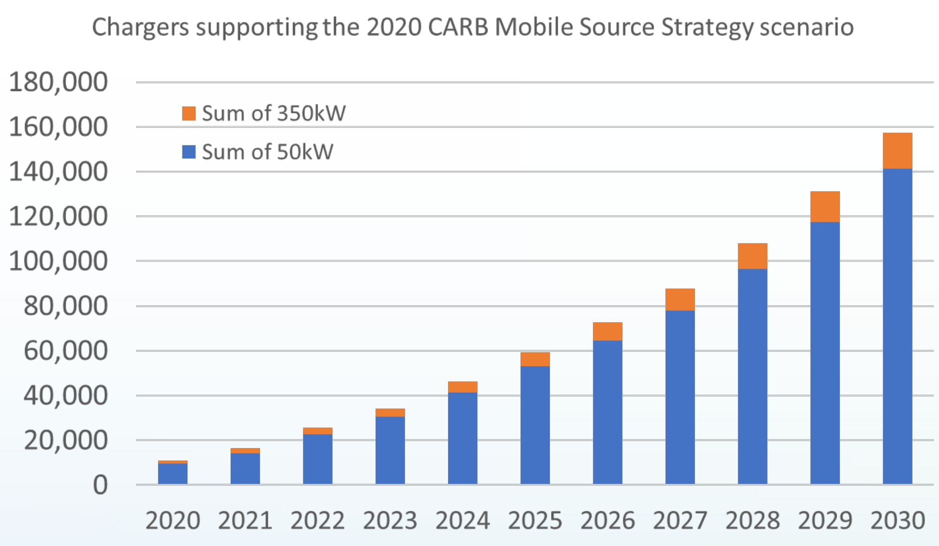
Medium and Heavy-Duty Vehicle Load Shapes

Noel Crisostomo
Fuels & Transportation Division, California Energy Commission
Demand Analysis Working Group Meeting – September 14, 2021

MHDVs in Assembly Bill 2127

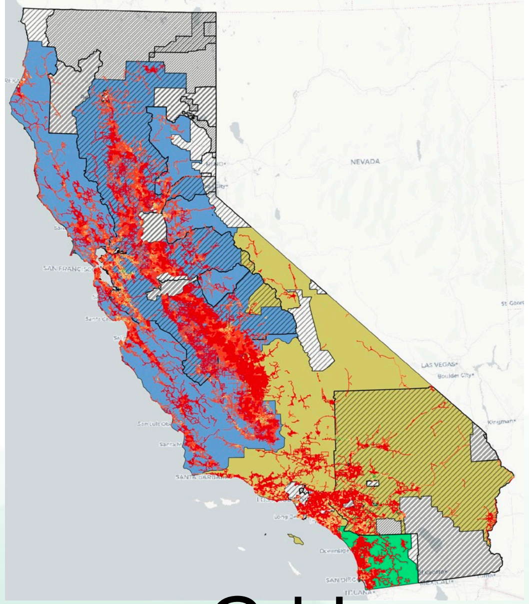
The *AB 2127 Electric Vehicle Charging Infrastructure Assessment* quantifies the charging network, electric grid infrastructure, charger technologies, and programs needed to serve California's zero emission vehicle deployment objectives for 2030.

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



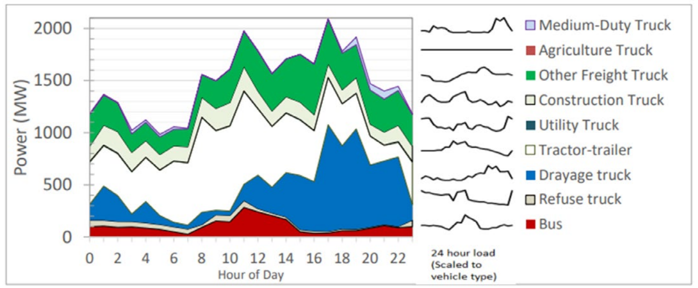
157k chargers needed to support **180,000 BEVs**

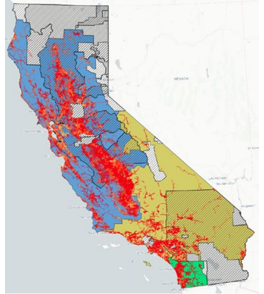
Standardized Equipment

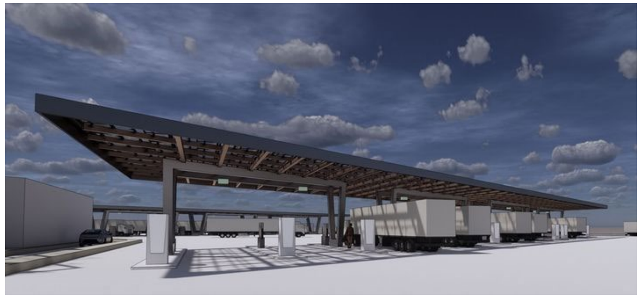


Grid **Integrated**

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!

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Thank You!

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Air Pollution Specialist

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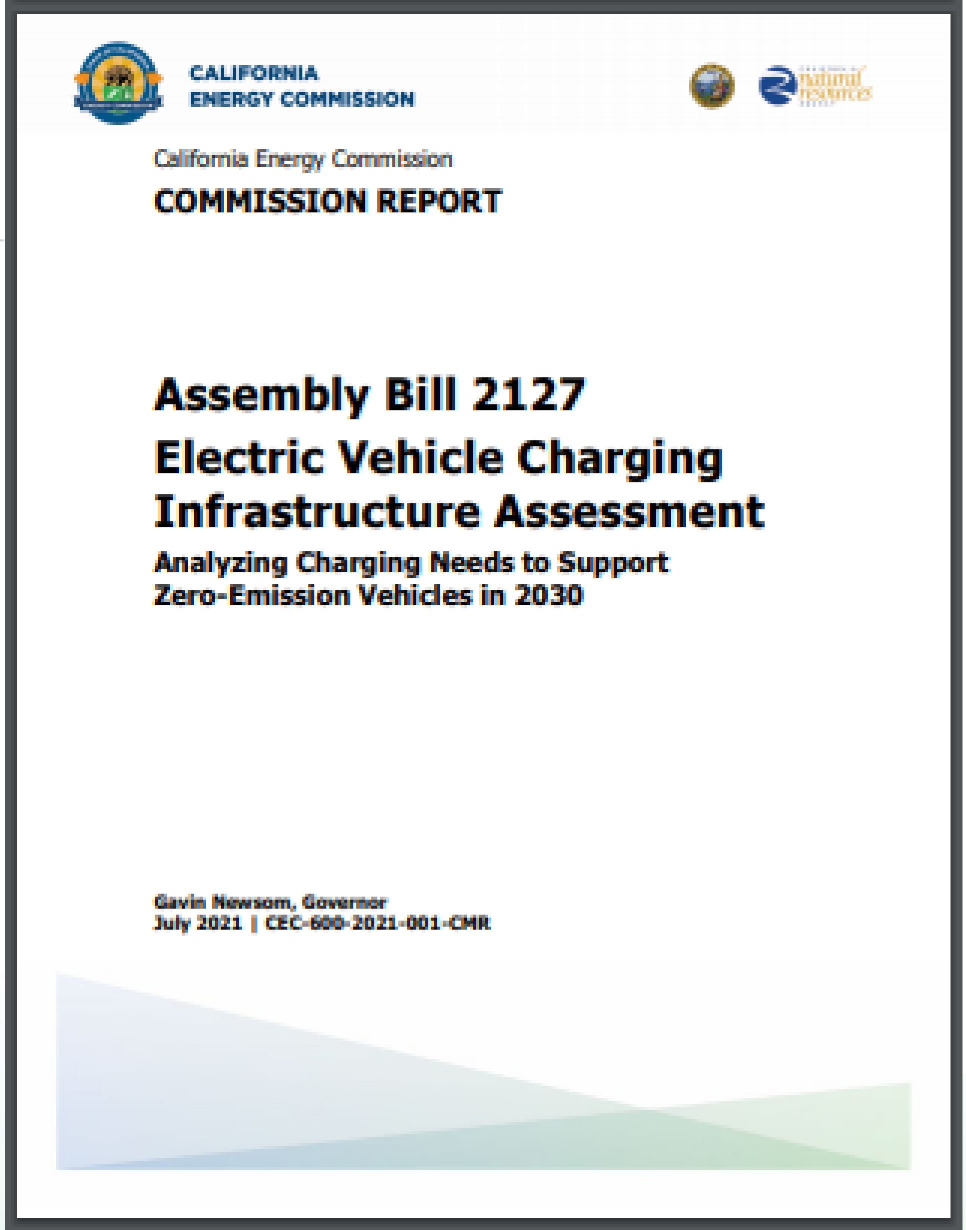


CALIFORNIA ENERGY COMMISSION

California Energy Commission

COMMISSION REPORT

Assembly Bill 2127

Electric Vehicle Charging Infrastructure Assessment

Analyzing Charging Needs to Support Zero-Emission Vehicles in 2030

Gavin Newsom, Governor

July 2021 | CEC-600-2021-001-CMR

https://www.energy.ca.gov/programs-and-topics/programs/electric-vehicle-charging-infrastructure-assessment-ab-2127

ENERGY TECHNOLOGIES AREA

LAWRENCE BERKELEY NATIONAL LABORATORY

Medium- & Heavy-Duty Electric Vehicle Infrastructure Load, Operations and Deployment Tool (HEVI-LOAD)

Methods, Scenarios, and Load Profiles

Bin Wang, Cong Zhang
Lawrence Berkeley National Laboratory

HEVI-LOAD Overview

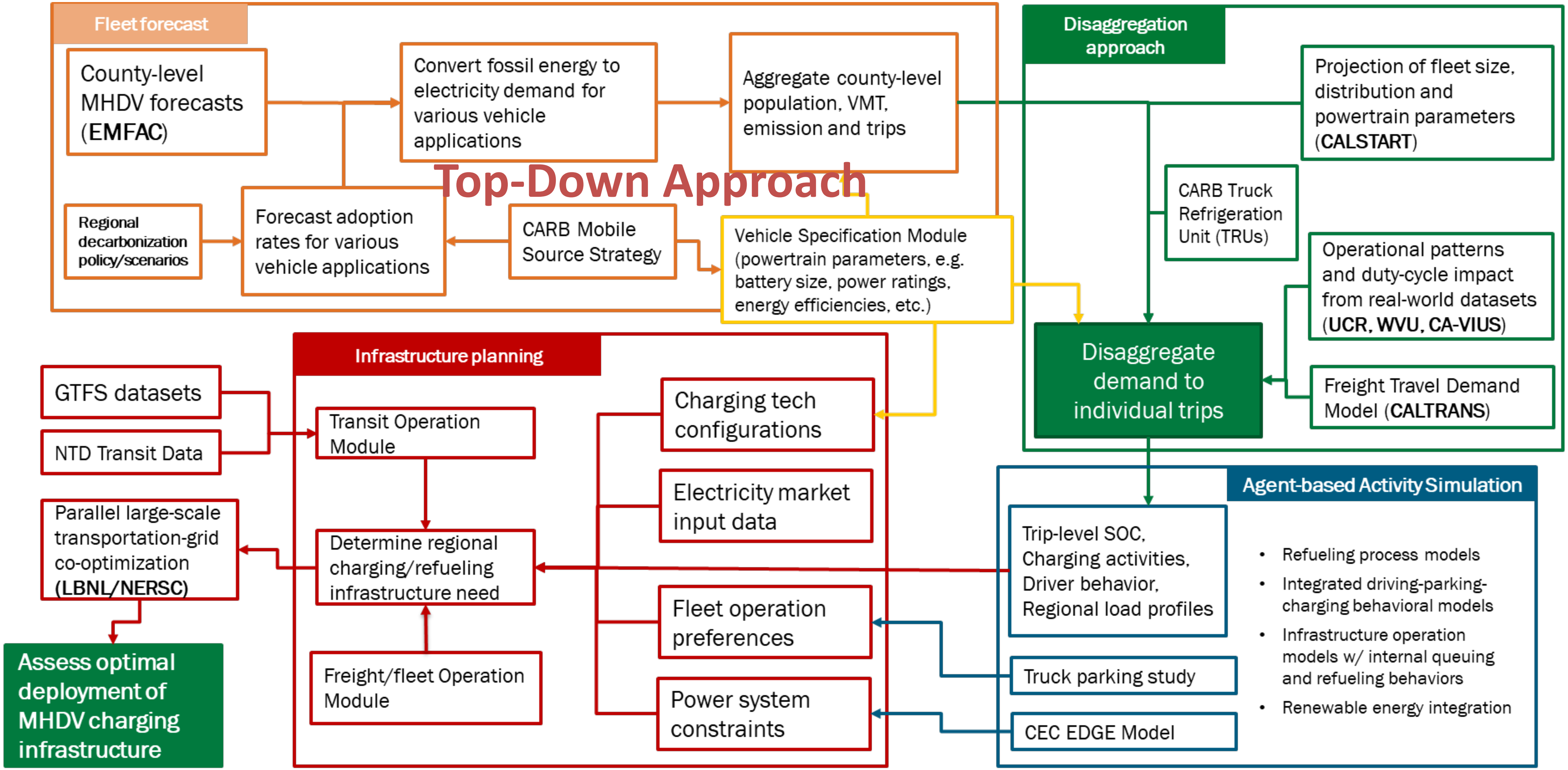
- AB 2127 calls for the CEC to project charging infrastructure needed to decarbonize trucking and to reduce the impact of diesel air pollution.
- LBNL is developing HEVI-LOAD in collaboration with the CEC, via applied research funds from the Clean Transportation Program.
- HEVI-LOAD will project infrastructure 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 Modeling Approach: HEVI-LOAD Metrics

Charging infrastructure need and load profiles for MHDVs

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

Scope of HEVI-LOAD Analysis

Vehicle use pattern	Region	Vehicle application and type	Charging		
			Behavior	Accessibility	Technical design
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		Public (shared)	

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

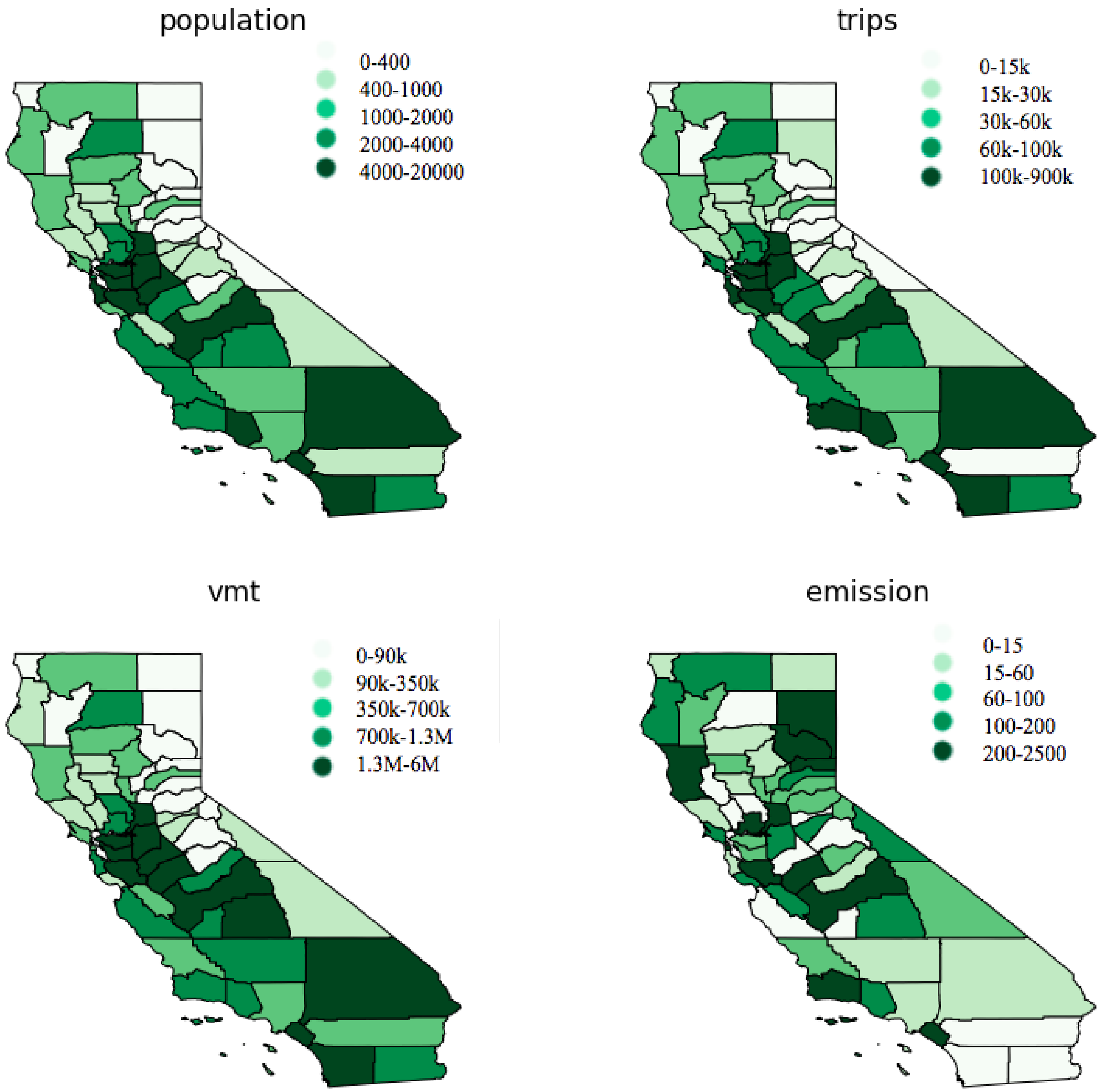
Electric grid inputs
- EDGE – capacity constraints

MHDV operation patterns

Fleet location/parking info, etc.

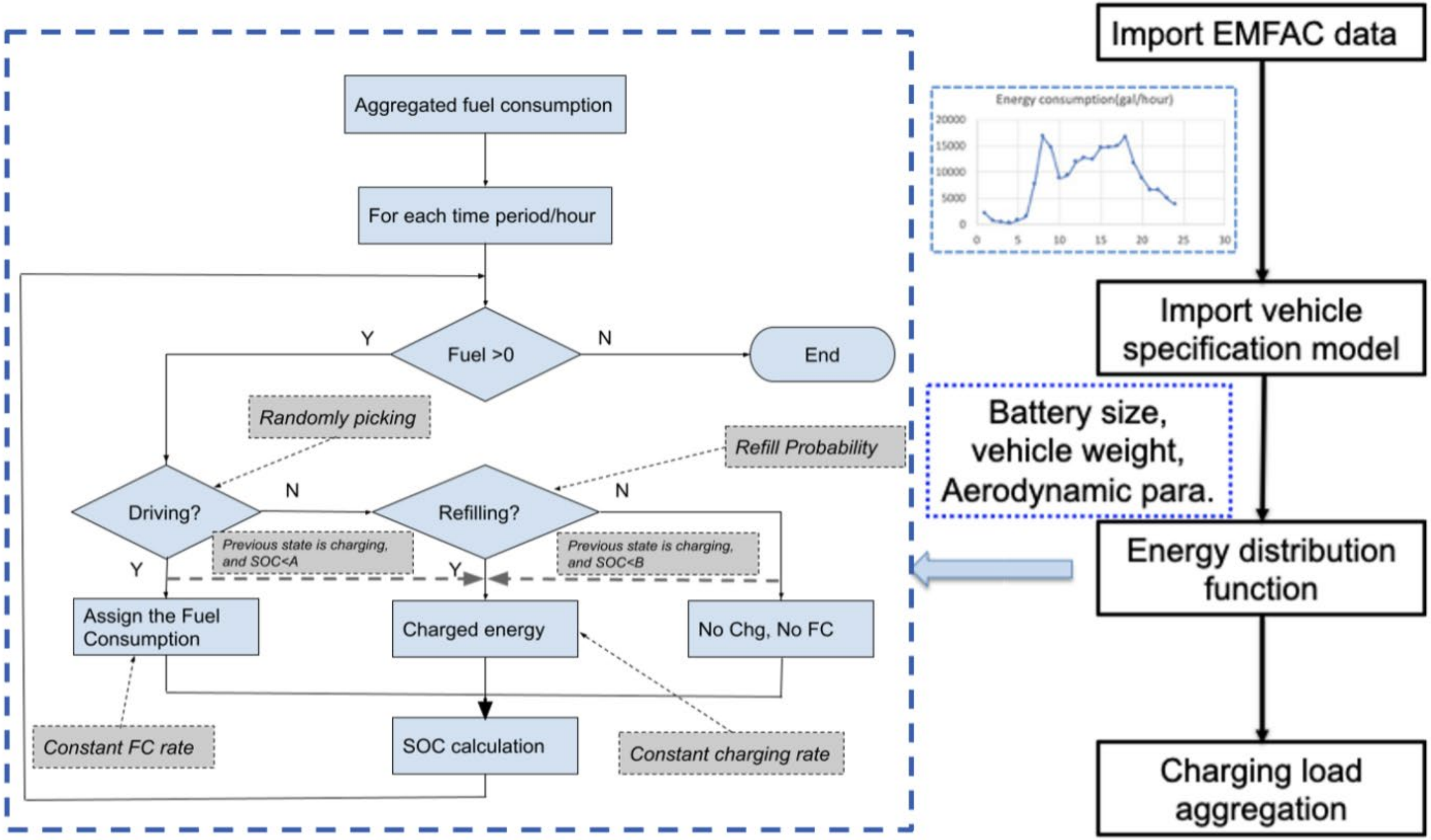
1. MHDV Projection

- 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.

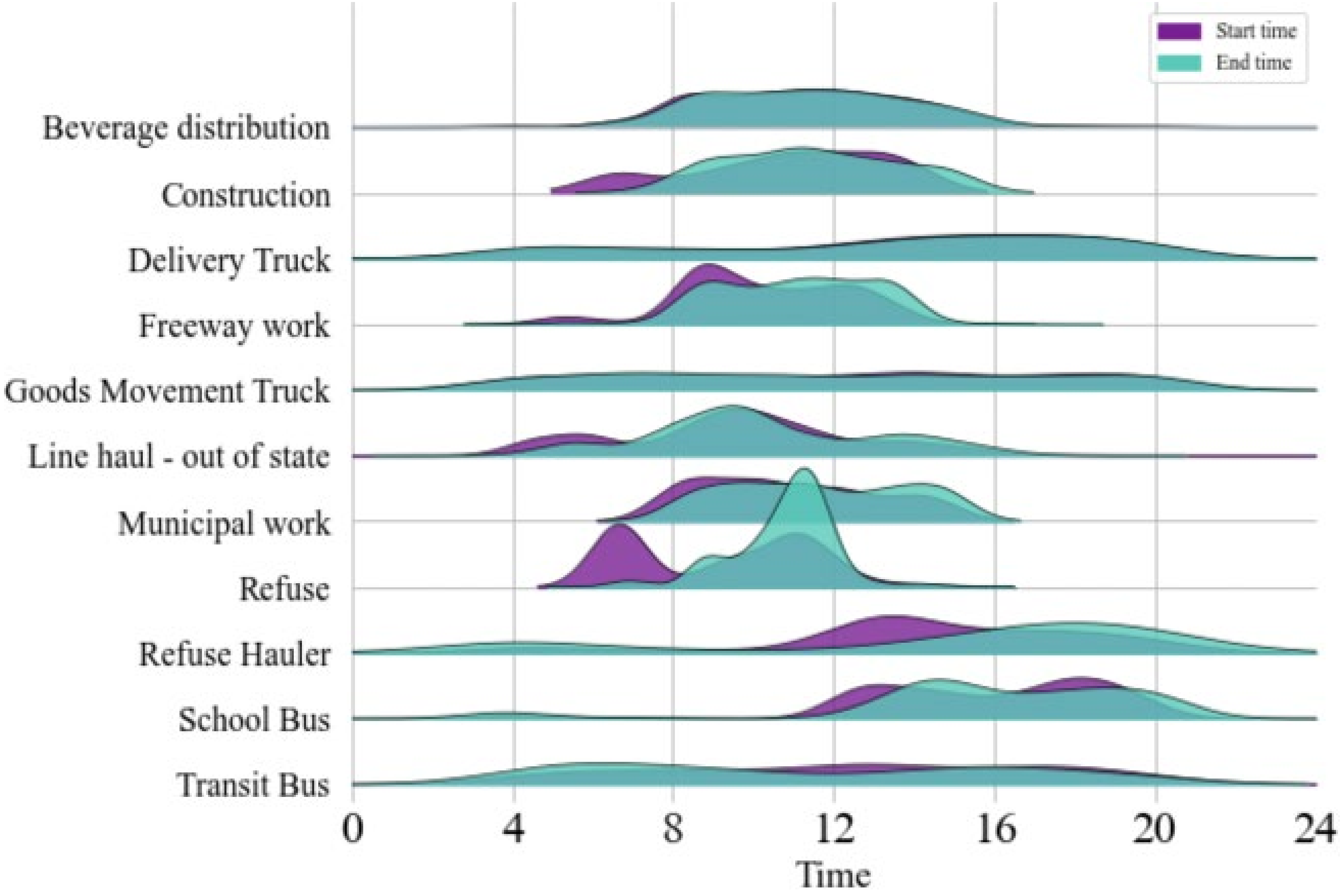


EMFAC Projections

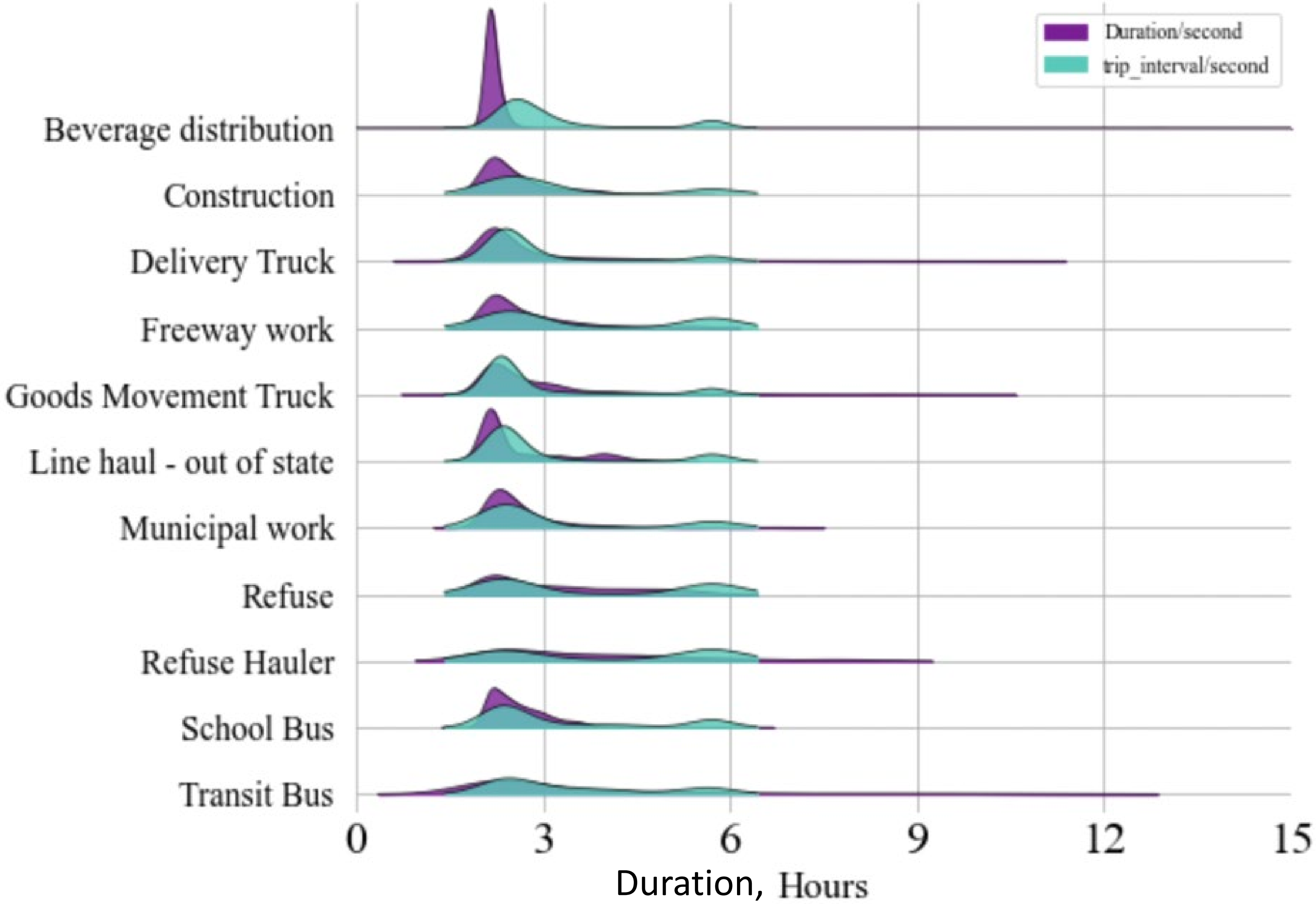
2. Data-driven Trip Disaggregation



Trip behavior statistics - I



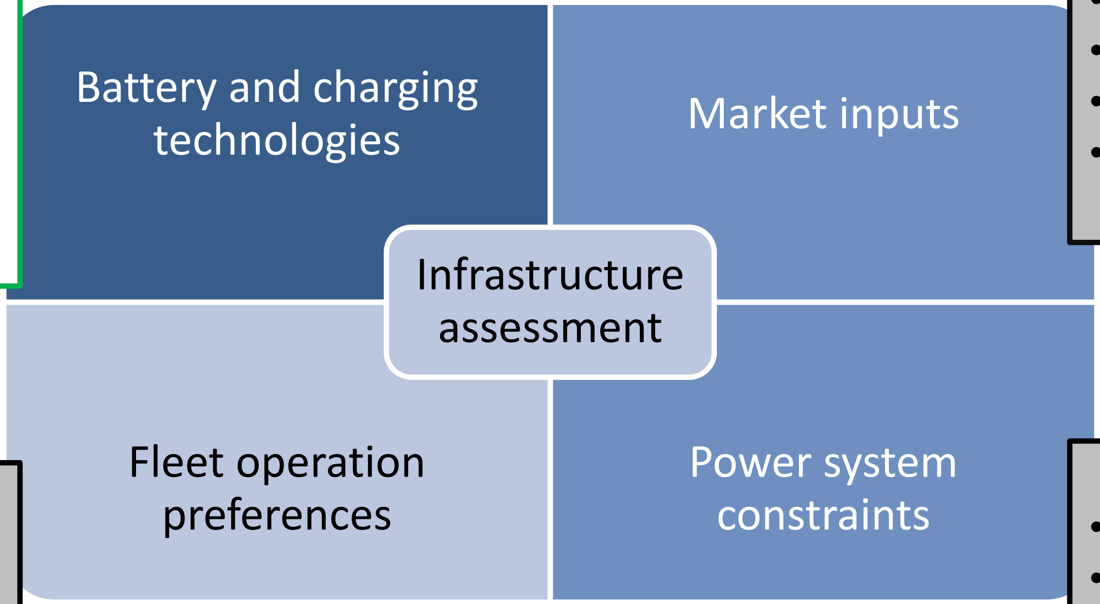
Trip behavior statistics - II



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.



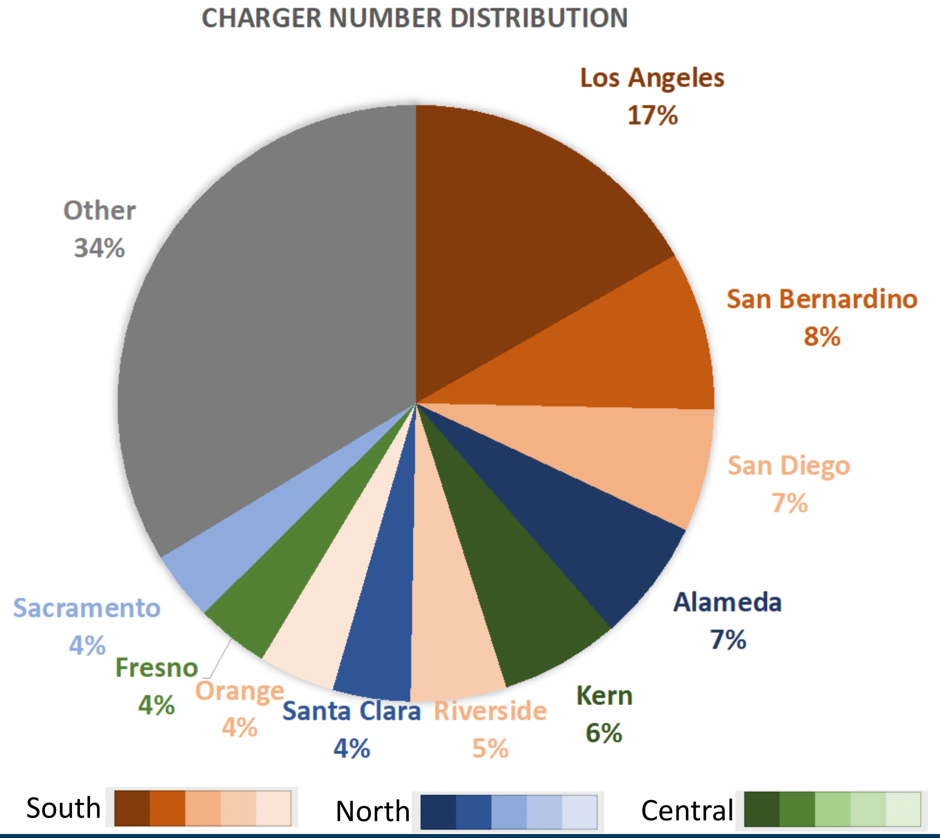
Operation preferences
- Fixed route or flexible routes;
- Managed or smart charging

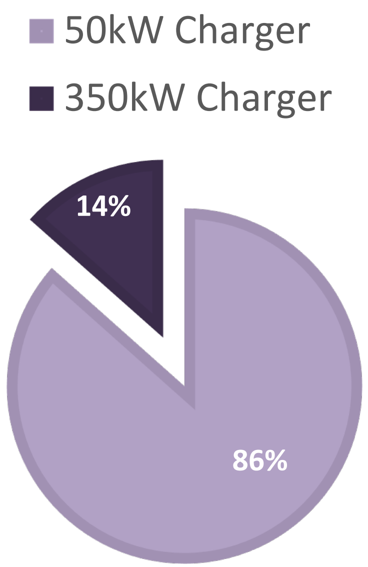
Grid constraints
- Feeder circuit capacities
- Grid connection points
- Location constraints
- Voltage requirements etc.

Analyses Forthcoming

Infrastructure Results
August 2020

Statewide in 2030	MD/HD Battery EVs	50 kW Chargers	350 kW Chargers
Total	133,808	67,365	10,527

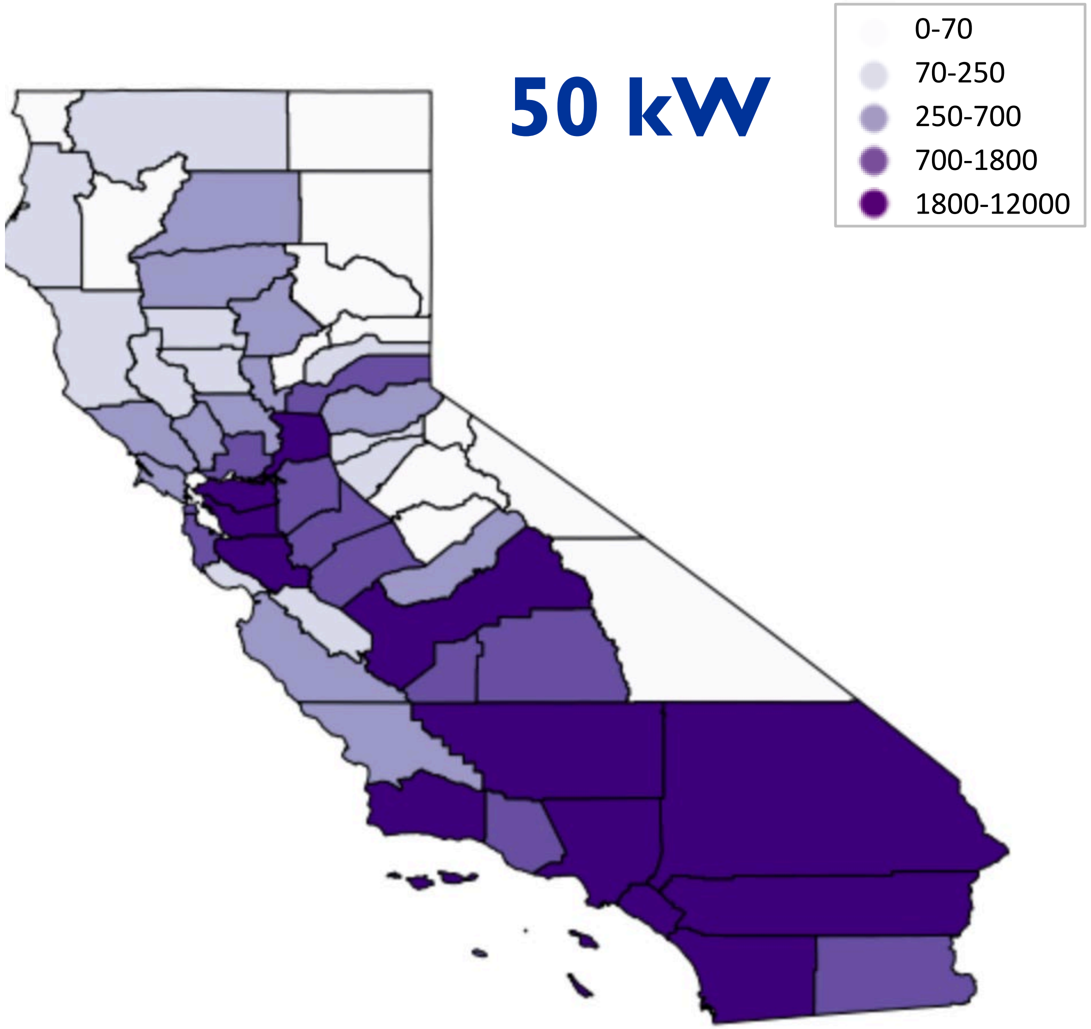


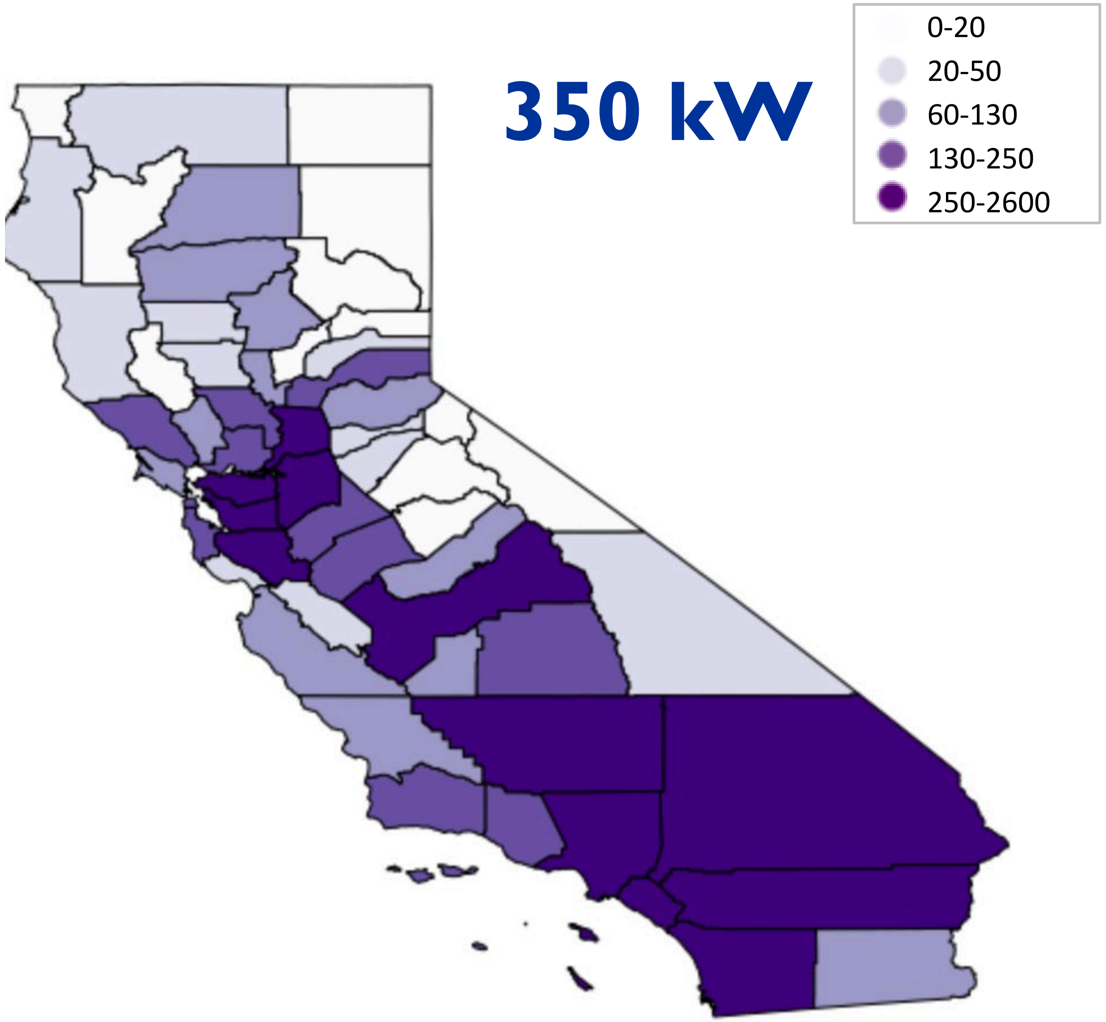


Key notes and assumptions:

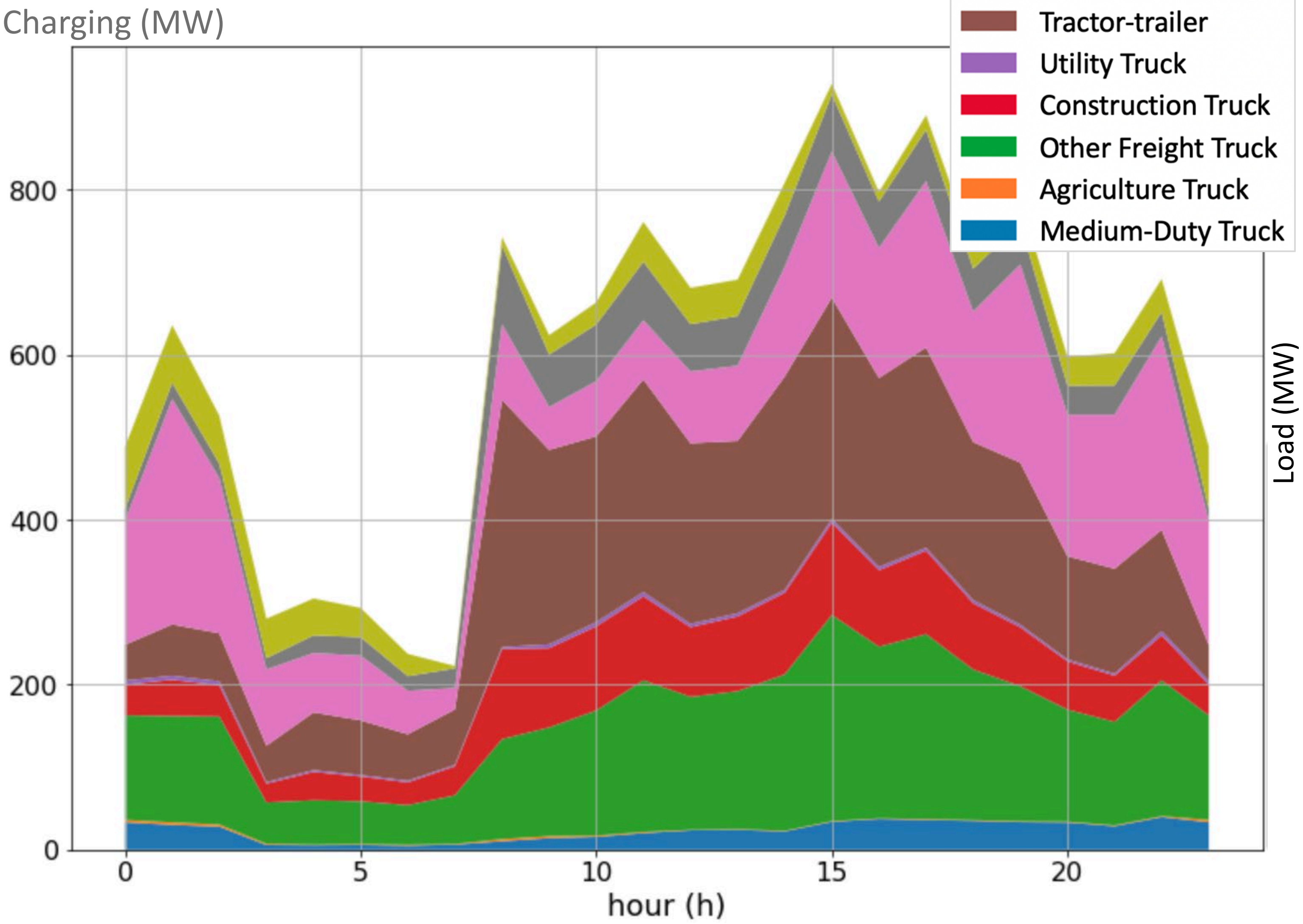
- Only 50kW and 350kW chargers are considered
- MHDVs prefer 350 kW charger during daytime and prefer 50 kW during nighttime
- Electrified MHDVs follow similar duty cycles as traditional vehicles
- Electrified MHDVs use night and parking times for charging
- 80% initial SOC for each MHDV simulated
- 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.***

Charger Counts by County and Power Capacity (August 2020)

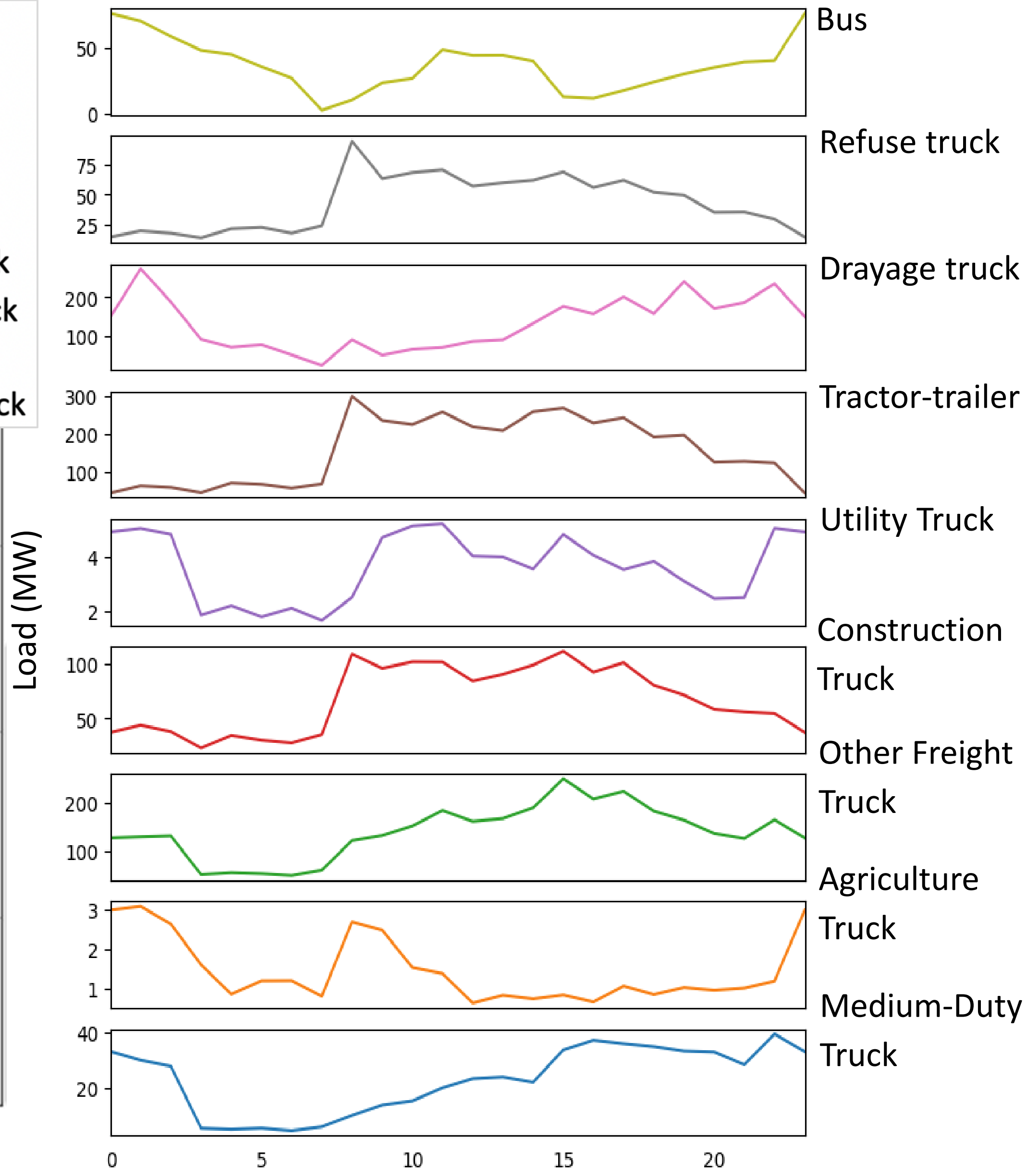




Statewide Load Profile (2030)



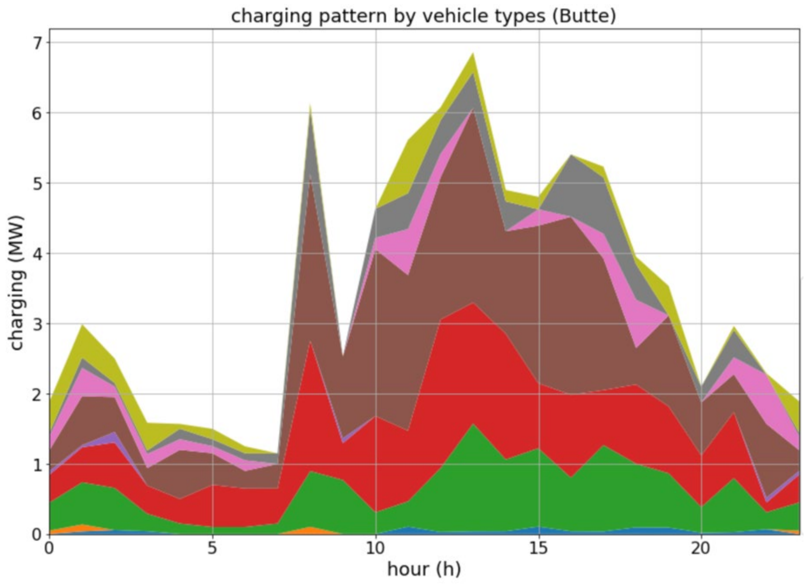
Hourly charging load profile by vehicle type



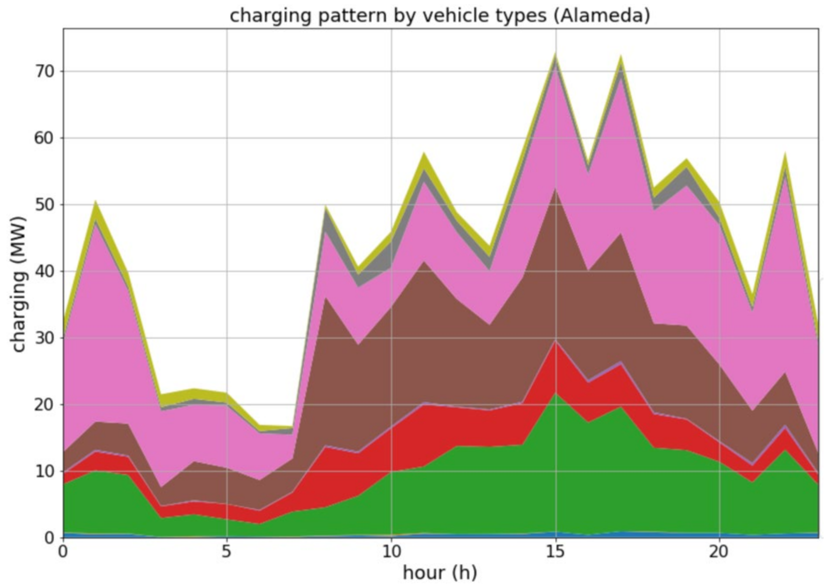
County Load Profile Examples (2030)

- 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)

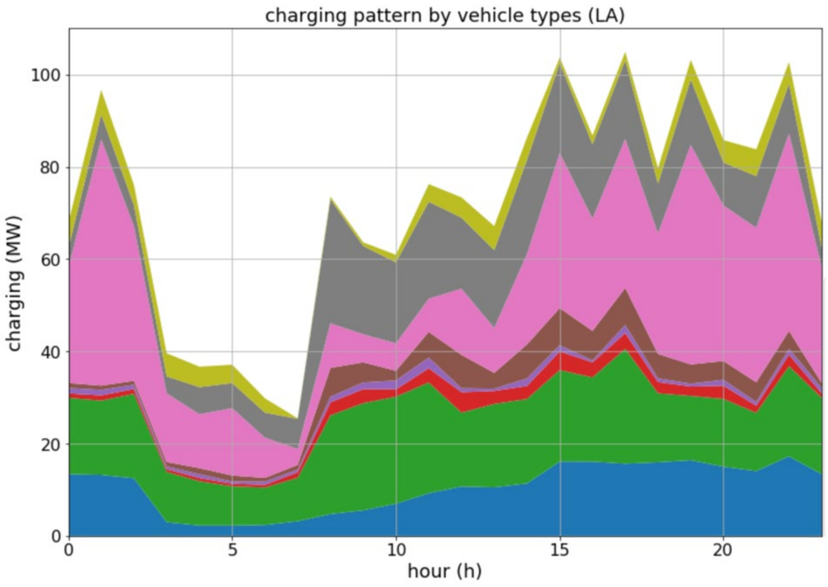
Butte



Alameda



Los Angeles



Scenario Update

Transportation Energy Demand Forecast (TEDF)
High/Low Charging Demand Scenarios

High/Low Charging Demand Scenario - Definitions

December 2020

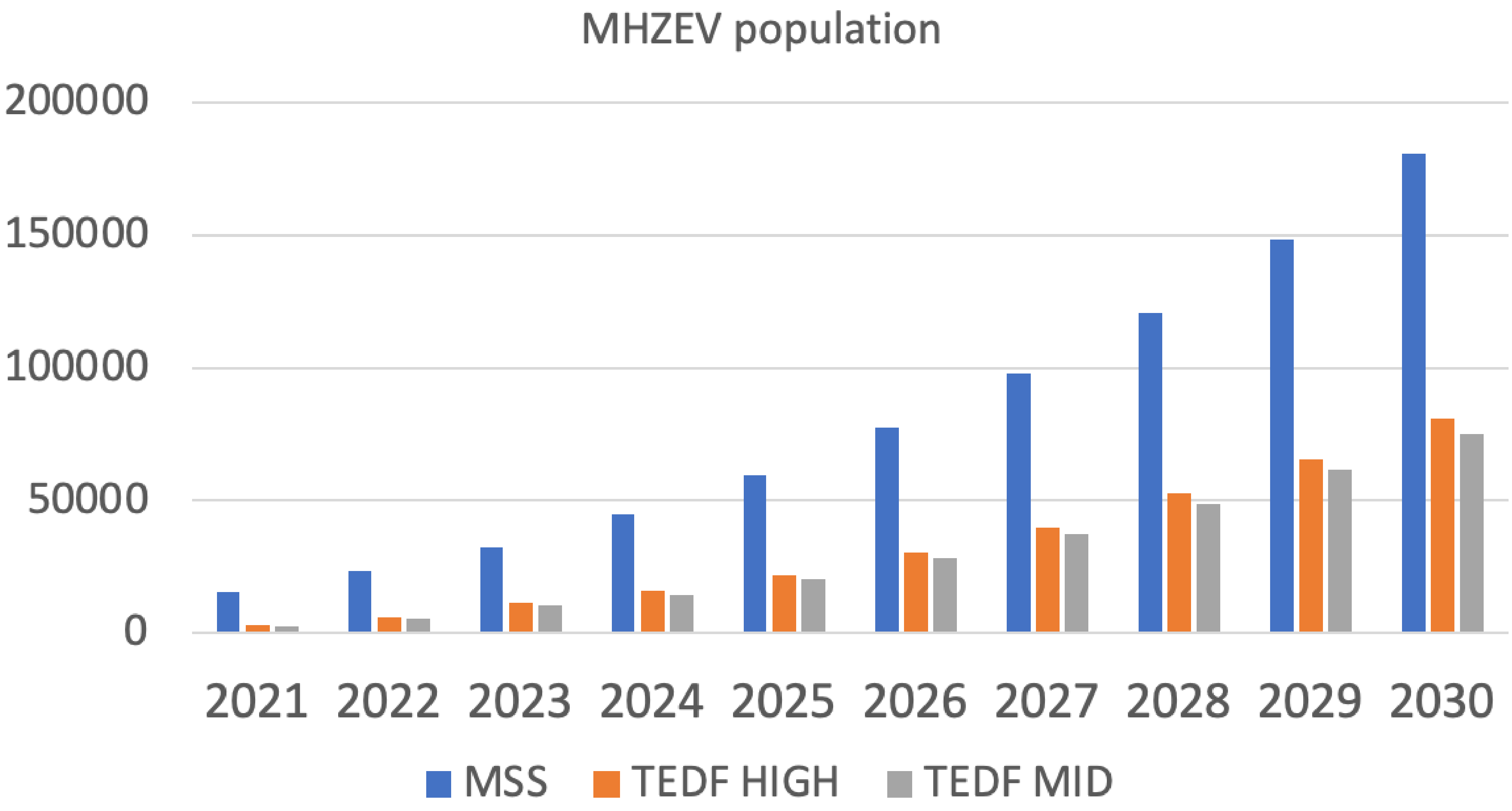
Scenarios	ZEV Population	Battery capacity (yearly factor)**	GVWR
MSS(HCD*)	Mobile Source Strategy	1.05	Heavier (full load)
TEDF-HIGH(HCD)	Transportation Energy Demand Forecast-High	1.05	Heavier (full load)
TEDF-MID(LCD*)	Transportation Energy Demand Forecast-Mid	1.07	Small (Empty)

* High or Low Charging Demand

** Yearly increasing ratio of battery energy density (kWh/L) or specific energy (kWh/kg).

High/Low Charging Demand Scenario – Vehicle Populations

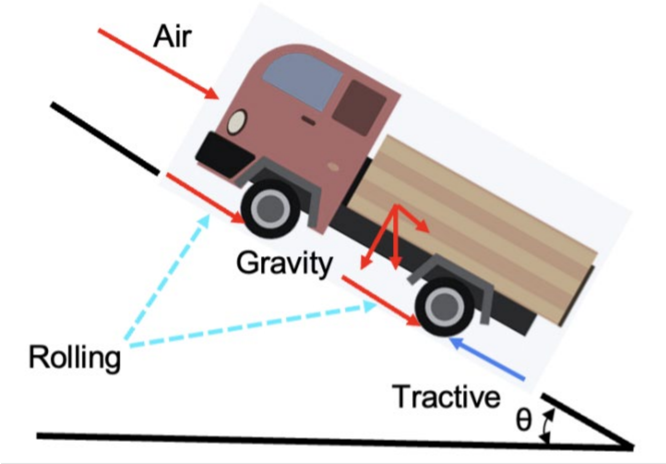
December 2020

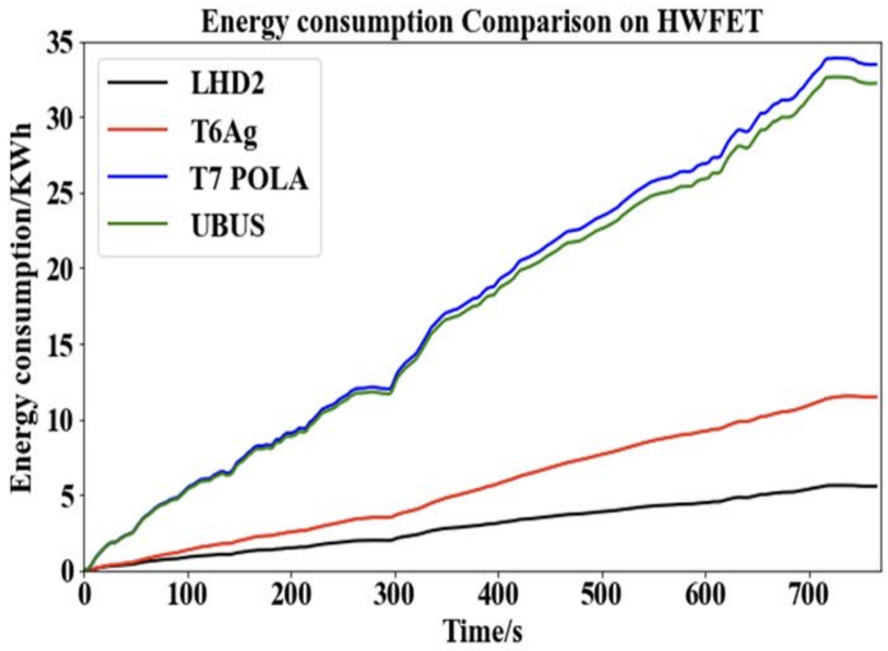


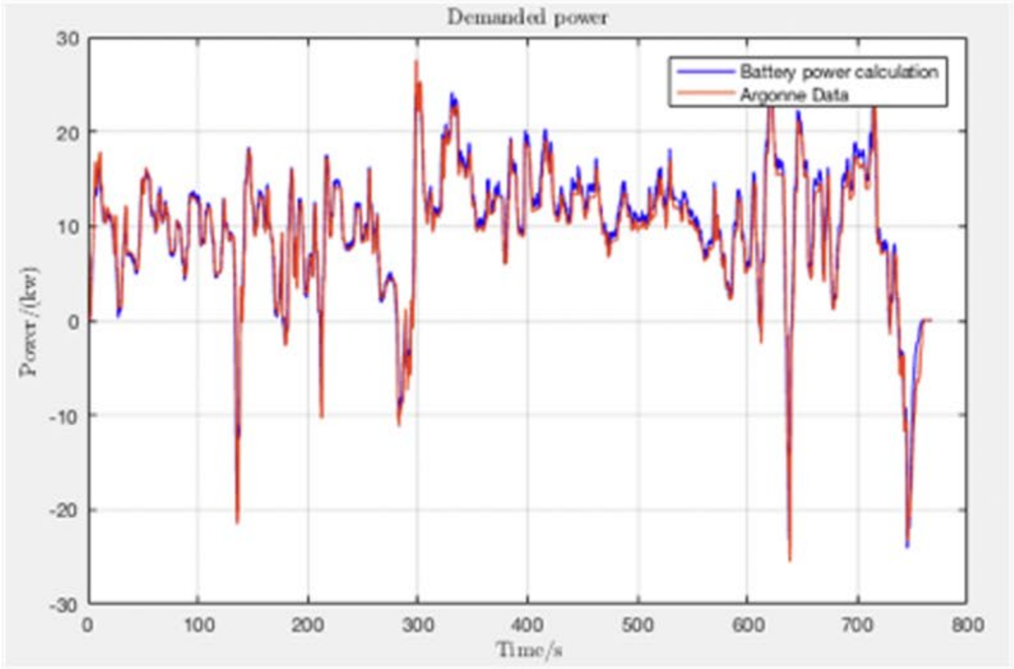
Note: New populations according to the CARB State SIP Strategy (SSS) will be incorporated within future runs.

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



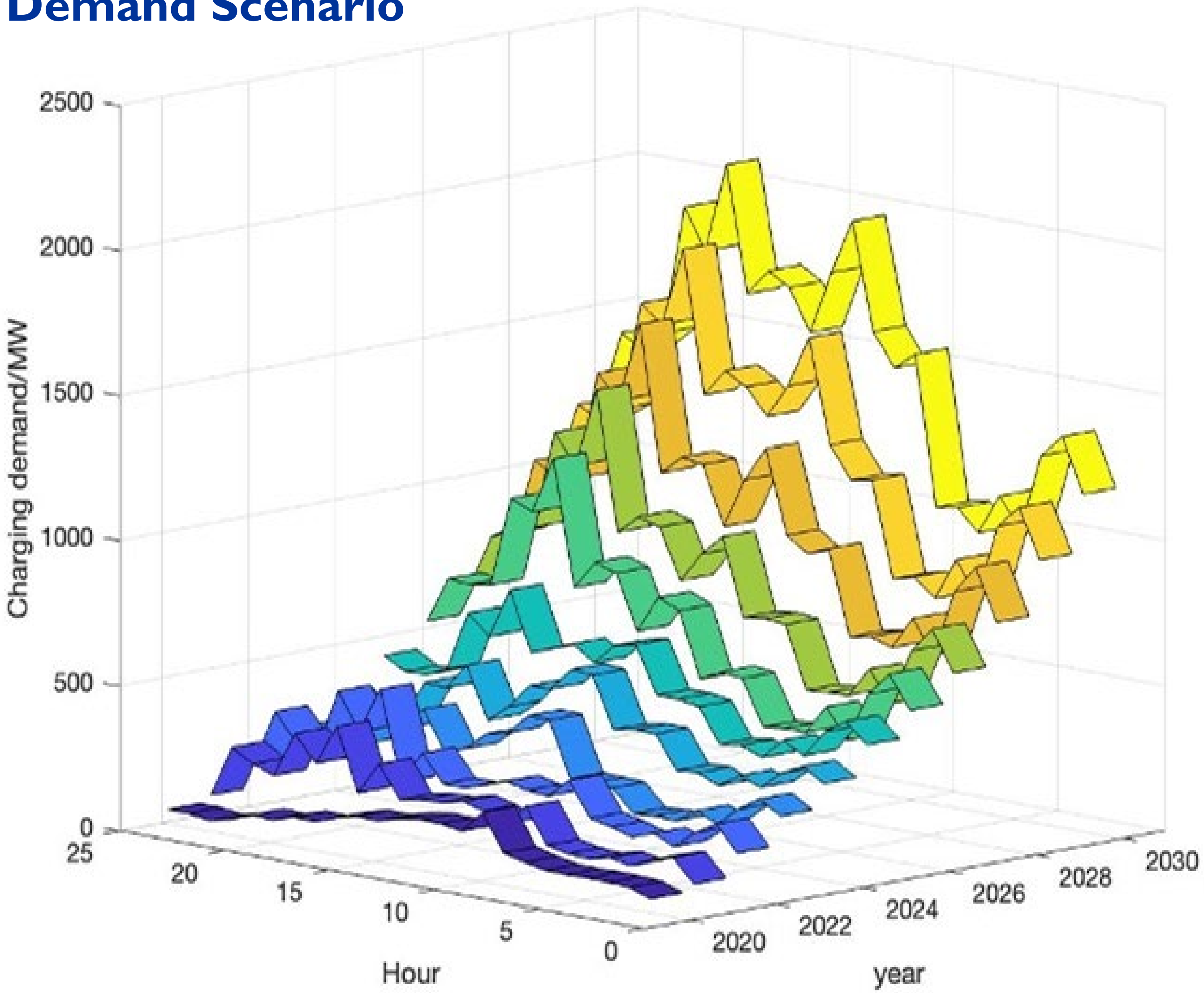




Statewide Charging Load Profiles, 2020-2030

Mobile Source Strategy High Charging Demand Scenario

December 2020

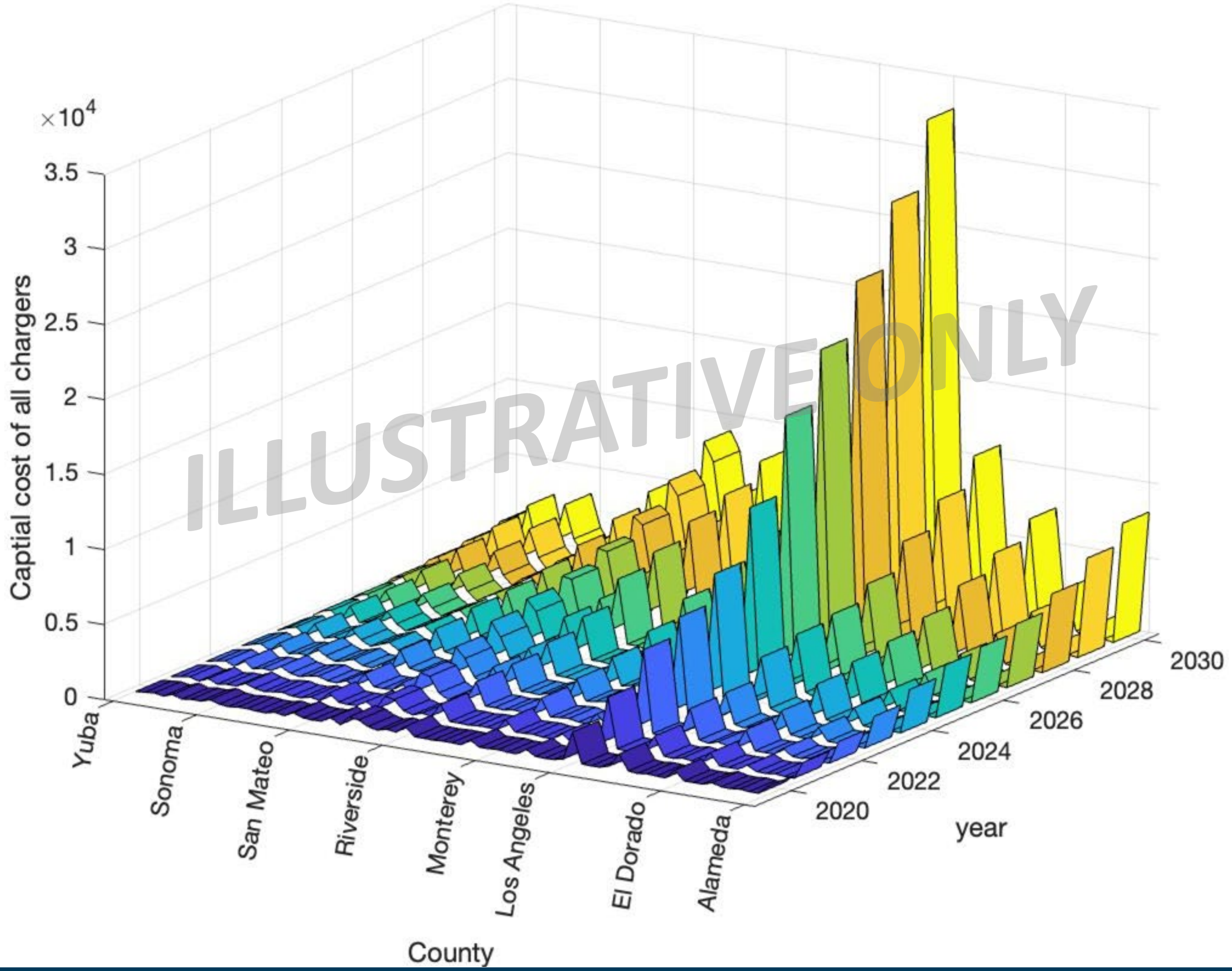


Statewide Charger Cost Estimate, 2020-2030

Mobile Source Strategy High Charging Demand Scenario
December 2020

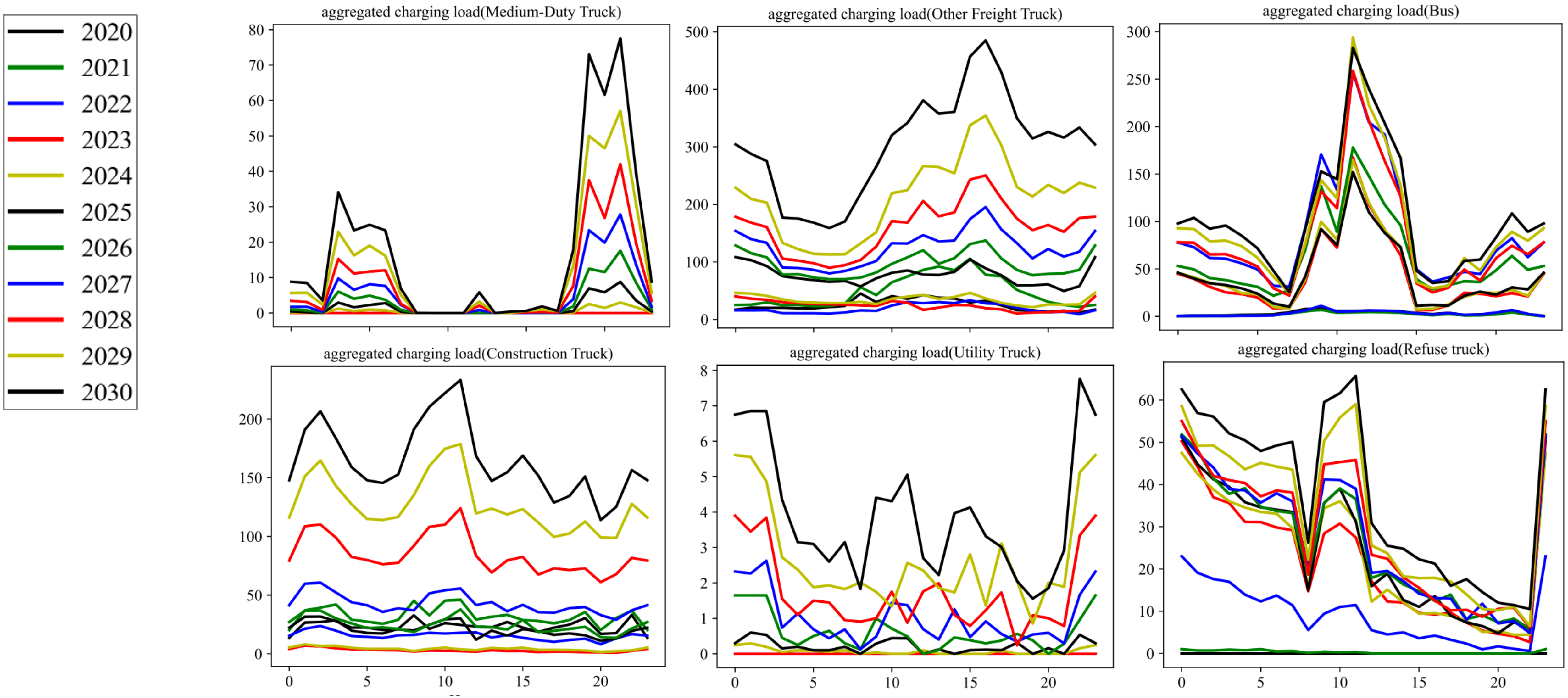
Table 2. Per charger public and workplace charger hardware cost.

Level	Type	Chargers per pedestal	Per-charger cost
Level 1	Non-networked	One	$813
Level 1	Non-networked	Two	$596
Level 2	Non-networked	One	$1,182
Level 2	Non-networked	Two	$938
Level 2	Networked	One	$3,127
Level 2	Networked	Two	$2,793
DC fast	Networked 50 kW	One	$28,401
DC fast	Networked 150 kW	One	$75,000
DC fast	Networked 350 kW	One	$140,000



ICCT, Estimating electric vehicle charging infrastructure costs across major U.S. metropolitan areas, 2019

Vehicle Application-specific Load Profiles



Scenario Update

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

Vehicle-specific Charging Powers

July 2021

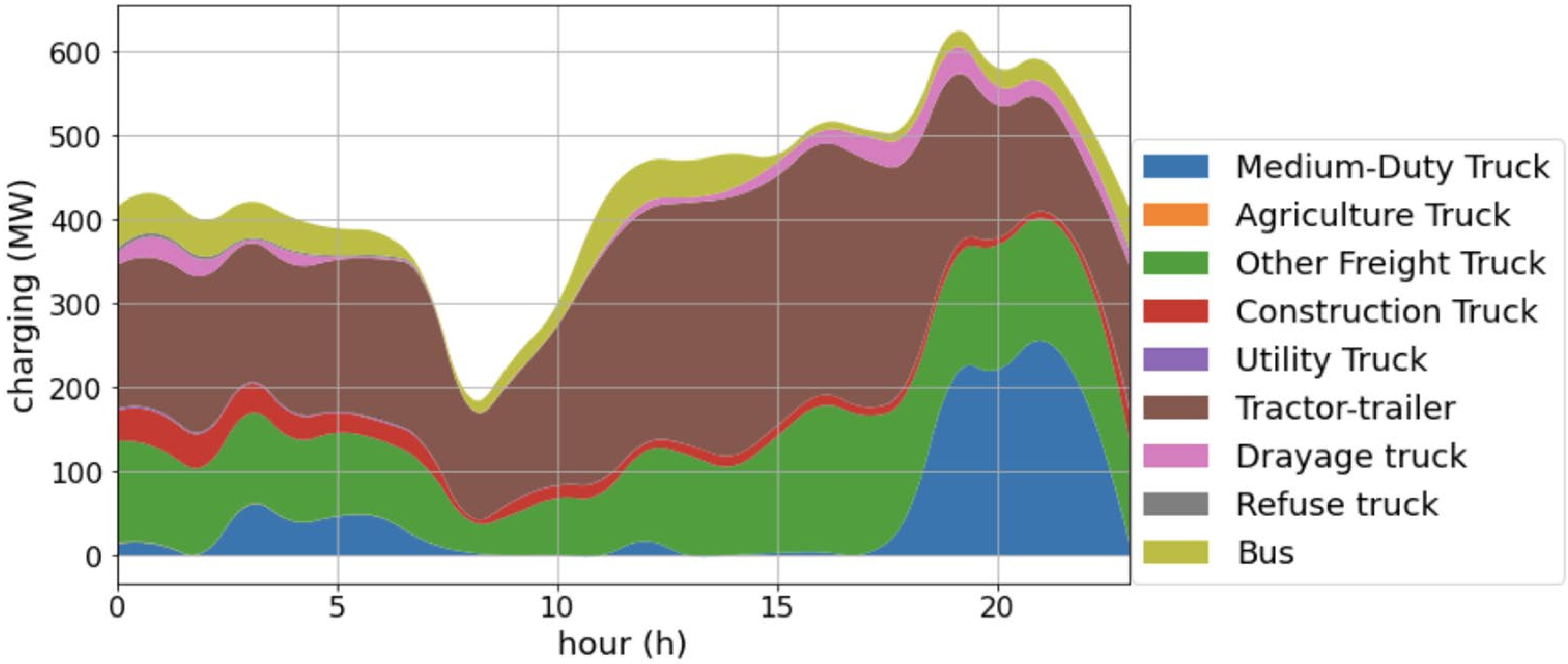
- Two charging power levels are defined to meet the driving requirements for recharging at
  - Depots (night time, Level A) and
  - Opportunistic Locations (day time, Level B).
- Level B assumed to be ~2-3x Level A, up to 200 kW

Vehicle type (EMFAC)	Battery capacity (kWh)	Charging level A (kW)	Charging level B (kW)
LHD2	100	13.5	50
T6 Ag	200	19.2	60
T6 CAIRP Heavy	250	19.2	60
T6 CAIRP Small	200	19.2	60
T6 Instate Construction Heavy	250	19.2	60
T6 Instate Construction Small	300	19.2	60
T6 Instate Heavy	400	50	150
T6 Instate Small	300	50	150
T6 OOS Heavy	400	50	150
T6 OOS Small	400	50	150
T6 Public	400	50	150
T6 Utility	400	50	150
T6TS	400	50	150
T7 Ag	600	100	200
T7 CAIRP	1000	100	200
T7 CAIRP Construction	1000	100	200
T7 NNOOS	1000	100	200
T7 NOOS	1000	100	200
T7 Other Port	600	100	200
T7 POAK	600	100	200
T7 POLA	600	100	200
T7 Public	600	100	200
T7 Single	600	100	200
T7 Single Construction	600	100	200
T7 SWCV	300	100	200
T7 Tractor	600	100	200
T7 Tractor Construction	600	100	200
T7 Utility	600	100	200
T7IS	600	100	200
SBUS	300	50	150
UBUS	700	50	150
Motor Coach	700	19.2	60
OBUS	400	50	150
All Other Buses	400	50	150

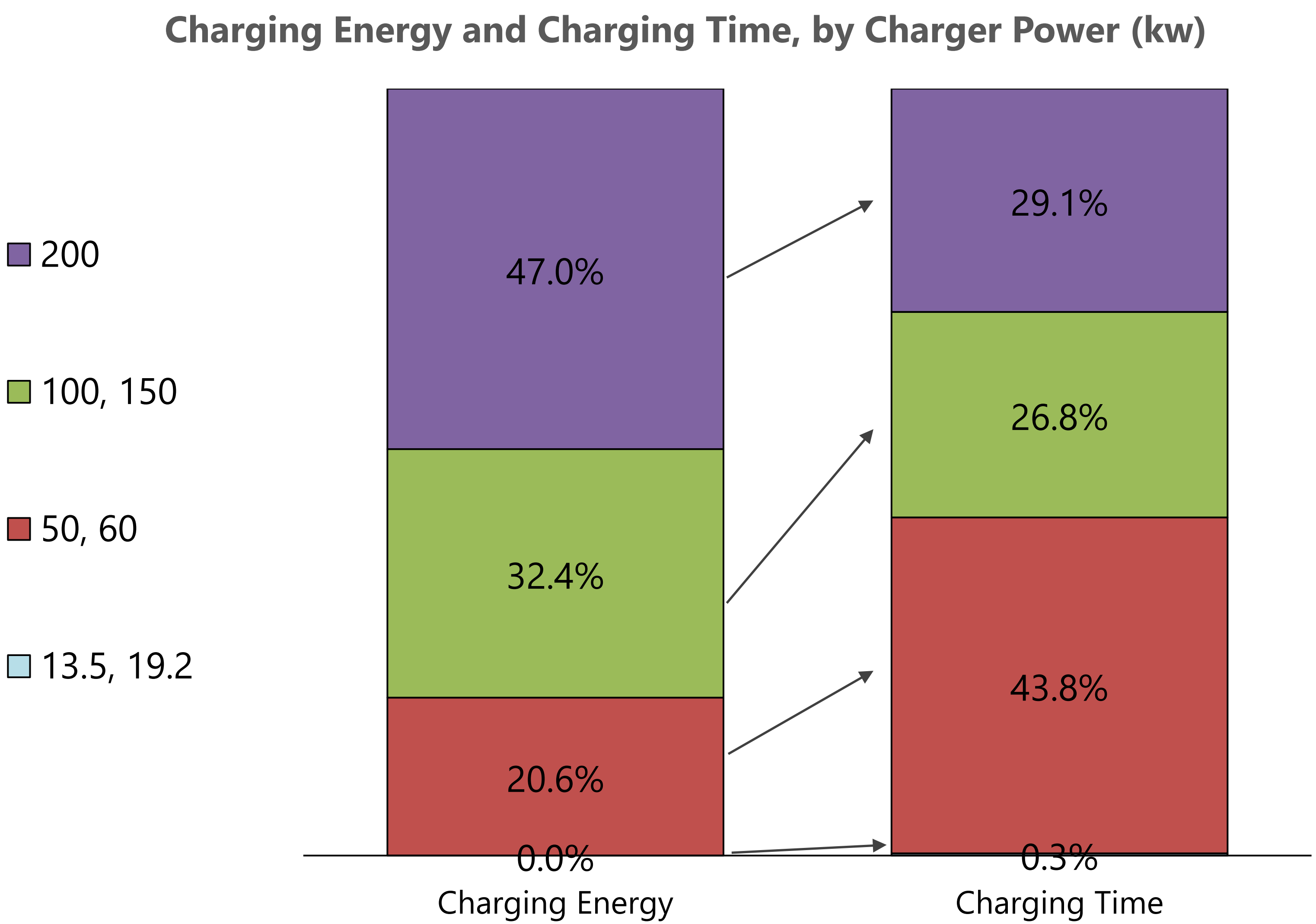
Statewide Load Profile (2030)

High Charging Demand Scenario – TEDF High

July 2021



Tradeoff between charging energy and time spent (<200 kW)



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)

Vehicle-specific Charging Power Quartiles

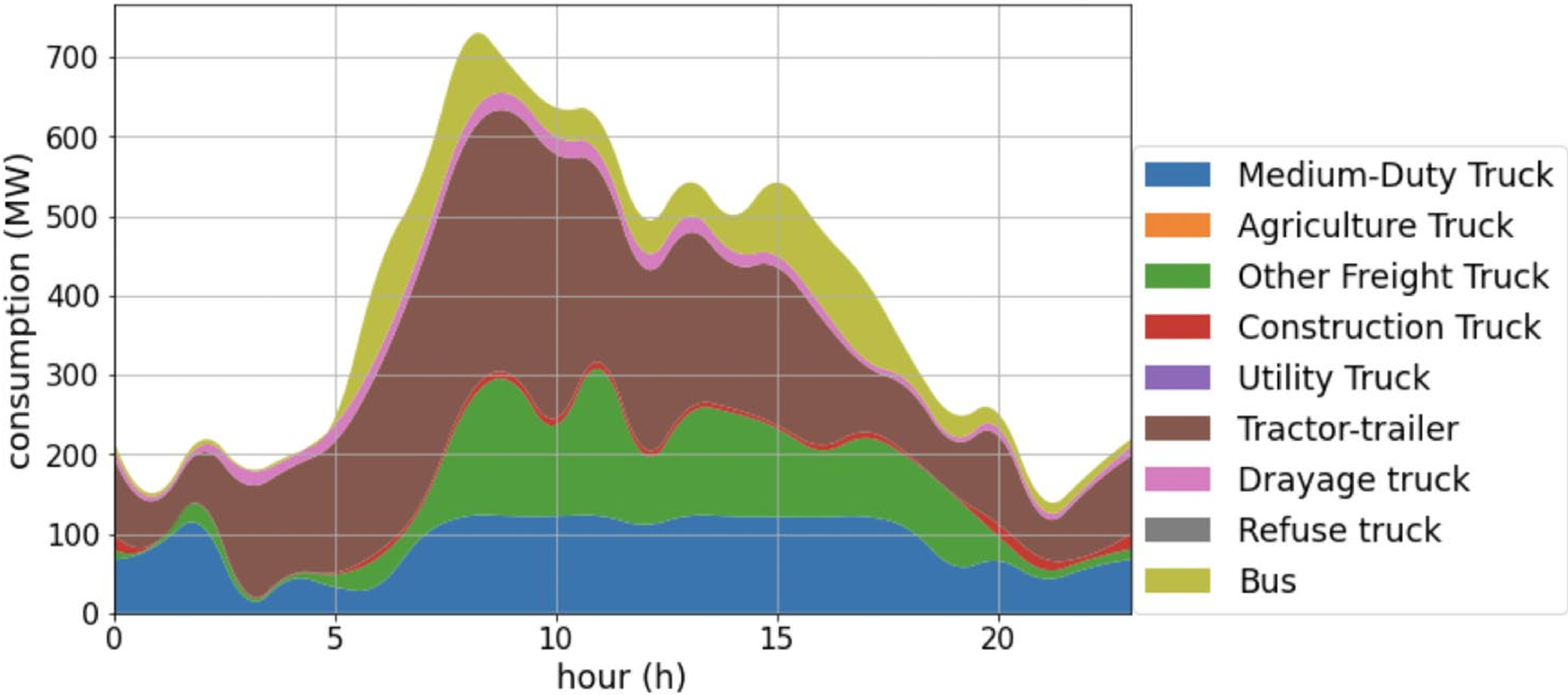
September 2021

- 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)

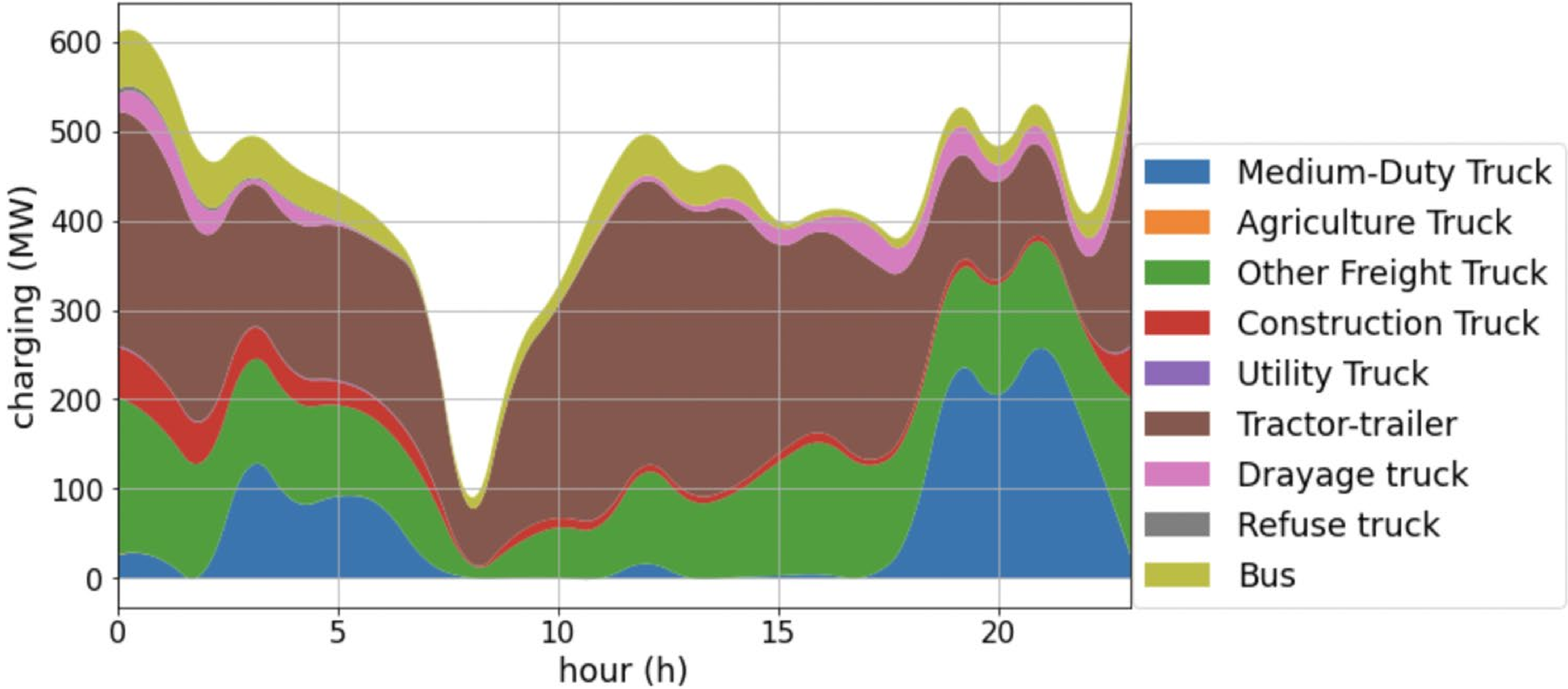
High Charging Demand Scenario – TEDF High

September 2021

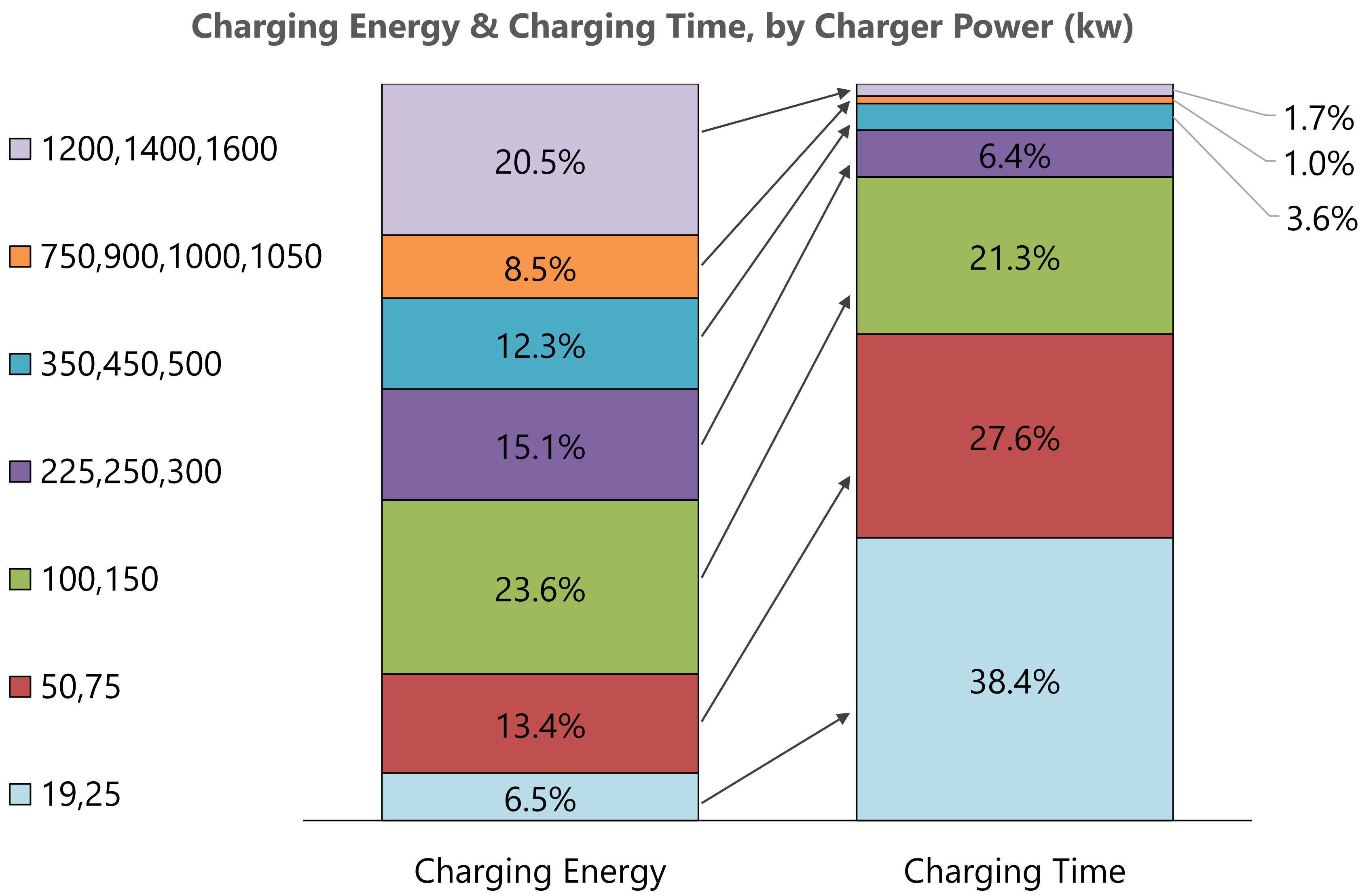


Statewide Load Profile (2030)

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.

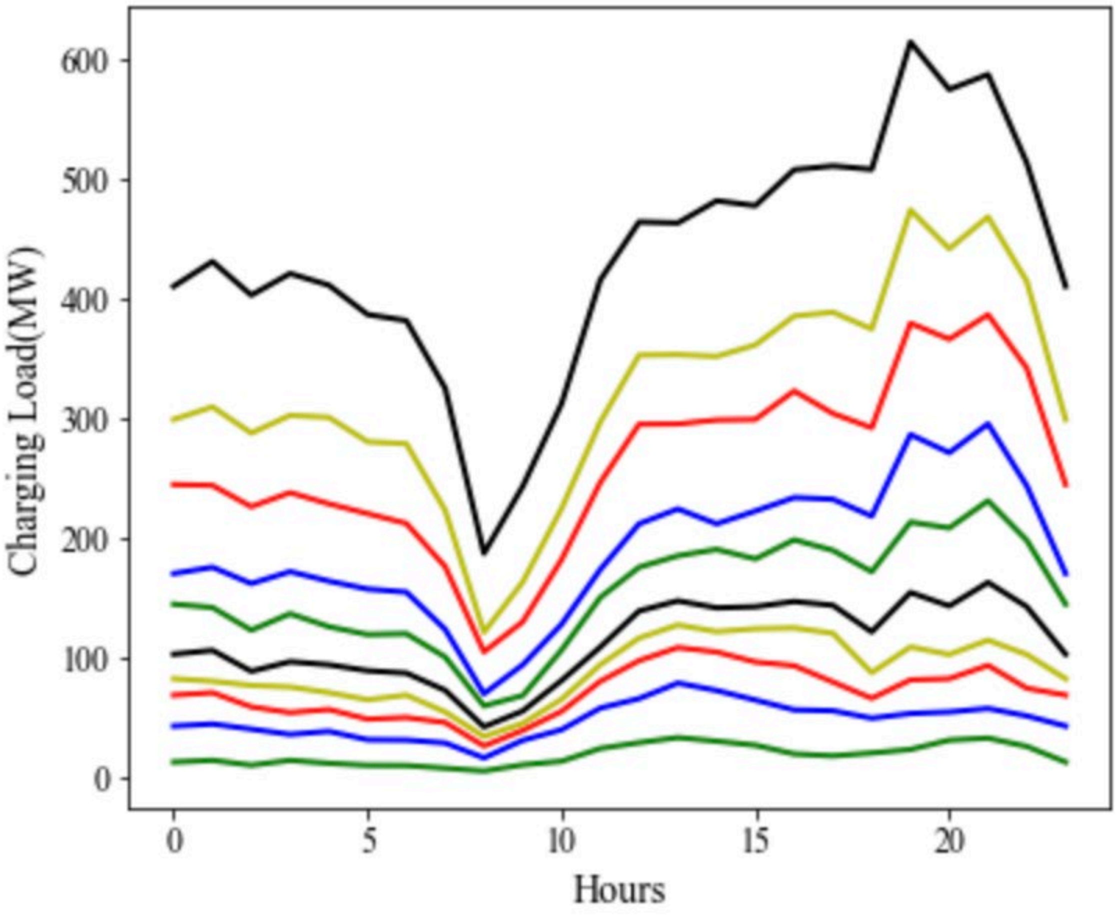
At chargers rated 75 kW or below, MHDVs spend 2/3 of all time dwelt while charging and receive about 20% of energy dispensed.

Discussion and Comparison of Results

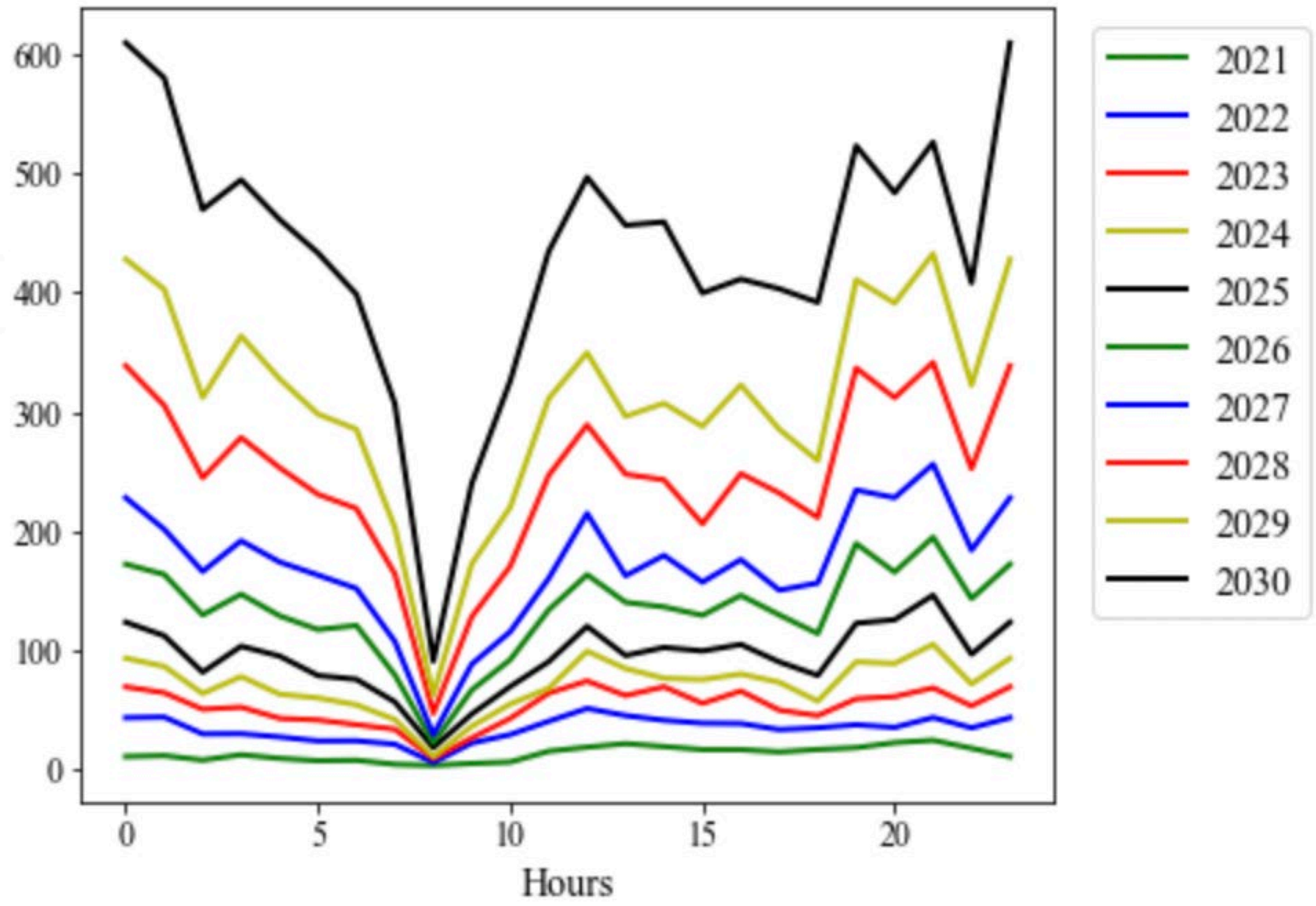
Statewide Load Profile (2021-2030)

High Charging Demand Scenario – TEDF High

Without Charge Power Quartiles

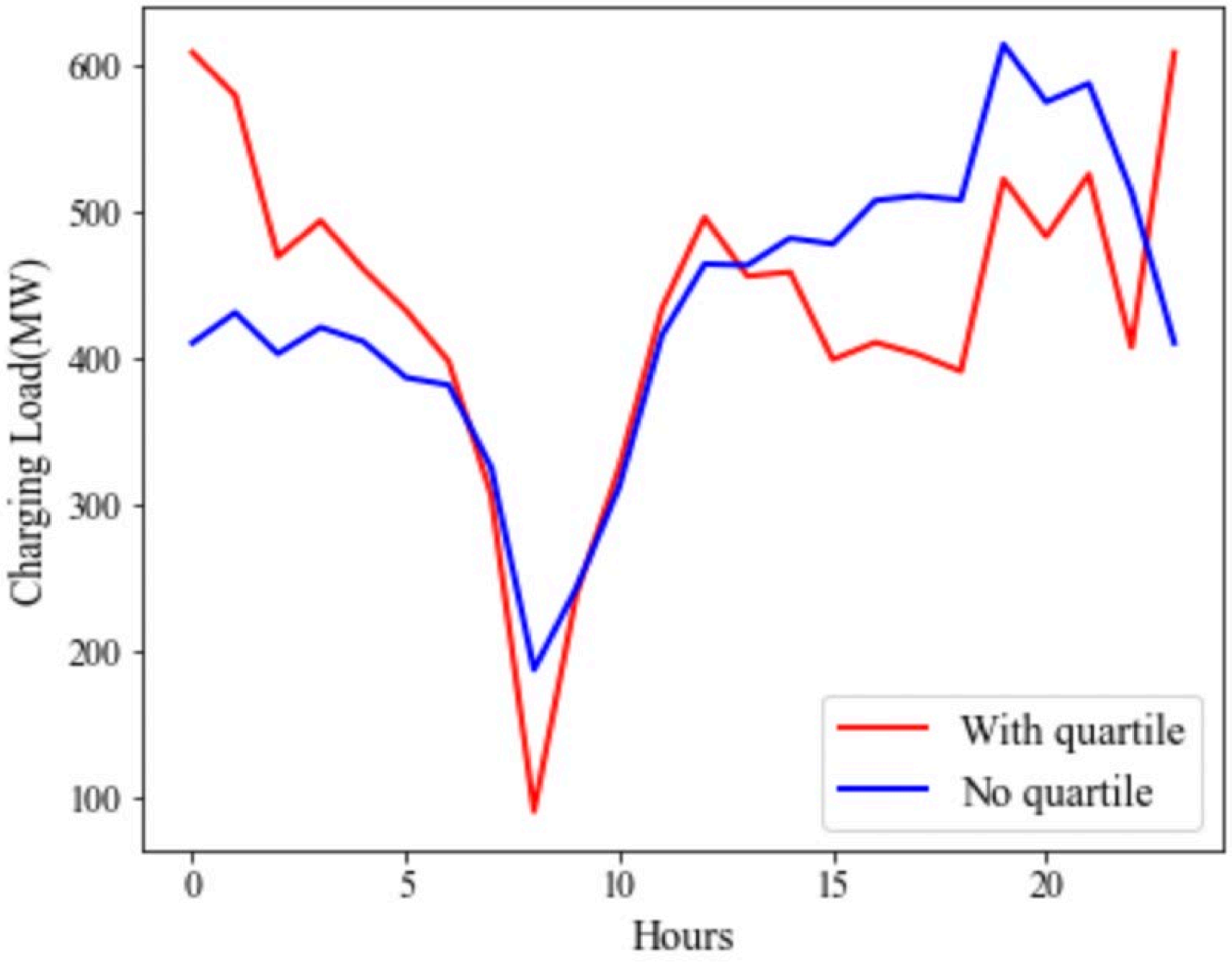


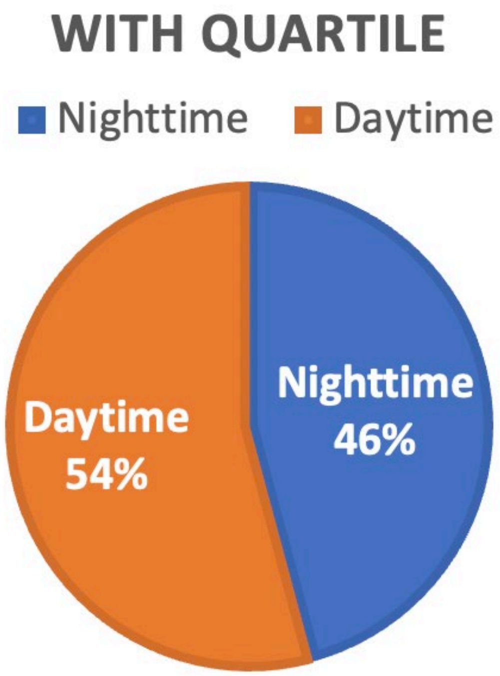
With Charge Power Quartiles

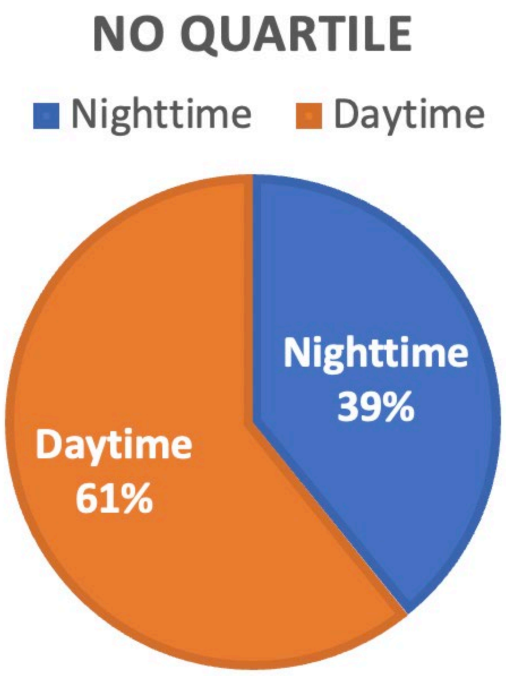


Statewide Load Profile and Diurnal Energy Demand (2030)

High Charging Demand Scenario – TEDF High



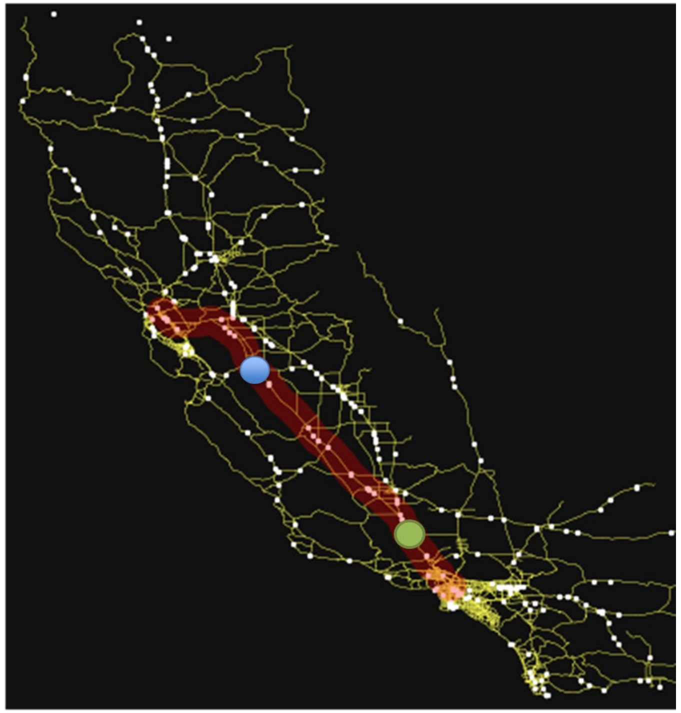


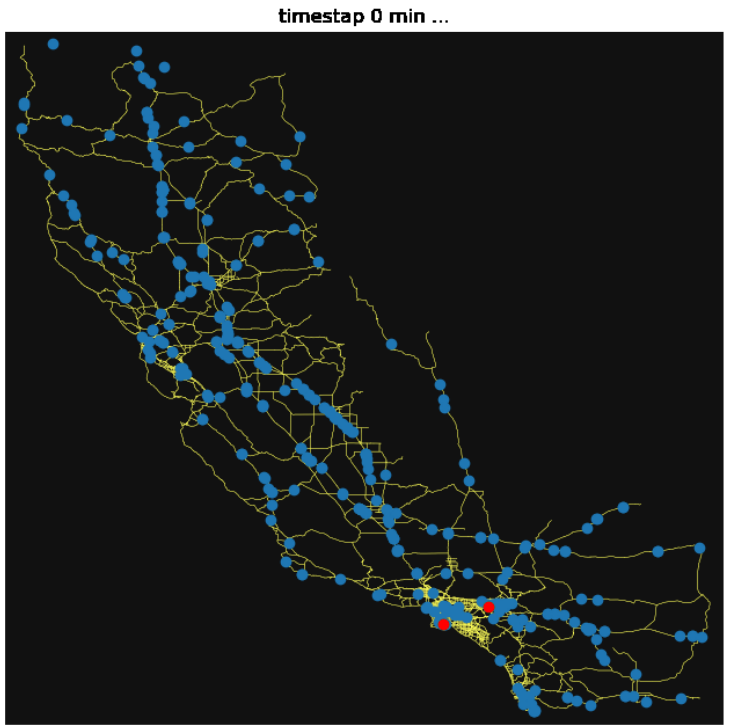


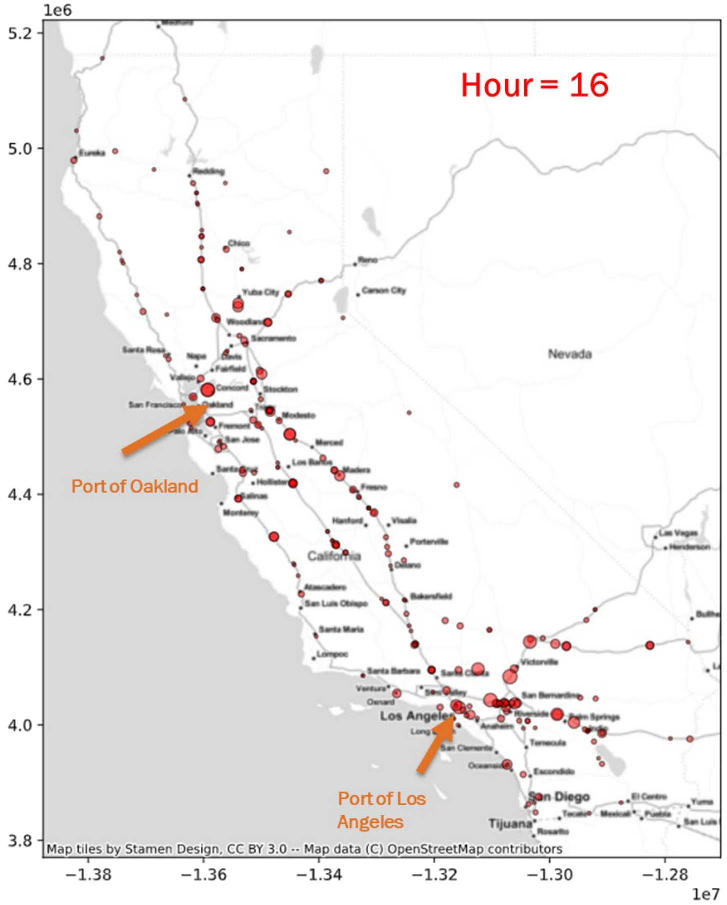
While further analysis on how MHDV specifications affect load, a higher range and diversity in charging power among the applications allowed more energy to be dispensed at night, slightly reducing the peak demand.

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?

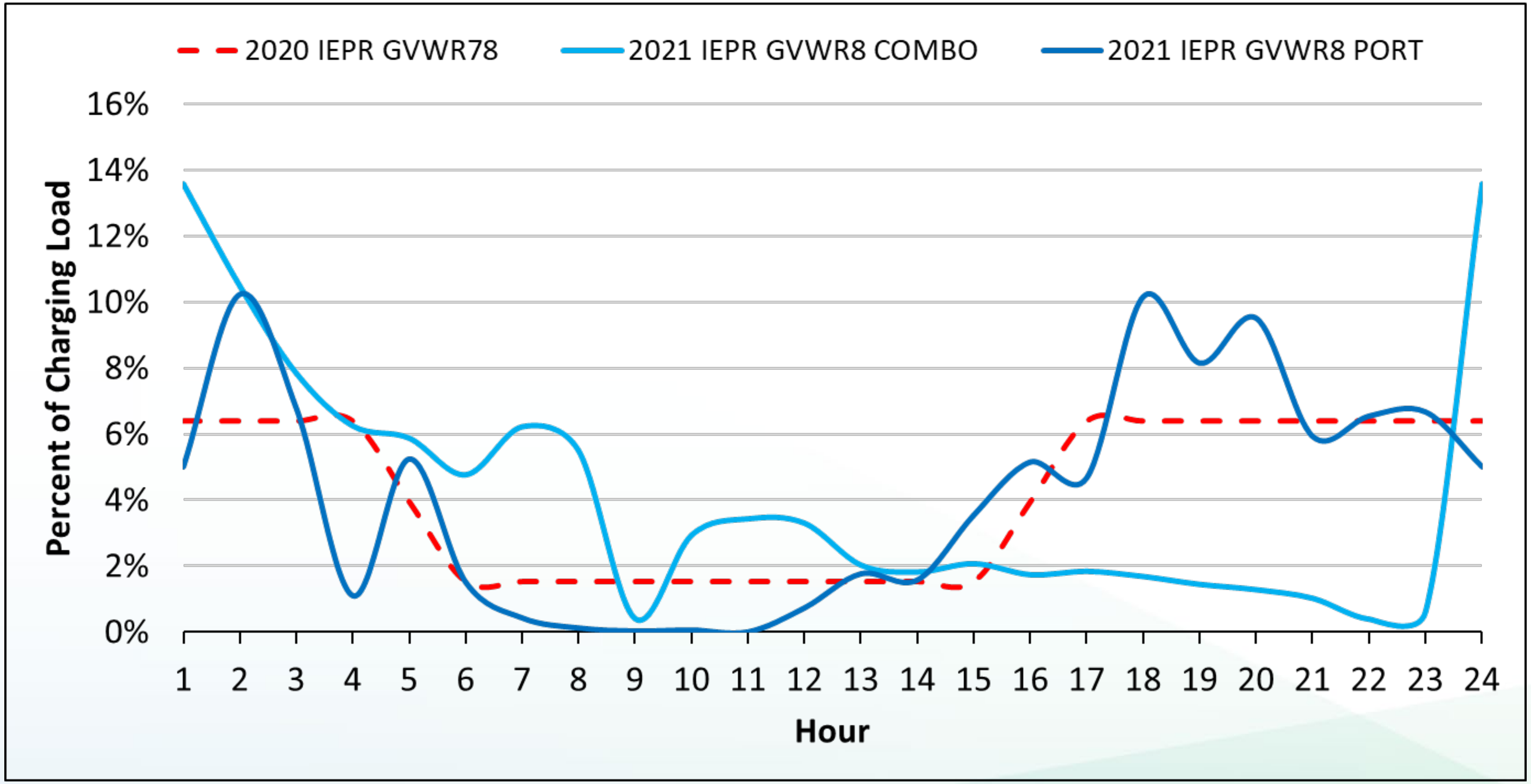
Medium- and Heavy-Duty Base Load Shapes For IEPR Forecast

Alex Lonsdale
Energy Assessments Division, California Energy Commission
Demand Analysis Working Group Meeting – September 14, 2021

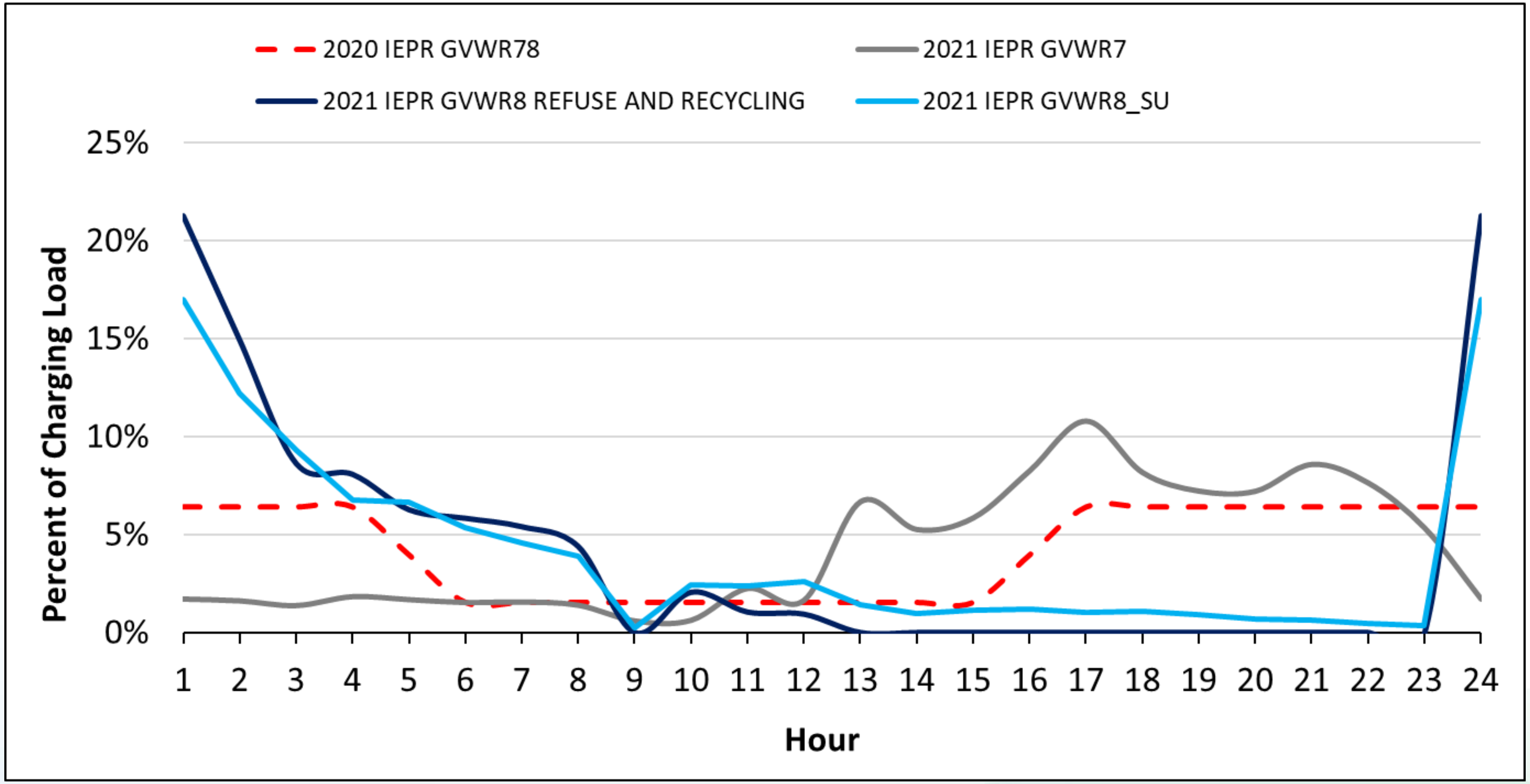
Medium- and Heavy-Duty Base Load Shapes

- 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.

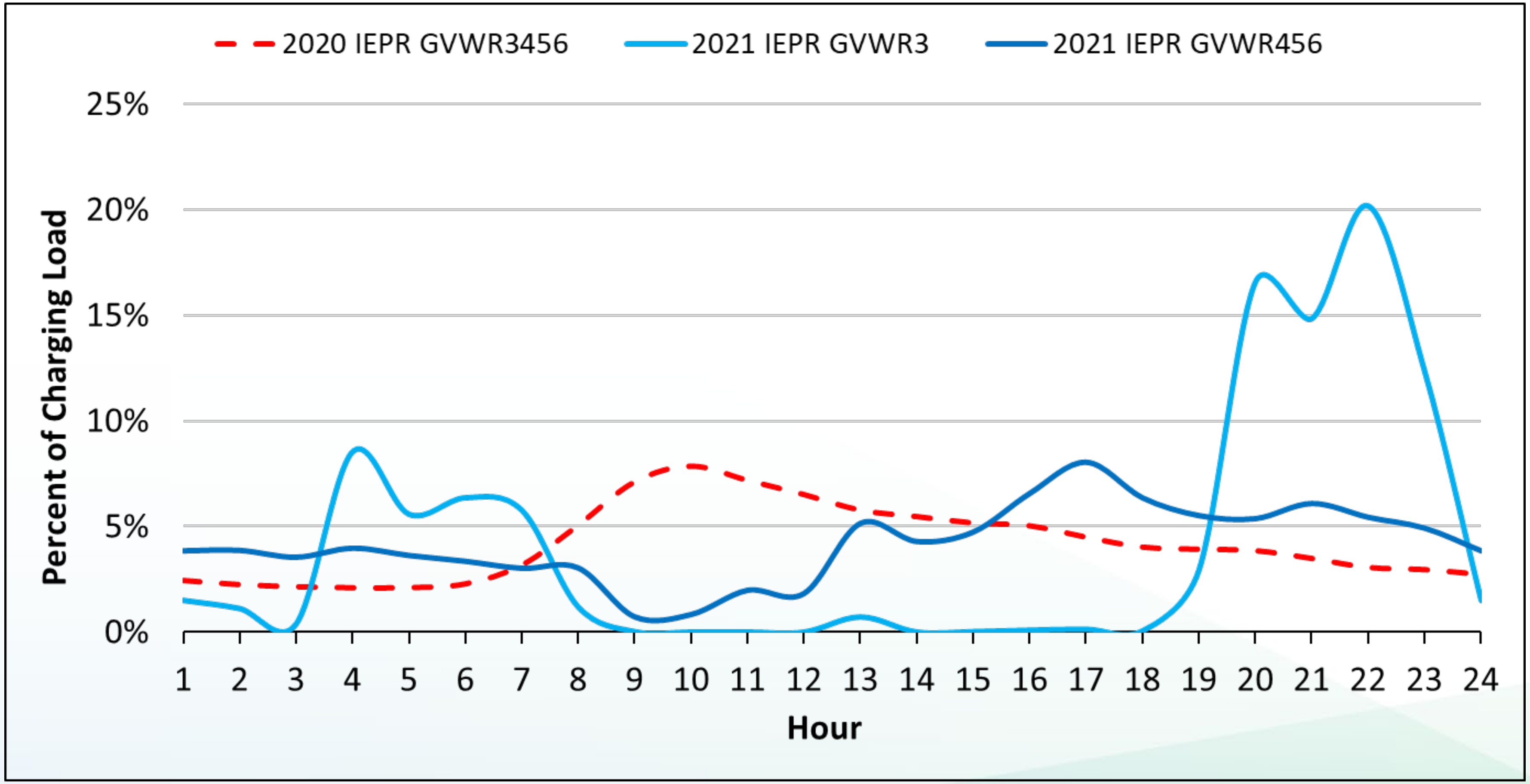
Heavy-Duty Base Load Shapes (1)



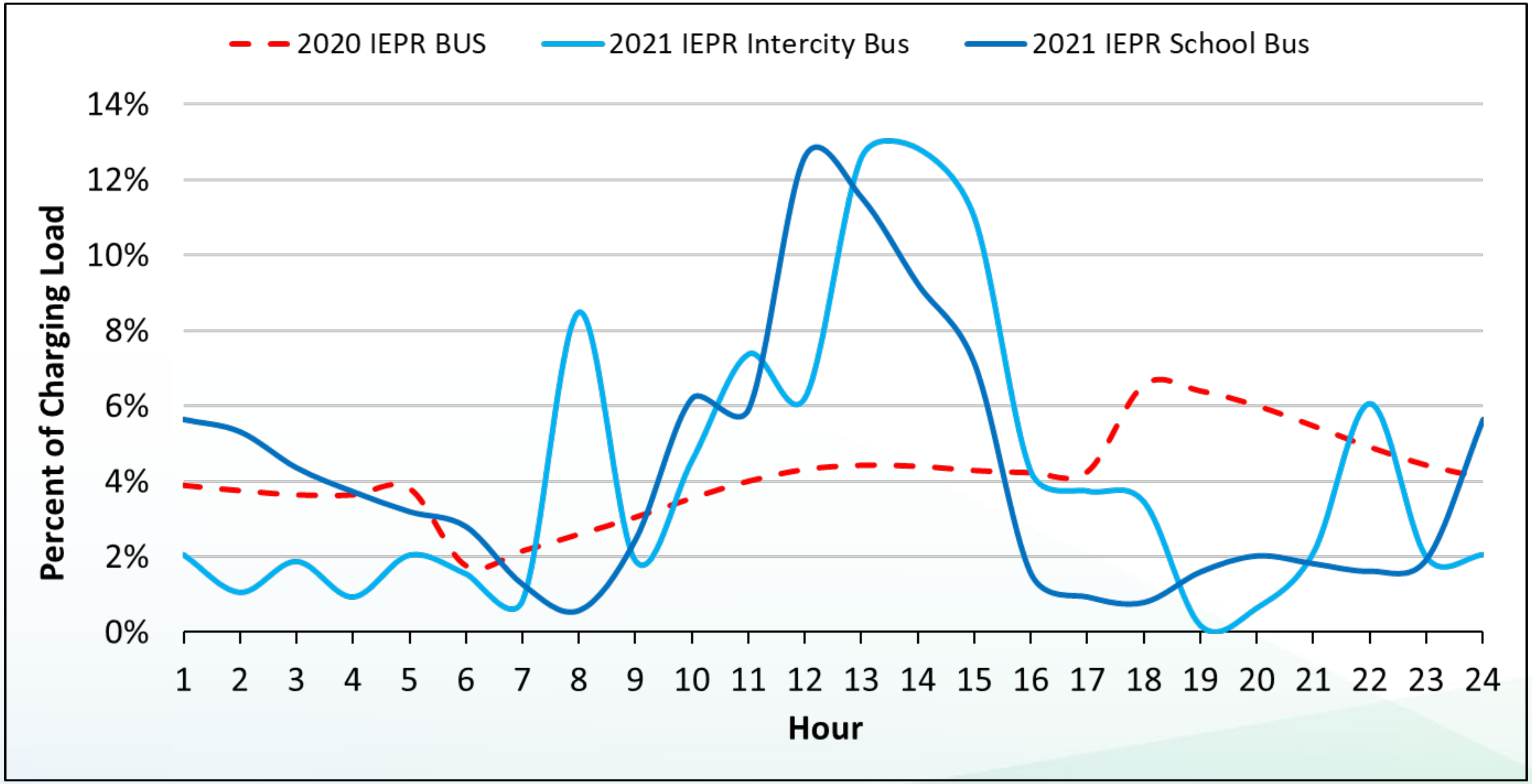
Heavy-Duty Base Load Shapes (2)



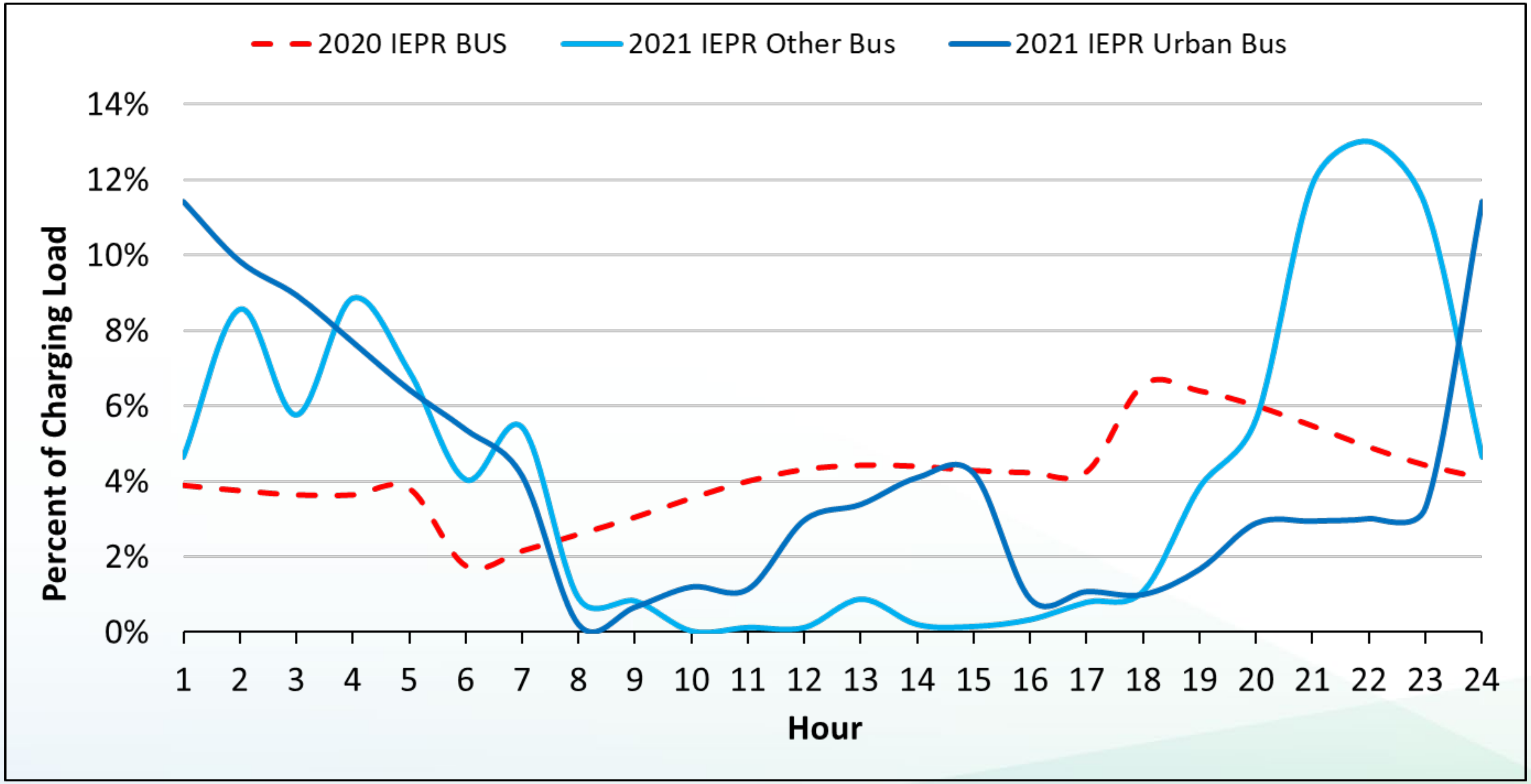
Medium-Duty Base Load Shapes



Bus Base Load Shapes (1)



Bus Base Load Shapes (2)



Appendix

Charging Power Quartiles, 1 of 2 (September 2021)

Vehicle type (EMFAC)	Battery capacity (kWh)	Charging level Q1A (kW)	Charging level Q1B (kW)	Charging level Q2A (kW)	Charging level Q2B (kW)	Charging level Q3A (kW)	Charging level Q3B (kW)	Charging level Q4A (kW)	Charging level Q4B (kW)
LHD2	100	19	50	19	50	50	150	75	225
T6 Ag	200	19	50	50	150	100	300	150	450
T6 CAIRP Heavy	250	25	1000	150	1200	150	1400	300	1600
T6 CAIRP Small	200	19	1000	50	1200	100	1400	150	1600
T6 Instate Construction Heavy	250	25	75	50	150	150	450	300	900
T6 Instate Construction Small	300	19	50	50	150	100	300	150	450
T6 Instate Heavy	400	100	300	150	450	150	450	300	900
T6 Instate Small	300	19	50	50	150	100	300	150	450
T6 OOS Heavy	400	100	1600	150	1600	150	1600	300	1600
T6 OOS Small	400	19	1600	50	1600	100	1600	150	1600
T6 Public	400	19	50	50	150	100	300	150	450
T6 Utility	400	19	50	50	150	100	300	150	450
T6TS	400	19	50	50	150	100	300	150	450

Charging Power Quartiles, 2 of 2 (September 2021)

Vehicle type (EMFAC)	Battery capacity (kWh)	Charging level Q1A (kW)	Charging level Q1B (kW)	Charging level Q2A (kW)	Charging level Q2B (kW)	Charging level Q3A (kW)	Charging level Q3B (kW)	Charging level Q4A (kW)	Charging level Q4B (kW)
T7 Ag	600	100	300	150	450	250	750	350	1600
T7 CAIRP	1000	100	1000	150	1200	250	1400	350	1600
T7 CAIRP Construction	1000	100	1000	150	1200	250	1400	350	1600
T7 NNOOS	1000	100	1000	150	1200	250	1400	350	1600
T7 NOOS	1000	100	1000	150	1200	250	1400	350	1600
T7 Other Port	600	100	300	150	450	250	750	350	1600
T7 POAK	600	100	300	150	450	250	750	350	1600
T7 POLA	600	100	300	150	450	250	750	350	1600
T7 Public	600	100	300	150	450	250	750	350	1600
T7 Single	600	100	300	150	450	250	750	350	1600
T7 Single Construction	600	100	300	150	450	250	750	350	1600
T7 SWCV	300	100	300	150	450	250	750	350	1600
T7 Tractor	600	100	300	150	450	250	750	350	1600
T7 Tractor Construction	600	100	300	150	450	250	750	350	1600
T7 Utility	600	100	300	150	450	250	750	350	1600
T7IS	600	100	300	150	450	250	750	350	1600
SBUS	300	19	50	50	150	75	225	100	300
UBUS	700	50	150	100	300	150	450	300	1000
Motor Coach	700	100	300	150	450	350	1050	500	1600
OBUS	400	19	150	50	300	75	450	300	900
All Other Buses	400	19	150	50	300	75	450	300	900