<table>
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<th><strong>Docket Number:</strong> 20-IEPR-02</th>
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<tr>
<td><strong>Project Title:</strong> Transportation</td>
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<tr>
<td><strong>TN #:</strong> 234209</td>
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<tr>
<td><strong>Document Title:</strong> Presentation - Medium-and Heavy-Duty Electric Vehicle Infrastructure Projections (HEVI-Pro)</td>
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<tr>
<td><strong>Description:</strong> S3. 5 Bin Wang, Lawrence Berkeley National Laboratory</td>
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<td><strong>Filer:</strong> Raquel Kravitz</td>
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<tr>
<td><strong>Organization:</strong> Lawrence Berkeley National Laboratory</td>
</tr>
<tr>
<td><strong>Submitter Role:</strong> Public Agency</td>
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<tr>
<td><strong>Submission Date:</strong> 8/3/2020 4:08:38 PM</td>
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<td><strong>Docked Date:</strong> 8/3/2020</td>
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Medium- and Heavy- Duty Electric Vehicle Infrastructure Projections (HEVI-Pro)

August 6, 2020 IEPR Workshop - California Energy Commission

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Electrifying Medium and Heavy-Duty Vehicles

- CARB’s Advanced Clean Trucks regulation requires an increasing share of trucks sold in California to be zero emission starting in 2024, leading to a full transition to ZEVs by 2045.

- AB 2127 calls for the CEC to project charging infrastructure needed to decarbonize trucking and to reduce the impact of diesel air pollution.

- LBNL is developing HEVI-Pro (heh·vee prow) in collaboration with the CEC, via applied research funds from the Clean Transportation Program.

- HEVI-Pro will project infrastructure needs for decarbonizing medium and heavy-duty vehicles; NREL’s EVI-Pro projects needs for light-duty vehicles (GVWR<10,000 lbs.).

### HEVI-Pro | Metrics

#### Charging infrastructure need and load profiles for MHDVs

<table>
<thead>
<tr>
<th>Region</th>
<th>Charging infrastructure requirements for each county. Aggregate estimates by: (1) City (2) Town (3) Rural area (4) Interstate/state highway</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1) Public (Shared) (2) Private (Dedicated) (3) Public/Private (Shared / Dedicated)</td>
</tr>
<tr>
<td></td>
<td>Examples include: (1) 50 kW (DCFC) (2) 125 kW (3) 250 kW (4) 350 kW (5) 1 - 4 MW</td>
</tr>
<tr>
<td></td>
<td>Charging stations servicing Class 8 heavy-duty trucks should be listed in a separate manner from “normal” charging stations (serving LDVs &amp; MHDVs).</td>
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<tr>
<td></td>
<td>For each type of chargers used for each type of use application, estimates shall be given as (1) # of plugs [Alternative metrics could also be given]</td>
</tr>
<tr>
<td></td>
<td>(2) # of stations (3) # of plugs per station (4) # of plugs per 1,000 PEVs</td>
</tr>
<tr>
<td>Vehicle use pattern</td>
<td>Region</td>
</tr>
<tr>
<td>------------------------</td>
<td>------------</td>
</tr>
<tr>
<td>Fixed route, fixed time, return-to-base</td>
<td>Urban</td>
</tr>
<tr>
<td>Fixed route</td>
<td>Urban</td>
</tr>
<tr>
<td>Non-fixed route</td>
<td>Rural area</td>
</tr>
<tr>
<td></td>
<td>Inter-county</td>
</tr>
<tr>
<td></td>
<td>Highways</td>
</tr>
</tbody>
</table>
Technical Solution: Top-down Approach

1. MHDV Projection (County Aggregation)
   - Aggregate county-level emission/energy projections
     • EMission FACtor (EMFAC)
   - Electric MHDV adoption projections
     • Mobile Source Strategy (MSS)
     • Midterm and long-term projections
     • South Coast AQMD projections
   - Vehicle specification
     • Powertrain parameters,
     • Battery parameters, etc.

2. Trip Disaggregation
   - Disaggregation approach
     • Allocate energy consumption to individual trips;
   - MHDV trip activity model informed by real-world datasets
   - Charging probability based on trip activity model, etc.

3. Infrastructure Assessment
   - Charger configuration
     • 50kW and 350kW chargers
   - Electric grid inputs
     • EDGE – capacity constraints
   - MHDV operation patterns
   - Fleet location/parking info, etc.
I. MHDV Projection

◆ Vehicle fleet
  - Vehicle population by county and by type (EMFAC)
  - Fleet registration locations
  - Hourly-based energy consumption profiles

◆ Projection of e-MHDV Adoption
  - Electrified MHDV population (CARB MSS)
  - South Coast AQMD attainment projections

◆ Electrified powertrain
  - Energy efficiency w.r.t vehicle type
  - Models of speed, payload, and duty-cycles
  - Regenerative braking, etc.
2. Data-driven Trip Disaggregation

**Usage and Survey Data**
- Number of trips per day;
- Number of “travel” days per week/season/year;
- Trip origins, destinations, waypoints, etc.
- Distribution of trip information: distance, duration;
- Purpose and payload of each trip

Time-based trip activity distributions

![Diagram of data-driven trip disaggregation process]
3. Infrastructure Assessment

**Battery and charging**
- Battery size (kWh);
- Charging power;
- Charger configuration;
- Private or shared;
- En route charger or depot;

**Operation preferences**
- Fixed route or flexible routes;
- Managed or smart charging

**Infrastructure assessment**

**Battery and charging technologies**
- Market inputs
  - Energy cost ($/kwh)
  - Peak demand charge ($/kW)
  - Cost saving as objectives
  - Price responsiveness, etc.

**Fleet operation preferences**

**Power system constraints**

**Grid constraints**
- Feeder circuit capacities
- Grid connection points
- Location constraints
- Voltage requirements etc.

**Analyses Forthcoming**
Preliminary Results

<table>
<thead>
<tr>
<th></th>
<th>MD/HD Battery EVs</th>
<th>50 kW Chargers</th>
<th>350 kW Chargers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Statewide in 2030</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>133,808</td>
<td>67,365</td>
<td>10,527</td>
</tr>
</tbody>
</table>

Key notes and assumptions:

- Only 50 kW and 350 kW chargers are considered
- MHDVs prefer 350 kW charger during daytime and prefer 50 kW during nighttime
- Electrified MHDVs follow similar duty cycles as traditional vehicles
- Electrified MHDVs use night and parking times for charging
- 80% initial SOC for each MHDV simulated
- Geospatial patterns not yet considered
- Results on the following slides will be modified as additional scenarios are run and are subject to change due to the scarcity of datasets on MHDV commercial vehicle operations thus far.
Preliminary Charger Counts by County and Power Capacity

50 kW

350 kW
Energy Consumption of Electric MHDVs While Driving (2030)
Statewide Load Profile Example (2030)

Hourly charging load profile by vehicle type

- Bus
- Refuse truck
- Drayage truck
- Tractor-trailer
- Utility Truck
- Construction Truck
- Other Freight Truck
- Agriculture Truck
- Medium-Duty Truck

Charging (MW) vs. hour (h)
County Load Profile Examples (2030)

- MHDV categories are aggregated from EMFAC categories
- Vehicle-specific charging probabilities are based on trip patterns
- Tractor-trailer type includes long-haul trucks (in/out state); Drayage trucks include T7 POLA (Port of Los Angeles) and T7 POAK (Port of Oakland)
Preliminary Findings (Phase 1)

- 67,365 50kW chargers (0.5 charger/vehicle) and 10,527 (0.08 charger/vehicle) 350kW high-power chargers are required to support 133,808 MHDVs in 2030.

- Accounting for ZEV scenarios to meet air quality standards, the South Coast Air Basin (LA, SB, OR, and RV) counties demand 35% (23,728 50kW chargers and 3,275 350kW chargers) of the infrastructure in California.

- The wide variation of MHDV charging patterns reflect the diversity of vehicle types, trip purposes, driving, and parking behaviors. Further characterization is needed.

- Drayage trucks show great potential for smart charging due to relatively predictable return-to-base travel patterns and the associated large power demands.

- Preliminary results from HEVI-Pro’s first illustrative scenario require stakeholder feedback to develop additional use cases. These results are subject to change due to the limited samples of data thus far and finer spatially-resolved analysis forthcoming.
Future Work (Phase 2)

◆ Bottom-up modeling and validation

  - Ensure applications meet commercial route scheduling requirements (e.g. fixed-route & return-to-base, fixed-route, non-fixed route)
  - Agent-based MHDV activity simulations
    - Return-to-base trucks / Urban delivery trucks / Inter-region / long-haul trucks
    - Optimization capability to investigate flexibility and impacts of smart charging
  - Collaborate w/ NREL EVI-Pro team for complex scenario development
  - Integrate parking location databases (Caltrans/UC Berkeley; Caltrans/Cambridge Analytics)
  - Incorporate more fleet location, operation and activity datasets

◆ Electricity demand, grid impact and mitigation analyses

  - Circuit capacity study using the CEC EVSE Deployment and Grid Evaluation (EDGE) model
  - Station operational economics by incorporating electricity prices, e.g. PG&E E-19
  - Grid impact analysis w.r.t. smart charging and charging load flexibility quantification
Collaboration with Current Partners and a Call to Action

We look forward to working with you!
Backup slides
## Vehicle Mapping Across CARB and CEC Typology

<table>
<thead>
<tr>
<th>EMFAC Type</th>
<th>HEVI-Pro Type</th>
<th>EMFAC Type</th>
<th>HEVI-Pro Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>T6 Ag</td>
<td>Agriculture Truck</td>
<td>T6 CAIRP Heavy</td>
<td></td>
</tr>
<tr>
<td>T7 Ag</td>
<td></td>
<td>T6 CAIRP Small</td>
<td></td>
</tr>
<tr>
<td>T6 Instate Construction Heavy</td>
<td>Construction Truck</td>
<td>T6 Instate Heavy</td>
<td></td>
</tr>
<tr>
<td>T6 Instate Construction Small</td>
<td></td>
<td>T6 Instate Small</td>
<td></td>
</tr>
<tr>
<td>T7 CAIRP Construction</td>
<td></td>
<td>T6 OOS Heavy</td>
<td></td>
</tr>
<tr>
<td>T7 Single Construction</td>
<td></td>
<td>T6 OOS Small</td>
<td></td>
</tr>
<tr>
<td>T7 Other Port</td>
<td>Drayage Truck</td>
<td>T6 Public</td>
<td></td>
</tr>
<tr>
<td>T7 POAK</td>
<td></td>
<td>T6TS</td>
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</tr>
<tr>
<td>T7 POLA</td>
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<td>T7 Public</td>
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<tr>
<td>LHD2</td>
<td>Medium-Duty Truck</td>
<td>T7 Single</td>
<td></td>
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<tr>
<td>T7 SWCV</td>
<td>Refuse truck</td>
<td>T7 CAIRP</td>
<td></td>
</tr>
<tr>
<td>T6 Utility</td>
<td>Utility Truck</td>
<td>T7 NNOOS</td>
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<tr>
<td></td>
<td></td>
<td>T7 NOOS</td>
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Other Freight Truck

Tractor-trailer
Transition from Top-down to Bottom-up Approach

1. County-level MHDV forecasts (EMFAC)
2. Forecast adoption rate for each vehicle type
3. Aggregate county-level population, VMT, emission and trips
4. Vehicle Specification Module (powertrain parameters, e.g., battery size, power ratings, efficiencies, etc.)
5. Operational patterns and speed impact (UCR, WVU, CA-VIUS)
6. Disaggregate demand to individual trips
7. Freight Travel Demand Model (CALTRANS)
8. CARB Mobile Source Strategy
9. DISAGGREGATION APPROACH
10. Charging tech configurations
11. Electricity market input data
12. Fleet operation preferences
13. Power system constraints
14. Trip-level SOC, Charging activities, Regional load profiles, etc.
15. EDGE Model
16. Transit Operation Module
17. Determine regional charging infrastructure need
18. Assess optimal deployment of MHDV charging infrastructure
19. GTFS datasets
20. NTD Transit Data
Next Steps: Bottom-up Approach

MHDV projection (aggregate at county level)

Assess optimal deployment of MHDV charging infrastructure

Infrastructure planning

- Flexibility quantification
- Determine regional charging infrastructure need
- Optimization (smart charging)

Charging tech configurations
- Electric market input data
- Fleet operations
- Power system constraints

Agent-based Activity Simulation
- Parking Location Data
- EDGE Model

MHDV activity generator (data-driven)
- GTFS datasets
- NTD Transit Data
- CARB TRU
- Freight Travel Demand Model (CALTRANS)
- Operational patterns and speed impact (UCR, WVU, CA-VIUS)
- Fleet size and distribution (CALSTART)
Energy Consumption of Electric MHDVs While Driving
CA Charging Load Profile (2030)