BACKGROUND

• The Department of Energy (DOE) identified vehicle technologies needed by the average American driver:
  – Affordable PEVs with increased all-electric range that meets all of their transportation needs
• One of the key roles of charging infrastructure is to support these extended range EVs with convenient charging that enables more electric miles driven, and promotes EV adoption
  – DOE also emphasizes that this must be done without negatively impacting the electric grid
• The most likely solution are well-placed Community and Corridor Charging Infrastructure Complexes equipped with DC Fast Chargers
METHOD

- Experts from plug-in electric vehicle (PEV) manufacturers, and charging infrastructure and electric utility industries were used to supplement the lessons the INL team has learned from vehicle and charging infrastructure studies
  - EPRI Infrastructure Working Council meeting input
  - Private conversations with industry members
- This input helped refine the concept criteria and rough order of magnitude (ROM) costs of a Community and Corridor DC Fast Charging Complex Blueprint
- The Charging Complex Blueprint must support today’s and tomorrow’s EVs and their much larger traction battery packs
CONCEPT DEFINITION

• The DC Fast Charging Blueprint is a conspicuous multi-station fast charging complex that provides fast and convenient away-from-home charging, and promotes further adoption and use of the longer range EVs.

• These complexes are intended to provide a connected network of the most convenient charging stations available to facilitate all-electric miles between and within metropolitan areas of the USA.
DCFC LESSONS LEARNED

• Most of the existing population of 50 kW DC fast chargers (DCFCs) are used to extend travel for current EV models that operate primarily within urban areas. This can be seen by:
  – 70% of all DCFC events occur within 20 miles of home\(^1\)
  – Average SOC at start of fast charge is 35%\(^1\)
  – In the EV Project, 61% of all DCFCs were less than 10 kWh\(^2\)
  – The most highly utilized DCFCs tended to be located close to interstate highway exits\(^2\)

DCFC LESSONS LEARNED, cont’d

- DCFCs are used most often between 4 pm and 6 pm, and the second most frequent time period is between 11 am and 2 pm\(^{(1)}\)

- Except Tesla Supercharging stations, nearly all existing DCFC stations have a single charger

- When comparing publicly accessible charging, DCFC is used five times more often than Level 2 EVSE convenience charging\(^{(2)}\)

Charging complexes are defined as either Rural or Urban locations.

Rural: fast charging complexes that are intended to support inter-urban travel.
- Located between urban centers and typically associated with other inter-urban facilities e.g. small towns, truck stops, fast food, convenience stores, tourist information centers.
- Charging at Rural Locations is expected to transfer more energy per charge event than at Urban Locations.
Urban: fast charging complex that is expected to support intra-urban travel and EV owners who do not have regular overnight charging opportunities (multi dwelling units). May also support inter-urban travel

- Not necessarily co-located with other activities, but are convenient to commuting travel corridors within a metropolitan area
- Urban complexes are also used to connect to other urban areas, so energy transfer will vary from top offs to full charges
DESIGN CRITERIA

• Assumptions drives ROM costs
  – Siting
  – Expandability
  – Dispensers
  – Power/Energy
  – Grid Impact
  – Renewables
  – Compliance
  – Cost Factors
  – Power and Energy Factors
SITING

• Rural
  – Direct access from State or Federal highway (<1,000 ft.)
  – Nearby access to grid power
  – Associated with other entities such as convenience stores, truck stops, restaurants, points of interest, etc.
  – Grid asset
    • Grid services provided from distributed energy storage or renewable energy generation

• Urban
  – Adjacent to high traffic streets and commuter routes
  – Nearby access to grid power
  – Direct access for site ingress and egress to street from both directions
EXPANDABILITY

- Charging complex designed to allow expansion from minimum capability required to full (Ultimate) capability
  - Site power supply
  - Dispenser power capability
- Minimum capability required
  - Six charge dispensers with a minimum of 50 kW capability
  - 100 kW grid power supply
  - Onsite energy storage
- Ultimate capability required
  - Six charge dispensers with ~350 kW capability
  - 200 kW grid power supply
  - Onsite energy storage
DISPENSERS

- Must be capable of meeting present and future energy throughput requirements

- Urban locations are more likely to provide a “top up” charge, while Rural locations are assumed to provide a near full charge
  - Minimum capability
    - Urban, 6 units at 50 kW
    - Rural, 6 units with a mixture of 50 kW and 150 kW
  - Ultimate capability
    - Urban, 6 units with a mixture of 50 kW and ~350 kW
    - Rural, 6 units with a mixture of 150 kW and ~350 kW
DISPENSERS, cont’d

• Dispensers to be either or both CHAdeMO and CCS, and the future standard established for ultimate capability fast chargers
• Upgrade to ~350 kW as vehicles become available
• Allocate power when demand exceeds capacity. This can be done using various priority algorithms (e.g. FIFO, lowest SOC gets most power)
POWER/ENERGY

• Modular design enables incremental growth from minimum to full capability without power system equipment replacement

• Capability to meet a defined Level of Service
  – Urban locations
    • Simultaneous full power delivery of 20 kWh from three dispensers
    • Immediately followed by full power delivery of 20 kWh from another three dispensers
  – (Assumes a fair amount of opportunity charges)
POWER/ENERGY, cont’d

- Rural locations
  - Simultaneous full power delivery of 80 kWh from three dispensers
  - Immediately followed by full power delivery of 80 kWh from another three dispensers
- (Assumes full, not opportunity charges)
GRID IMPACT

• Charging facility grid Load Factor\(^{(1)}\)
  – Minimum ≥ 30%
  – Ultimate ≥ 50%

• Energy storage preferred
  – Enables demand reduction
  – Supports Load Factor compliance
  – Recycle plan must be included
    • End-of-life recycle
    • End-of-life responsibility defined

• Charge power limitation may be employed for demand reduction after minimum service level is achieved

(1) Load Factor = Monthly Peak Demand / Monthly Energy Consumed X 730
RENEWABLES

• Rural
  – 40% of actual charge energy supplied shall be renewable
  – Renewable source need NOT be co-located, but more likely to be in rural settings than urban
  – This does NOT include energy supplied to grid services or local facilities

• Urban
  – 25% of actual charge energy supplied shall be renewable
  – Renewable source need NOT be co-located
COMPLIANCE

• Fully permitted by local authorities meeting National Electric Code standards

• Addresses Americans with Disabilities Act accessibility
  – Vehicle Parking
  – Dispenser Access
  – Access to any other Facilities

• Point-Of-Sale security
  – Payment Card Industry (PCI) Data Security Standard (DSS)
COST FACTORS

- Costs need to account for both minimum or initial costs as well as updating to meet ultimate fast charging capability
  - Capital costs
    - For equipment, land improvements, engineering
  - Operations costs
    - Electricity (energy, access and demand)
    - Facility running costs (property lease, insurance, communications, staffing, etc.)
    - Maintenance & repairs
    - Warranty
<table>
<thead>
<tr>
<th>Description</th>
<th>Minimum Rural Six 50-kW</th>
<th>Minimum Urban Six 50-kW</th>
<th>Ultimate Rural Six 350-kW</th>
<th>Ultimate Urban Six 350-kW</th>
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<tbody>
<tr>
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<td>Load center and meter section</td>
<td>$3,500</td>
<td>$3,500</td>
<td>$6,000</td>
<td>$6,000</td>
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<tr>
<td>Energy storage system (ESS)</td>
<td>$83,200(4)</td>
<td>$20,800(5)</td>
<td>$353,600(6)</td>
<td>$126,286(7)</td>
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<tr>
<td>Photovoltaic Energy System (40% rural &amp; 25% urban)</td>
<td>$8,000(8)</td>
<td>$5,000(9)</td>
<td>$24,000(10)</td>
<td>$16,000(11)</td>
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<td>DCFC unit hardware</td>
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<td>Concrete pads materials and labor</td>
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<td>$30,000</td>
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<tr>
<td>Total</td>
<td>$354,700</td>
<td>$292,300</td>
<td>$876,700</td>
<td>$649,786</td>
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</tbody>
</table>
ROM CHARGING FACILITY COST (notes)

(1) Utility interconnection costs include line extension at distribution voltage

(2) Transformers are utility property, so are priced separately

(3) Separate meter section with CTs

(4) 160 kWh at 50 kW supplied by ESS. ESS cost of $400/kWh. ESS sized 30% over required energy

(5) 40 kWh at 50 kW supplied by ESS. ESS cost of $400/kWh. ESS sized 30% over required energy

(6) 389 kWh at 850 kW supplied by ESS. ESS cost of $700/kWh kWh as a result of high power requirement. ESS sized 30% over required energy

(7) 97 kWh at 850 kW supplied by ESS. ESS cost of $1,000/kWh kWh as a result of very high power requirement. ESS sized 30% over required energy

(8) 40 kW of solar providing 8 equivalent hours of energy at full power, costing $200/kW
(9) 25 kW of solar providing 8 equivalent hours of energy at full power, costing $200/kW

(10) 120 kW of solar providing 8 equivalent hours of energy at full power, costing $200/kW

(11) 80 kW of solar providing 8 equivalent hours of energy at full power, costing $200/kW

(12) Rural labor includes travel costs

(13) Costs include site preparation (excavation, boring, concrete cutting), lighting, shelter, and signage equipment and installation, curbing, asphalt paving and striping, and landscaping

(14) Costs include conduit and cabling installation, electrical equipment installation, grid connection hardware and labor
# ROM Monthly & Annual Operating Costs

<table>
<thead>
<tr>
<th>Cost</th>
<th>Rate</th>
<th>Minimum Capability</th>
<th>Ultimate Capability</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Rural</td>
<td>Urban</td>
</tr>
<tr>
<td>Demand</td>
<td>$12/kWh</td>
<td>$1,200(^{(1)})</td>
<td>$1,200(^{(1)})</td>
</tr>
<tr>
<td>Energy</td>
<td>12¢/kWh</td>
<td>$1,577(^{(3)})</td>
<td>$1,971(^{(4)})</td>
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<tr>
<td>Site lease</td>
<td>$1/sq-ft</td>
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<tr>
<td>Warranty</td>
<td>1%</td>
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<tr>
<td>Maintenance</td>
<td>$50/unit</td>
<td>$300</td>
<td>$300</td>
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<tr>
<td>Communications</td>
<td>$150</td>
<td>$150</td>
<td>$150</td>
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<tr>
<td>TOTAL MONTHLY</td>
<td>- -</td>
<td>$11,727</td>
<td>$11,321</td>
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<tr>
<td>TOTAL ANNUALLY</td>
<td></td>
<td>$140,724</td>
<td>$135,852</td>
</tr>
</tbody>
</table>
ROM OPERATING COST (notes)

1. Peak monthly demand = 100 kW. Higher power required to meet Service Level requirements provided by ESS.

2. Peak monthly demand = 200 kW. Higher power required to meet Service Level requirements provided by ESS.

3. Load Factor of 30% requires 2 charges of 80 kWh per dispenser per day. 40% of energy supplied by photovoltaic.

4. Load Factor of 30% requires 6 charges of 20 kWh per dispenser per day. 25% of energy supplied by photovoltaic.

5. Load Factor of 50% requires 5 charges of 80 kWh per dispenser per day. 40% of energy supplied by photovoltaic.

6. Load Factor of 50% requires 20 charges of 20 kWh per dispenser per day. 25% of energy supplied by photovoltaic.
## ROM POWER AND ENERGY ASSUMPTIONS
FOR SIZING ENERGY STORAGE SYSTEM (ESS)

<table>
<thead>
<tr>
<th></th>
<th>Rural</th>
<th>Urban</th>
<th>Rural</th>
<th>Urban</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dispenser Power (kW)</td>
<td>50</td>
<td>50</td>
<td>350</td>
<td>350</td>
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<tr>
<td>Vehicle Charge Energy (kWh)</td>
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<td>20</td>
<td>80</td>
<td>20</td>
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<tr>
<td>Service Level (simultaneous vehicles)</td>
<td>3</td>
<td>3</td>
<td>3</td>
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<tr>
<td>Service Level (repeats)</td>
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<td>2</td>
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<tr>
<td>Grid Power (kW)</td>
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<td>100</td>
<td>200</td>
<td>200</td>
</tr>
<tr>
<td>Load Factor</td>
<td>30%</td>
<td>30%</td>
<td>50%</td>
<td>50%</td>
</tr>
<tr>
<td>Charge Demand (kW)</td>
<td>150</td>
<td>150</td>
<td>1,050</td>
<td>1,050</td>
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<tr>
<td>ESS Power (kWh)</td>
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<td>50</td>
<td>850</td>
<td>850</td>
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<td>Minimum Grid Energy (kWh)</td>
<td>21,900</td>
<td>21,900</td>
<td>73,000</td>
<td>73,000</td>
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<tr>
<td>Minimum Service (charges/dispenser/day)</td>
<td>2</td>
<td>6</td>
<td>5</td>
<td>20</td>
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<tr>
<td>Grid Energy Cost @ 12¢/kWh</td>
<td>$2,628</td>
<td>$2,628</td>
<td>$8,760</td>
<td>$8,760</td>
</tr>
<tr>
<td>Grid Power Cost @ $12/kW/month</td>
<td>$1,200</td>
<td>$1,200</td>
<td>$2,400</td>
<td>$2,400</td>
</tr>
<tr>
<td>ESS Capacity (kWh)</td>
<td>160</td>
<td>40</td>
<td>389</td>
<td>97.14</td>
</tr>
<tr>
<td>ESS Cost ($/kWh)</td>
<td>$400</td>
<td>$400</td>
<td>$700</td>
<td>$1,000</td>
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<tr>
<td>ESS System Costs ($)</td>
<td>$83,200</td>
<td>$20,800</td>
<td>$353,600</td>
<td>$126,286</td>
</tr>
</tbody>
</table>

- Set the number of vehicles you want to charge simultaneously at FULL dispenser power (with maximum grid power, sizes the ESS power).
- Set the number of times you want to repeat the Full power charges back-to-back (sizes ESS energy).
- Set the Maximum Grid Power (limits demand charges and sizes the ESS power).
- Set the Load Factor to something reasonable to protect the grid (with Maximum grid Power, determines how many vehicles need to be charged during the month).
- Then the number of charges/dispenser/month reacts to Grid Power and Load Factor.
SAMPLE LAYOUTS – CHARGE ISLAND
SAMPLE LAYOUTS – FRONTAGE SITE
SAMPLE LAYOUTS – CORNER SITE
SUMMARY

- Comments from EPRI meeting considered
- Obtained additional input from DCFC providers in the U.S. and Europe, U.S. electric utilities, and PEV OEMs
- All hardware and subsystems are identified and costs estimated
- The most likely use cases are identified
- We defined as narrowly as possible, the ROM for costs
- The business case analysis is being performed by Atlas Public Policy

- Thank you for your attention