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<th><strong>Docket Number:</strong></th>
<th>20-IEPR-02</th>
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<td><strong>Project Title:</strong></td>
<td>Transportation</td>
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<td><strong>TN #:</strong></td>
<td>234212</td>
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<tr>
<td><strong>Document Title:</strong></td>
<td>Presentation - Economics of Public Electric Vehicle Charging Quantifying Tangible Value and Financial Analysis</td>
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<tr>
<td><strong>Description:</strong></td>
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<td><strong>Filer:</strong></td>
<td>Raquel Kravitz</td>
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<tr>
<td><strong>Organization:</strong></td>
<td>University of Illinois</td>
</tr>
<tr>
<td><strong>Submitter Role:</strong></td>
<td>Public Agency</td>
</tr>
<tr>
<td><strong>Submission Date:</strong></td>
<td>8/3/2020 4:08:38 PM</td>
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<td><strong>Docketed Date:</strong></td>
<td>8/3/2020</td>
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Economics of Public Electric Vehicle Charging
Quantifying Tangible Value and Financial Analysis

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Joint work with:
Eric Wood, Matteo Muratori & NREL colleagues as well as David Greene UTK
Noel Crisostomo & Kadir Bedir CEC
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

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

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

- **WTP functions**
  - 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.
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)
BEV Driver Value of Direct Current Fast Charging

- When range $\leq 200$ 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

CEC Feedback

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

Scenarios

E-VI-Pro Runs by CEC

GIS Analysis

Electric-Financial Analysis Simulation Tool

Electric-Financial Analysis Simulation Tool

Literature Review & Rate Analysis

### Power Requirements & Performance Definitions

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

<table>
<thead>
<tr>
<th>Scenarios &amp; Metrics</th>
<th>12 Plugs - DCFC 125kW</th>
<th>24 Plugs - DCFC 125kW</th>
<th>48 Plugs - DCFC 125kW</th>
</tr>
</thead>
<tbody>
<tr>
<td>BEP [$/kWh]</td>
<td>PI IRR</td>
<td>BEP [$/kWh]</td>
<td>PI IRR</td>
</tr>
<tr>
<td>Base Scenario</td>
<td>0.49 4.36%</td>
<td>0.48 8.52%</td>
<td>0.43 8.10%</td>
</tr>
<tr>
<td>Alt Scenario 1</td>
<td>0.45 7.41%</td>
<td>0.42 8.45%</td>
<td>0.42 8.52%</td>
</tr>
<tr>
<td>Energy Storage</td>
<td>0.50 2.22%</td>
<td>0.42 8.33%</td>
<td>0.38 11.48%</td>
</tr>
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</table>

### 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

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.

Financial and DER Analysis of a DCFC plaza

Project 1

• 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.
Questions?

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Noel Crisostomo noel.crisostomo@energy.ca.gov

Paper on public charging value:  

Paper on DCFC financial analysis:  

The California Energy Commission (CEC)’s Alternative and Renewable Fuel and Vehicle Technology Program (ARFVTP) supported this work. The authors would like to acknowledge guidance and input provided by Energy Commission staff. Any opinion, error, and omission are the sole responsibility of the authors.

The views and opinions of the authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof. Neither the United States The views and opinions expressed in this presentation are those of the author alone and do not reflect the positions of NREL or of the US government.
Appendix – San Diego DCFC Location Selection

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

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

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)

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

PVWatts Reference:
Appendix – Utilization Assumptions

Monthly charging station energy use

- **a. 125kW ports**
  - Station with 12 ports
  - Station with 24 ports
  - Station with 48 ports

- **b. 400kW ports**

Average BEV battery power levels over the analysis years

- **Vehicle Power Levels**
  - (2 scenarios based on charger power level)
  - 125kW charger power
  - 400kW charger power

Years:
- 2018
- 2019
- 2020
- 2021
- 2022
- 2023
- 2024
- 2025
San Diego Gas and Electric electricity rate applicable to public DCFC

Best case - no CPP adders

Worst case - CPP adders

Appendix – Capital and Installation Costs

Rate data retrieved from:
Appendix – Levelized Electricity Costs (1)
Appendix – Levelized Electricity Costs (2)