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Economics of Public Electric Vehicle Charging
Quantifying Tangible Value and Financial Analysis

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ILLINOIS

Research Outline

Project 1

Quantify tangible value of public PEV charging

- Estimate the tangible value of the existing public charging infrastructure network to the PEV driver
- Estimates correspond to willingness to pay (WTP) for public charging

WTP for Charging Infrastructure is a function of:
electric range, charging availability & location, annual VMT, vehicle type, income

Project 2

Financial and DER Analysis of a DCFC plaza Case Study in San Diego

Evaluate financial viability of high power (125 kW & 400 kW) electric vehicle charging stations

- Estimation of operational costs for public charging
- Calculation of investors net income/profitability indices/cash flow
- Insights on break-even retail electricity price [in $ per kWh]

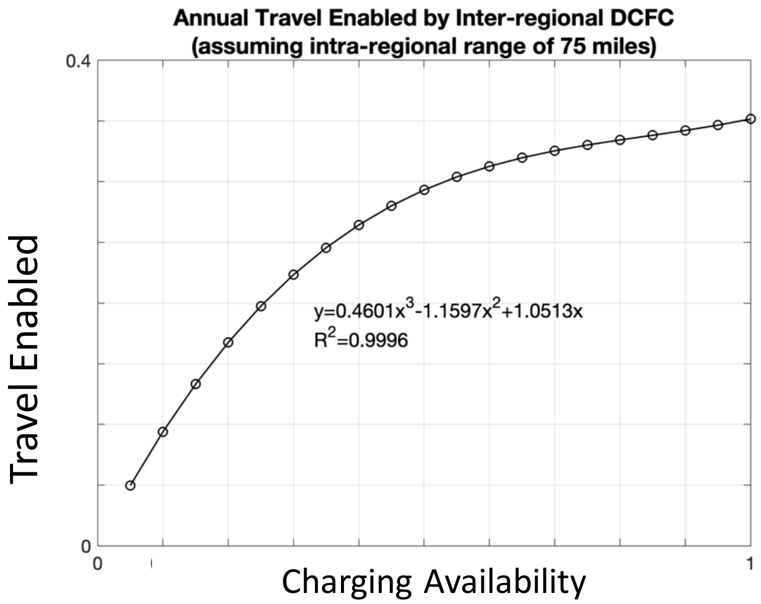
Project 1: Methods

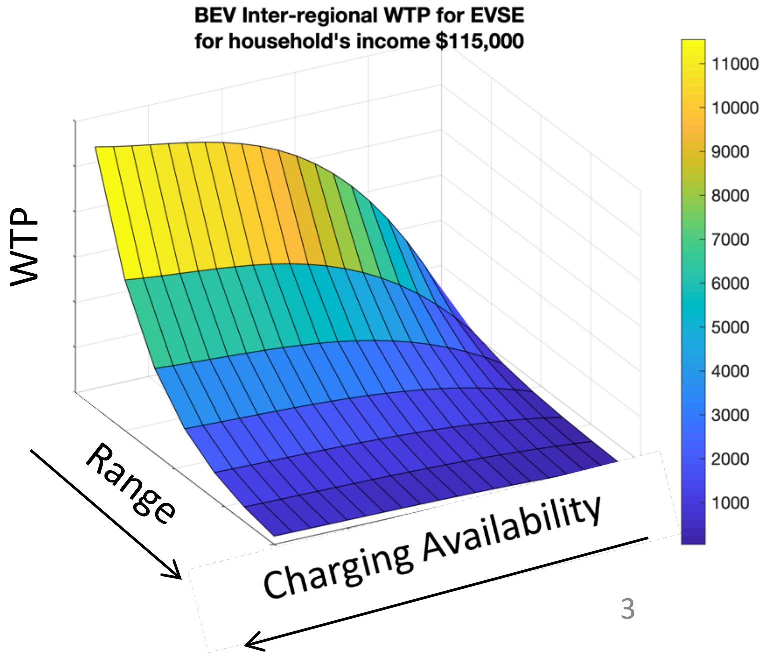
- Estimate **e-miles enabled by public chargers** (effect of chargers on e-miles, decreasing with vehicle range)

- Estimate **willingness to pay for enabled mile of travel** (based on WTP for vehicle range, which also enables additional e-travel)

- Function of **vehicle range and charging availability**
- **Heterogeneity**: income (marginal utility increase & value of time), annual VMT and daily distribution, charger type

Caveat: Awareness of public charging infrastructure differs from its actual availability, especially during early PEV adoption.





Project 1: Analysis

PHEV traveler's value for public charging:

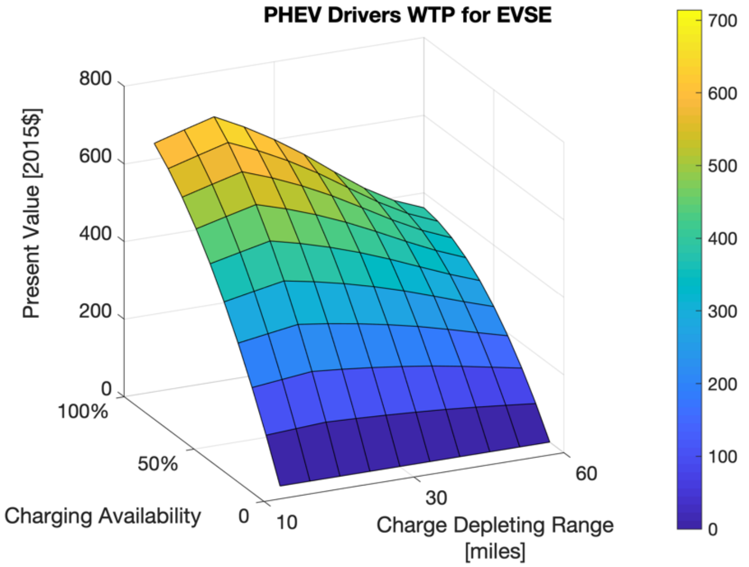
- value of **energy savings from additional miles conducted in charge-depleting mode**

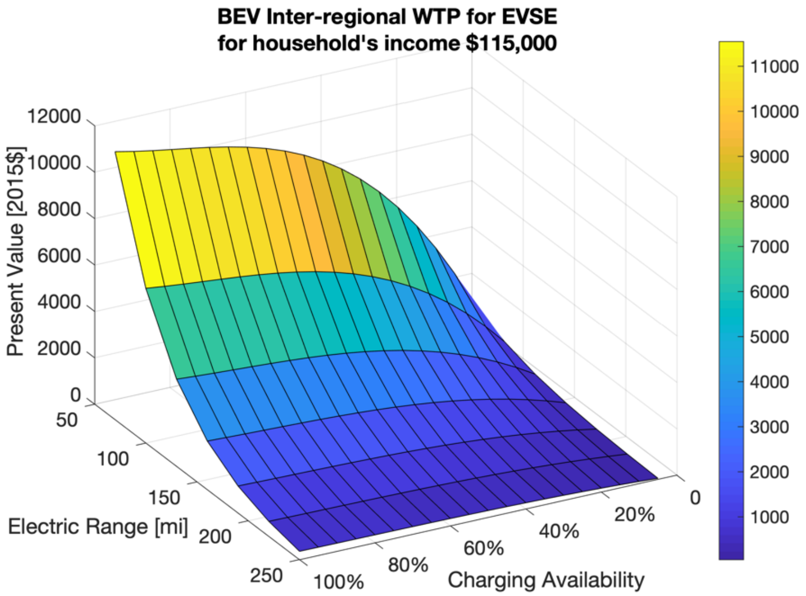
BEV intra-regional traveler's value for public charging:

- **value of added electrified miles** (additionally depends on the value of an enabled mile and the value of reduced time to access a charger)

BEV inter-regional traveler's value for public charging:

- based on the **value of added miles** (accounting for recharging time)

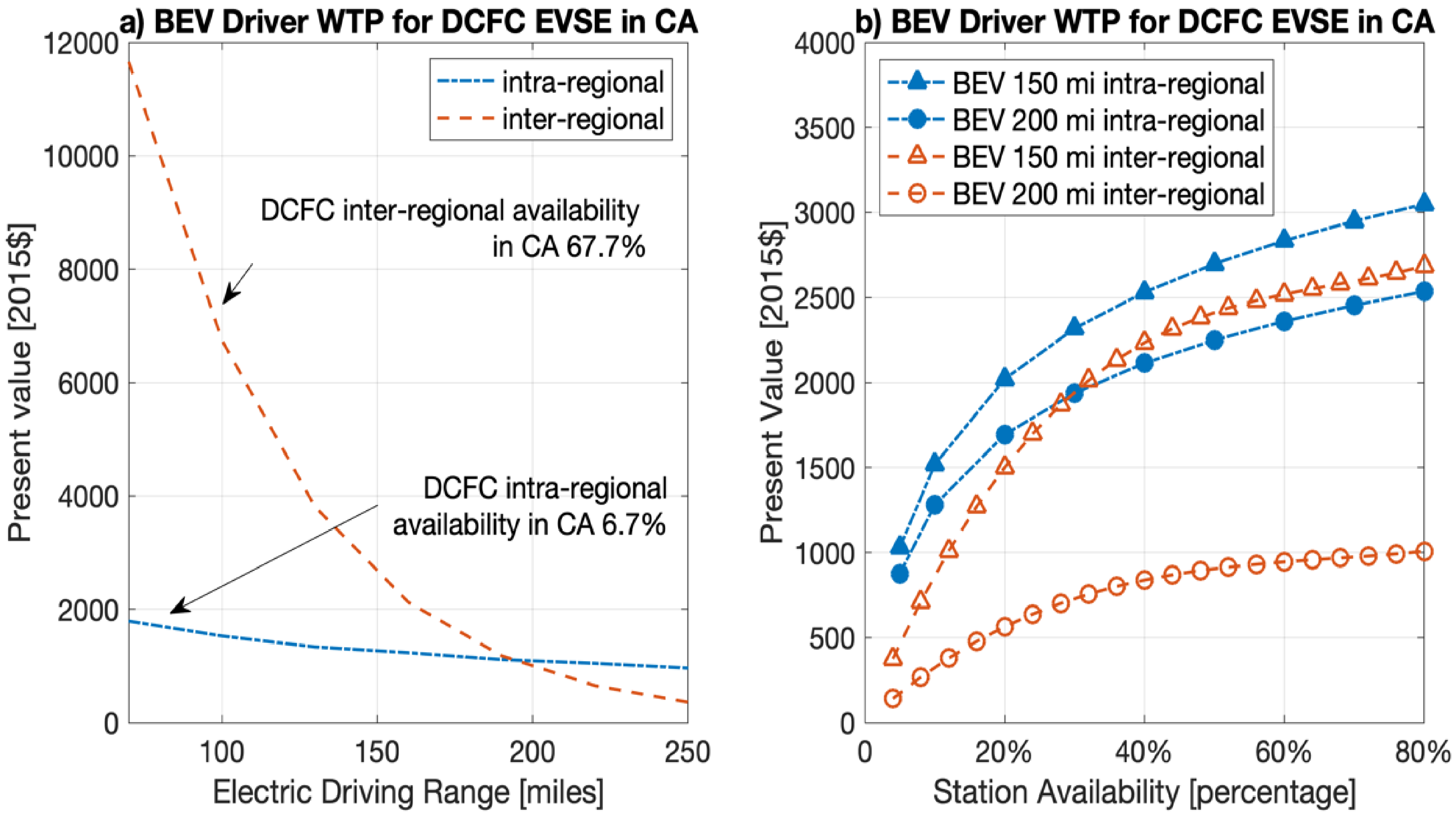




Project 1: Results

BEV Driver Value of Direct Current Fast Charging

- When range ≤ 200 mi high value of dense inter-regional fast charging network
- Value of charging increases as charging availability increases with diminishing returns, for both intra- and inter-regional travel



Project 2: Methods

Scenarios
- Direct current fast charging stations scenarios
- 12, 24, 48 plugs
- 125 or 400kW
- w & w/o energy storage & PVs output

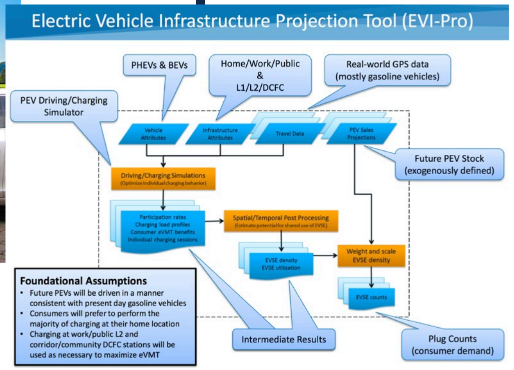
EVI-Pro Runs by CEC
- Years 2018-2025
- Annual charging events # hour-to-hour specification for DCFC plug
- Average vehicle kW

Location Selection
- San Diego CA
- Selection criteria
  - -Location
  - -Substations
  - -Land use
  - -Parking lot space
  - -Land costs

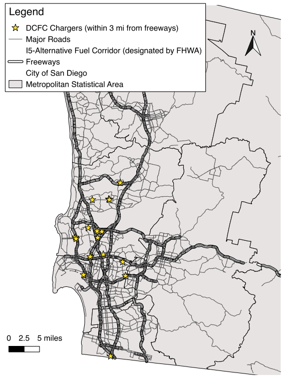
Grid Inputs & Electricity Rates
- Capital & installation costs from literature & PG&E data
- SDG&E electricity rate analysis

E-FAST Financial Analysis
- Financial performance of stations
- Net income
- Operational costs

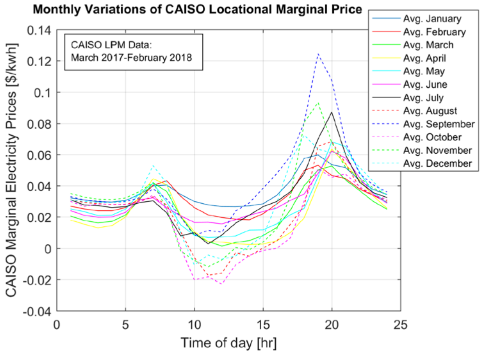
CEC Feedback



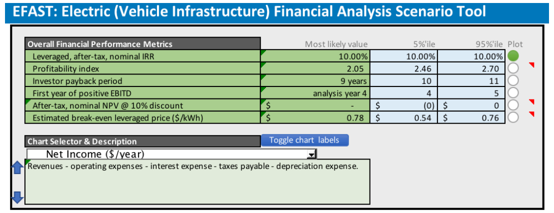
EVI-Pro Model Runs



GIS Analysis



Literature Review & Rate Analysis

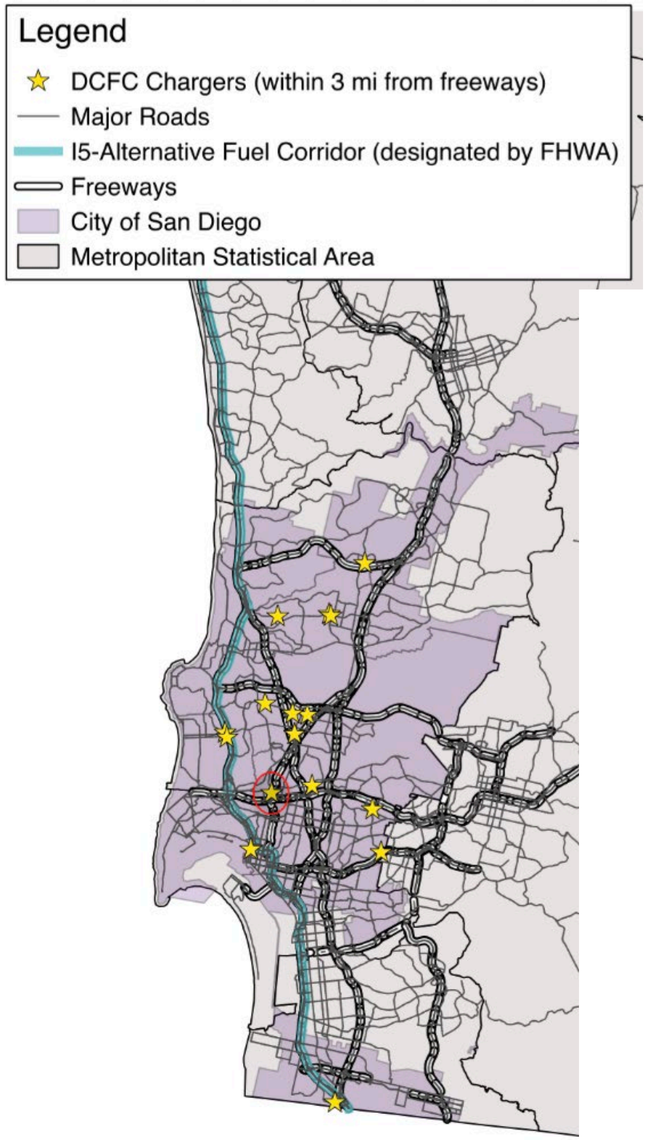


Electric-Financial Analysis Simulation Tool

EFAST adapted from: Penev M, Melaina M, Bush B, Zuboy J. Hydrogen Financial Analysis Scenario Tool (H2FAST): Spreadsheet Tool User's Manual. 2017.

Project 2: Analysis

Location



Scenarios Definitions

Power Requirements & Performance Definitions	**DCFC – 125 kW 12 / 24 / 48 ports**	**DCFC – 400 kW 12 / 24 / 48 ports**
Peak plug power (KW)	125 kW	400 kW
Peak power-sharing (W/station)	500 kW / 1.5 MW / 4 MW	2 MW / 4.4 MW / 8 MW
Alternative scenario 1: Only ES Energy storage power (kW): Battery capacity (kWh):	46 kW / 139 kW / 367 kW 122 kWh / 366 kWh / 970 kWh	184 kW / 404 kW / 735 kW 485 kWh / 1,067 kWh / 1,939 kWh
Alternative scenario 2: Energy storage + PV size	ES: same as above PV: 393.1 kW (PVWatts)	ES: same as above PV: 393.1 kW (PVWatts)

Other Data Definitions

- Monthly charging station energy use
- Average battery electric vehicle power levels over the analysis year
- Capital and installation costs for scenarios considered
- San Diego Gas and Electric electricity rate applicable to public DCFC

Project 2: Results

Break-even Electricity Prices (BEP), Profitability Indices (PI), and Internal Rate of Return (IRR) of DCFC Station with 125 kW Ports

	12 Plugs - DCFC 125kW			24 Plugs - DCFC 125kW			48 Plugs - DCFC 125kW		
Scenarios & Metrics	**BEP [$/kWh]**	**PI**	**IRR**	**BEP [$/kWh]**	**PI**	**IRR**	**BEP [$/kWh]**	**PI**	**IRR**
Base Scenario	0.49	1.04	4.36%	0.48	1.08	8.52%	0.43	1.34	8.10%
Alt Scenario 1 Energy Storage	0.45	1.23	7.41%	0.42	1.38	8.45%	0.42	1.40	8.52%
Alt Scenario 2 Energy Storage + PV	0.50	1.10	2.22%	0.42	1.39	8.33%	0.38	1.64	11.48%

Break-even electricity price (BEP)

- Lower with ES and the lowest with ES and PVs due to operational cost savings achieved
- Variations as # of stations increase due to utilization levels increase

- **Profitability index (PI)**
  - Increases for Alt Scenarios & as utilization increases for larger stations

Conclusion and Policy Implications

Project 1

WTP Functions for Charging Infrastructure

- Drivers' benefit from the installation of additional public charging (energy efficiency, range extension, and time savings from DCFC)
- A new modeling framework assesses the benefits of investment in expanding the public charging network to drivers.

California Insights

To the purchaser of a new BEV with a 100-mile range and home charging in Sacramento:

- **Urban** public fast chargers are worth ~ $1,500 per driver for *intra-regional* travel,
- **Highway** fast chargers are worth > $6,500 per driver along *inter-city* routes.

Project 2

Financial and DER Analysis of a DCFC plaza

- Charging utilization is the most significant factor for achieving financial viability,
- DCFC station Internal Rate of Returns improve with the installation energy storage and photovoltaics, by reducing operational costs as driver demands grow
- Break-even prices range $ 0.36 - 0.50 / kWh and are similar to current subscription offerings like EVgo's Pay As You Go or Membership plans in San Diego.

Contact Info

Questions?

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Paper on public charging value:
https://efiling.energy.ca.gov/GetDocument.aspx?tn=233987&DocumentContentId=66806

Paper on DCFC financial analysis:
https://efiling.energy.ca.gov/GetDocument.aspx?tn=233876&DocumentContentId=66659

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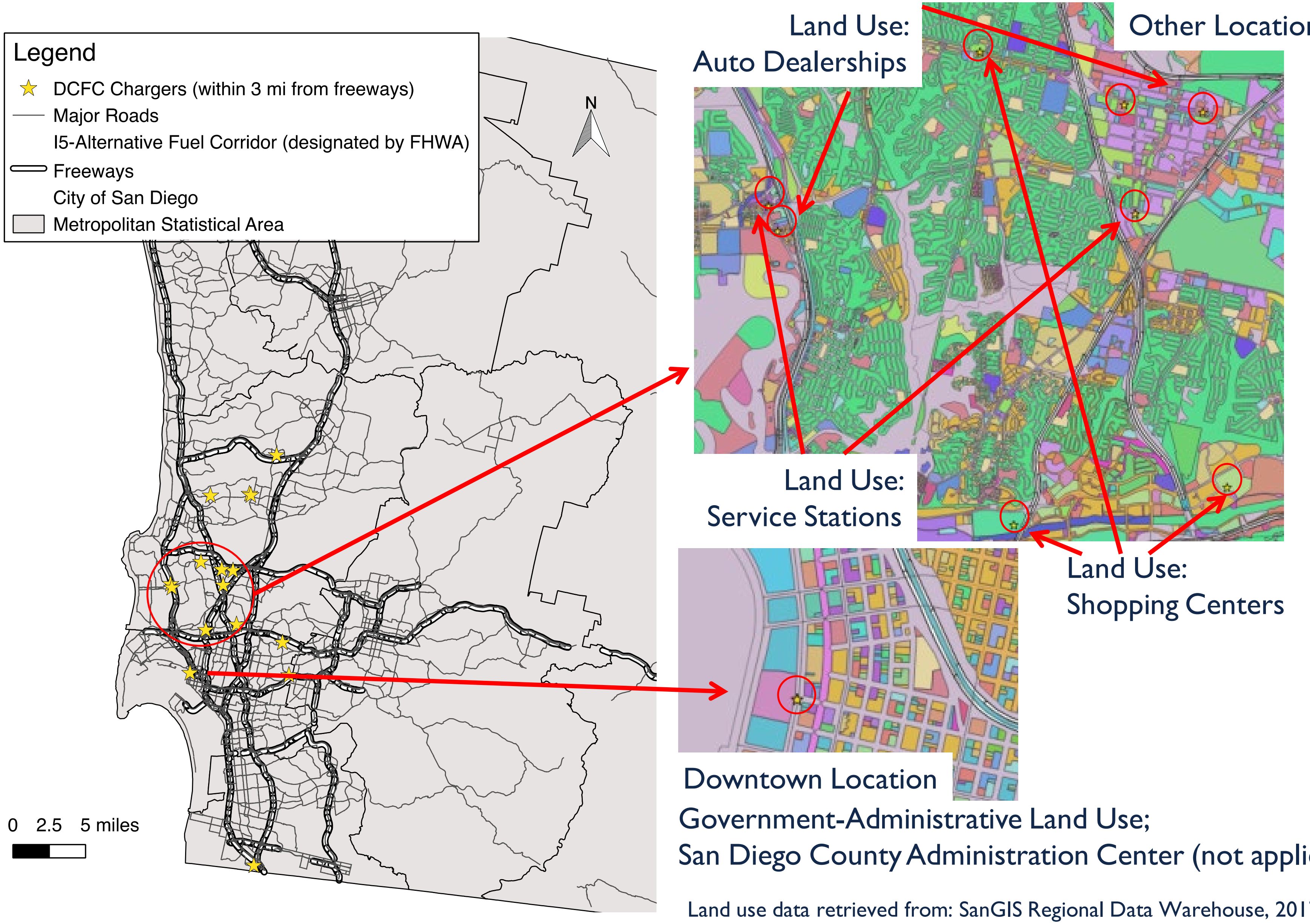
Appendix – San Diego DCFC Location Selection



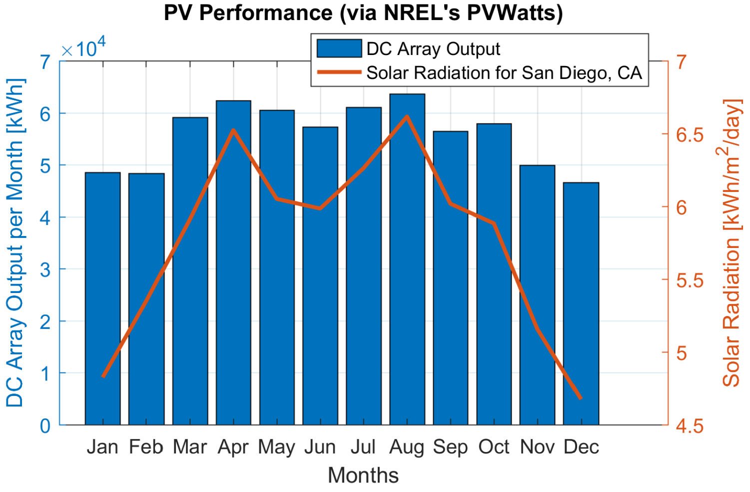
Government-Administrative Land Use;
San Diego County Administration Center (not applicable)

Land use data retrieved from: SanGIS Regional Data Warehouse, 2017
http://www.sangis.org/

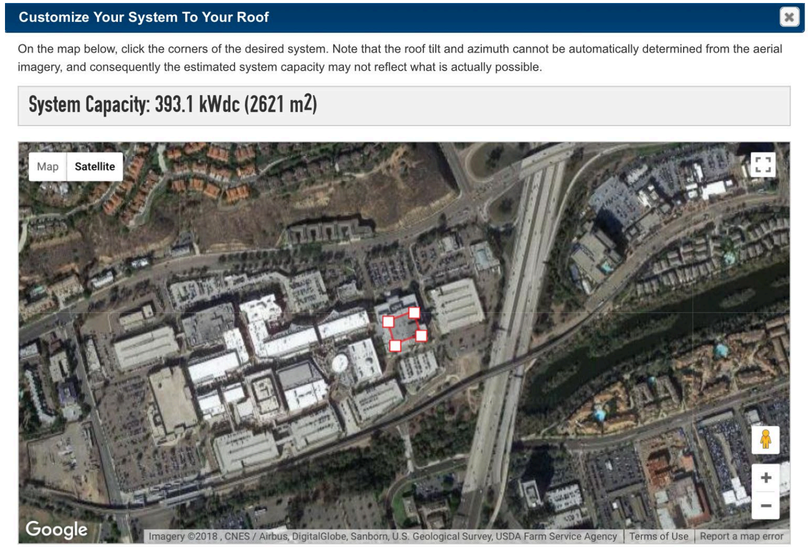
Appendix – Photovoltaic Performance Estimation

Performance Estimation for PVs

- Example:
  Using NREL PVWatts (http://pvwatts.nrel.gov/)



PVWatts Reference:
Dobos, A. P. (2014). PVWatts version 5 manual (No. NREL/TP-6A20-62641). National Renewable Energy Laboratory (NREL), Golden, CO.



Assumptions – based on PVWatts

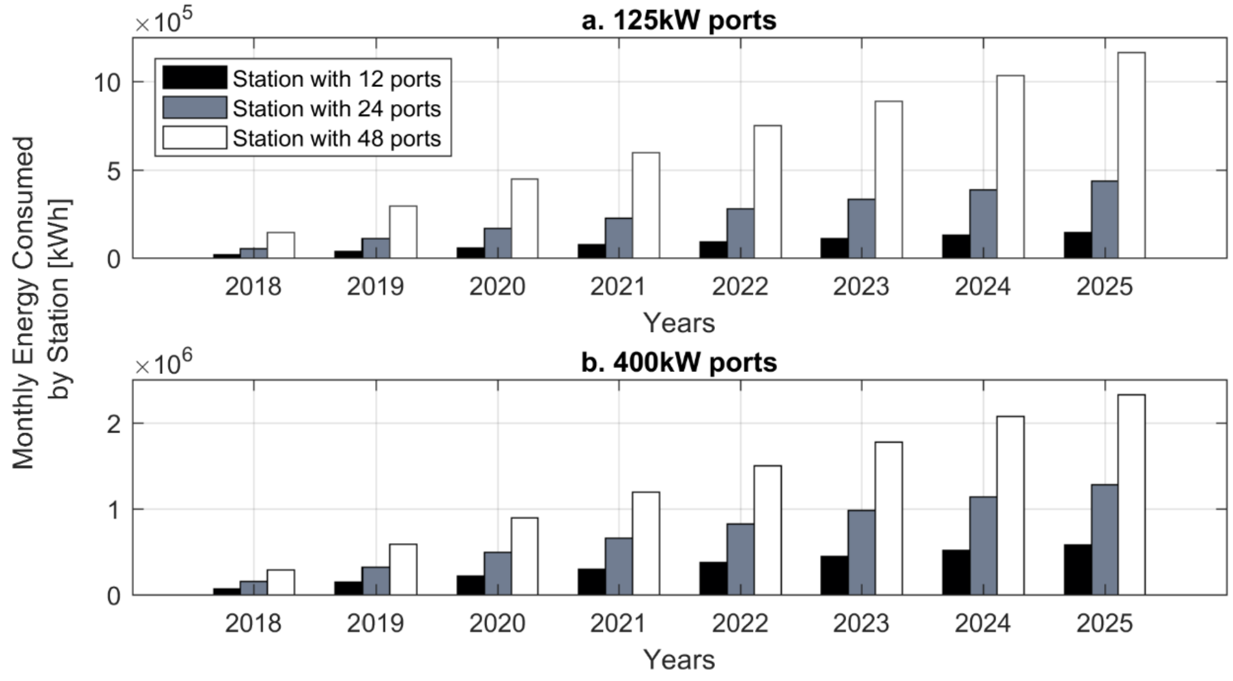
Location	San Diego, CA
DC System Size (kW)	393.1
Module Type	Standard
Array Type	Fixed (open rack)
Array Tilt (deg)	32.7
Array Azimuth (deg)	180
System Losses (%)	14
Invert Efficiency (%)	96
DC to AC Size Ratio	1.1
Capacity Factor (%)	18.7

Accomplished Savings

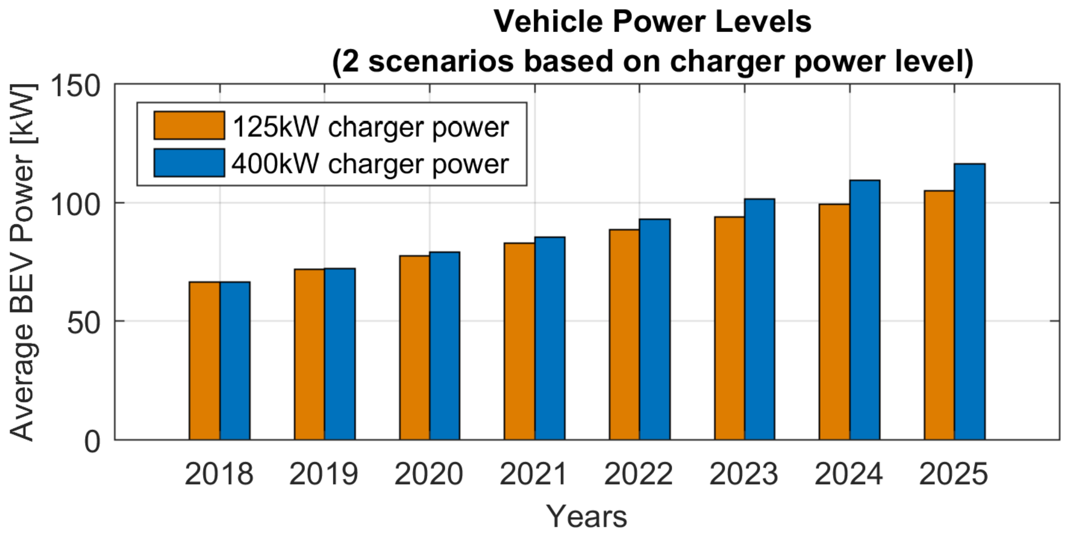
- Alt Scenario 2
  - Power reduced due to ES (impacts only on worst case scenario)
  - PV performance reduces energy consumed per month (impacts in best case as well)

Appendix – Utilization Assumptions

Monthly charging station energy use

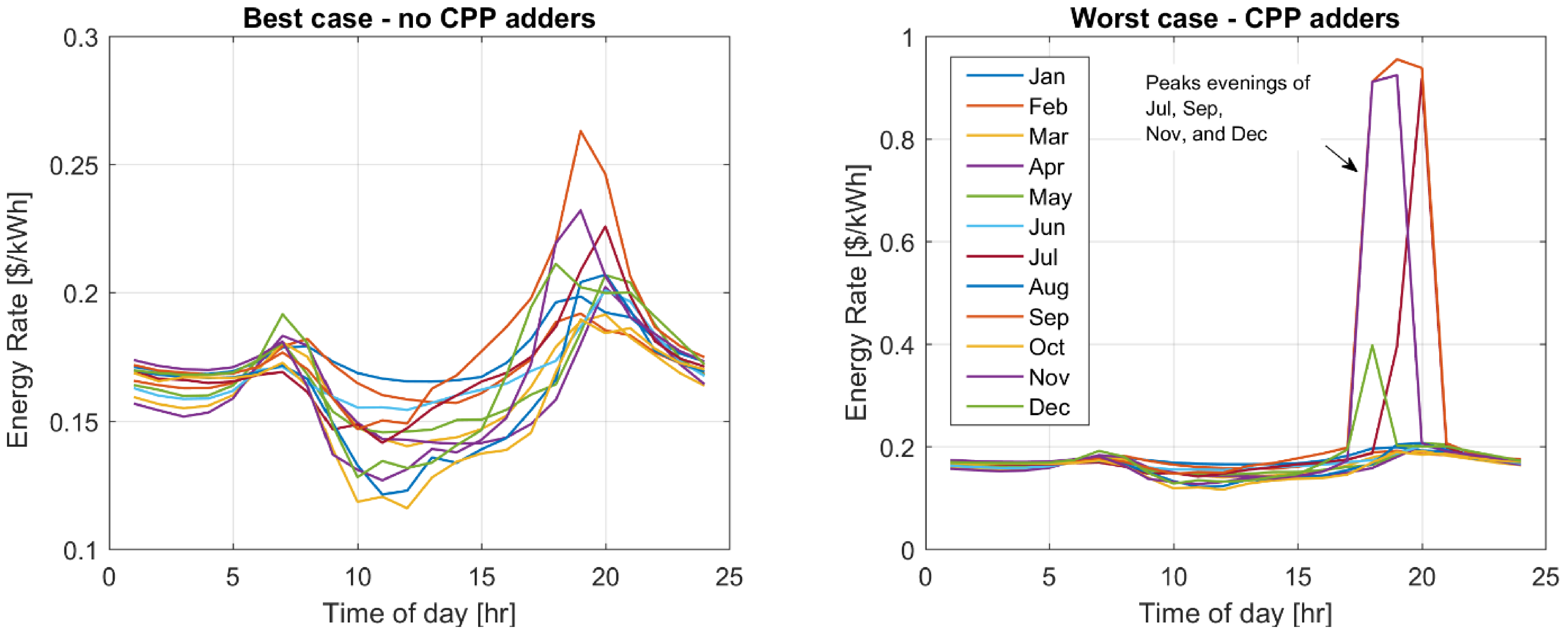


Average BEV battery power levels over the analysis years



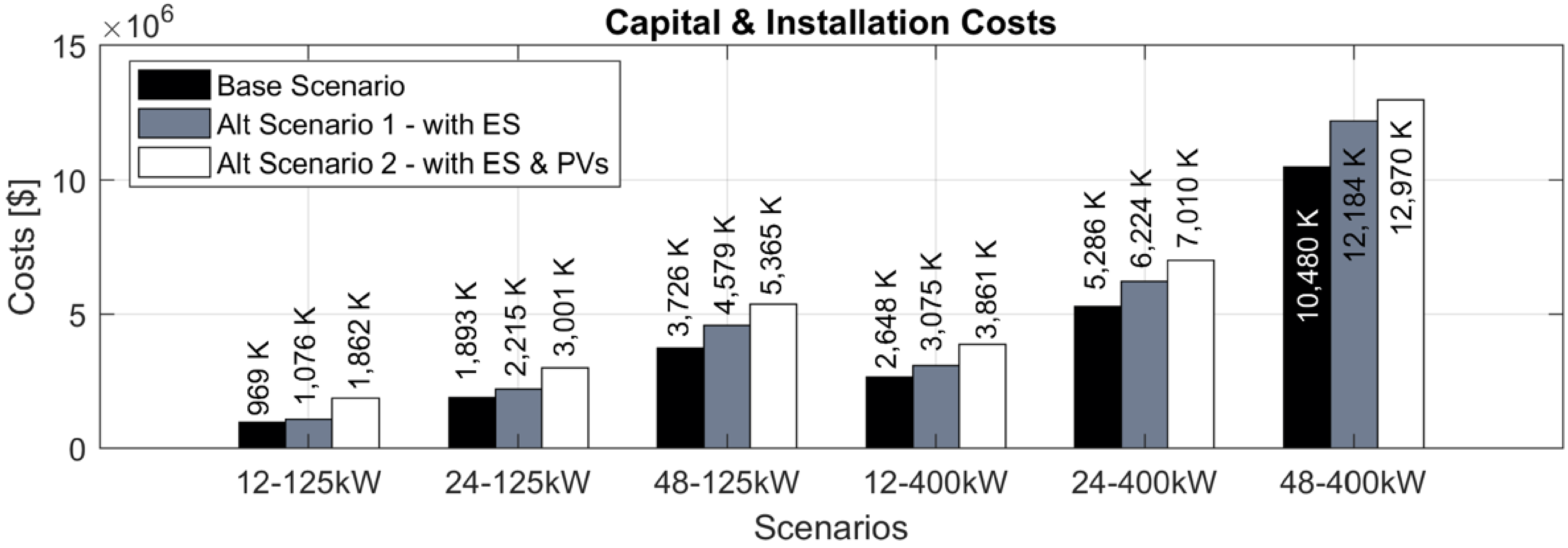
Appendix – San Diego Gas & Electric Rate

San Diego Gas and Electric electricity rate applicable to public DCFC



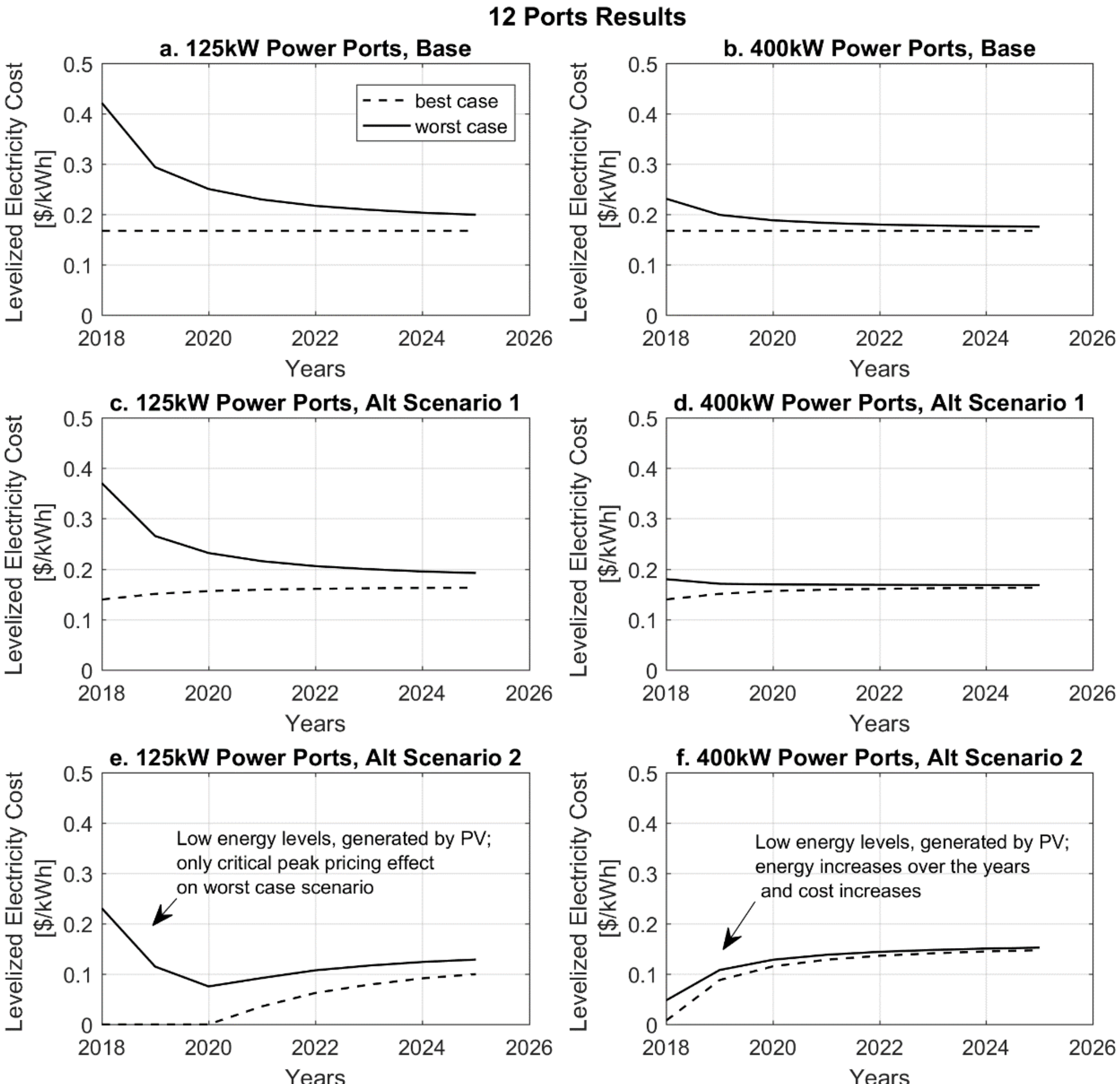
Rate data retrieved from: San Diego Gas and Electric. Prepared Direct Testimony of Cynthia Fang on Behalf of San Diego Gas & Electric Company 2017. https://www.sdge.com/sites/default/files/chapter_1_-_prepared_direct_testimony_of_cynthia_fang_0.pdf

Appendix – Capital and Installation Costs



Rate data retrieved from:
Francfort J, Salisbury S, Smart J, Garetson T, Karner D. Considerations for Corridor and Community DC Fast Charging Complex System Design 2017.
Cutler D, Olis D, Elgqvist E, Li X, Laws N, DiOrio N, et al. REopt: A Platform for Energy System Integration and Optimization 2017:1–8.
Meintz A, Zhang J, Vijayagopal R, Kreutzer C, Ahmed S, Bloom I, et al. Enabling fast charging – Vehicle considerations. J Power Sources 2017;367:216–27. doi:10.1016/j.jpowsour.2017.07.093.

Appendix – Levelized Electricity Costs (1)



Appendix – Levelized Electricity Costs (2)