June 22, 2021

Project ID: VAN028

Electric Vehicle (EV)-Grid Analysis Modeling

PI: Srinath Ravulaparthy

Team: Fan Tong, Wanshi Hong, Alan Jenn* and Cong Zhong

*Lawrence Berkeley National Laboratory; *University of California, Davis*

2021 DOE VTO Annual Merit Review

June 21-25, 2021

This presentation does not contain any proprietary, confidential, or otherwise restricted information

Overview

Timeline

- Start date: FY-20
- End date: FY-22
- Percent complete: 42%

Barriers

- Indicators and methodology for evaluating environmental sustainability and cost impacts
- Relating component-level technologies to national-level benefits

Budget

- Total project funding: $750K
  - DOE share: 100%
- FY 2021: $250K

Partners

- Project Lead: LBNL
- Partners: UC Davis, Marain Inc.

Milestones FY-21

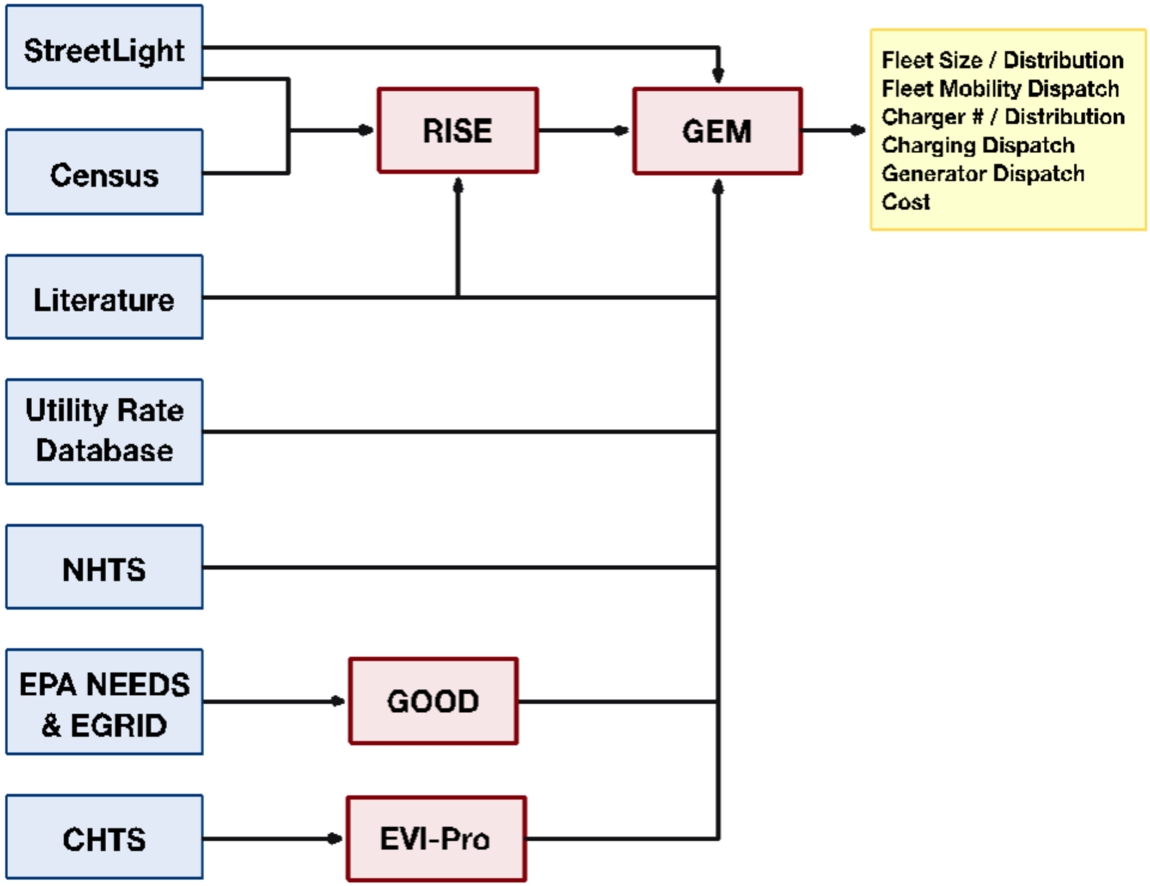
Date	Milestone	Status
FY21 - Q1	Establish scenarios of battery technologies and battery capacities, and the resulting ranges for long-haul freight electric trucks	Complete
FY21 - Q2	Incorporate micromobility patterns into GEM with preliminary results demonstrating baseline and sensitivity analyses	Complete
FY21 - Q3	Determine impact of autonomous freight truck technology on the charging load profile	On Schedule
FY21 - Q4	Complete freight charging load shape scenario sensitivity based on battery capacities and potential autonomous trucking technologies; Complete micromobility baseline and sensitivity analyses; Produce standardized outputs for use by other Analysis project teams	On Schedule

PART 1: GEM Model Overview & Approach

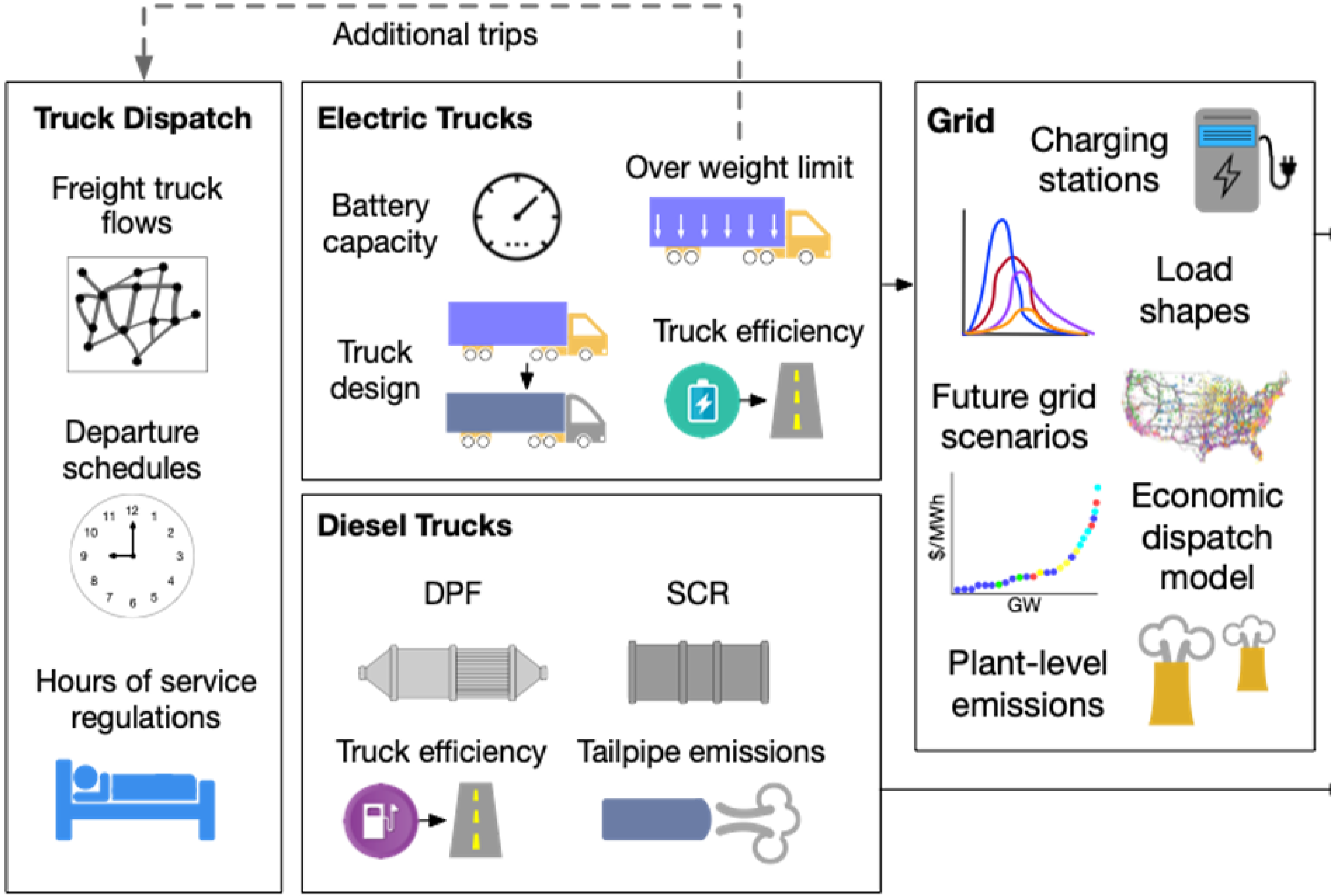
Grid-Integrated Electric Mobility (GEM) Model

- Cost and benefit estimates from integrated transportation & power systems from PEVs
  - Impact on grid operating cost
  - Impact on fleet and charging infrastructure requirements
- Accounts for charging profile and load flexibility within existing and emerging modes of transportation
  - Shared Automated Electric Vehicles (SAEVS)
  - Micromobility (e.g., Bikes and E-Bikes)
  - Freight Trucks (e.g., Medium/Heavy Duty Vehicles)
- The grid is simulated as dispatched, allowing the system costs to be minimized across both transportation and power sectors

GEM Model Framework



GEM Truck Electrification Model



We built a comprehensive bottom-up model including a freight demand model, a vehicle energy model, truck flow and payload model, charging infrastructure model, and truck dispatch and operation model.

Demand

- HDV travel demand
- Travel distance
- Charging demand

Battery & Charging

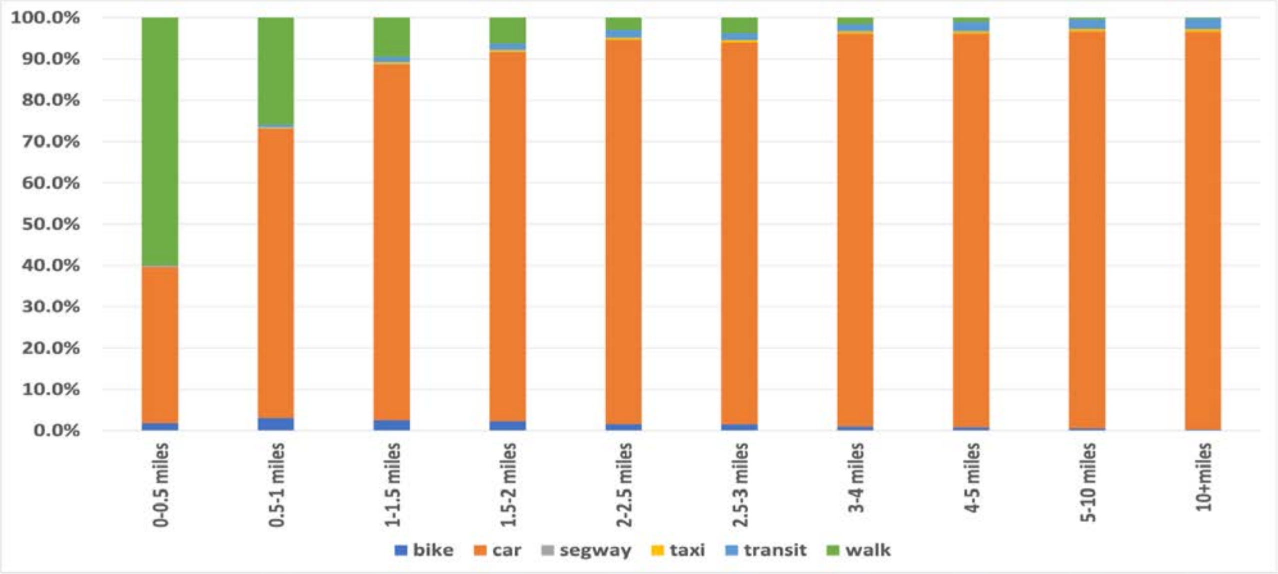
- Battery lifetime and capital cost
- Charger power and distribution

Micromobilty in GEM Model

- **Demand**
  - Passenger travel demand
  - Travel distance
  - Charging demand
- **Cost Components**
  - Maintenance
  - Infrastructure
  - Fleet
- **Demand Allocation**
  - Energy
  - Vehicle movement
  - Fleet dispatch
- **Charging Behavior**
  - State of Charging

The model formulation has been modified throughout GEM in order to incorporate micromobility into the analysis

- Micromobility primarily serves short-distance trips within 10 miles
- Modal shift opportunities for trips from cars to bike is larger



Mode Share by Trip Distance 2017 National Household Travel Survey

➢ **Decision variables for e-Bikes**
  - Energy charged/consumed
  - Bike Costs (fleet, infrastructure, maintenance, demand charge cost, ...)
  - Fleet size
  - Vehicle states (charging, moving, idle)
  - Demand allocated
  - Number of chargers

PART 2: GEM Model Results

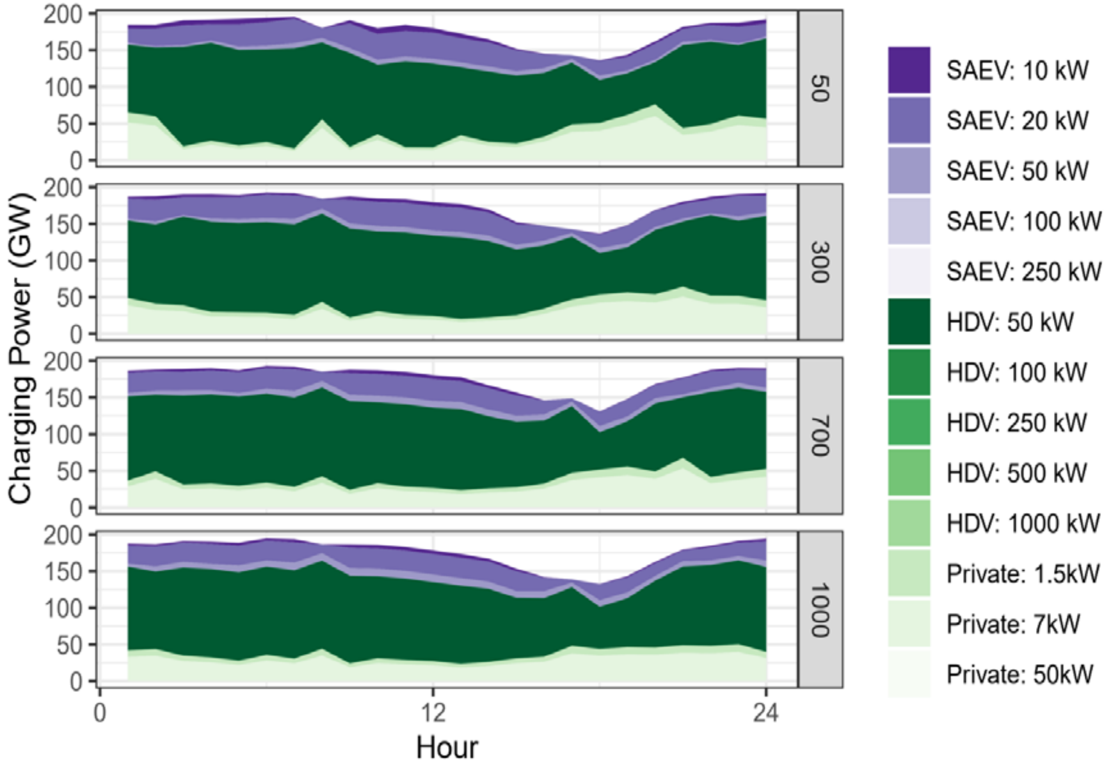
Accomplishment

HDV Daily Charging Load Distribution

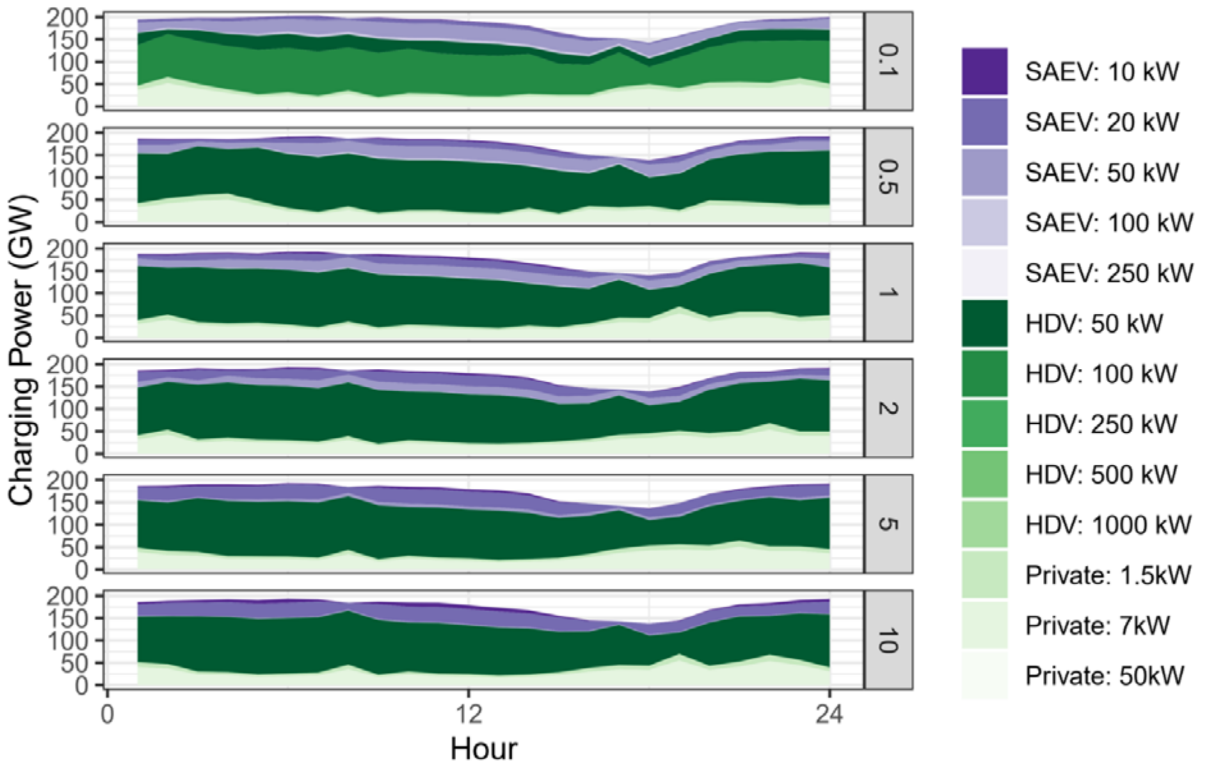
Charger cost effect test: $C_n = C_1 + (l_n - l_1) * k$

Parameters: 1) C is the infrastructure cost in \$/kW, (2) k is the number of vehicles per charging station and (3) l is the battery capacity

Charging power by C_1 charger cost (k = 5 vehicles per charger)



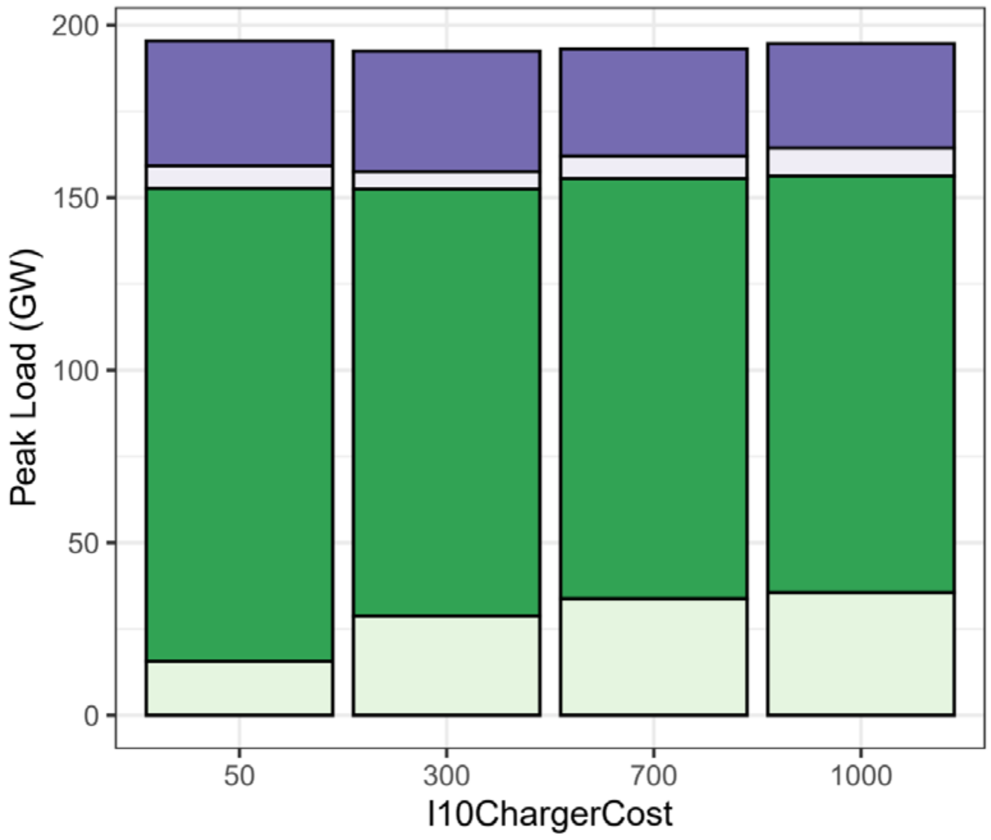
Charging power by k (C_1 = 300)



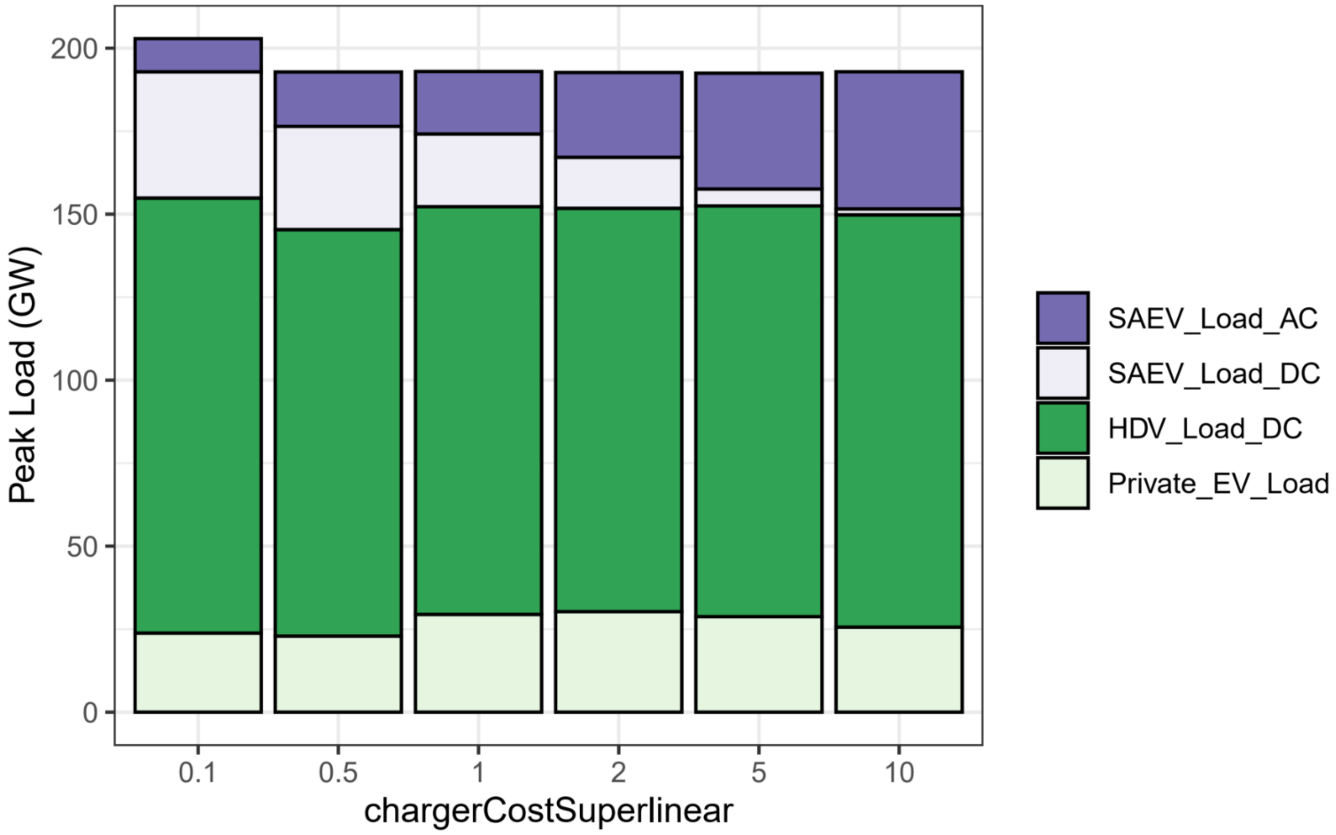
HDV Peak Load Distribution

Parameters: 1) C is the infrastructure cost in \$/kW, (2) k is the number of vehicles per charging station

Charging power by C_1 charger cost (k = 5)

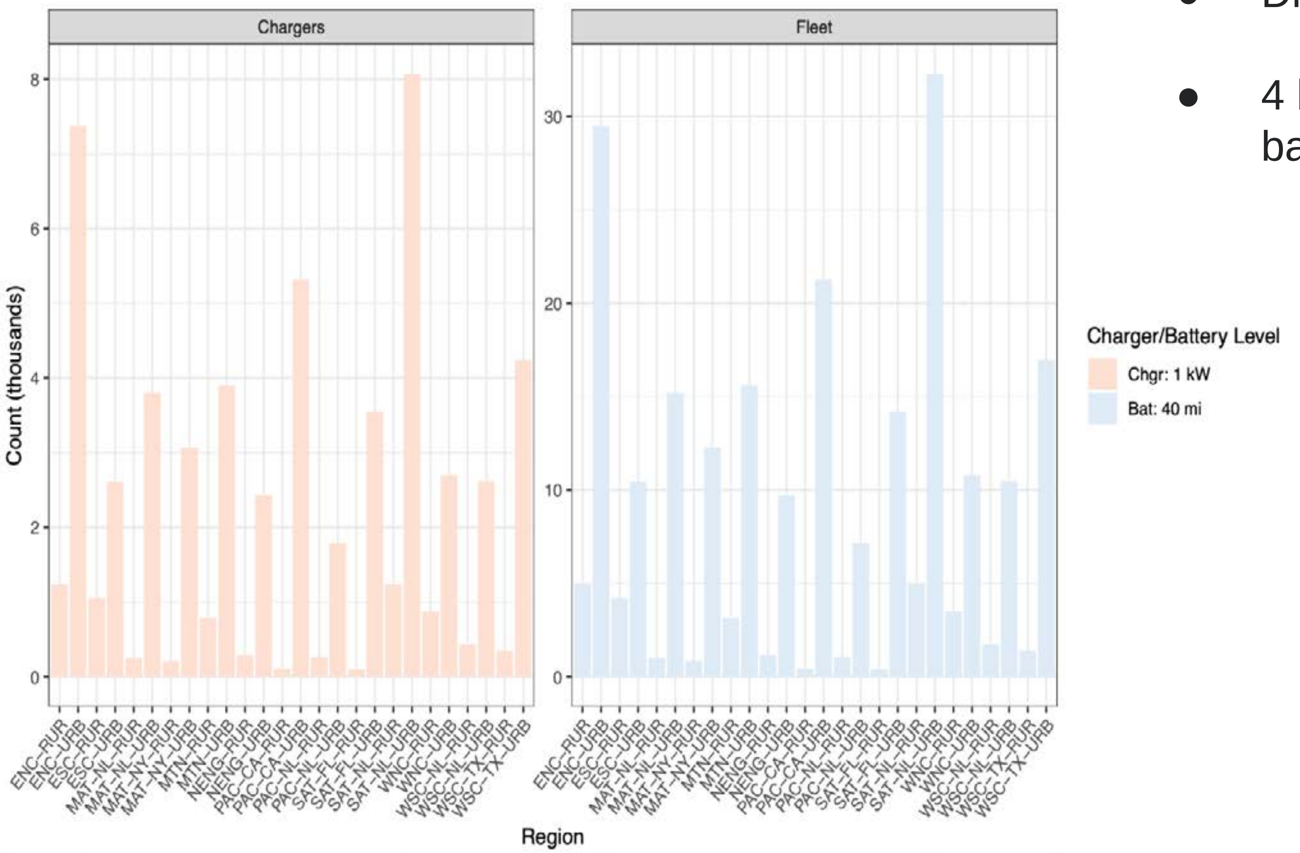


Charging power by k (C_1 = 300)



Micromobility Baseline Conditions

Preliminary Results

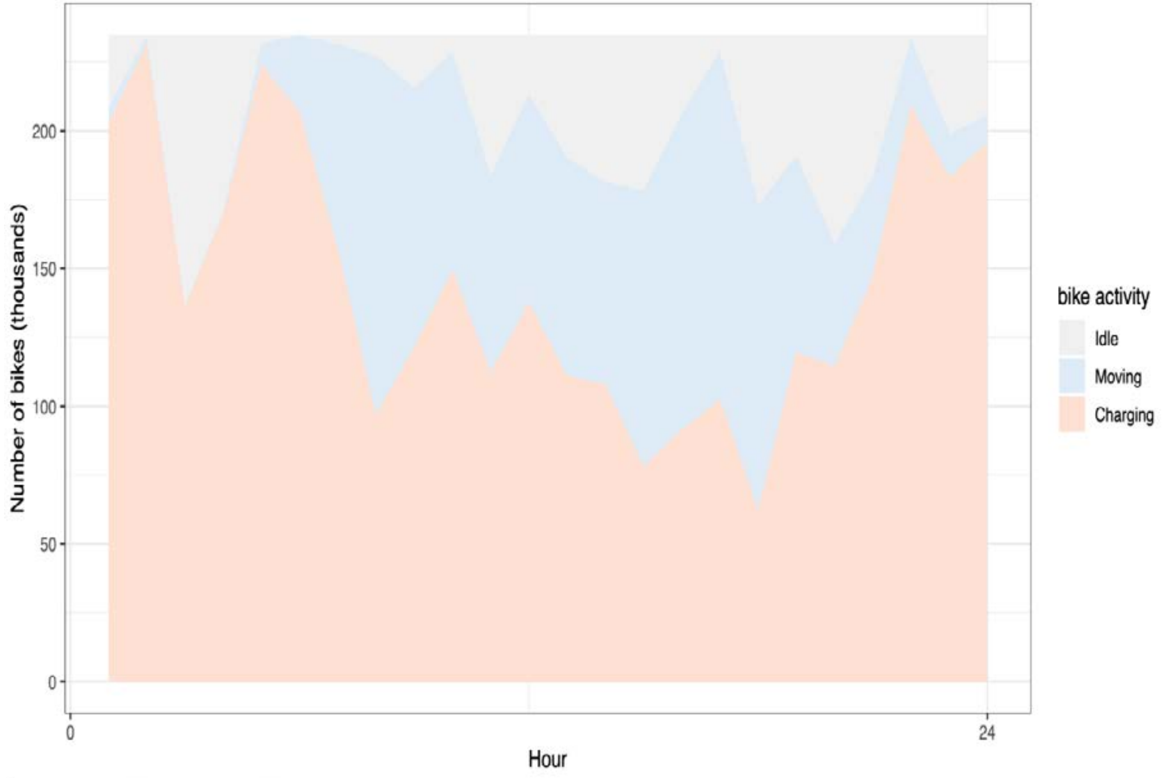


Bike Fleet Size & Charger Distributions

X-axis is U.S. Grid Geographical Region by Urban/Rural
Y-axis is Number of Chargers and Total Fleet Size

Parametric Assumptions

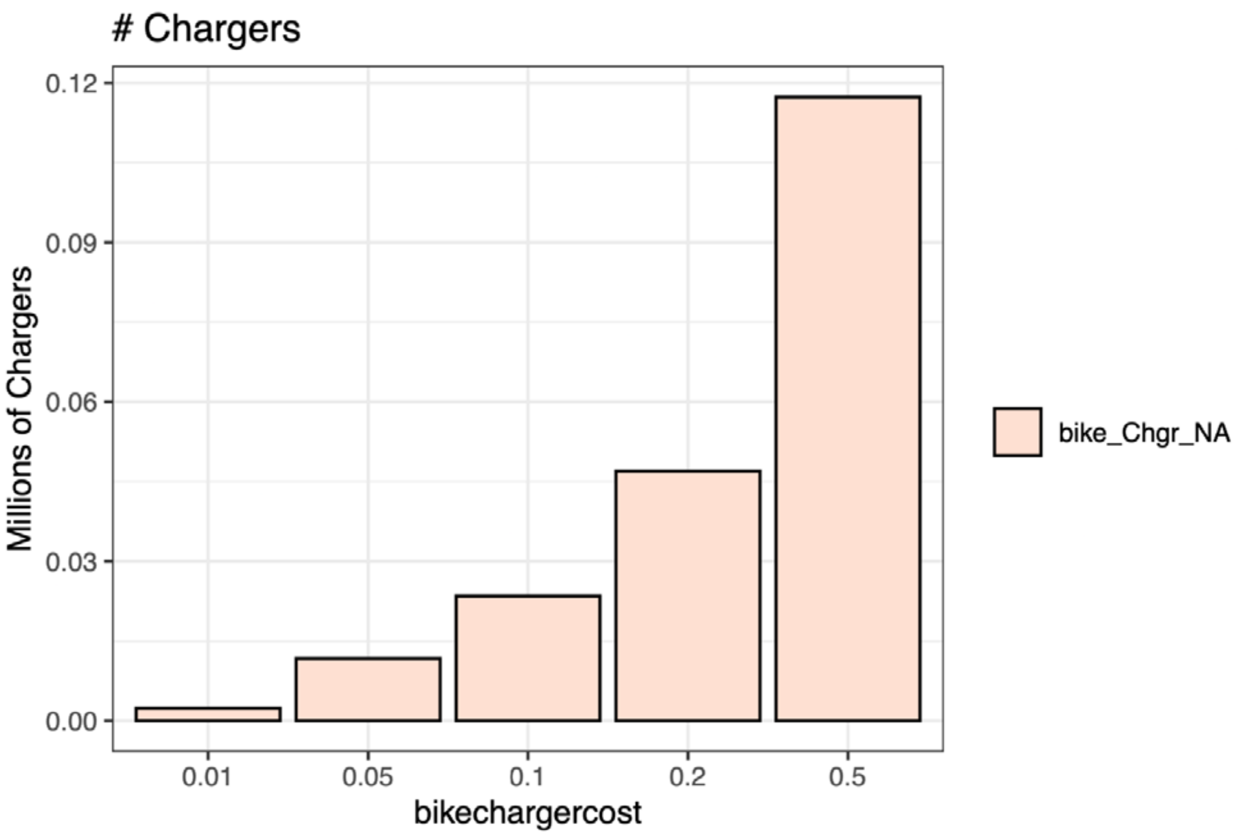
- Car to Bike Mode Shifts - 0.2%, 0.4%, 0.5%, 1.3%, 3.6%
- Distance Bins: 0-2 miles, 2-5 miles, 5-10 miles, 10-20 miles, 20+ miles
- 4 bikes per charger with 1KW charger level of up to 40 miles battery capacity



24-hour bike movement profile

Micromobility Bike Charging Capacities

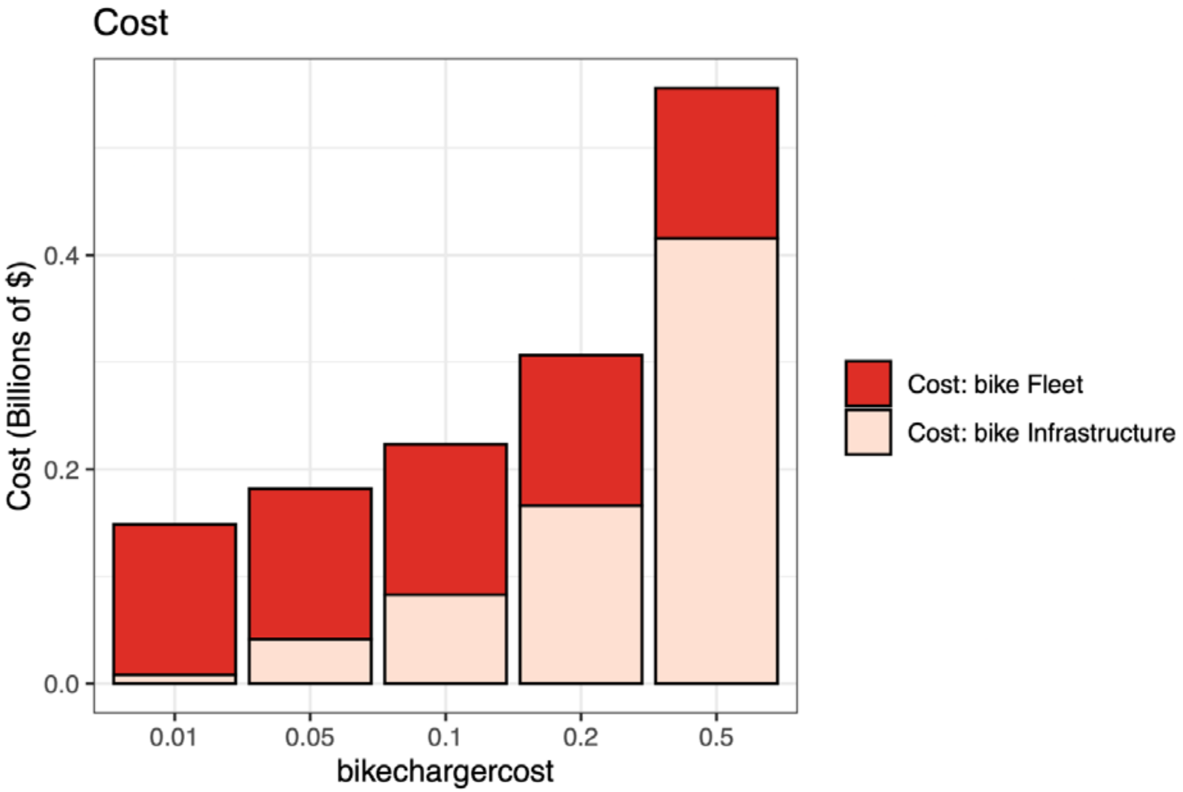
Preliminary Results



Number of Bike Chargers Needed

Parametric Assumptions

- All same as baseline conditions
- Bikes to charger ratio[bike charge cost] - 100[0.01], 20[0.05], 10[0.1], 5[0.2], 2[0.5] bikes per charger



Bike Fleet & Infrastructure Costs

Response to FY19 Reviewer Comments

Accomplishment

- **One reviewer highlighted the relevance and impact of the work**
  - *"The reviewer remarked that this is a very ambitious project with an approach to match and commended the researchers on a straightforward methodology that helps provide incredible insights into the benefits and costs of a world with SAEVs. […] The [reviewer] indicated that the question about faster or slower chargers is a major technology decision that charging system providers and local and state governments are wrestling with at the moment."*
- **Response**
  - We thank the reviewer for illustrating how the modeled scenarios is relevant for the real-world decisions made by state and local governments. We will continue to update the model and perform the analysis to stay impactful.

- **Several reviewers were concerned about the computational efficiency**
  - *"This reviewer agreed with the research team that tackling the computational efficiency needs to be a high priority for next steps. Doing so will allow great numbers of insights on the optimized SAEV world."*
  - *"As the team recognized, the reviewer commented that the optimization problem quickly becomes too large to solve."*
- **Response**
  - We took this task of improving computational efficiency as a top priority. We are now able to run the GEM model for 14 days (consisting of representative and extreme days for each season in a year) within a reasonable running time. This improvement enables our results to be more representative and relevant.

- **One reviewers was concerned about the lack of publications**
  - *"This reviewer said the project appears to have made good progress, but publications and presentations are lacking."*
- **Response**
  - We have published an article to a peer-review journal and the article is currently under review.

Major Accomplishments

Accomplishment

- Peer-review publication process
  - Article has been published in Environmental Science and Technology Review
    - *Sheppard et al., (2021). Private vs. SAEVS for U.S. Personal Mobility: Energy Use, GHG Emissions, Grid Integration and Cost Impacts.*
  - Article in progress that accounts for GEM model with HDVs and micromobility formulations. Expected to be submitted towards end of the year with inputs from reviewers and program manager.

- Providing an open-access version of GEM
  - Successful implementation and publication of opensource version of GEM model with passenger mobility
    - https://github.com/LBNL-UCB-STI/gem
  - User tutorial with example setup and flexible use to allow customization of scenarios

PART 3: Future Work & Summary

Proposed Future Research

- **FY 2021**
  - Determine impacts of autonomous freight truck technology on the charging load profile
  - Complete micromobility baseline and sensitivity analyses based on battery capacities, and charging infrastructure along with changing travel demand patterns (e.g., first-mile/last-mile connectivity)
- **Beyond FY 2021**
  - Multimodal integrations of ride-hail and micromobility operations and impacts on energy usage and the grid
  - Finalize scenario definitions and results from automated trucking, ride-hail electrifications and micromobility scenarios.

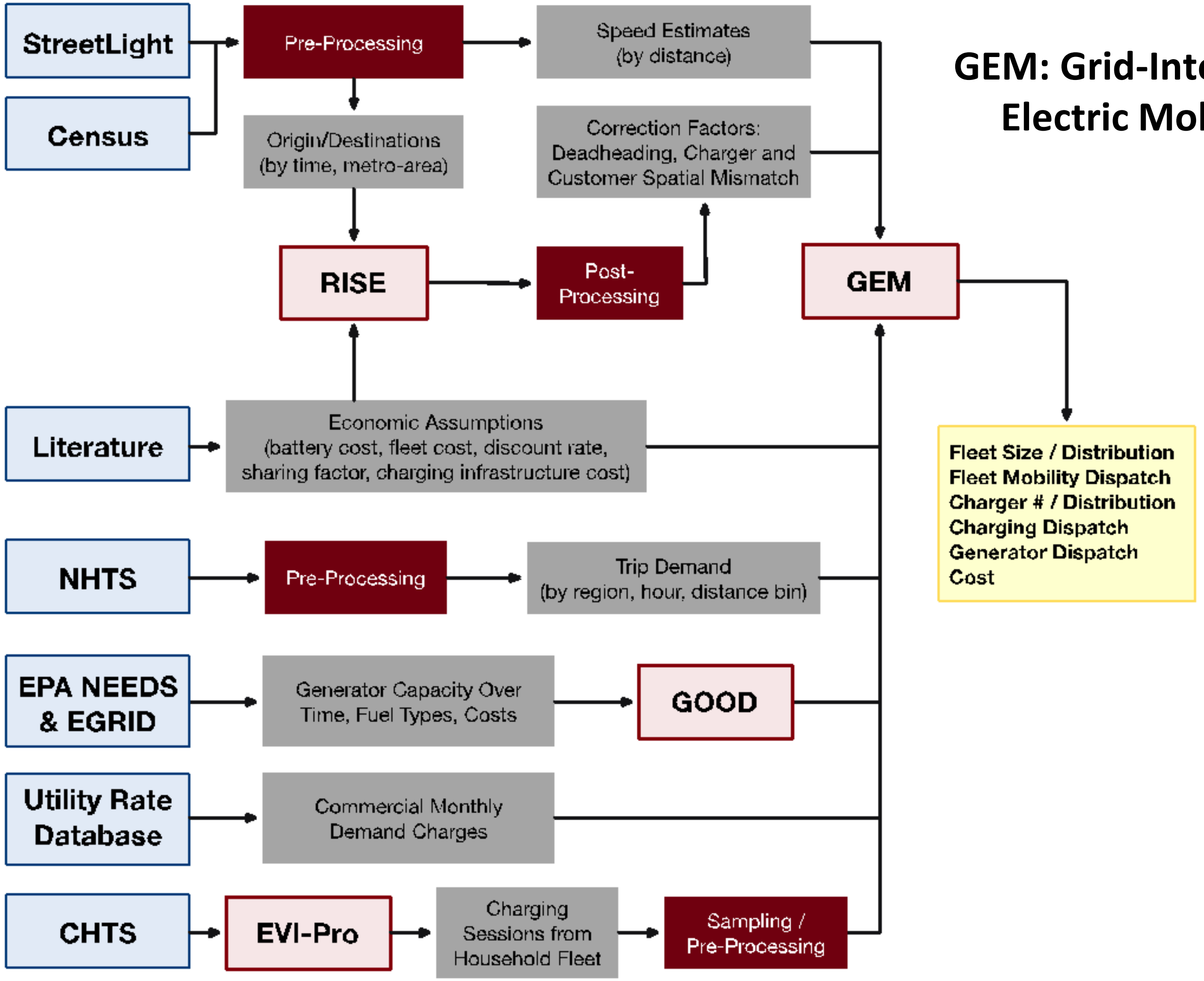
Any proposed future work is subject to change based on funding levels

Summary

- Approach – outlined technical details of optimization and associated constraints of the system
- Technical Accomplishments/Progress – finalized integration of long-haul truck electrification and micromobility and grid modeling
- Collaboration – partners with universities and other national labs
- Relevance – extending VTO Benefits Analysis to include the upstream costs and benefits of EVs to the grid
- Resources -- given our current resources we have been successful at accomplishing our goals to date

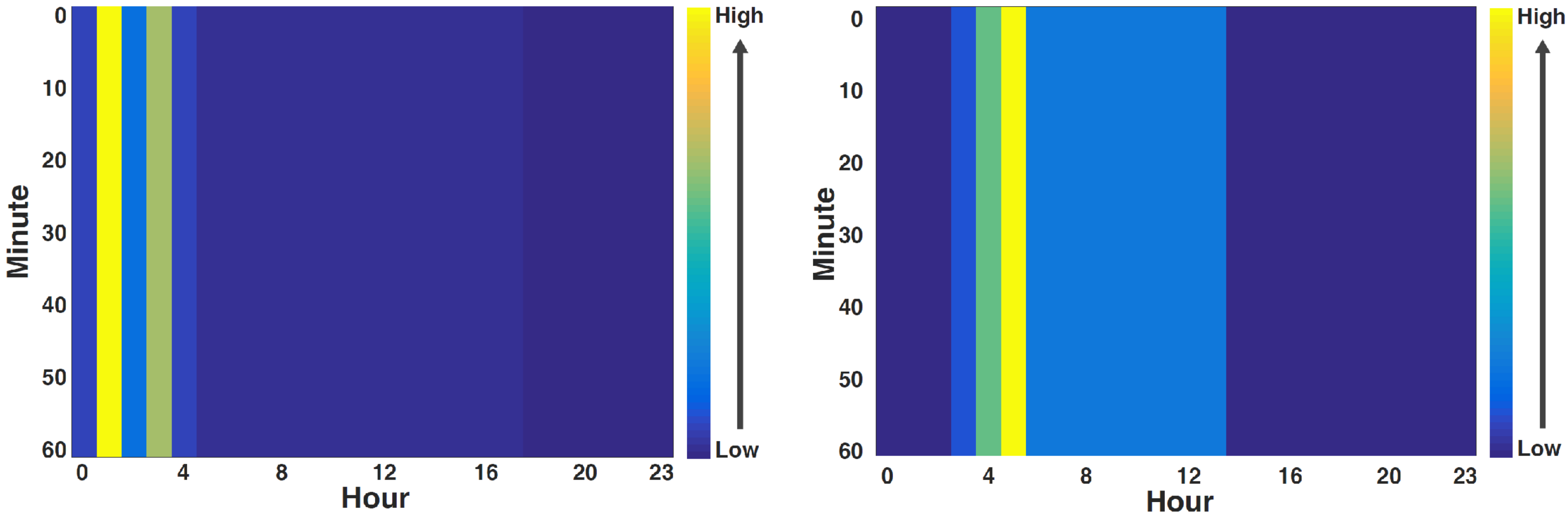
TECHNICAL BACKUP SLIDES

GEM Model Co-Optimizes Mobility and Grid



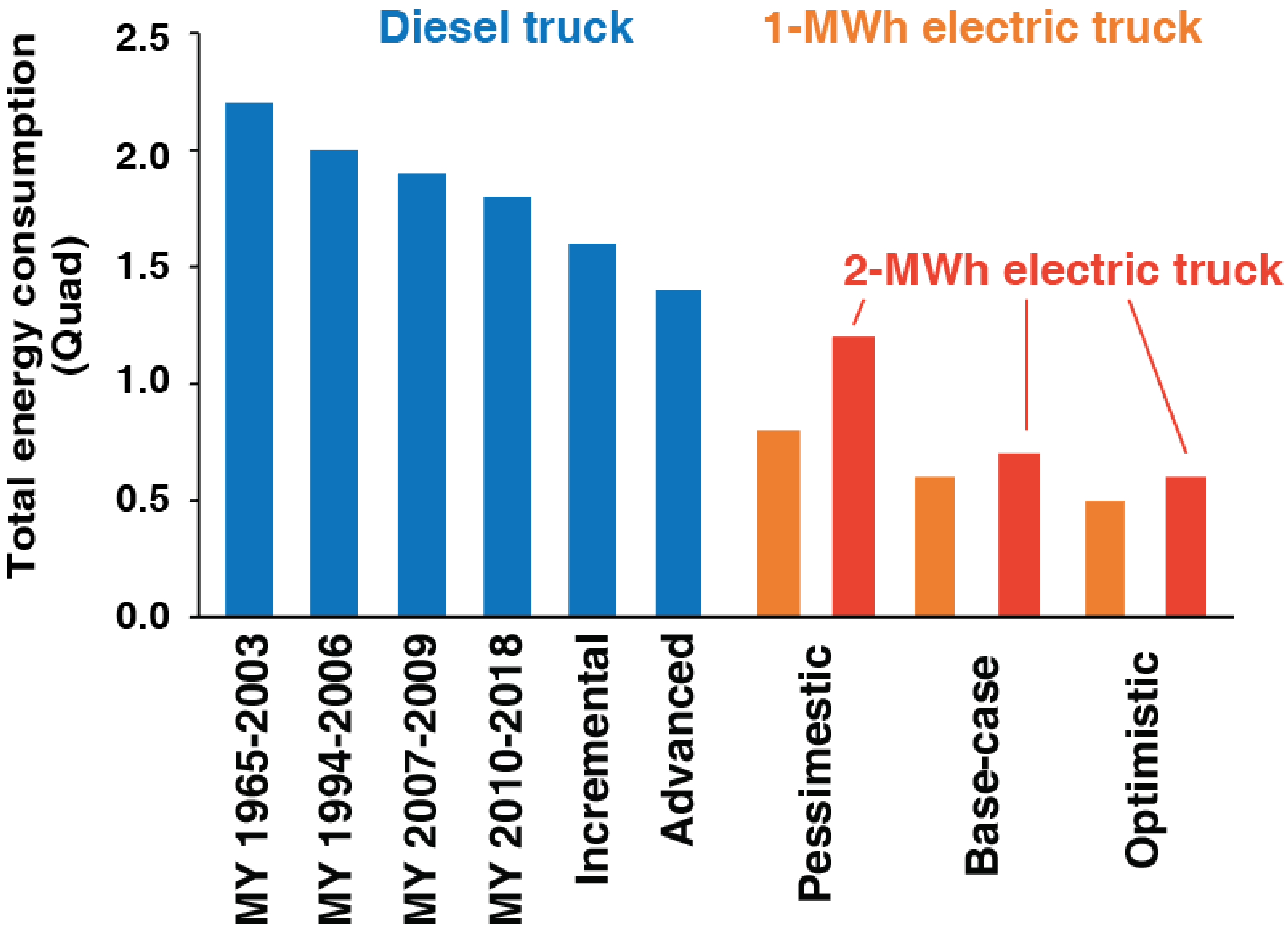
GEM: Grid-Integrated Electric Mobility

Scenarios of Truck Departure Times



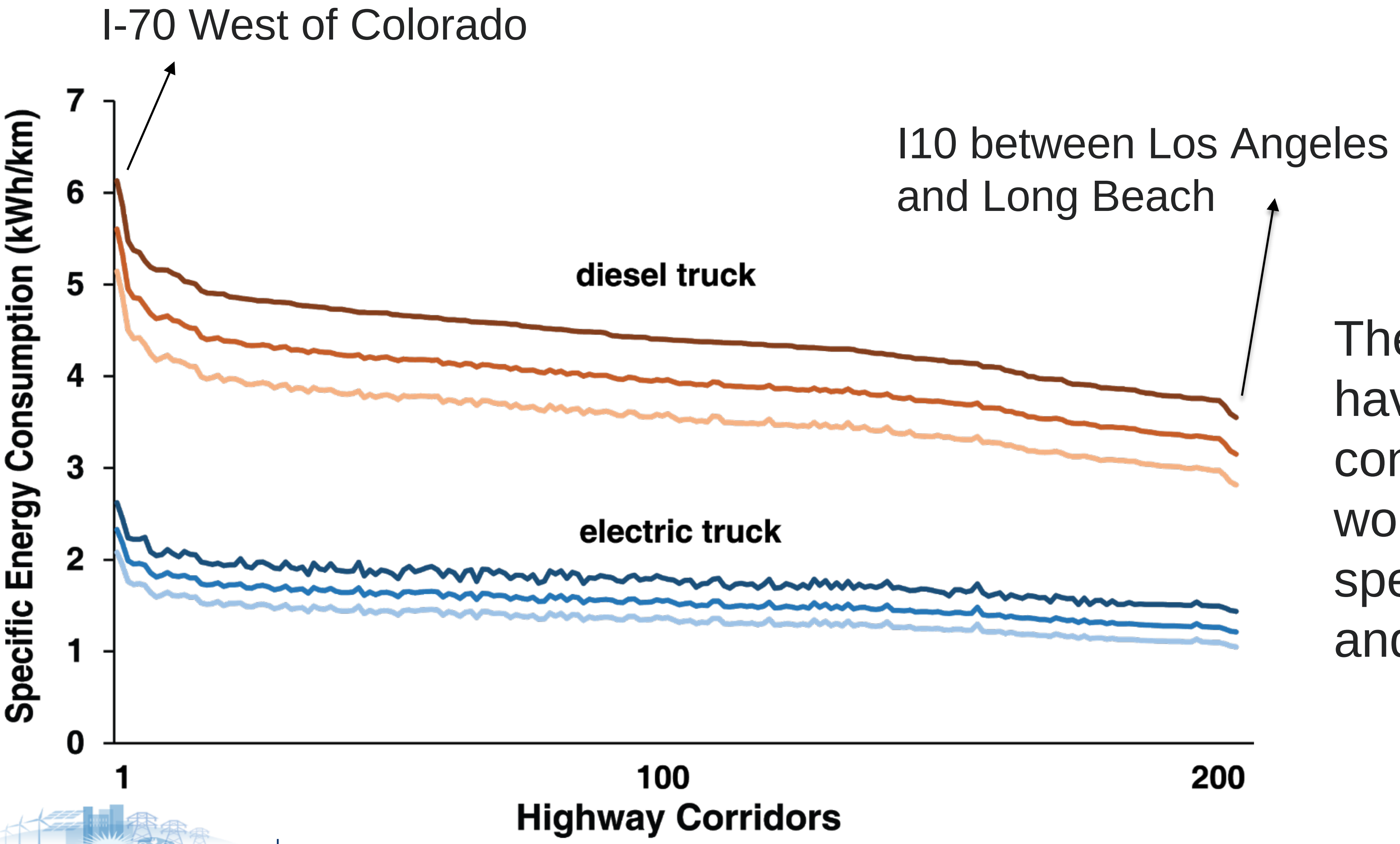
The probability distribution of truck departure in a typical day: an early-departure scenario (left), and a late-departure scenario (right). The color in each cell represents the probability of truck departure in that hour and minute. The sum of the probability equals one.

Fleet-wide Energy Consumption



Electric long-haul trucks could **save up to 1 Quad end-use energy** compared to diesel long-haul trucks.

Energy Consumption for Long-haul Trucks



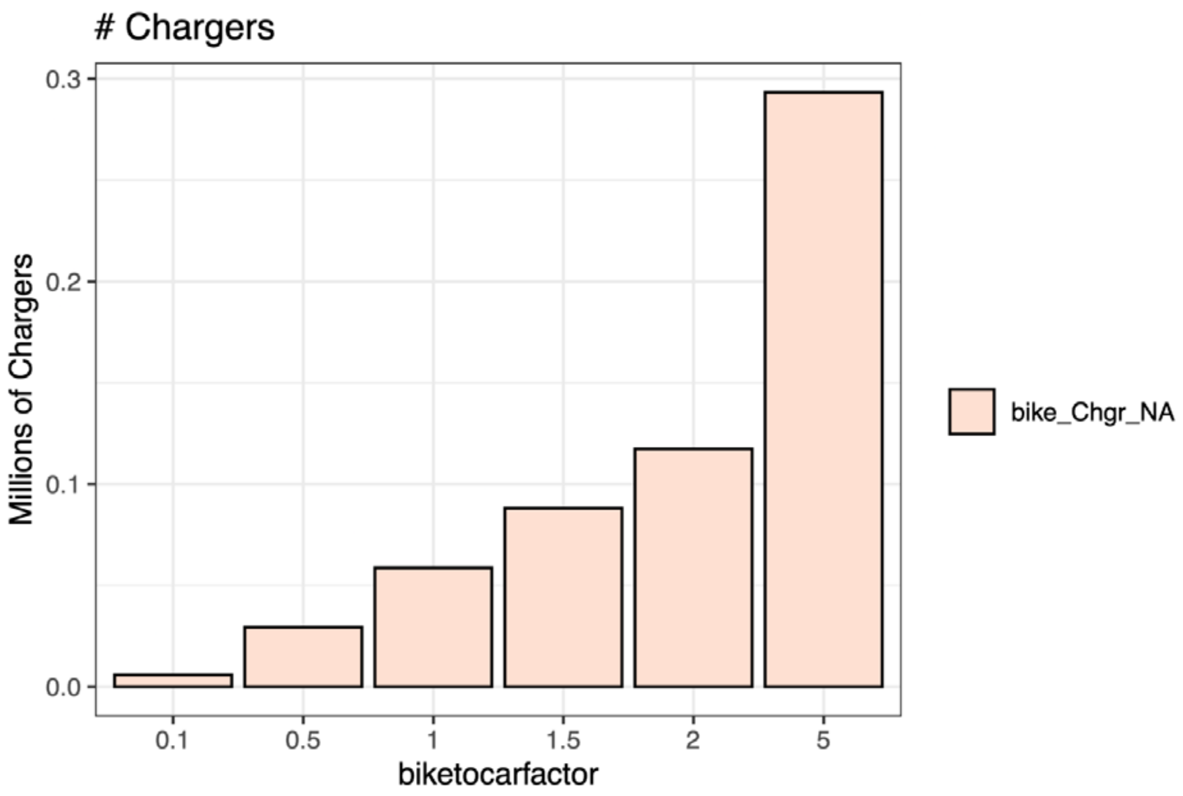
The same truck would have different energy consumption due to real-world factors, such as speed, vehicle weight, and road grade.

Micromobility GEM Preliminary Results

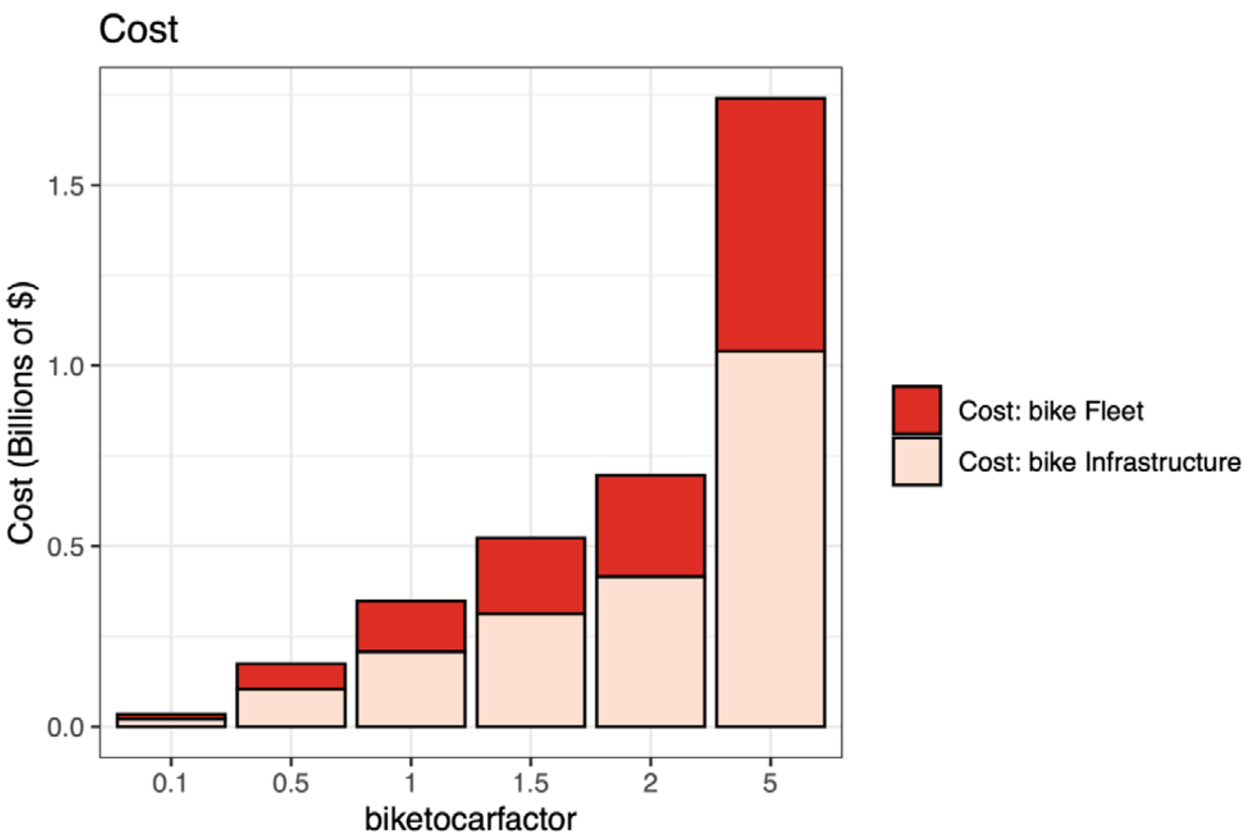
Experiment 1: Mode Shift Changes from Baseline

Parametric Assumptions

- Car to Bike Mode Shifts - 0.1x, 0.5x, 1x, 1.5x, 2x, 5x
- Bikes to charger ratio - 4 bikes per charger with 1KW charger level of up to 40 miles battery capacity



Number of Bike Chargers Needed



Bike Fleet & Infrastructure Costs