MHDVs in Assembly Bill 2127

The **AB 2127 Electric Vehicle Charging Infrastructure Assessment** quantifies the charging network, electric grid infrastructure, charger technologies, and programs needed to serve California’s zero emission vehicle deployment objectives for 2030.

Inaugural findings from the Energy Commission’s ongoing analyses to support the emergent medium- and heavy-duty charging sector:

- **157k chargers needed to support 180,000 BEVs**
- **Standardized Equipment**
- **Grid Integrated**
Planning for MHDV Charging Load

Market Input & Technology Analysis

HEVI-LOAD

Transportation Energy Demand Forecast

Resource Planning and Distribution Planning

Installation Programs

Types, quantities and locations of charging to meet California’s climate change, air quality and petroleum reduction goals

Load Profiles

Econometric forecasts of statewide electricity demand to be served by load serving entities
We appreciate the collaborative efforts!
Thank You!

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Fuels and Transportation Division
California Energy Commission
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https://www.energy.ca.gov/programs-and-topics/programs/electric-vehicle-charging-infrastructure-assessment-ab-2127
HEVI-LOAD Overview

- 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-LOAD in collaboration with the CEC, via applied research funds from the Clean Transportation Program.
- HEVI-LOAD will project infrastructure needs for decarbonizing medium and heavy-duty vehicles (GVWR > 10,000 lbs.).
- Within HEVI-LOAD, The LBNL team has been developing multiple assessment scenarios for medium and heavy electric vehicles that are based on both the top-down and the bottom-up approaches.
Outline

◆ HEVI-LOAD Methodology and Preliminary Results

◆ Scenario Updates
  □ Transportation Energy Demand Forecast - High/Low Charging Demand Scenarios
  □ Vehicle-specific Charging Power Levels (up to 200 kW)
  □ Vehicle-specific Charging Power Quartiles (up to 2 MW)

◆ Comparison and Discussion of Results

◆ Ongoing and Future Work
HEVI-LOAD Methodology and Preliminary Results
HEVI-LOAD Framework: Top-Down and Bottom-Up Models

**Top-Down Approach**

- **Fleet forecast**
  - County-level MHDV forecasts (EMFAC)
  - Regional decarbonization policy or scenarios
- **Convert fossil energy to electricity demand for various vehicle applications**
- **Aggregate county-level population, VMT, emission and trips**

**Disaggregation approach**

- **Projection of fleet size, distribution and powertrain parameters (CALSTART)**
- **CARB Truck Refrigeration Unit (TRUs)**
- **Operational patterns and duty-cycle impact from real-world datasets (UCR, WVU, CA-VIUS)**
- **Freight Travel Demand Model (CALTRANS)**

**Infrastructure planning**

- **GTFS datasets**
- **NTD Transit Data**
- **Parallel large-scale transportation-grid co-optimization (LBLN/NERSC)**

- **Transit Operation Module**
  - Determine regional charging/refueling infrastructure need
  - Freight/fleet Operation Module

**Charging tech configurations**

- Electricity market input data

**Fleet operation preferences**

- Power system constraints

**Agent-based Activity Simulation**

- Trip-level SOC, Charging activities, Driver behavior, Regional load profiles
- Truck parking study
- CEC EDGE Model

- Refueling process models
- Integrated driving-parking-charging behavioral models
- Infrastructure operation models w/ internal queuing and refueling behaviors
- Renewable energy integration
# Top-Down Modeling Approach: HEVI-LOAD Metrics

Charging infrastructure need and load profiles for MHDVs

<table>
<thead>
<tr>
<th>Region</th>
<th>Type of accessibility</th>
<th>Charger type</th>
<th>Number of chargers/plugs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Charging infrastructure requirements for each county.</td>
<td>(1) Public (Shared) (2) Private (Dedicated) (3) Public/Private (Shared / Dedicated)</td>
<td>Examples include: (1) 50 kW (DCFC) (2) 125 kW (3) 250 kW (4) 350 kW (5) 1 - 4 MW</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>Aggregate estimates by: (1) City (2) Town (3) Rural area (4) Interstate/state highway</td>
<td>Charging stations servicing Class 8 heavy-duty trucks should be listed in a separate manner from &quot;normal&quot; charging stations (serving LDVs &amp; MHDVs).</td>
<td>(2) # of stations (3) # of plugs per station (4) # of plugs per 1,000 PEVs</td>
<td></td>
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</tbody>
</table>
### Scope of HEVI-LOAD Analysis

<table>
<thead>
<tr>
<th>Vehicle use pattern</th>
<th>Region</th>
<th>Vehicle application and type</th>
<th>Charging</th>
</tr>
</thead>
</table>
| Fixed route, fixed time, return-to-base | Urban | (1) Transit bus  
(2) School bus  
(3) Refuse truck                                                                 | Overnight slow charging  
Private (i.e. dedicated)  
Slow-charging, lower charging power |
| Fixed route | Urban | (4) Port drayage trucks                                                                                      | Between trips  
Public/Private (Shared/dedicated)  
Fast-charging, high charging power  
Opportunities to co-support several types of LDV/MHDVs |
| Non-fixed route | Urban | (5) Last mile delivery (e.g. package delivery trucks)  
(6) Local-haul trucks (merchandise)  
(7) Regional-haul trucks  
(8) Vocational vehicles (e.g. emergency vans/trucks, construction trucks) |                                        |
| Rural area | (9) “Rural trucks” (e.g. farm trucks)                                                                       | Before, during, or after trips.  
Public/Private (Shared/dedicated)  
Heavy-duty accessible, very high charging power (e.g. 1 MW) |
| Inter-county | (10) Heavy-duty local-haul trucks                                                                             |                                        |
| Highways | (11) Heavy-duty long-haul trucks                                                                             |                                        |
HEVI-LOAD Technical Workflow

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.
1. 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
Trip behavior statistics - I
Trip behavior statistics - II

![Graph showing trip behavior statistics for different types of vehicles, including Beverage distribution, Construction, Delivery Truck, Freeway work, Goods Movement Truck, Line haul - out of state, Municipal work, Refuse, Refuse Hauler, School Bus, and Transit Bus. The graph displays duration in hours on the x-axis and duration per second on the y-axis.](image-url)
3. Infrastructure Assessment

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

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

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

**Infrastructure assessment**

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

**Analyses Forthcoming**
Infrastructure Results
August 2020

Key notes and assumptions:
- Only 50kW and 350kW 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.

<table>
<thead>
<tr>
<th>Statewide in 2030</th>
<th>MD/HD Battery EVs</th>
<th>50 kW Chargers</th>
<th>350 kW Chargers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>133,808</td>
<td>67,365</td>
<td>10,527</td>
</tr>
</tbody>
</table>
Charger Counts by County and Power Capacity (August 2020)

50 kW

350 kW
Statewide Load Profile (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)

hour (h)

Load (MW)
**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)

Butte

Alameda

Los Angeles
Scenario Update

Transportation Energy Demand Forecast (TEDF)
High/Low Charging Demand Scenarios
# High/Low Charging Demand Scenario - Definitions

**December 2020**

<table>
<thead>
<tr>
<th>Scenarios</th>
<th>ZEV Population</th>
<th>Battery capacity (yearly factor)**</th>
<th>GVWR</th>
</tr>
</thead>
<tbody>
<tr>
<td>MSS(HCD*)</td>
<td>Mobile Source Strategy</td>
<td>1.05</td>
<td>Heavier (full load)</td>
</tr>
<tr>
<td>TEDF-HIGH(HCD)</td>
<td>Transportation Energy Demand Forecast-High</td>
<td>1.05</td>
<td>Heavier (full load)</td>
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<tr>
<td>TEDF-MID(LCD*)</td>
<td>Transportation Energy Demand Forecast-Mid</td>
<td>1.07</td>
<td>Small (Empty)</td>
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</table>

* High or Low Charging Demand  
** Yearly increasing ratio of battery energy density (kWh/L) or specific energy (kWh/kg).
MHZEV population

Note: New populations according to the CARB State SIP Strategy (SSS) will be incorporated within future runs.
Estimate Trip Energy Request

- Vehicle specification module
  - Based on the vehicle driving dynamic resistance formula
  - Consider the weight, Cd (driving resistance coefficient), Front area, Rolling resistance
Statewide Charging Load Profiles, 2020-2030

Mobile Source Strategy High Charging Demand Scenario
December 2020
Statewide Charger Cost Estimate, 2020-2030
Mobile Source Strategy High Charging Demand Scenario
December 2020

Table 2. Per-charger public and workplace charger hardware cost.

<table>
<thead>
<tr>
<th>Level</th>
<th>Type</th>
<th>Chargers per pedestal</th>
<th>Per-charger cost</th>
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</thead>
<tbody>
<tr>
<td>Level 1</td>
<td>Non-networked</td>
<td>One</td>
<td>$813</td>
</tr>
<tr>
<td>Level 1</td>
<td>Non-networked</td>
<td>Two</td>
<td>$956</td>
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<tr>
<td>Level 2</td>
<td>Non-networked</td>
<td>One</td>
<td>$1,182</td>
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<tr>
<td>Level 2</td>
<td>Non-networked</td>
<td>Two</td>
<td>$938</td>
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<td>Level 2</td>
<td>Networked</td>
<td>One</td>
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<tr>
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<td>$2,793</td>
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<td>DC fast</td>
<td>Networked 50 kW</td>
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<td>$28,401</td>
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<tr>
<td>DC fast</td>
<td>Networked 150 kW</td>
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</tr>
<tr>
<td>DC fast</td>
<td>Networked 350 kW</td>
<td>One</td>
<td>$140,000</td>
</tr>
</tbody>
</table>

ICCT, Estimating electric vehicle charging infrastructure costs across major U.S. metropolitan areas, 2019
Vehicle Application-specific Load Profiles

- Aggregated charging load (Medium-Duty Truck)
- Aggregated charging load (Other Freight Truck)
- Aggregated charging load (Bus)
- Aggregated charging load (Construction Truck)
- Aggregated charging load (Utility Truck)
- Aggregated charging load (Refuse truck)
Scenario Update

Vehicle-specific Charging Power Levels (up to 200 kW)
Vehicle-specific Charging Powers
July 2021

◆ Two charging power levels are defined to meet the driving requirements for recharging at
  □ Depots (night time, Level A) and
  □ Opportunistic Locations (day time, Level B).

◆ Level B assumed to be ~2-3x Level A, up to 200 kW
Statewide Load Profile (2030)
High Charging Demand Scenario – TEDF High
July 2021
Tradeoff between charging energy and time spent (<200 kW)

In the diagram, the charging energy and charging time are shown for different charger power levels (200 kW, 100-150 kW, 50-60 kW, 13.5-19.2 kW).

- For 200 kW chargers, 47.0% of energy is charged in 0.0% time.
- For 100-150 kW chargers, 32.4% of energy is charged in 20.6% time.
- For 50-60 kW chargers, 20.6% of energy is charged in 29.1% time.
- For 13.5-19.2 kW chargers, 43.8% of energy is charged in 43.8% time.

There is an inverse relationship between charge power and the time spent receiving energy while dwelling.

Higher power charging can offer greater flexibility when in the future, time-of-use price-based shifting is applied to the load profile.
Scenario Update

Vehicle-specific Charging Power Quartiles (up to 2 MW)
Recent and anticipated Class 3 to Class 8 electric vehicle model specifications were analyzed. To observe the change of one variable, battery capacity (kWh) was held constant.

GVWR-specific quartiles of charging power were applied to the 34 EMFAC vehicle types
- 34 vehicle types x 4 quartiles x 2 powers (Level A and Level B)

Two charging powers are defined for each vehicle type to meet the driving requirements at
- Depots (night time, Level A) – based on the quartile analysis
- Opportunistic Locations (day time, Level B).

Level B assumed to be ~3x Level A
- “Heavy” applications charge faster than “Small” or “Light” counterparts in similar applications.
- International registration and out-of-state vehicles have faster charging capabilities
- For T6 and T7 vehicles, the Megawatt Charging System is conservatively assumed to deliver up to 1.6 MW.

See appendix slides for detail.
Statewide Energy Consumption while Driving (2030)
High Charging Demand Scenario – TEDF High
September 2021
Statewide Load Profile (2030)
High Charging Demand Scenario – TEDF High
September 2021
Tradeoff between charging energy and time spent (< 2 MW)

At chargers rated above 750 kW, MHDVs spend 3% of time charging but receive nearly 30% of all energy dispensed.

At chargers rated 75 kW or below, MHDVs spend 2/3 of all time dwelt while charging and receive about 20% of energy dispensed.
Discussion and Comparison of Results
Statewide Load Profile (2021-2030)
High Charging Demand Scenario – TEDF High

Without Charge Power Quartiles

With Charge Power Quartiles
While further analysis on how MHDV specifications affect load, a higher range and diversity in charging power among the applications allowed more energy to be dispensed at night, slightly reducing the peak demand.
Ongoing Efforts and Future Updates

◆ Bottom-up approach with more granular temporal and geospatial resolutions
Questions and input sought from DAWG Participants

◆ Are efforts to further define and diversify charging power reasonable?
  - Like battery capacity, should charge power grow over time for future vehicles?
  - Is it fair to assume all vehicles have faster (e.g. Level B) charging capabilities, or will some well-defined applications entirely charge at their depot?
  - Should a relationship between battery kWh and charge power be set? Should utility price and schedule delays be valued to upsize the charging capability of the vehicle?

◆ Battery energy capacity
  - Is the 5% annual growth factor in energy density reasonable? How should the growth in energy density affect the GVWR of the vehicle?
  - Should battery kWh be set into quartiles for each vehicle type?

◆ What other information about driver patterns can be incorporated into the behavioral logic model?
Medium- and Heavy-Duty Base Load Shapes For IEPR Forecast

Alex Lonsdale
Energy Assessments Division, California Energy Commission
Demand Analysis Working Group Meeting – September 14, 2021
Medium- and Heavy-Duty Base Load Shapes

- The following load shapes are preliminary and subject to change based on feedback provided at today’s meeting.
- 2020 IEPR base load shapes originate from ADM’s medium- and heavy-duty charge profile analysis.
- Preliminary 2021 IEPR base load shapes derived from HEVI-LOAD modelling results (With charging power quartiles).
- As a reminder, base load shapes serve as input to the EV Infrastructure Load Model.
  - Please note, effects of TOU rates are not included in the following comparisons.
Heavy-Duty Base Load Shapes (1)
Medium-Duty Base Load Shapes
Bus Base Load Shapes (1)
Bus Base Load Shapes (2)
Appendix
<table>
<thead>
<tr>
<th>Vehicle type (EMFAC)</th>
<th>Battery capacity (kWh)</th>
<th>Charging level Q1A (kW)</th>
<th>Charging level Q1B (kW)</th>
<th>Charging level Q2A (kW)</th>
<th>Charging level Q2B (kW)</th>
<th>Charging level Q3A (kW)</th>
<th>Charging level Q3B (kW)</th>
<th>Charging level Q4A (kW)</th>
<th>Charging level Q4B (kW)</th>
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<td>Vehicle type (EMFAC)</td>
<td>Battery capacity (kWh)</td>
<td>Charging level Q1A (kW)</td>
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<td>Charging level Q2B (kW)</td>
<td>Charging level Q3A (kW)</td>
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<td>Charging level Q4A (kW)</td>
<td>Charging level Q4B (kW)</td>
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