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ENERGY TECHNOLOGIES AREA

LAWRENCE BERKELEY NATIONAL LABORATORY

Medium- and Heavy- Duty Electric Vehicle Infrastructure Projections (HEVI-Pro)

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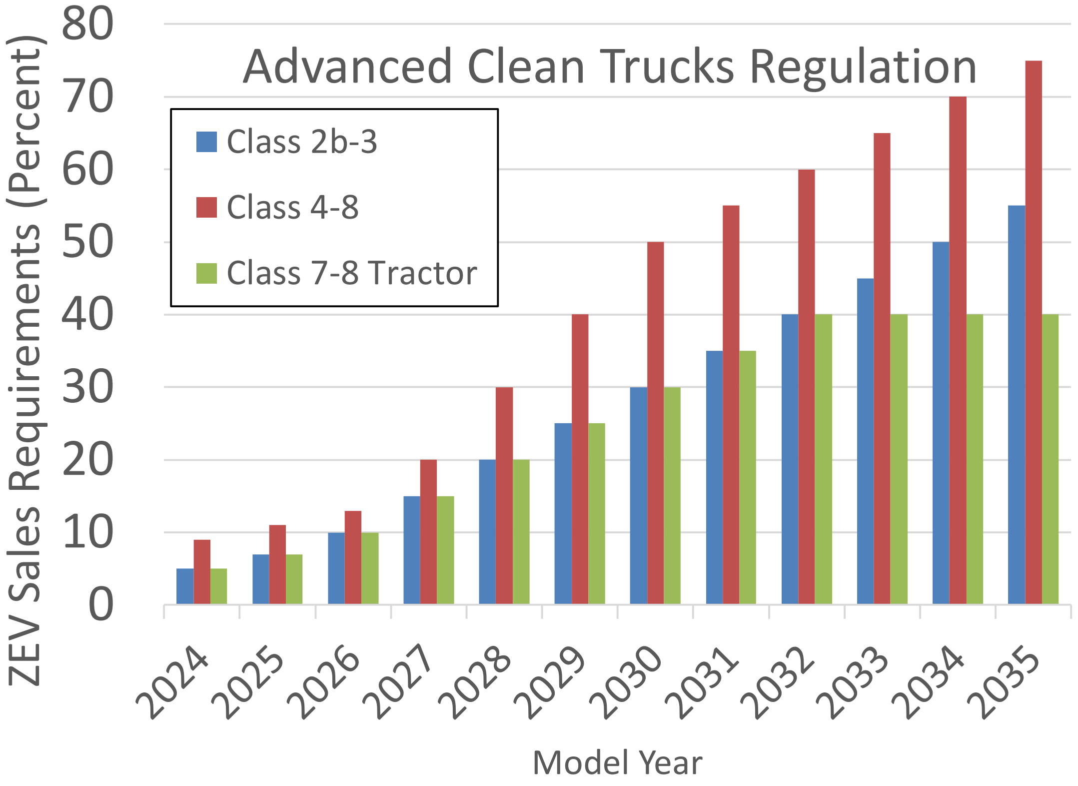
Electrifying Medium and Heavy-Duty Vehicles

- 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.).



https://ww2.arb.ca.gov/news/california-takes-bold-step-reduce-truck-pollution
https://ww3.arb.ca.gov/regact/2019/act2019/30dayattb.pdf

HEVI-Pro | Metrics

Charging infrastructure need and load profiles for MHDVs

<table>
<tr><th rowspan="2">Region</th><th colspan="2">Charging infrastructure</th><th rowspan="2">Number of chargers/plugs</th></tr>
<tr><th>Type of accessibility</th><th>Charger type</th></tr>
<tr><td>Charging infrastructure requirements for <u>each county</u>.

Aggregate estimates by:

(1) City
(2) Town
(3) Rural area
(4) Interstate/state highway</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

Charging stations servicing Class 8 heavy-duty trucks should be listed in a separate manner from “normal” charging stations (serving LDVs & MHDVs).</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]

(2) # of stations
(3) # of plugs per station
(4) # of plugs per 1,000 PEVs</td></tr>
</table>

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		Public (shared)	
	Highways	(11) Heavy-duty long-haul trucks			

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

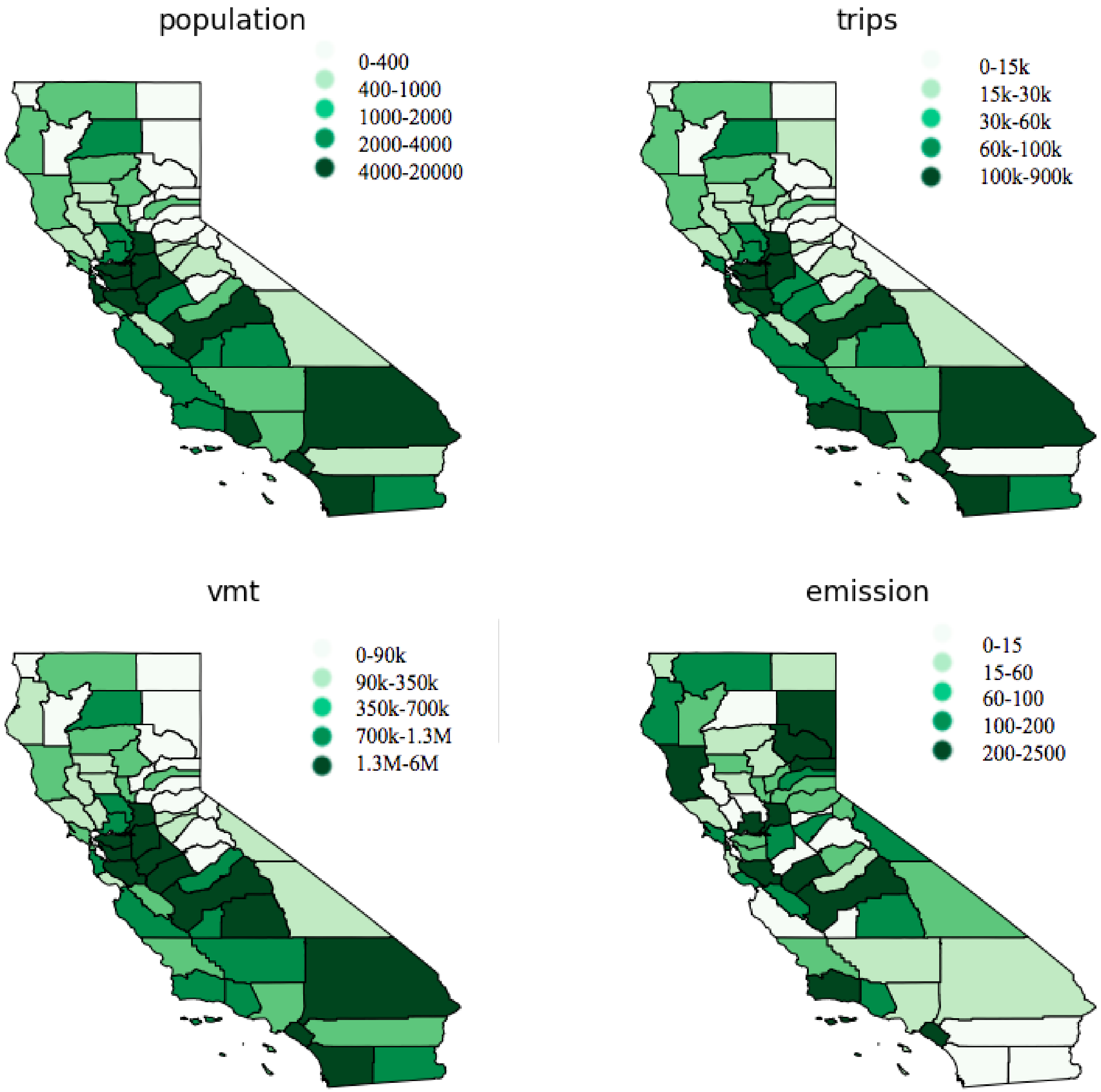
Electric grid inputs
- EDGE – capacity constraints

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.

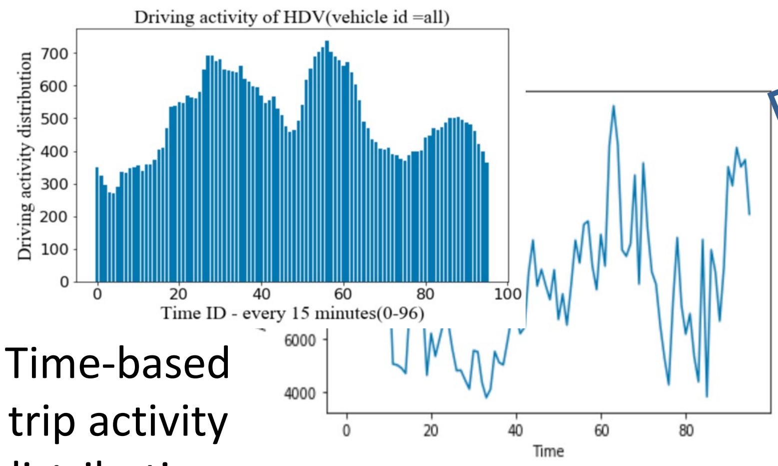


EMFAC Projections

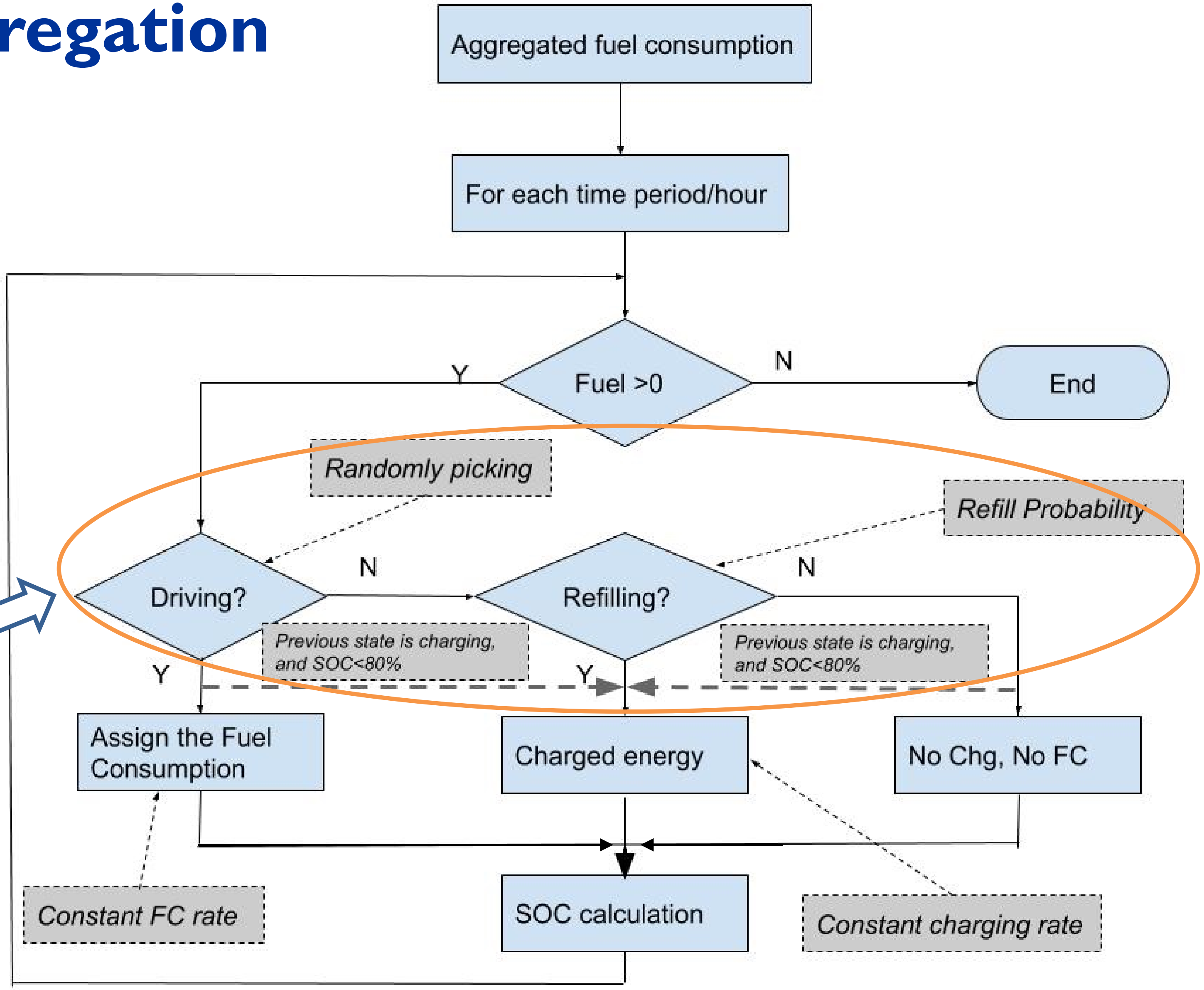
2. Data-driven Trip Disaggregation

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



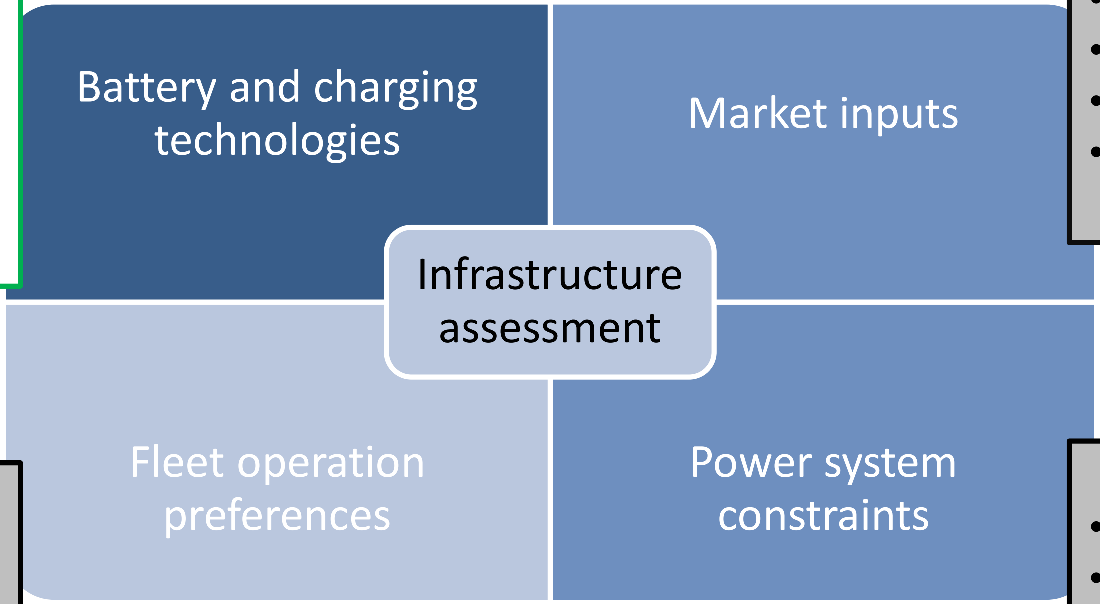
Time-based trip activity distributions



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.



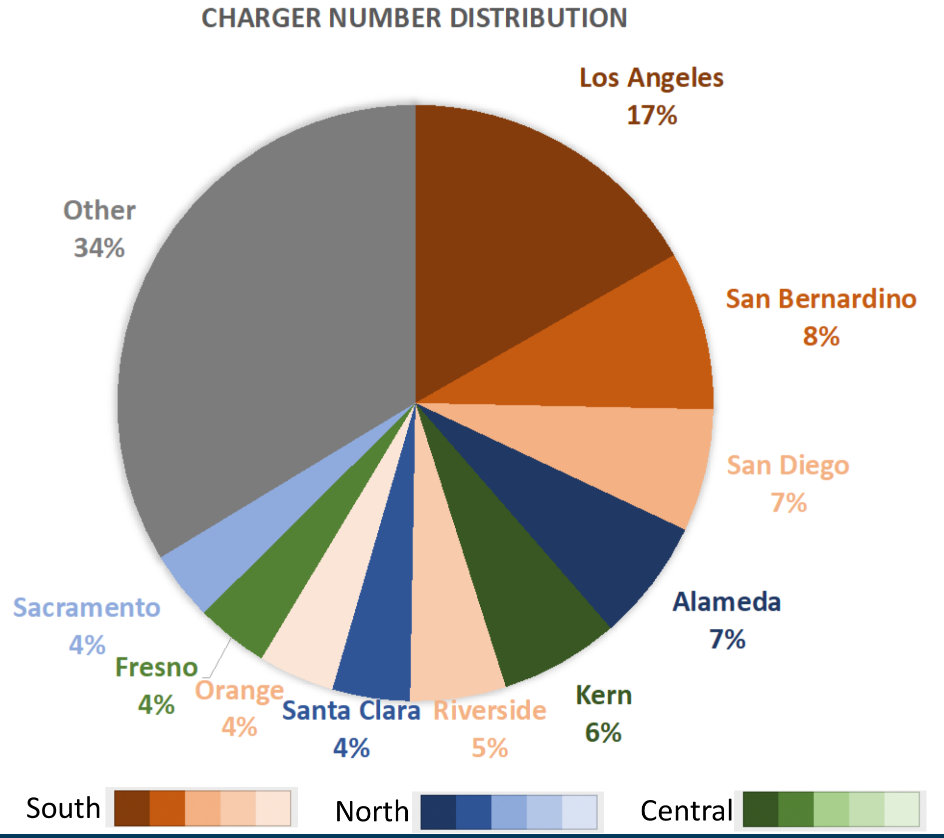
Operation preferences
- Fixed route or flexible routes;
- Managed or smart charging

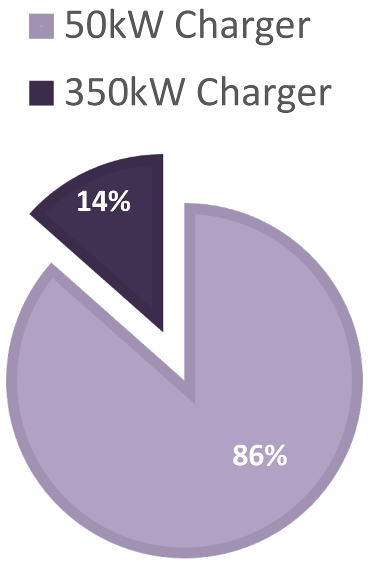
Grid constraints
- Feeder circuit capacities
- Grid connection points
- Location constraints
- Voltage requirements etc.

Analyses Forthcoming

Preliminary Results

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

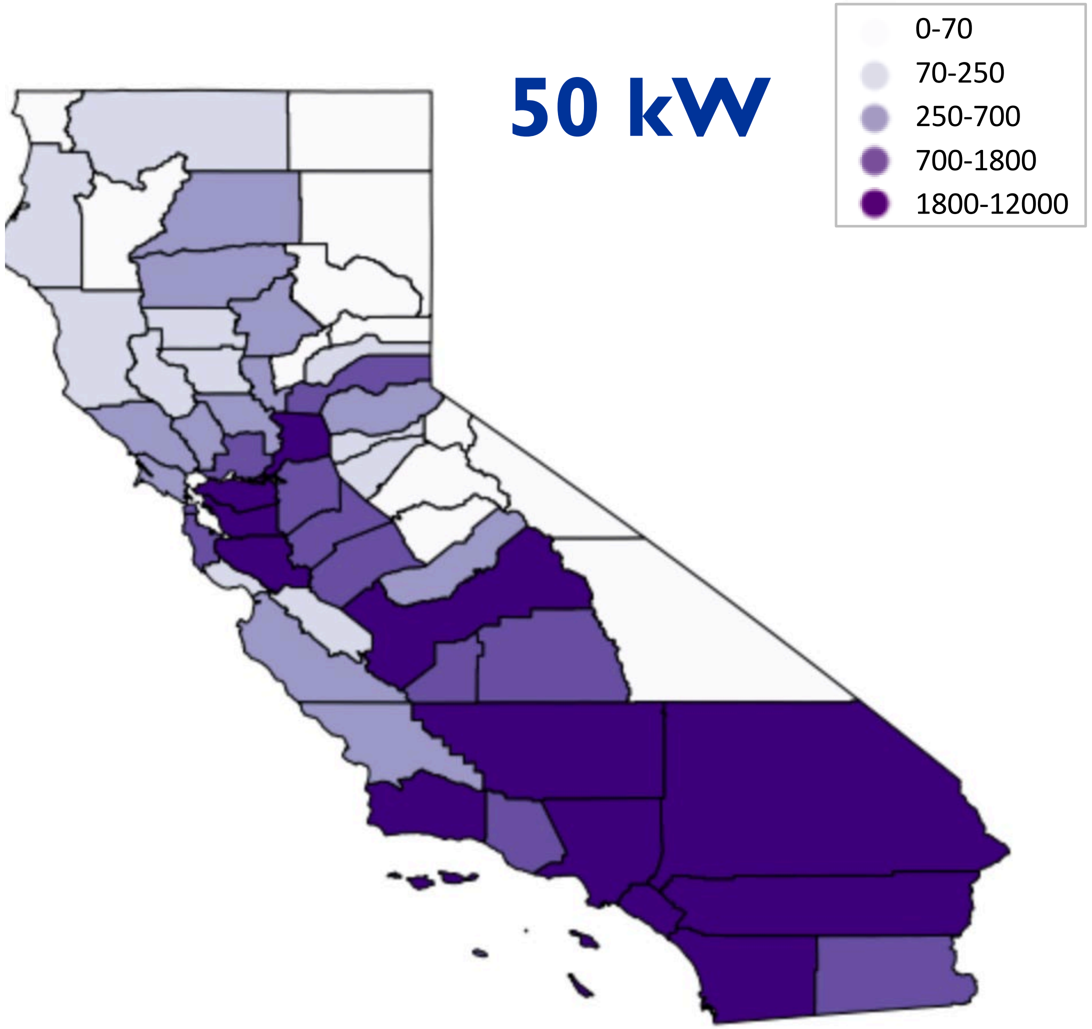


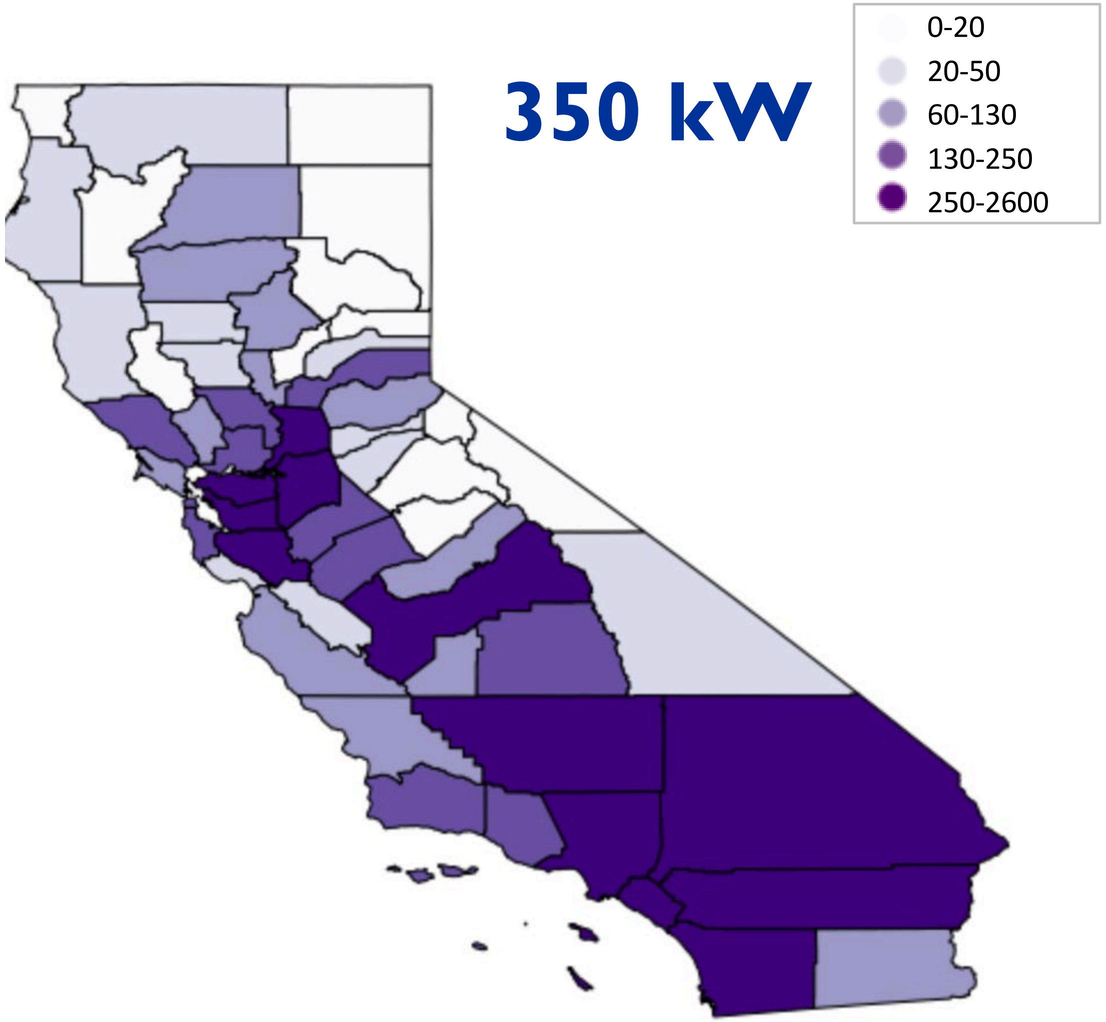


Key notes and assumptions:

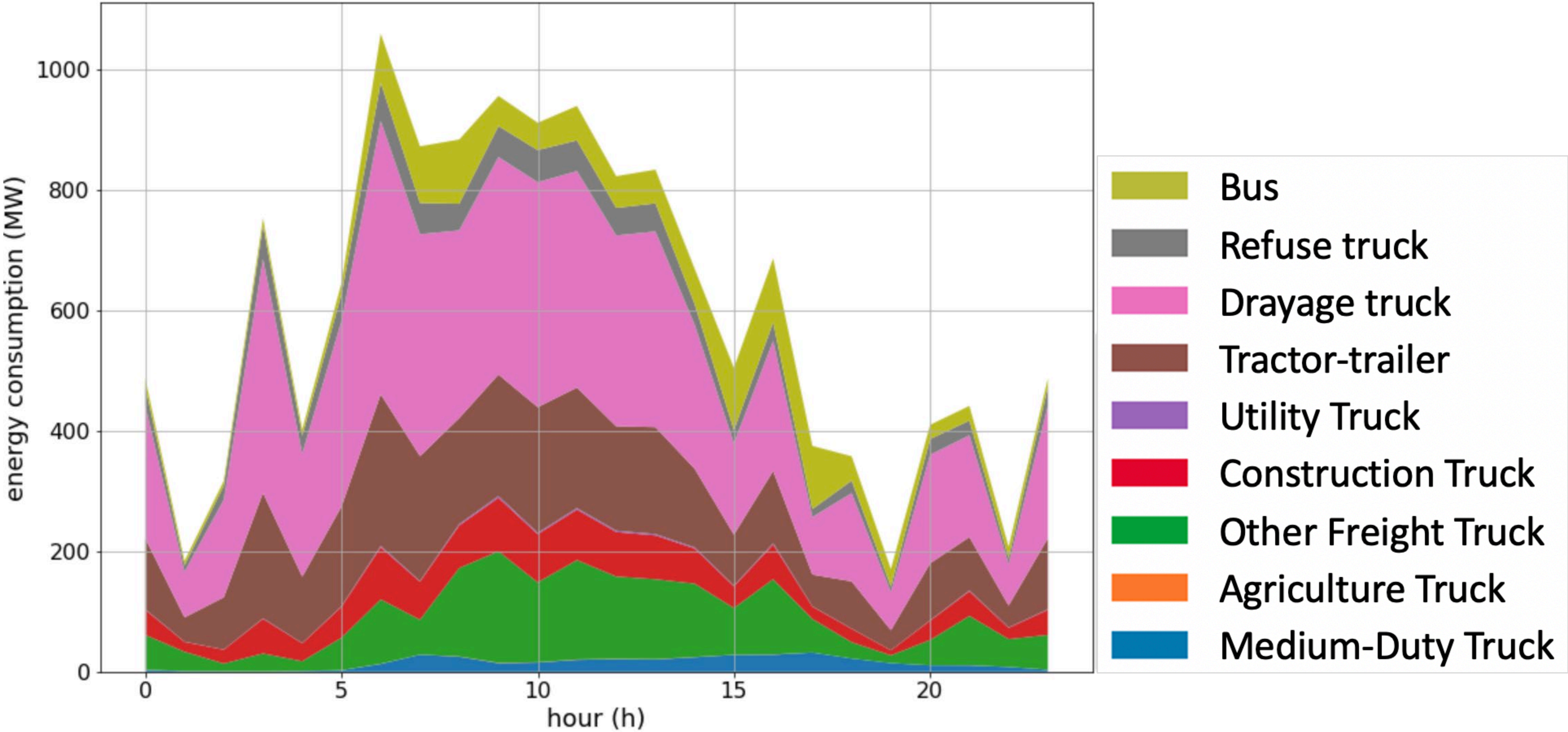
- Only 50kW and 350kW chargers are considered
- MHDVs prefer 350 kW charger during daytime and prefer 50 kW during nighttime
- Electrified MHDVs follow similar duty cycles as traditional vehicles
- Electrified MHDVs use night and parking times for charging
- 80% initial SOC for each MHDV simulated
-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

Preliminary Charger Counts by County and Power Capacity

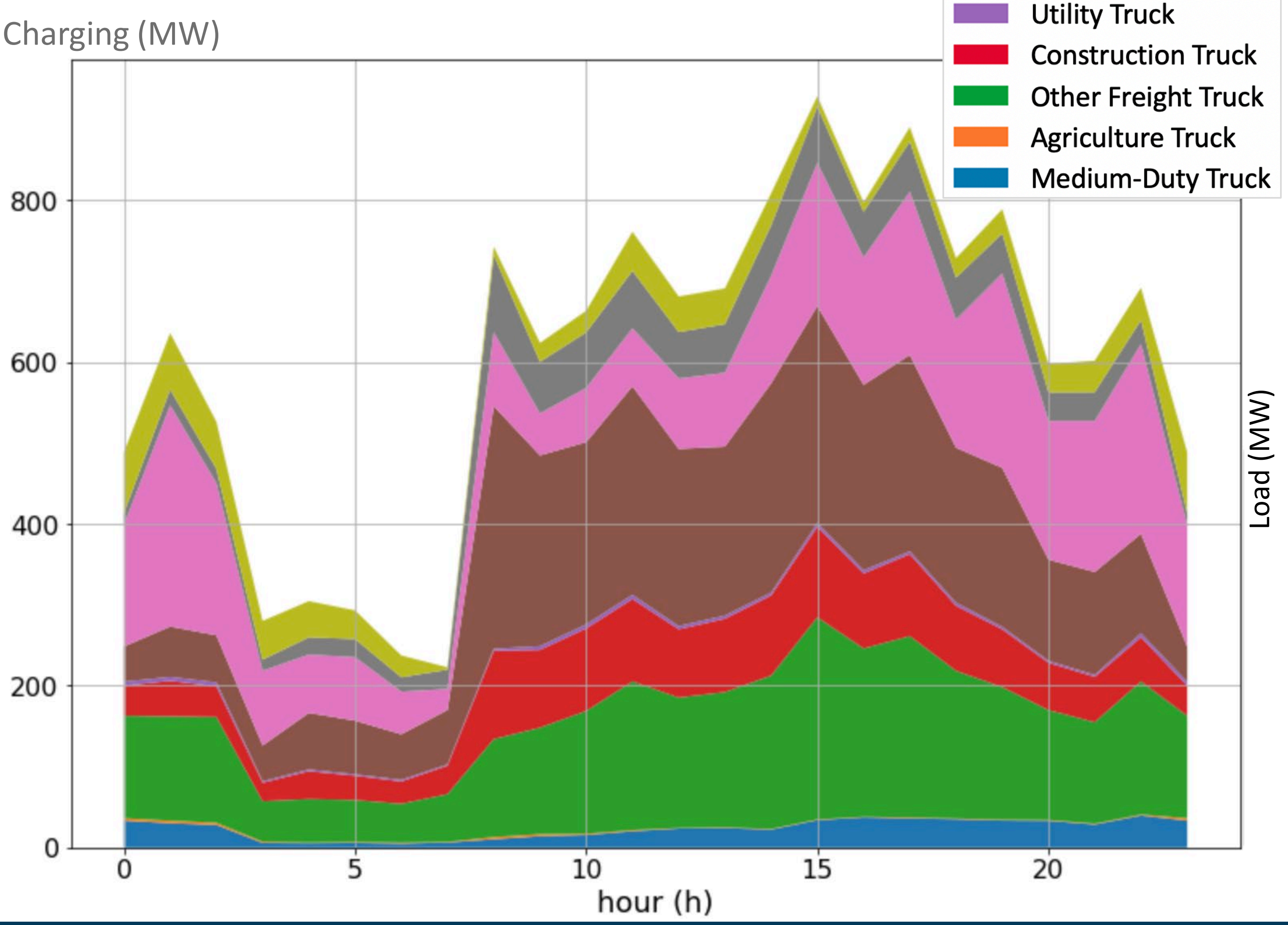


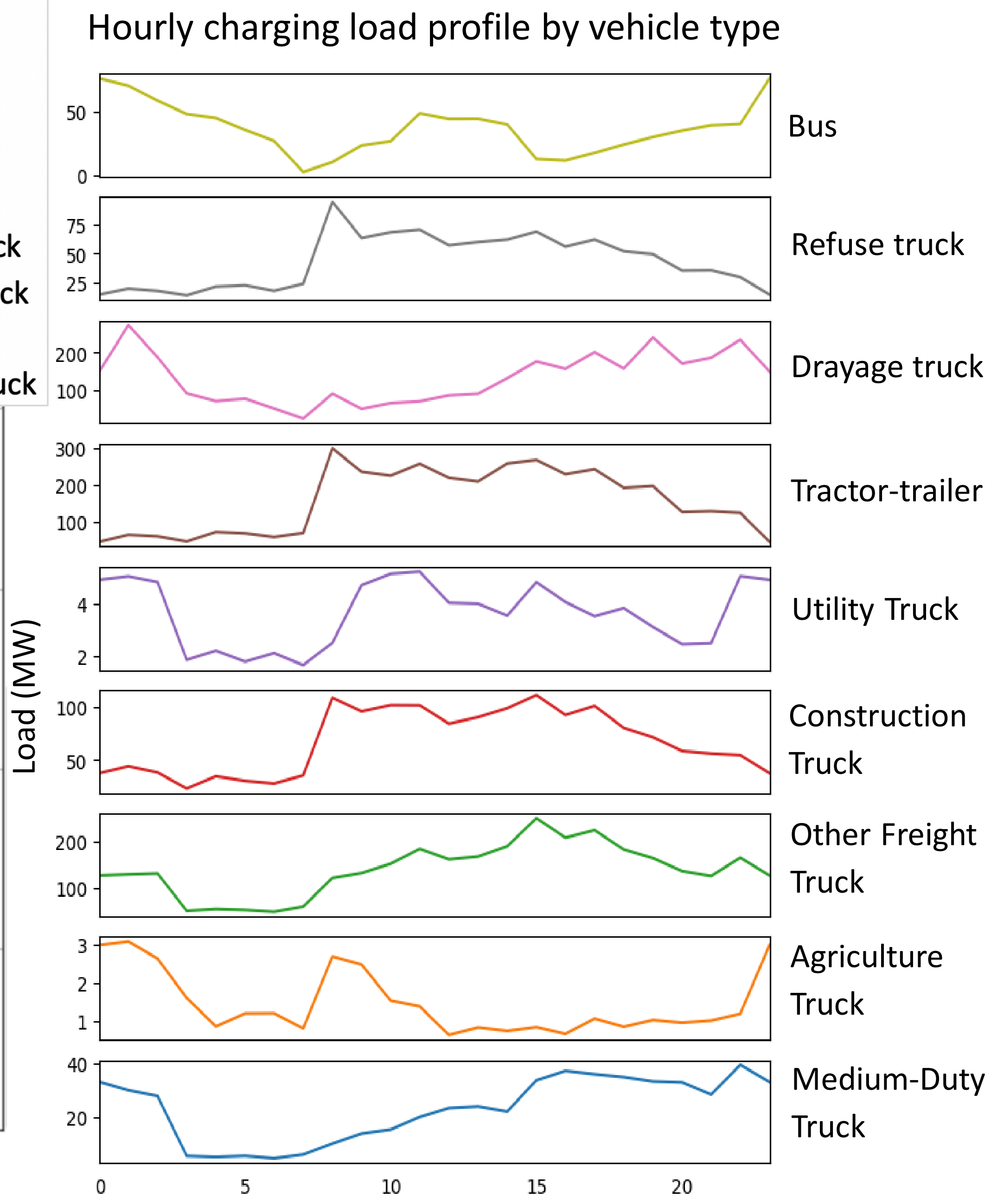


Energy Consumption of Electric MHDVs While Driving (2030)



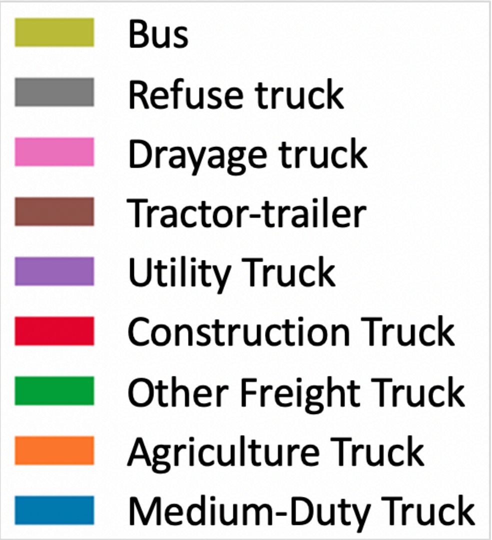
Statewide Load Profile Example (2030)



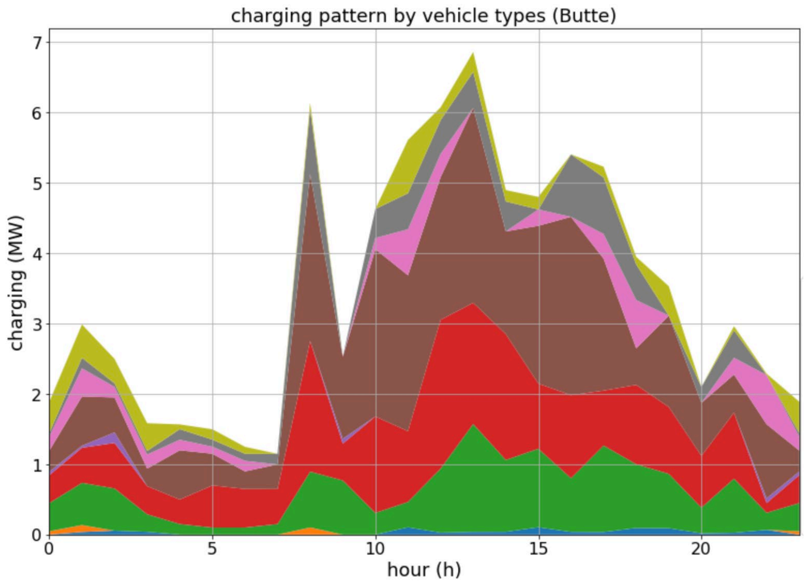


County Load Profile Examples (2030)

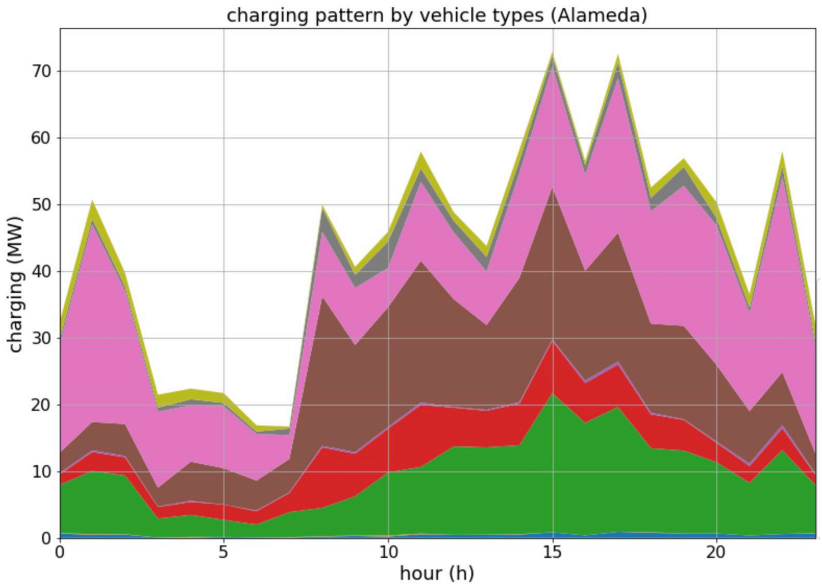
- MHDV categories are aggregated from EMFAC categories
- Vehicle-specific charging probabilities are based on trip patterns
- Tractor-trailer type includes long-haul trucks (in/out state); Drayage trucks include T7 POLA (Port of Los Angeles) and T7 POAK (Port of Oakland)



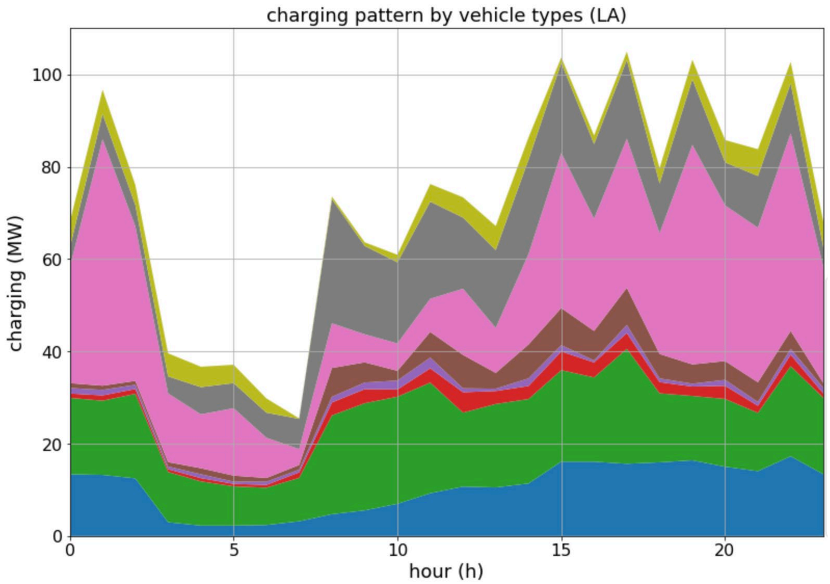
Butte



Alameda



Los Angeles



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

Berkeley Lab · California Energy Commission · California Air Resources Board · Caltrans · NREL · South Coast AQMD · SCAG · CALSTART · West Virginia University · UC Riverside · UC Davis · UC Berkeley

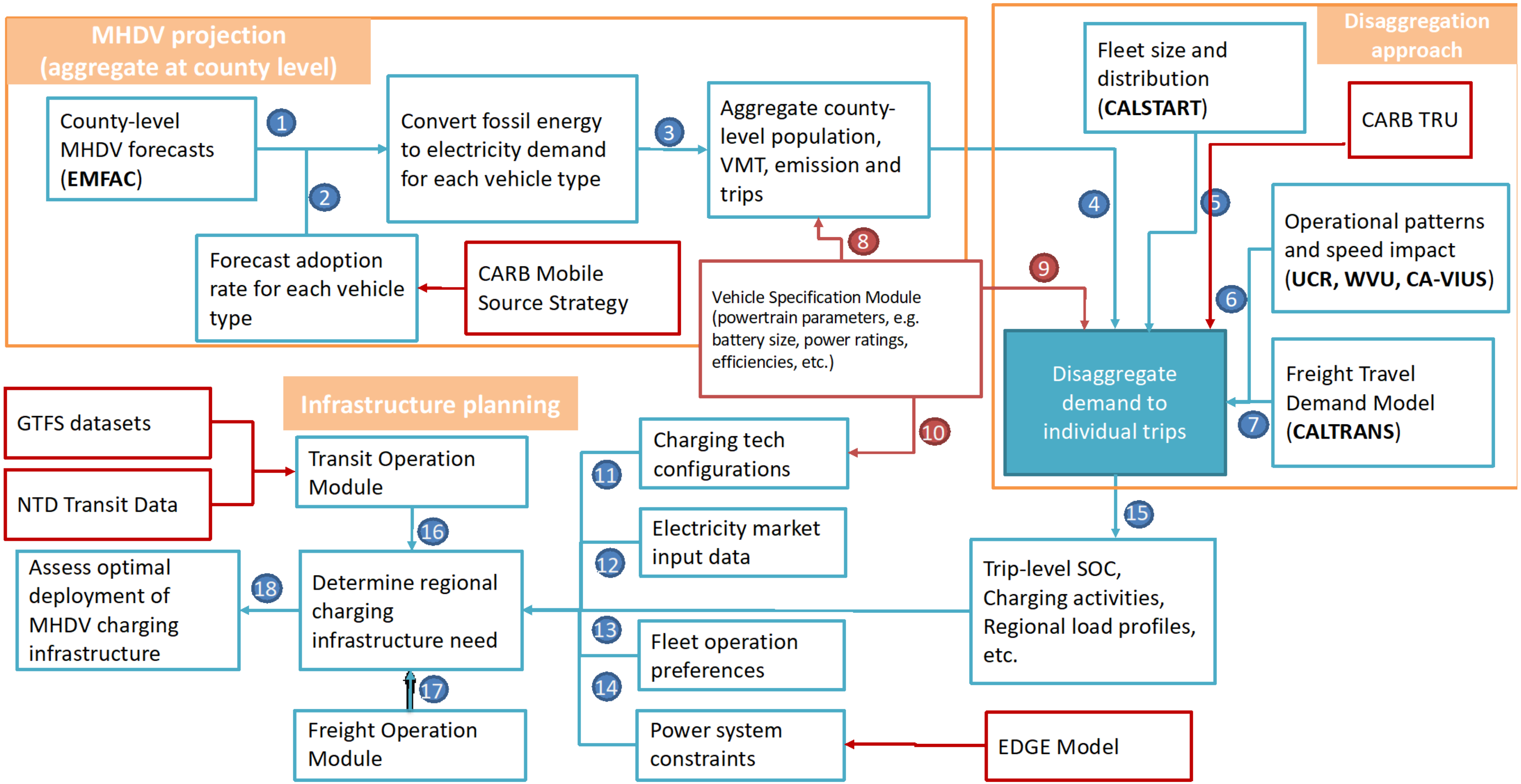
We look forward to working with you!

Backup slides

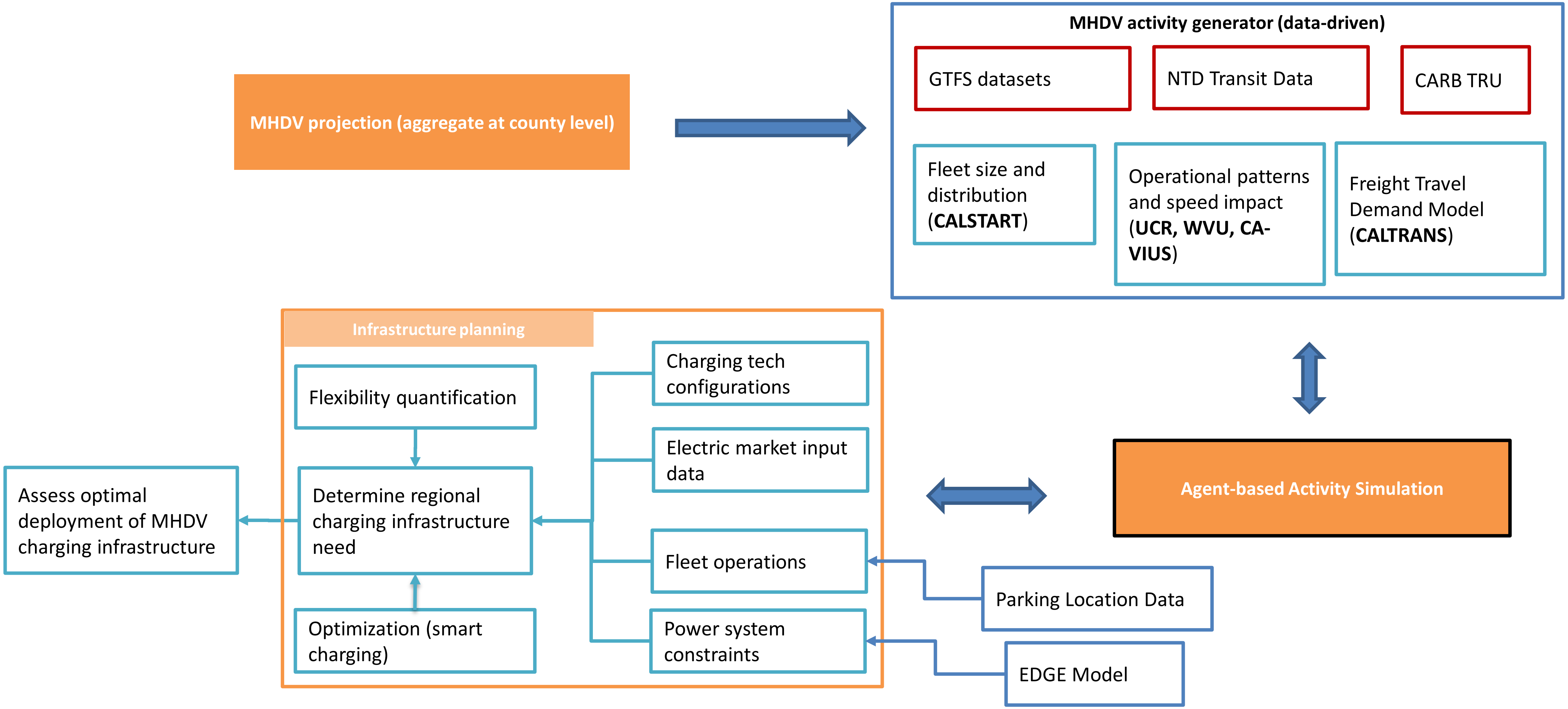
Vehicle Mapping Across CARB and CEC Typology

EMFAC Type	HEVI-Pro Type	EMFAC Type	HEVI-Pro Type
T6 Ag	Agriculture Truck	T6 CAIRP Heavy	Other Freight Truck
T7 Ag		T6 CAIRP Small	
T6 Instate Construction Heavy	Construction Truck	T6 Instate Heavy	
T6 Instate Construction Small		T6 Instate Small	
T7 CAIRP Construction		T6 OOS Heavy	
T7 Single Construction		T6 OOS Small	
T7 Other Port	Drayage Truck	T6 Public	
T7 POAK		T6TS	
T7 POLA		T7 Public	
LHD2	Medium-Duty Truck	T7 Single	
T7 SWCV	Refuse truck	T7 CAIRP	Tractor-trailer
T6 Utility	Utility Truck	T7 NNOOS	
		T7 NOOS	

Transition from Top-down to Bottom-up Approach



Next Steps: Bottom-up Approach



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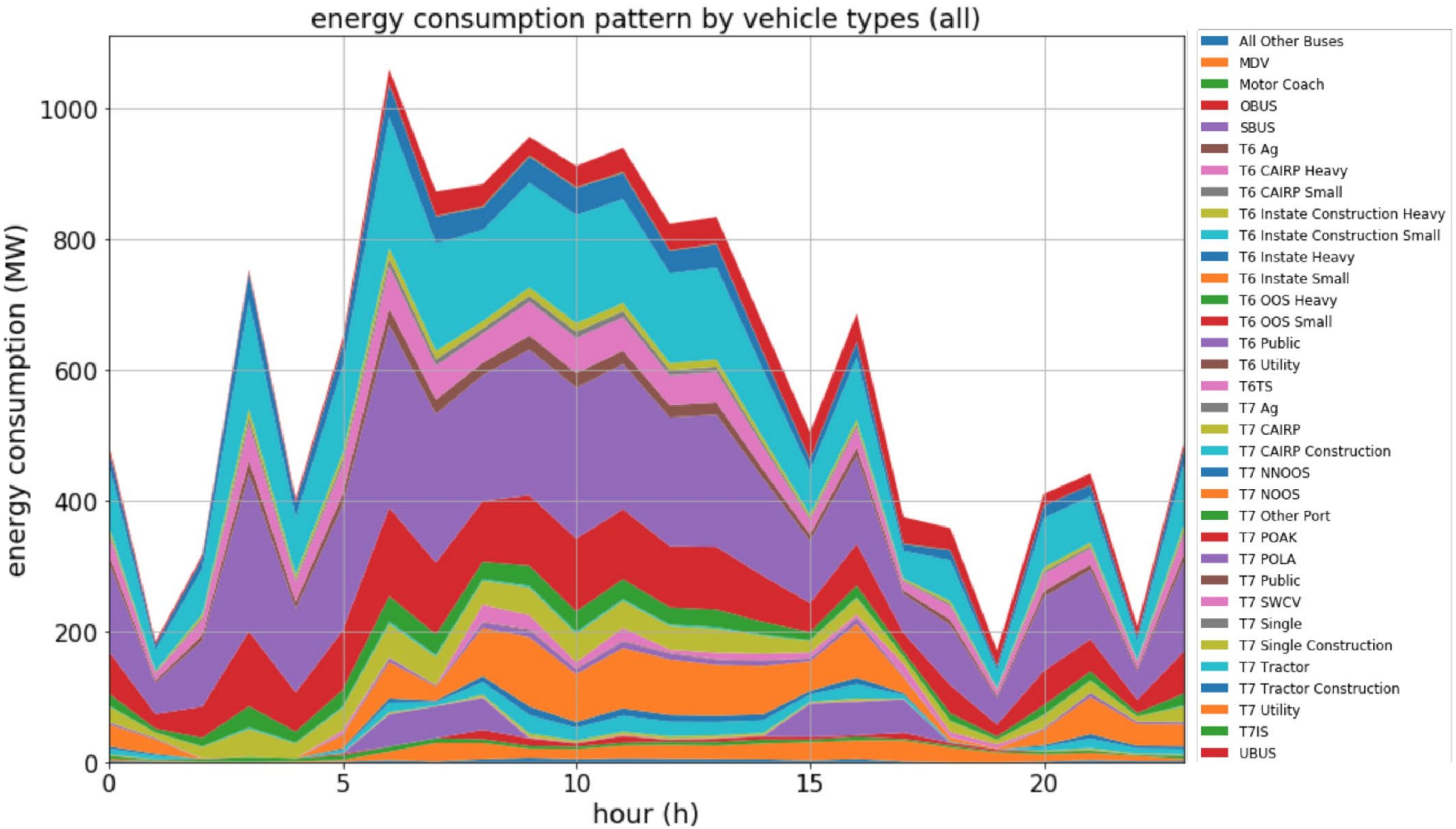

CA Charging Load Profile (2030)