



Reducing Air Pollution and Health Impacts of Freight Movement in Environmental Justice Communities through Truck Electrification

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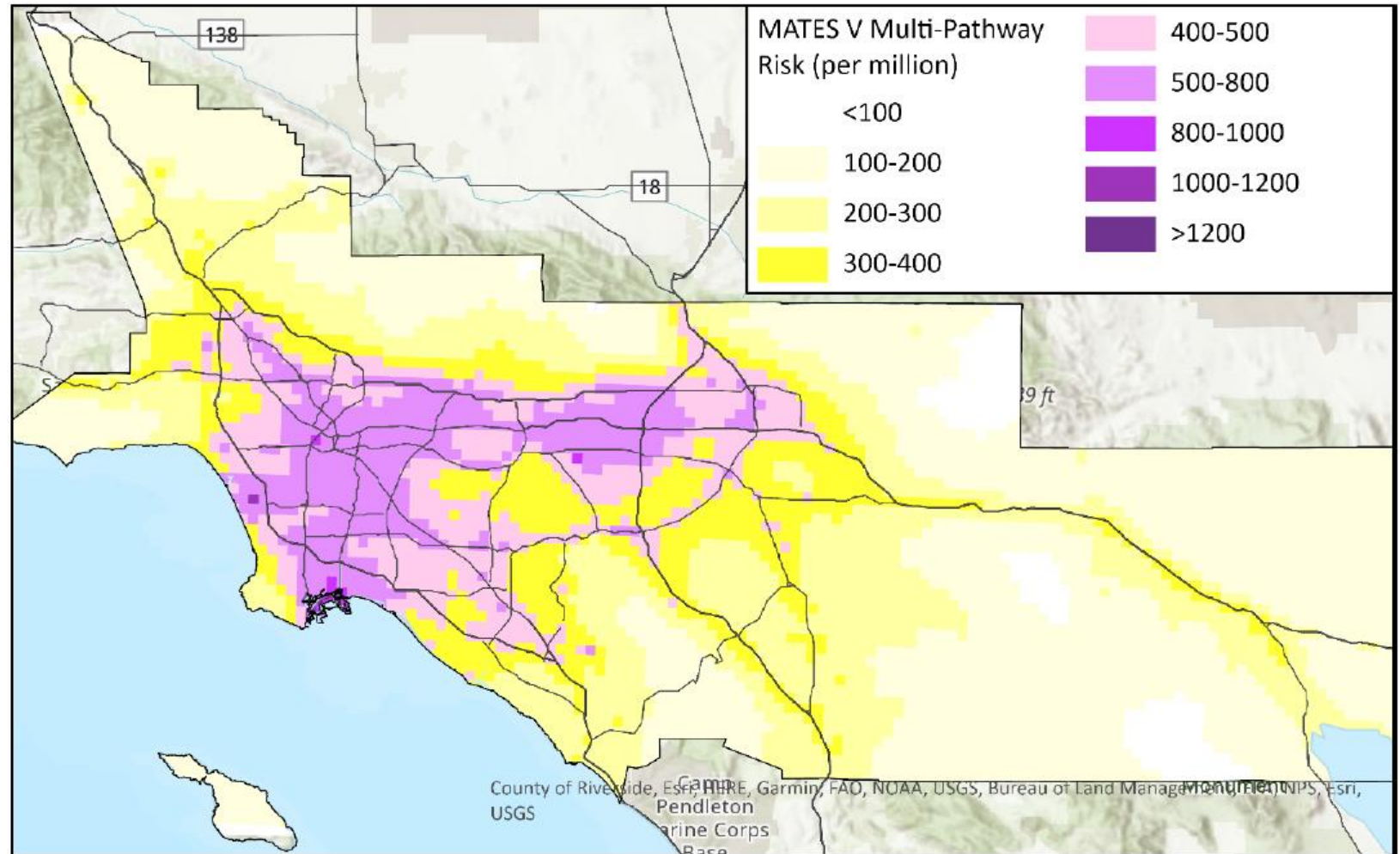
CARTEEH Webinar

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Transportation can have profound impacts on health

- **88%** of the carcinogenic air toxics emissions are from mobile sources
- **Air toxics cancer risk** is highest in and around Ports of Los Angeles & Long Beach

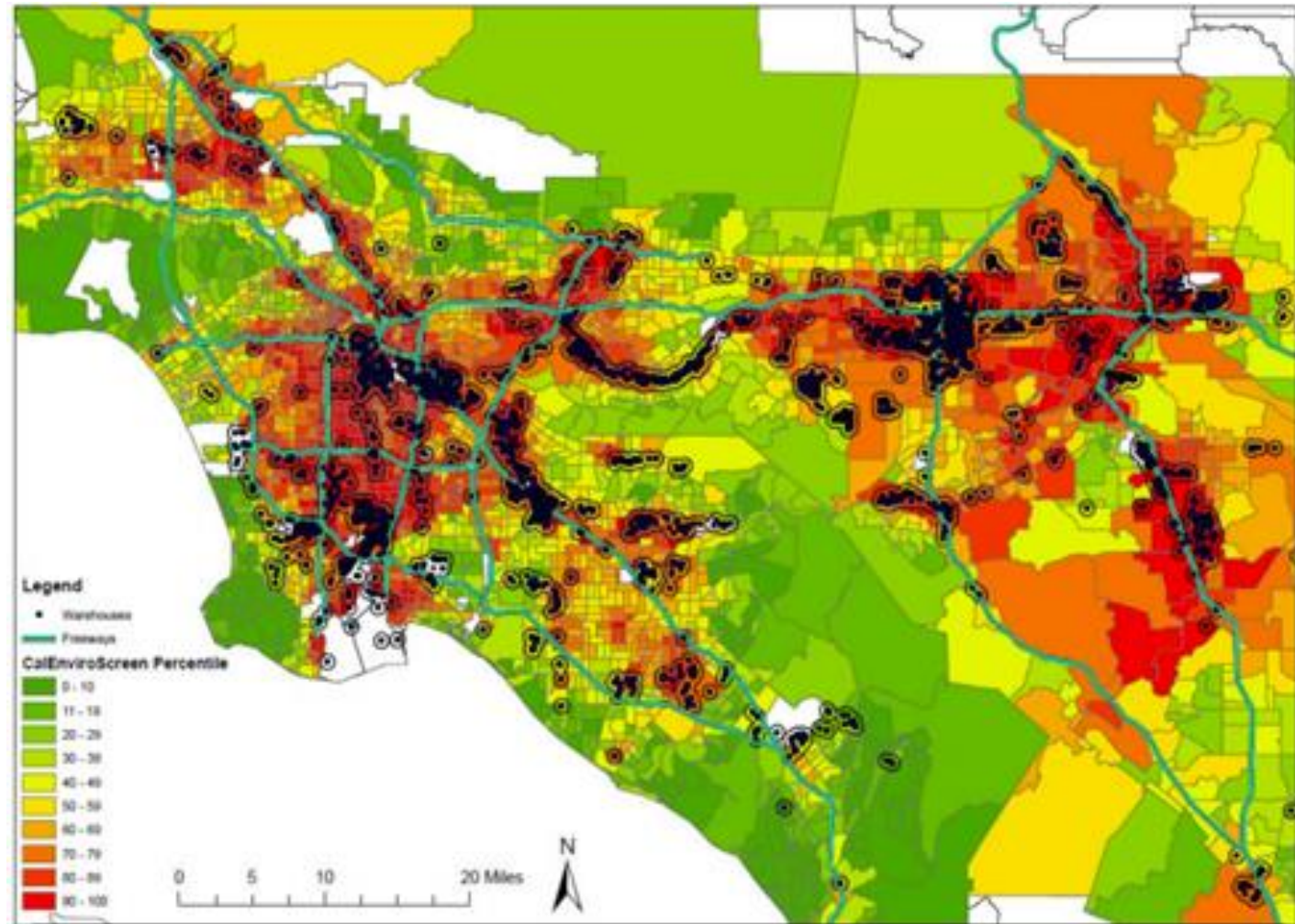


Source: SCAQMD (2021). Draft MATES V Study.



Impacts are higher in communities near freight hubs.

- **61st** – Average CalEnviroScreen percentile for the region
- **80th** – Average CalEnviroScreen percentile for communities within 0.5 miles of a warehouse





Reducing emissions from trucks is critical

- **7.5%** of total U.S. GHG emissions come from medium/heavy-duty trucks
 - Projected to grow larger as a result of increasing e-commerce activity
- **31%** of total NOx emissions in California are from these trucks
- California aims to have **300,000** zero-emission truck sales by 2035
- Most of early zero-emission trucks would be **battery electric**
 - Hydrogen fuel cell trucks would follow and have important roles to play



There are many operational barriers to the adoption of battery electric trucks (BETs)

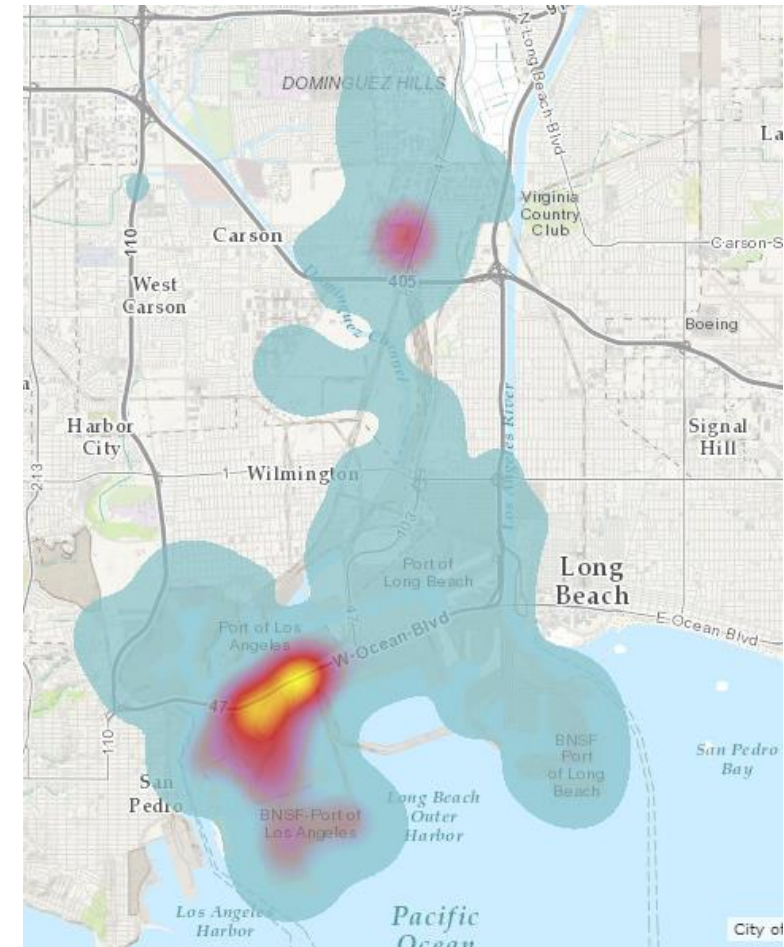
- **Range** is still short
 - 250 miles for commercially available model
- **Charging time** is too long
 - 90 minutes or longer
- **Charging infrastructure** is very limited
 - Public charging stations almost non-existent





Drayage is an ideal early application for BETs

- Run **limited daily distance**
- **Return to home base** every night
- Spend a large amount of time **creeping and idling**
- Tend to operate in **environmental justice communities**





Not all drayage operators are the same way

- **Business model** – Fleet operator vs. independent owner operator
- **Operation model** – One vs. dual shift; near dock vs. regional haul

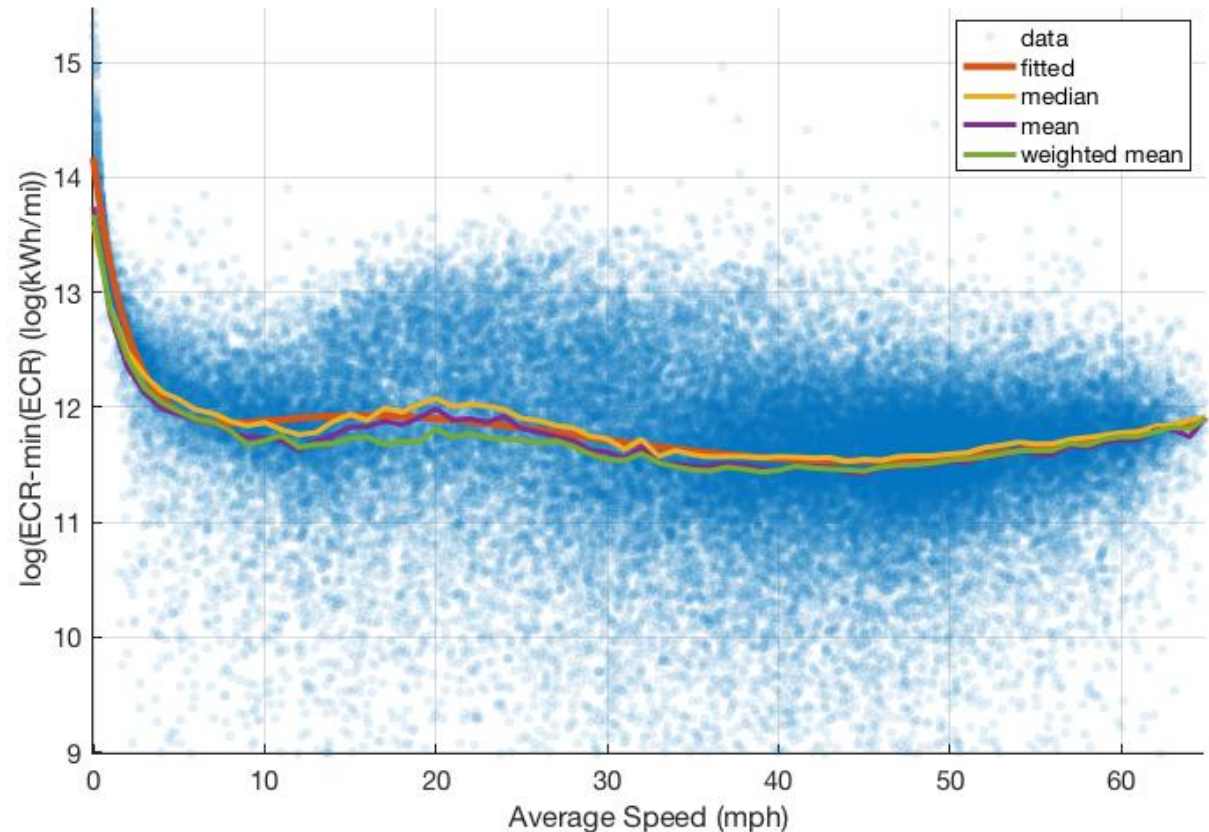
| Speed Bin | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 | 60 | 65 | 70 | 75 | 80 | 85 | 90 | Sum |
|-----------|-------|-------|-------|------|------|-------|-------|------|------|------|------|------|------|------|----|----|----|----|-----|
| | 8.07 | 18.88 | 15.82 | 9.96 | 9.92 | 13.28 | 11.47 | 5.34 | 1.79 | 1.64 | 2.29 | 0.68 | 0.85 | 0 | 0 | 0 | 0 | 0 | 100 |
| Hour | | | | | | | | | | | | | | | | | | | |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 | 0.09 | 0.03 | 0.03 | 0.01 | 0.01 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6 | 0.01 | 0.01 | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7 | 9.45 | 1.38 | 2.39 | 1.40 | 0.76 | 0.93 | 1.26 | 0.94 | 0.35 | 0.05 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8 | 8.40 | 0.76 | 2.08 | 1.84 | 0.94 | 0.71 | 0.90 | 0.81 | 0.33 | 0.05 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 9 | 12.09 | 0.78 | 1.98 | 1.75 | 1.04 | 1.22 | 1.58 | 1.38 | 0.63 | 0.26 | 0.35 | 0.94 | 0.17 | 0.00 | 0 | 0 | 0 | 0 | 0 |
| 10 | 12.16 | 0.75 | 1.97 | 1.73 | 1.02 | 1.21 | 1.43 | 1.22 | 0.92 | 0.50 | 0.34 | 0.48 | 0.14 | 0.45 | 0 | 0 | 0 | 0 | 0 |
| 11 | 10.21 | 0.88 | 1.98 | 1.65 | 1.13 | 1.15 | 1.56 | 1.18 | 0.58 | 0.09 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 12 | 5.54 | 0.49 | 1.01 | 0.84 | 0.68 | 0.67 | 0.90 | 0.71 | 0.21 | 0.03 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 13 | 8.91 | 0.88 | 1.87 | 1.55 | 0.93 | 0.73 | 0.95 | 0.88 | 0.36 | 0.17 | 0.25 | 0.22 | 0.10 | 0 | 0 | 0 | 0 | 0 | 0 |
| 14 | 11.74 | 0.76 | 2.01 | 1.65 | 1.06 | 1.11 | 1.64 | 1.73 | 0.66 | 0.29 | 0.46 | 0.32 | 0.04 | 0 | 0 | 0 | 0 | 0 | 0 |
| 15 | 11.00 | 0.70 | 1.88 | 1.64 | 1.06 | 0.93 | 1.59 | 1.39 | 0.50 | 0.14 | 0.22 | 0.33 | 0.23 | 0.40 | 0 | 0 | 0 | 0 | 0 |
| 16 | 9.01 | 0.53 | 1.43 | 1.53 | 1.16 | 1.09 | 1.27 | 1.01 | 0.77 | 0.21 | 0.02 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 17 | 1.36 | 0.11 | 0.24 | 0.23 | 0.17 | 0.18 | 0.20 | 0.20 | 0.03 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 18 | 0.04 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 0.01 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 19 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 21 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 22 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 23 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Sum | 100 | | | | | | | | | | | | | | | | | | 100 |

| Speed Bin | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 | 60 | 65 | 70 | 75 | 80 | 85 | 90 | Sum |
|-----------|------|------|------|------|------|------|------|-------|-------|-------|-------|------|------|------|------|----|----|----|-----|
| | 2.41 | 6.65 | 7.12 | 6.17 | 5.87 | 6.84 | 8.56 | 10.62 | 11.46 | 12.34 | 11.46 | 7.57 | 2.89 | 0.06 | 0 | 0 | 0 | 0 | 100 |
| Hour | | | | | | | | | | | | | | | | | | | |
| 0 | 6.52 | 0.18 | 0.50 | 0.52 | 0.42 | 0.39 | 0.42 | 0.49 | 0.66 | 0.74 | 0.73 | 0.75 | 0.50 | 0.22 | 0.00 | 0 | 0 | 0 | 0 |
| 1 | 6.20 | 0.17 | 0.51 | 0.55 | 0.46 | 0.40 | 0.43 | 0.49 | 0.58 | 0.72 | 0.77 | 0.64 | 0.38 | 0.11 | 0.00 | 0 | 0 | 0 | 0 |
| 2 | 6.18 | 0.12 | 0.35 | 0.42 | 0.39 | 0.41 | 0.52 | 0.62 | 0.78 | 0.90 | 0.81 | 0.53 | 0.29 | 0.05 | 0 | 0 | 0 | 0 | 0 |
| 3 | 2.41 | 0.03 | 0.09 | 0.13 | 0.11 | 0.13 | 0.17 | 0.24 | 0.37 | 0.46 | 0.34 | 0.20 | 0.12 | 0.03 | 0 | 0 | 0 | 0 | 0 |
| 4 | 0.40 | 0.01 | 0.01 | 0.02 | 0.02 | 0.02 | 0.05 | 0.03 | 0.05 | 0.07 | 0.08 | 0.03 | 0.01 | 0.00 | 0 | 0 | 0 | 0 | 0 |
| 5 | 0.00 | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6 | 2.77 | 0.05 | 0.15 | 0.12 | 0.12 | 0.16 | 0.24 | 0.33 | 0.39 | 0.44 | 0.35 | 0.27 | 0.12 | 0.03 | 0 | 0 | 0 | 0 | 0 |
| 7 | 4.19 | 0.09 | 0.25 | 0.26 | 0.27 | 0.32 | 0.38 | 0.54 | 0.68 | 0.55 | 0.41 | 0.25 | 0.17 | 0.03 | 0 | 0 | 0 | 0 | 0 |
| 8 | 3.62 | 0.08 | 0.23 | 0.33 | 0.28 | 0.23 | 0.23 | 0.31 | 0.34 | 0.33 | 0.39 | 0.48 | 0.33 | 0.06 | 0 | 0 | 0 | 0 | 0 |
| 9 | 3.42 | 0.07 | 0.21 | 0.24 | 0.22 | 0.20 | 0.24 | 0.30 | 0.38 | 0.37 | 0.39 | 0.31 | 0.29 | 0.21 | 0.00 | 0 | 0 | 0 | 0 |
| 10 | 4.32 | 0.07 | 0.20 | 0.22 | 0.20 | 0.21 | 0.23 | 0.30 | 0.42 | 0.41 | 0.57 | 0.72 | 0.45 | 0.30 | 0.01 | 0 | 0 | 0 | 0 |
| 11 | 3.30 | 0.07 | 0.18 | 0.20 | 0.19 | 0.20 | 0.28 | 0.35 | 0.34 | 0.30 | 0.35 | 0.40 | 0.32 | 0.10 | 0.00 | 0 | 0 | 0 | 0 |
| 12 | 3.26 | 0.05 | 0.14 | 0.16 | 0.16 | 0.20 | 0.26 | 0.31 | 0.34 | 0.31 | 0.42 | 0.33 | 0.37 | 0.21 | 0.00 | 0 | 0 | 0 | 0 |
| 13 | 2.97 | 0.06 | 0.18 | 0.21 | 0.19 | 0.20 | 0.23 | 0.26 | 0.27 | 0.25 | 0.33 | 0.39 | 0.31 | 0.08 | 0 | 0 | 0 | 0 | 0 |
| 14 | 2.99 | 0.06 | 0.18 | 0.21 | 0.18 | 0.18 | 0.21 | 0.22 | 0.26 | 0.28 | 0.28 | 0.39 | 0.31 | 0.20 | 0.02 | 0 | 0 | 0 | 0 |
| 15 | 3.28 | 0.05 | 0.18 | 0.24 | 0.23 | 0.23 | 0.24 | 0.34 | 0.41 | 0.41 | 0.47 | 0.35 | 0.12 | 0.00 | 0 | 0 | 0 | 0 | 0 |
| 16 | 1.79 | 0.04 | 0.13 | 0.14 | 0.15 | 0.14 | 0.18 | 0.20 | 0.26 | 0.23 | 0.18 | 0.10 | 0.03 | 0.00 | 0 | 0 | 0 | 0 | 0 |
| 17 | 3.50 | 0.12 | 0.30 | 0.25 | 0.22 | 0.25 | 0.31 | 0.38 | 0.47 | 0.45 | 0.37 | 0.26 | 0.10 | 0.02 | 0.00 | 0 | 0 | 0 | 0 |
| 18 | 6.15 | 0.21 | 0.52 | 0.55 | 0.46 | 0.43 | 0.52 | 0.67 | 0.77 | 0.72 | 0.56 | 0.46 | 0.25 | 0.03 | 0 | 0 | 0 | 0 | 0 |
| 19 | 5.55 | 0.21 | 0.49 | 0.52 | 0.42 | 0.33 | 0.34 | 0.45 | 0.57 | 0.71 | 0.75 | 0.53 | 0.20 | 0.02 | 0 | 0 | 0 | 0 | 0 |
| 20 | 6.12 | 0.21 | 0.52 | 0.50 | 0.39 | 0.30 | 0.32 | 0.36 | 0.53 | 0.84 | 0.95 | 0.80 | 0.35 | 0.04 | 0 | 0 | 0 | 0 | 0 |
| 21 | 8.34 | 0.20 | 0.50 | 0.53 | 0.46 | 0.41 | 0.46 | 0.58 | 0.71 | 0.82 | 1.30 | 1.50 | 0.68 | 0.17 | 0.00 | 0 | 0 | 0 | 0 |
| 22 | 6.46 | 0.13 | 0.37 | 0.34 | 0.29 | 0.27 | 0.32 | 0.44 | 0.62 | 0.73 | 0.82 | 0.87 | 0.94 | 0.32 | 0.00 | 0 | 0 | 0 | 0 |
| 23 | 6.24 | 0.15 | 0.44 | 0.43 | 0.34 | 0.25 | 0.25 | 0.35 | 0.40 | 0.42 | 0.71 | 0.89 | 0.92 | 0.65 | 0.02 | 0 | 0 | 0 | 0 |
| Sum | 100 | | | | | | | | | | | | | | | | | | 100 |



Your mileage (BET range) may vary

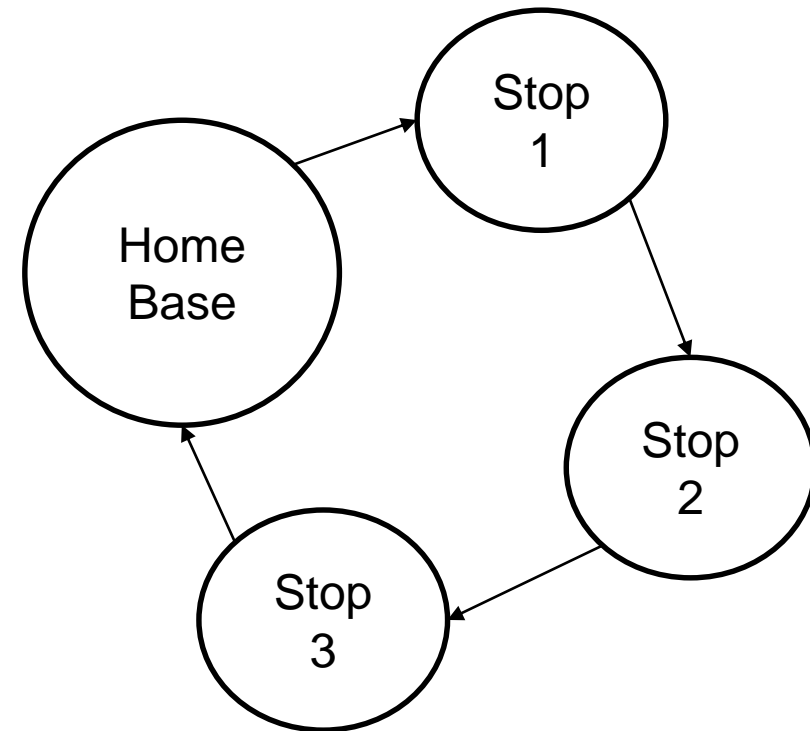
- **Advertised range** is for ideal operating condition
- **Real-world range** can be impacted by many factors
 - Weight carried
 - Road terrain
 - Traffic condition
 - Weather condition
 - Driving behavior
 - Etc.





Operational feasibility of drayage BETs needs to be verified

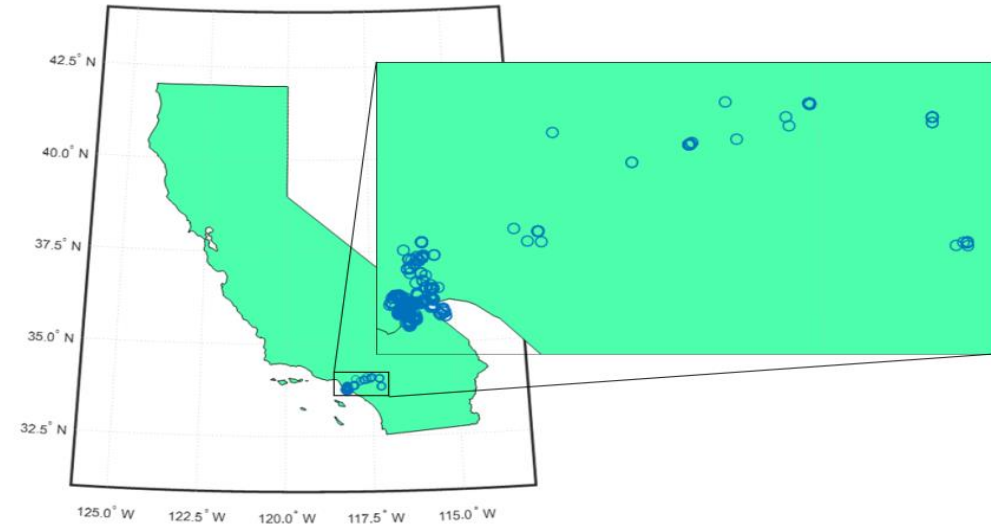
- Use **real-world truck operation data**
 - Coupled with high-fidelity BET energy consumption model
- Consider **complete tour** from home base to home base
 - Assuming BETs are charged at home base only





Operational feasibility evaluation of drayage BET

- Performed for **one drayage fleet** near Port of L.A.
 - Operates dual shift
 - Services locations primarily in Greater L.A. Metro near the port, and occasionally in Inland Empire
- Evaluated for a **commercially available BET** at the time of research (2019)
 - Estimated range of ~150 miles





Truck tour statistics vary greatly

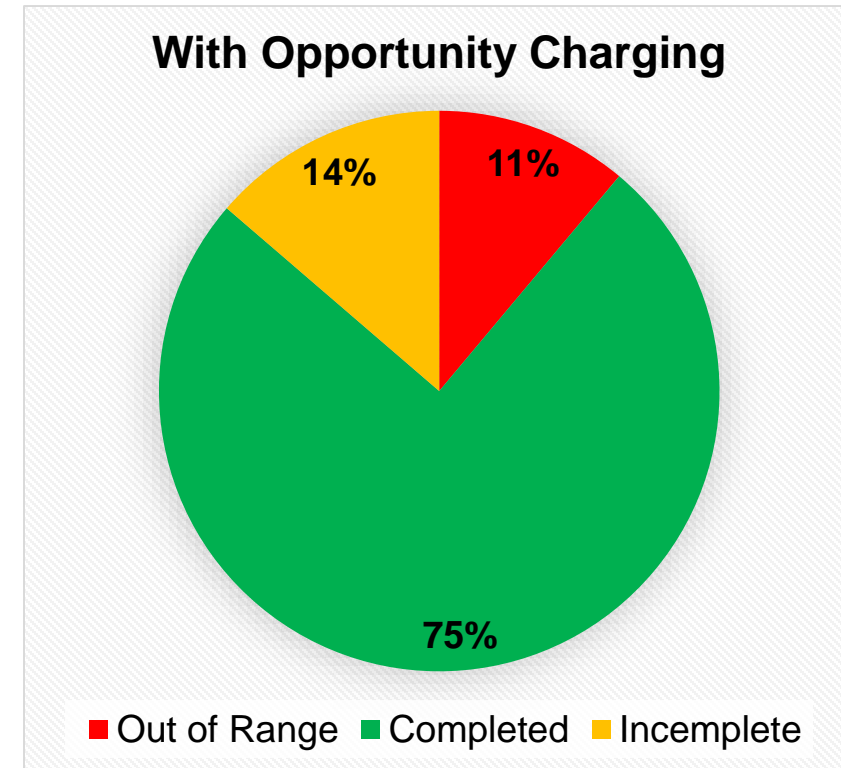
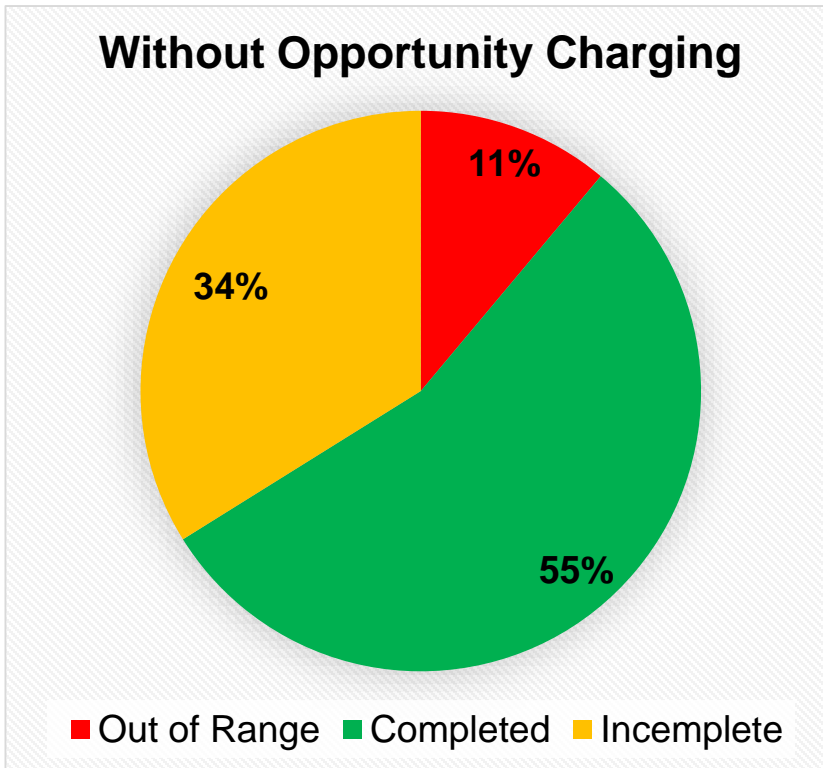
- Data from **20 trucks** for **1 week** with combined distance of >11,000 miles

| | Average | Range |
|-----------------------------------|---------|--------------|
| Number of tours per day | 2.2 | 1 – 7 |
| Tour distance (miles) | 58.9 | 5.7 – 122.5 |
| Tour travel time (min) | 244.3 | 43.6 – 401.9 |
| Time spent at home base (min) | 21.1 | 0 – 44.9 |
| Time spent at outside stops (min) | 262.8 | 0 – 490.6 |
| Tour battery consumption (%) | 39% | 6% – 76% |



Only 55% of the tours can be performed by BET

- **75% with opportunity charging** at home base





Other technological solutions can help

- Zero-emission trucks with **longer range**
- **Faster chargers** to cut down charging time
- **New charging technologies** that enable more opportunities for charging
- **New fleet management systems** that consider unique characteristics of BETs



Source: Hwang et al. (2018).



We are studying innovative opportunity charging

- To provide opportunity charging **where and when BETs would normally idle** such as queuing at terminal gates and loading/unloading at warehouses
 - Reduce deadhead miles
 - Keep BET productivity high
- Based on real-world **Big Data**
 - 1,500+ drayage trucks
 - 12 months of operation





More research is needed

- **Supporting technologies** for BET operations
 - Schedule & dispatching
 - Charging management
- **Charging infrastructure planning** for BETs
 - Transportation and electrical grid network integration
 - Public-private partnership
- **Public health and other benefits** of truck electrification
 - Ensuring equitable deployment of BETs and charging infrastructure
 - Protecting against unintended consequences



Thank You

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