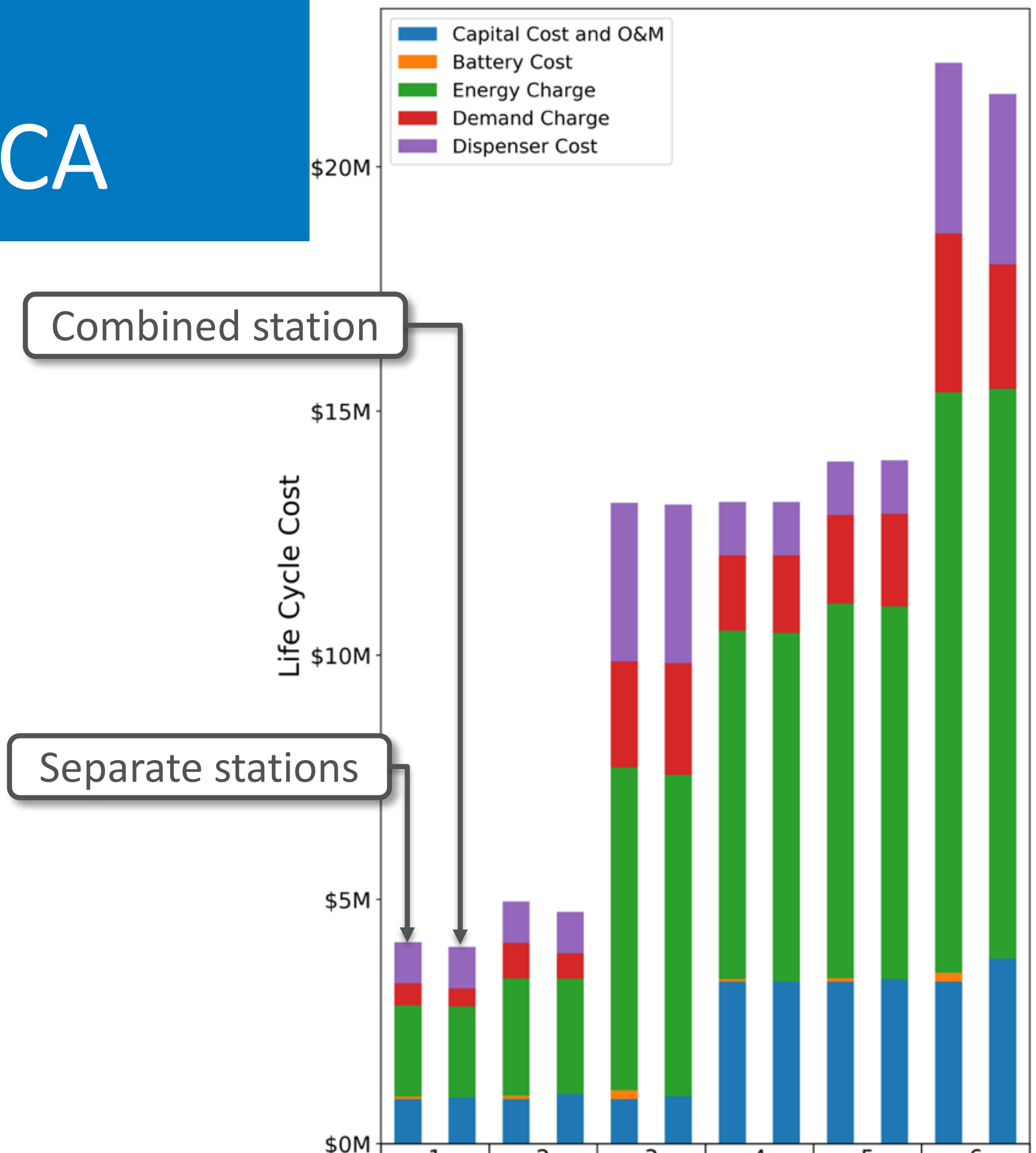
CA Graphics

Value of combining fueling/charging stations: CA

- Combining DCFC and hydrogen stations results in a **savings of up to 4.2%** of the total life cycle costs for CA sites.
- The savings is highly dependent on the fueling/charging needs; however, it appears that matching consumption between fueling and charging results in the greatest benefit (e.g., 4 plug DCFC and low hydrogen use; 20 plug and high hydrogen use).

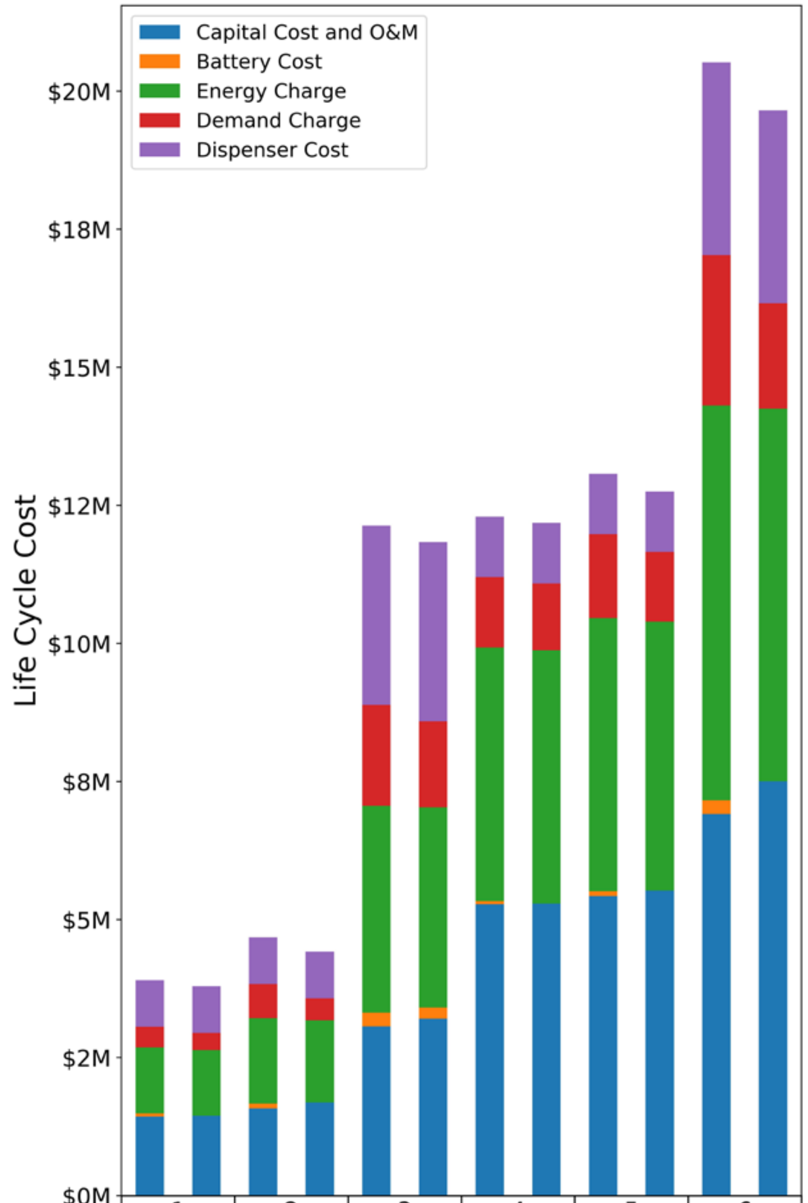


	1	2	3	4	5	6
% Savings	2.4	4.2	0.3	0.0	0.0	2.9
Location	CA	CA	CA	CA	CA	CA
Hydrogen	Low	Low	Low	High	High	High
DCFC (Plugs)	4_lu	4	20	4_lu	4	20
Storage	Yes	Yes	Yes	Yes	Yes	Yes
PV	No	No	No	No	No	No

4_lu = 4 plugs, low utilization

Value of Adding PV: CA

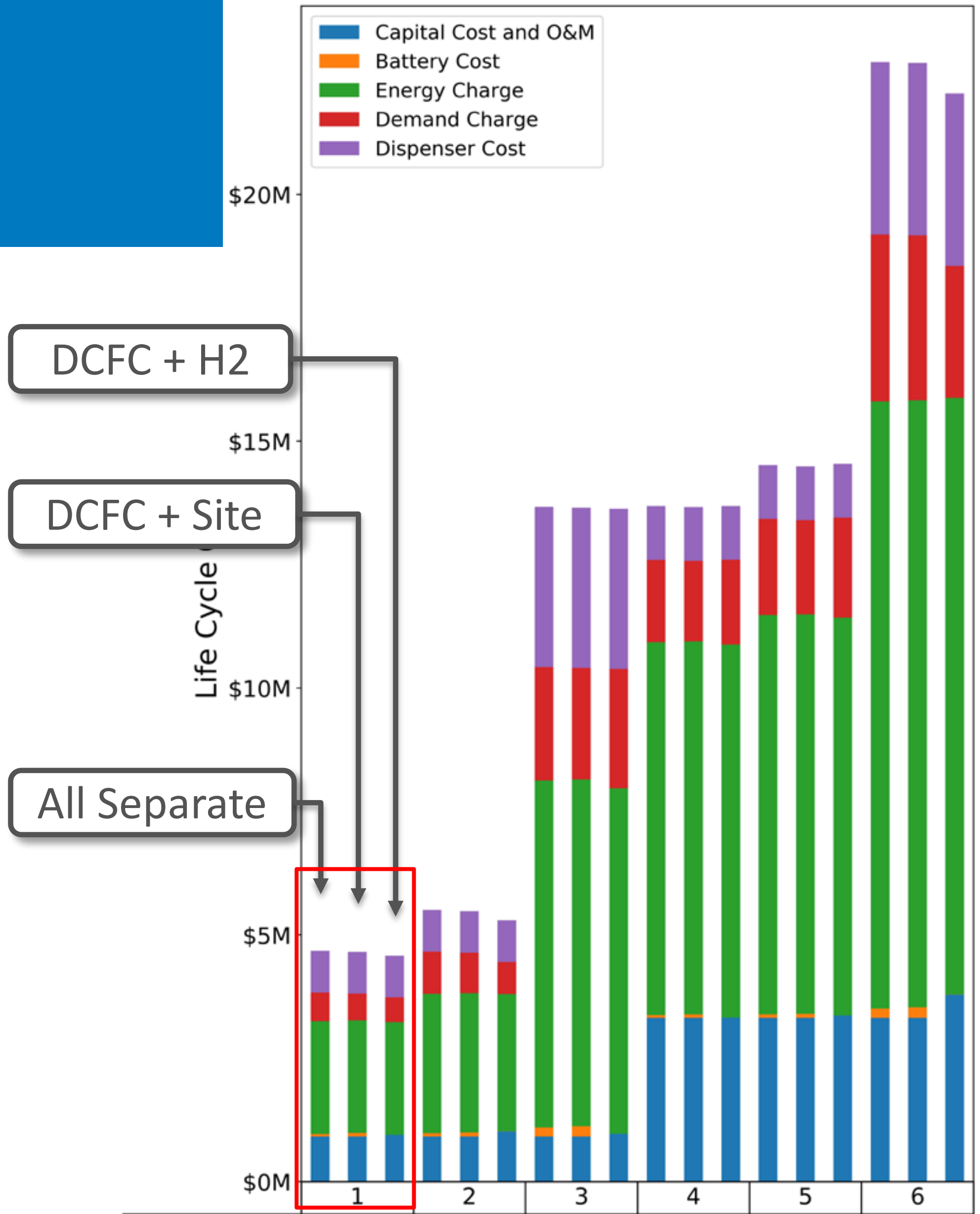
- While all sites benefit from adding PV, CA sites benefit the most.
- We recognize that land is not available at all fueling/charging stations; however, PV integration should be considered when possible.



	1	2	3	4	5	6
% Savings	3.5	6.8	3.3	1.0	2.7	5.1
Location	CA	CA	CA	CA	CA	CA
Hydrogen	Low	Low	Low	High	High	High
DCFC (Plugs)	4_lu	4	20	4_lu	4	20
Storage	Yes	Yes	Yes	Yes	Yes	Yes
PV	Yes	Yes	Yes	Yes	Yes	Yes

Impact of Co-location: CA

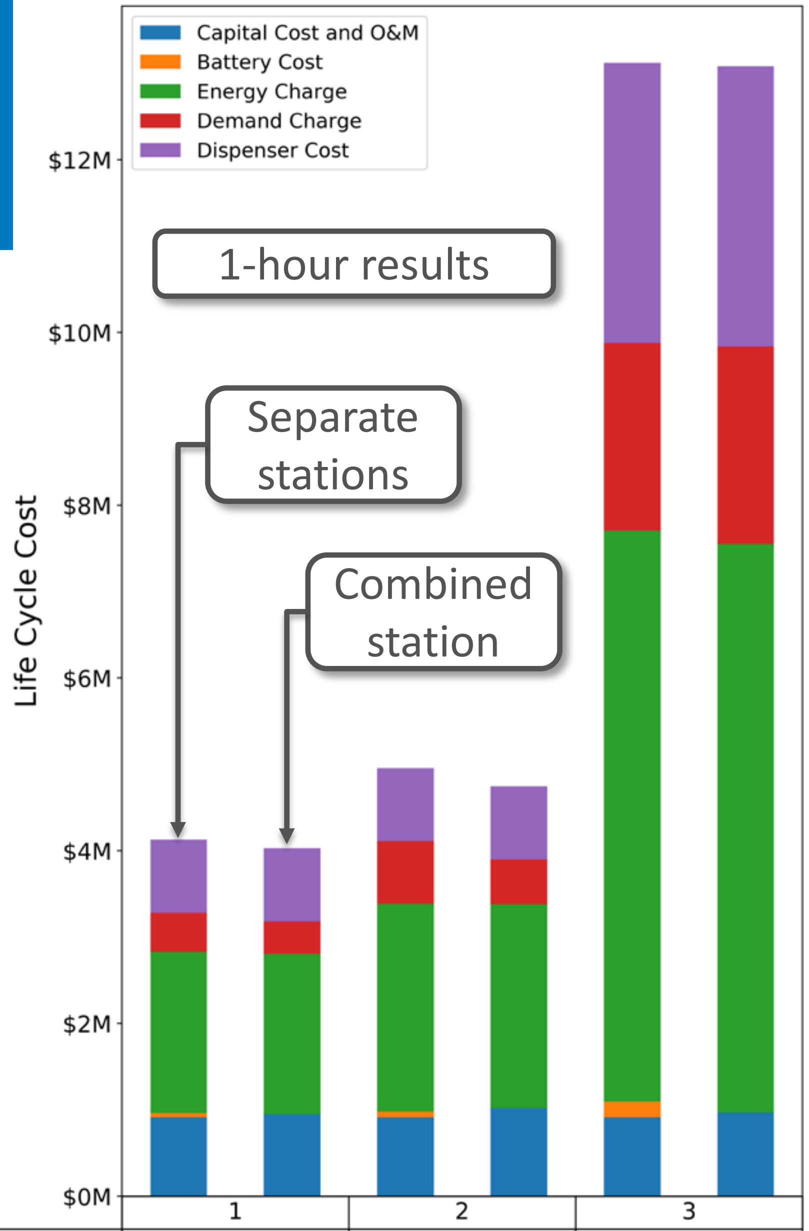
- Co-location with a supermarket load can slightly reduce DCFC system costs
- However, DCFC + hydrogen stations have the potential to reduce cost significantly beyond DCFC + co-location.



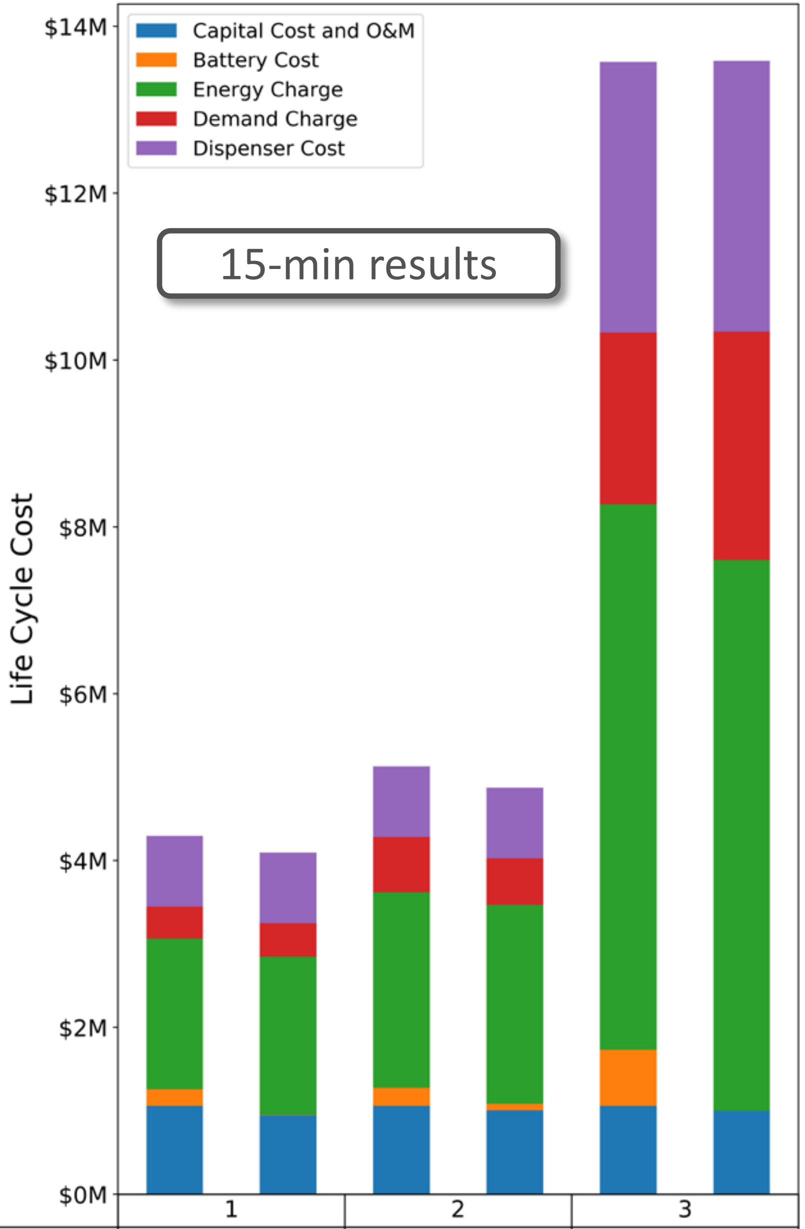
% Savings	0.4|2.1	0.4|3.8	0.1|0.3	0.1|0.0	0.2|0.0	0.1|2.8
Location	CA	CA	CA	CA	CA	CA
Hydrogen	Low	Low	Low	High	High	High
DCFC (Plugs)	4_lu	4	20	4_lu	4	20
Storage	Yes	Yes	Yes	Yes	Yes	Yes
PV	No	No	No	No	No	No

Evaluating 15-min Impacts

- Comparing % savings moving from 1-hour to 15-min resolution
- Greater savings with 15min analysis



	1	2	3
% Savings	2.4	4.2	0.3
Location	CA	CA	CA
Hydrogen	Low	Low	Low
DCFC (Plugs)	4_lu	4	20
Storage	Yes	Yes	Yes
PV	No	No	No



	1	2	3
% Savings	5.9	5.9	0.0
Location	CA	CA	CA
Hydrogen	Low	Low	Low
DCFC (Plugs)	4_lu	4	20
Storage	Yes	Yes	Yes
PV	No	No	No

System Sizes - NY

Location	NY	NY	NY	NY	NY	NY
H2 Load	Low	Low	Low	High	High	High
DCFC (plugs)	4	4 Low	20	4	4 Low	20

	1	1	2	2	3	3	4	4	5	5	6	6
Electrolyzer (kg/hr)	7.2	6.6	7.2	5.8	7.2	5.8	28.6	28.7	28.6	27.8	28.6	26.3
Low Pressure Storage (kg)	177.0	141.7	177.0	95.3	177.0	53.0	707.4	702.0	707.4	664.5	707.4	369.1
Compressor (kg/hr)	4.4	4.4	4.4	4.4	4.4	4.3	17.5	17.9	17.5	18.2	17.5	17.8
High Pressure Storage (kg)	70.5	75.6	70.5	72.2	70.5	71.0	277.9	309.7	277.9	297.9	277.9	287.0
Battery (kWh)	200.2	26.9	596.5	47.4	2,000.6	744.6	214.6	78.0	610.9	163.9	2,014.9	58.3
Inverter (kW)	95.3	20.4	169.7	36.0	461.7	310.1	96.0	38.1	170.4	59.0	462.4	44.2
Solar PV (kW)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

System Sizes - CA

Location	CA	CA	CA	CA	CA	CA
H2 Load	Low	Low	Low	High	High	High
DCFC (plugs)	4	4 Low	20	4	4 Low	20

	1	1	2	2	3	3	4	4	5	5	6	6
Electrolyzer (kg/hr)	4.3	4.4	4.3	4.9	4.3	4.6	17.1	17.1	17.1	17.4	17.1	19.9
Low Pressure Storage (kg)	7.7	14.8	7.7	31.3	7.7	22.3	30.2	30.9	30.2	46.8	30.2	117.9
Compressor (kg/hr)	4.3	4.4	4.3	4.3	4.3	4.4	17.1	17.2	17.1	17.3	17.1	17.7
High Pressure Storage (kg)	68.9	68.6	68.9	71.3	68.9	70.4	274.8	273.1	274.8	269.0	274.8	274.5
Battery (kWh)	51.9	0.0	69.2	0.0	188.3	0.0	51.9	0.0	69.2	0.0	188.3	0.0
Inverter (kW)	39.3	0.0	52.4	0.0	142.8	0.0	39.3	0.0	52.4	0.0	142.8	0.0
Solar PV (kW)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Snapshot of consumption profiles

- Hydrogen consumption profile for 1 example week out of the year
- DCFC electricity consumption for 1 example week out of the year
- Site load for 1 example week out of the year