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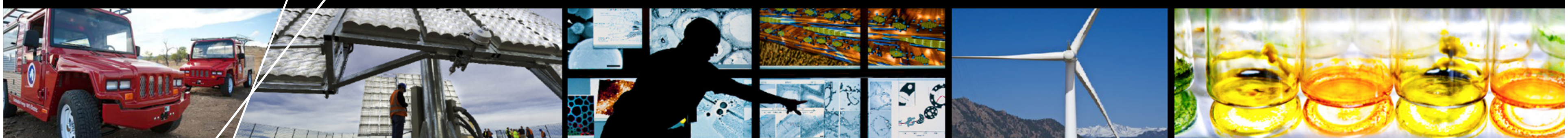
NATIONAL RENEWABLE ENERGY LABORATORY

Fuel Savings Potential from Future In-motion Wireless Power Transfer (WPT)



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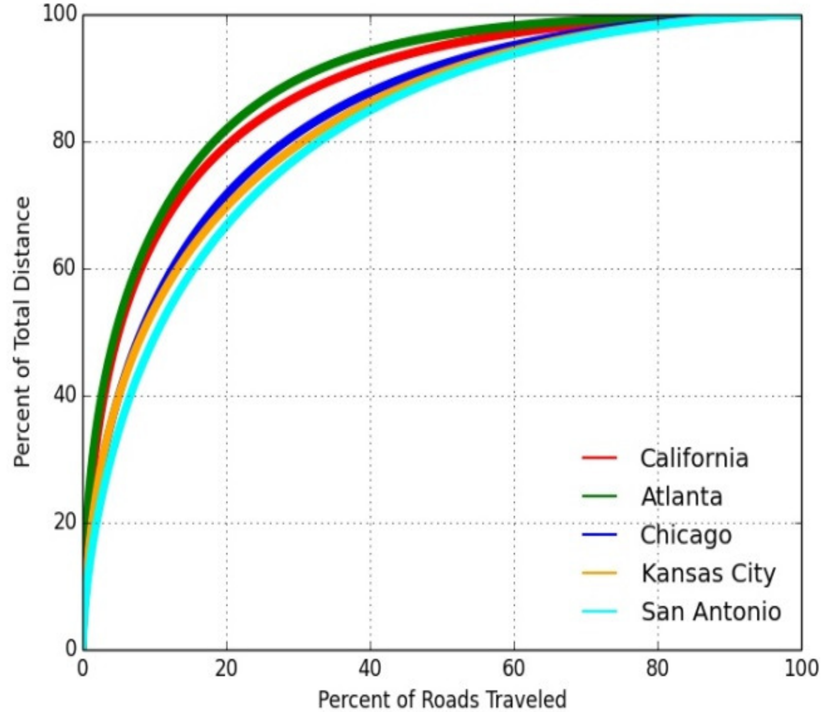
Conference on Electric Roads & Vehicles
February 10, 2015
Park City, Utah

Regional Road Usage

- 1% of roads are used for 25% of the vehicle miles traveled
- Extensive overlap in road usage apparent across regional vehicle population
- Overlap occurs on high capacity roads

Transportation Secure Data Center Vehicle GPS samples



In-Motion Power Transfer

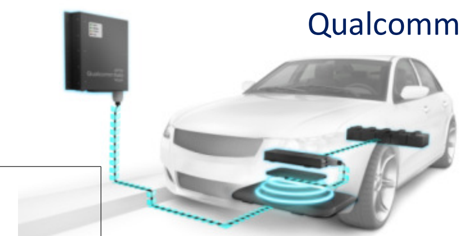
Potential: Road electrification could remove range restrictions of EVs, and increase the fuel savings of PHEVs or HEVs if implemented on a large scale

- ~1% of all roads nationally to be electrified
- <u>Full build out is a major endeavor, so what might incremental benefit be?</u>
- Who might benefit most a state, an urban area?
  - What would be the incentive?

Question: If a government entity wanted to deploy In-Motion WPT what is the fuel savings potential for the regional hybrid personal vehicle population

- **Metrics:**
  - Cost: Infrastructure Mileage
  - Benefit: Fuel Displaced
- **Assumptions:**
  - Only hybrid vehicle benefits considered
  - Incremental roll out of infrastructure
  - All fuel is displaced during time spent on infrastructure

Source: Qualcomm



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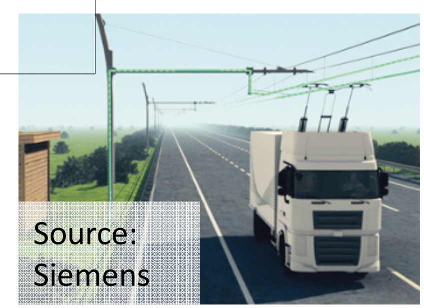


Source: Siemens

BEV: Battery Electric Vehicles PHEV: Plug in Hybrid Vehicles HEV: Hybrid Electric Vehicles

WPT Fuel Savings Estimation

Resources & Tools

[Transportation Secure Data Center (TSDC)]

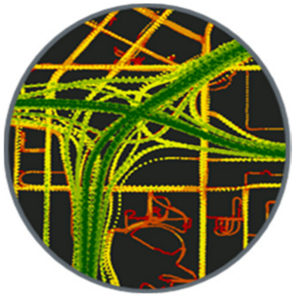
Warehouse of personal vehicle drive cycles collected as part of the households travel surveys

[Future Automotive Systems Technology Simulator (FASTSim)]

Drive cycle simulation tool

High Performance Computing

Workflow

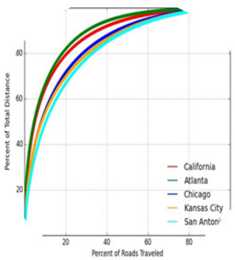


Step 1: Spatial Indexing

- Match drive cycles to census geographies
- Match drive cycles to road network

Step 2: Simulation

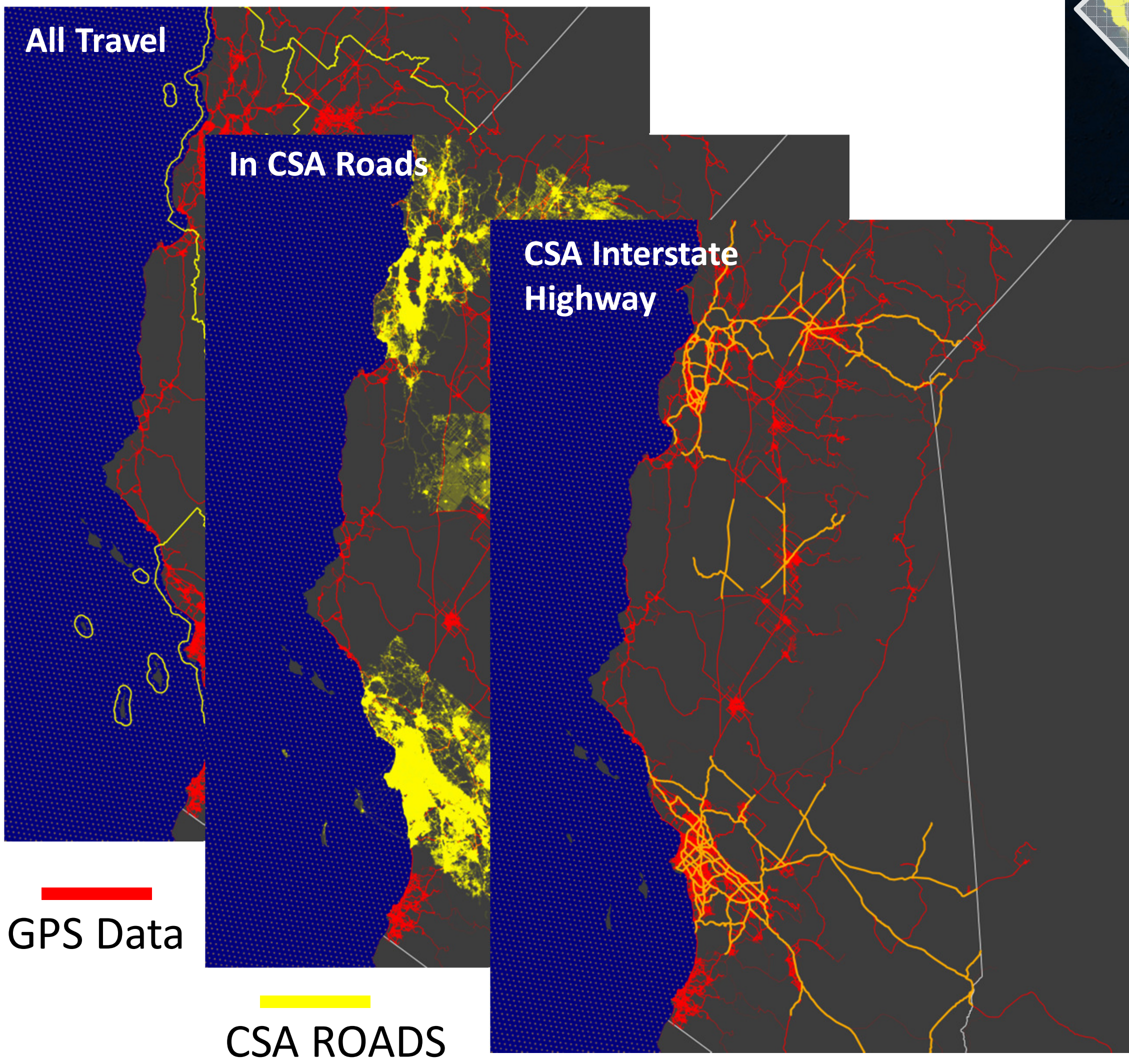
- Identify vehicle fuel use through simulation across vehicle models using approximately 1 million miles of on road data



Step 3: Data Fusion

- Merge result from step 1 & 2 to quantify fuel use by road segment across a variety of vehicle models
- Assign priority for roll out based on potential fuel displacement

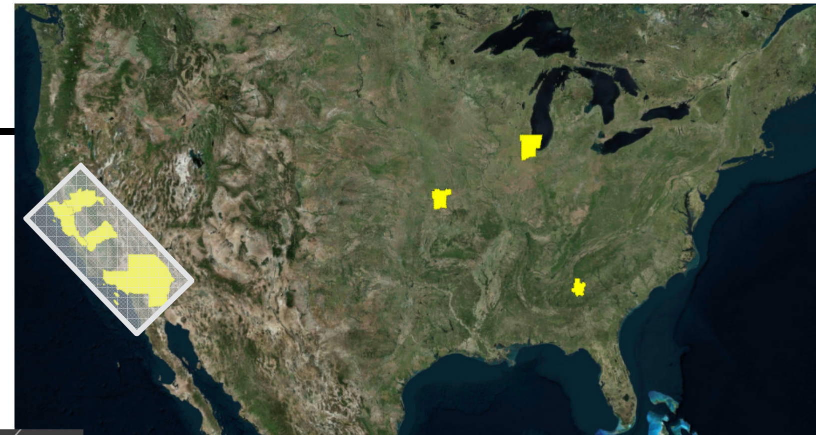
Census Geographies



GPS Data

CSA ROADS

URBAN FC1 AND FC2 ROADS



Source: Census Tiger Files\Bing Aerial Layer

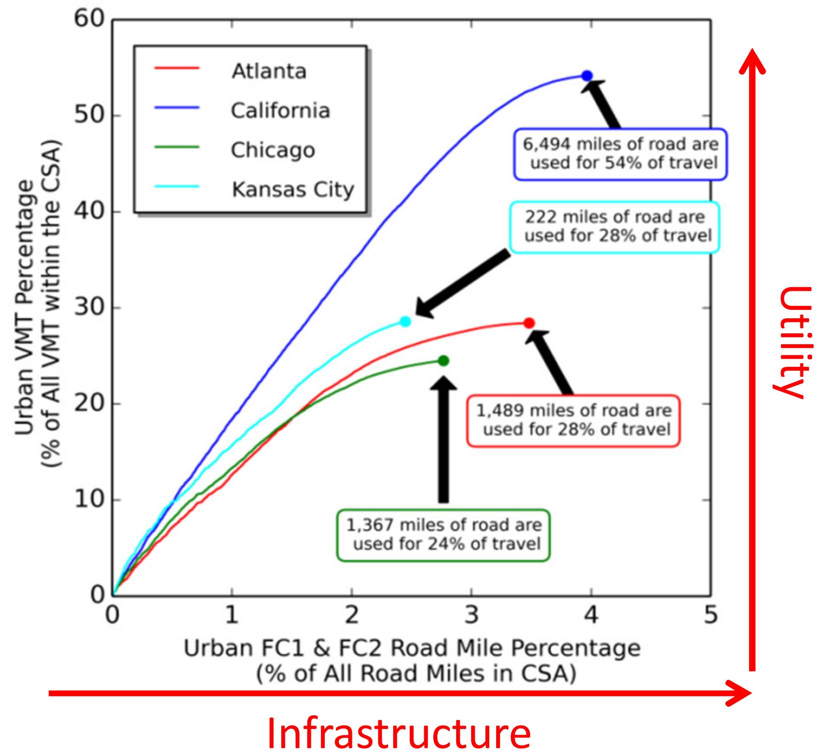
- **Consolidated Statistical Area (CSA):**
  - CSAs represent groupings of metropolitan and/or micropolitan statistical areas
- **GPS data divided by In-CSA and Out of CSA**
- **GPS In-CSA divided on high capacity, and not on high capacity roads using map match**

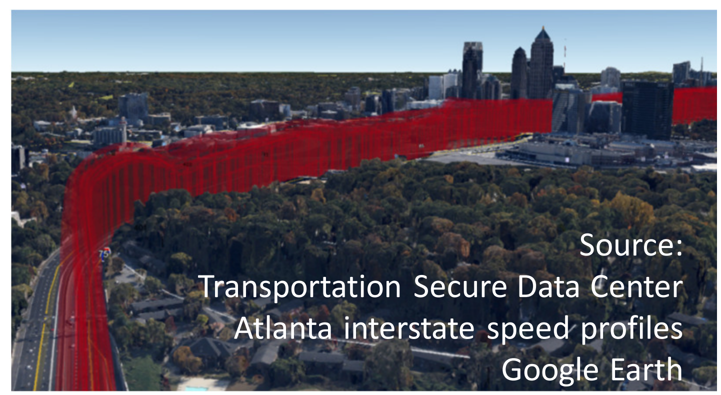
Drive Cycle Match

Region	In-CSA Interstate\ Highway Miles	% Of Travel Captured
Atlanta	1,489 (3.6%)	24%
California	6,494 (4%)	54%
Chicago	1,367 (2.78%)	24%
Kansas City	222 (2.72%)	28%

- Interstates and Highways make up between 2.5% and 4% of the total roads within the CSAs
- The mileage traveled on the interstates and highways ranges from 54% in California to 24% in Chicago
- Consistent with previous observations

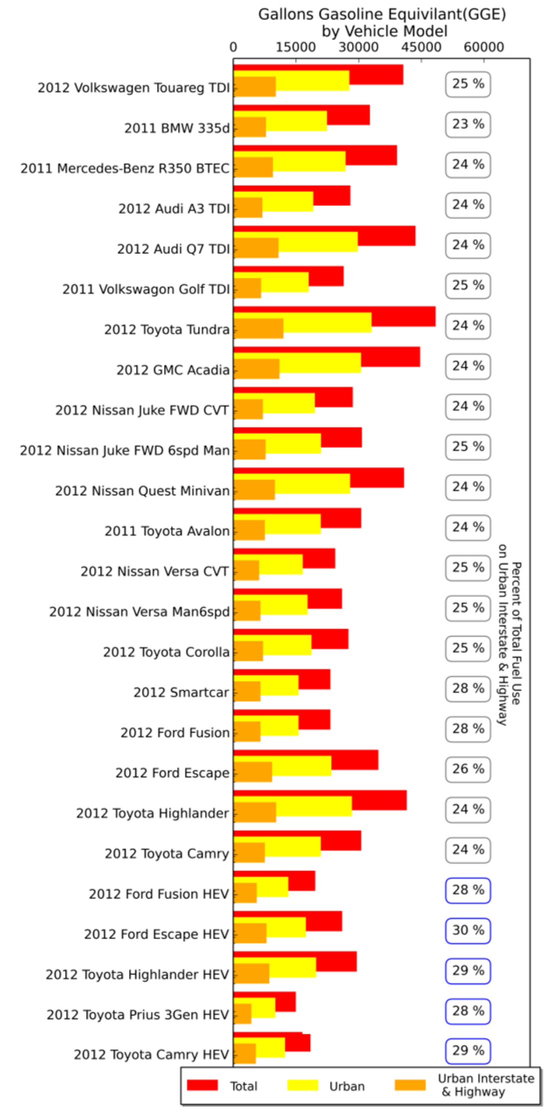
In-CSA Road Usage

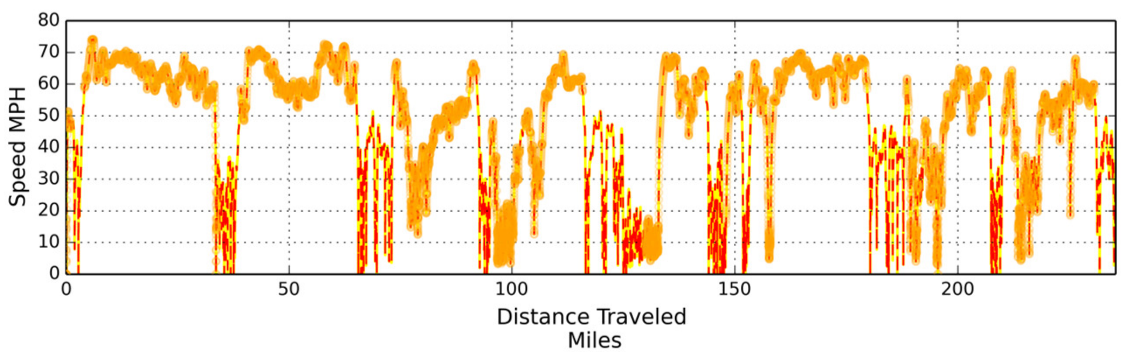


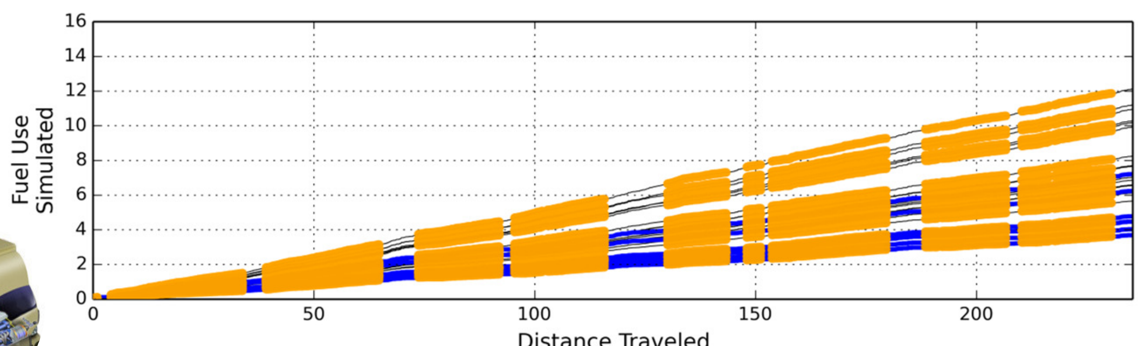


Simulations Using GPS data

- Simulator takes speed profiles and simulates fuel consumption
- Merging the TSDC data, FASTSim, and the HPC we can simulate millions of vehicle miles as dozens of vehicle models
- Merge with drive cycle match to identify where fuel usage is occurring

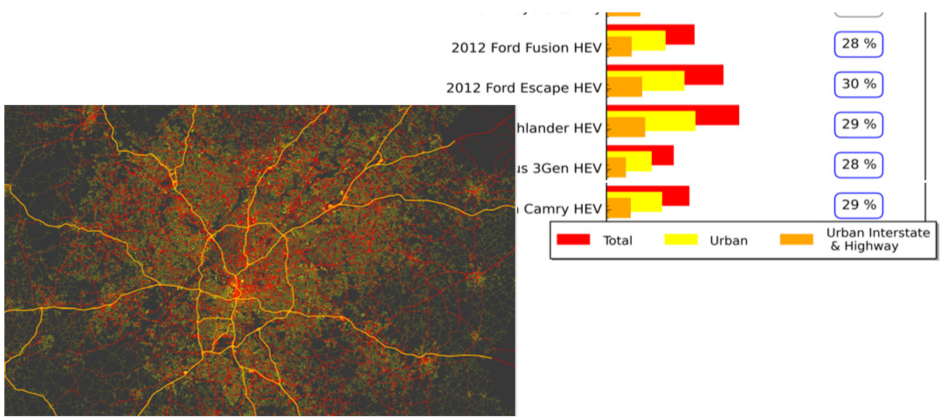


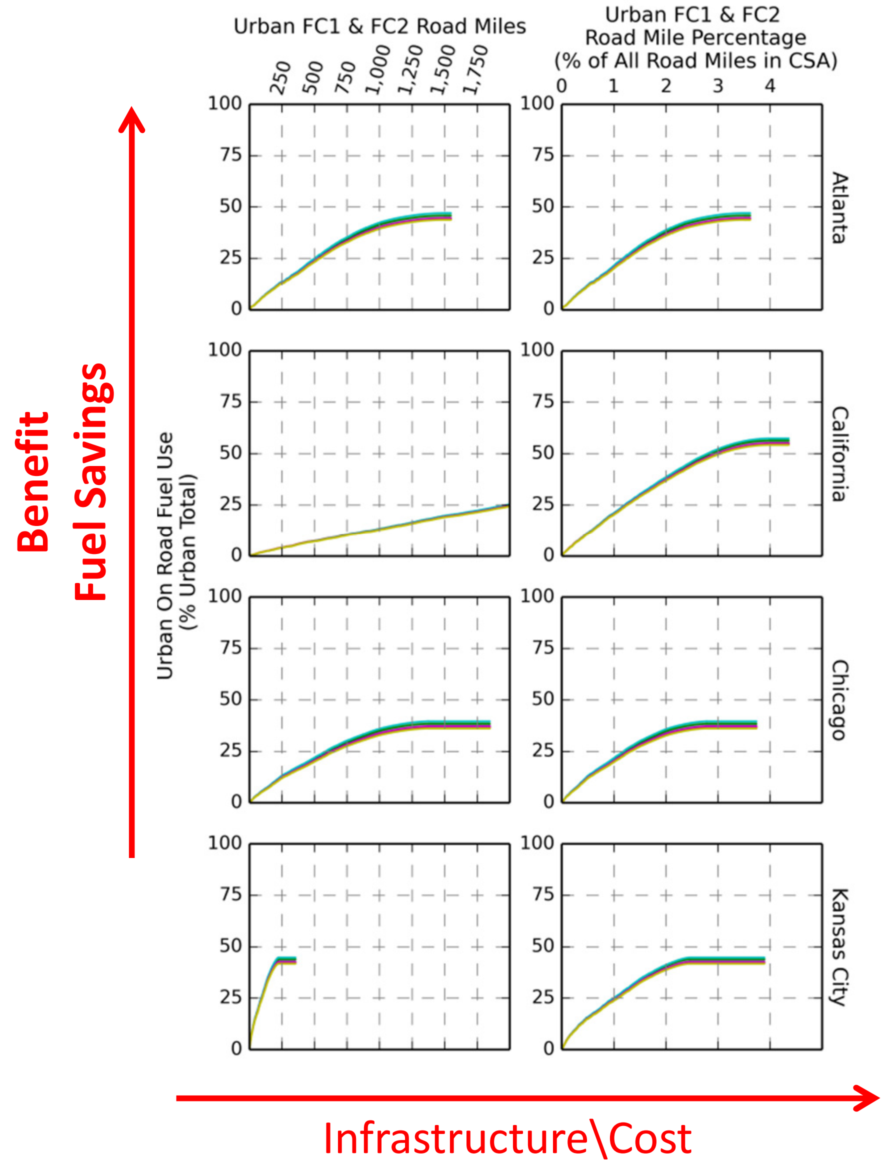




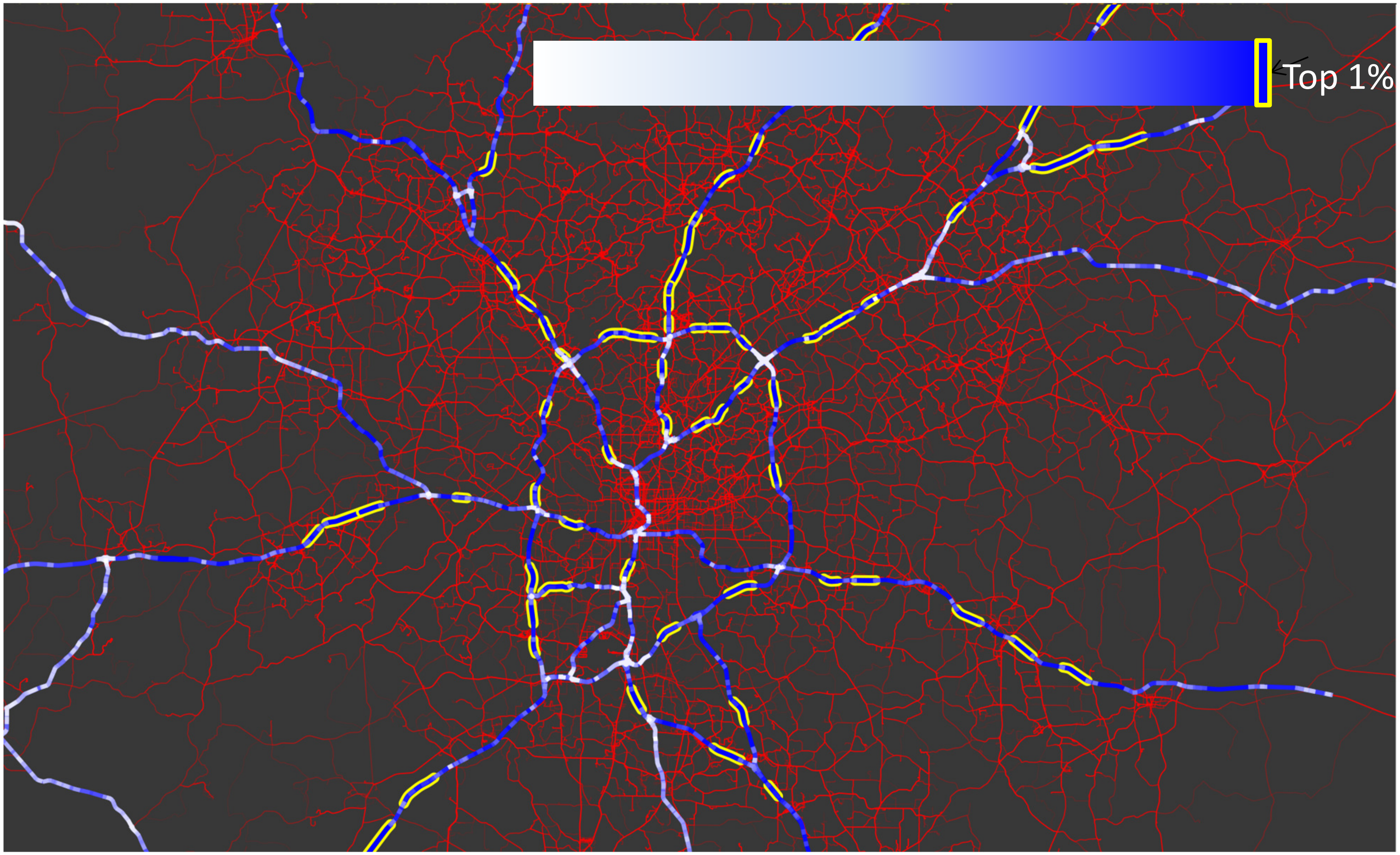
Data Fusion

- Each urban interstate and highway road segment is given a priority using the total fuel displaced per road segment
  - Increased fuel consumption higher priority, and earlier deployment
- Variation in mileage, but similar trends when regional totals are normalized



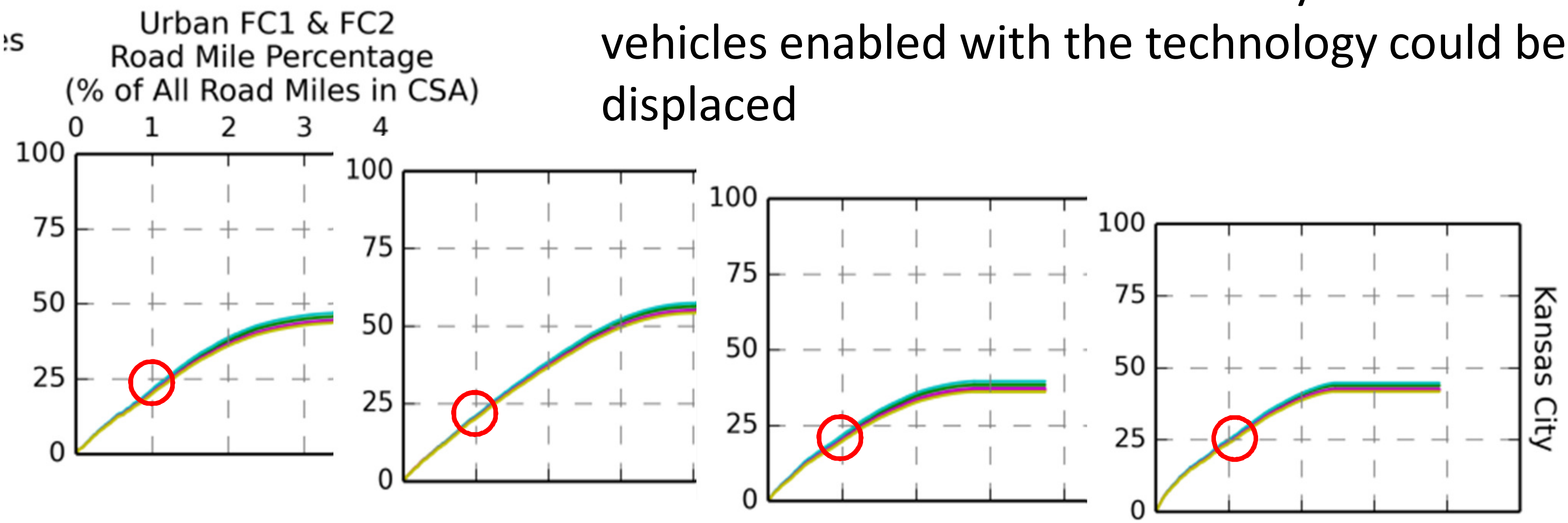


Prioritization

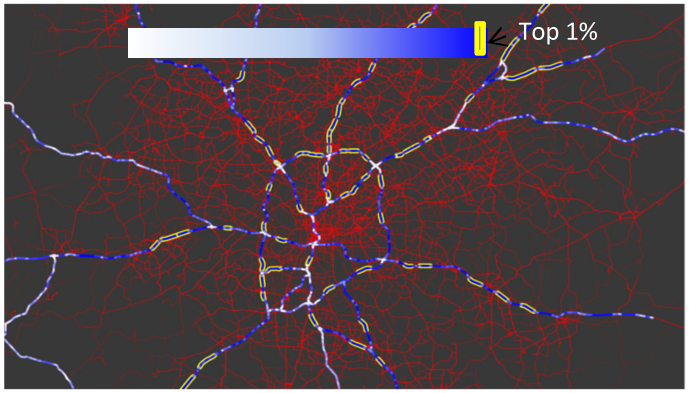


Results

- If 1% of the road miles within a geography are electrified 25% of the fuel used by a ‘fleet’ of vehicles enabled with the technology could be displaced



Region	1% Mileage	Cost $3 Million/Mile	% Fuel Displaced
Atlanta	413	1.2 Billion	25%
California	1803	5.4 Billion	25%
Chicago	491	1.4 Billion	25%
Kansas City	55	166 Million	25%



Considerations – Further Exploration

- **Geography**
  - Other census geographies
  - Road Segmentation – Needs better normalization to eliminate weighting by segment length
  - Defines the denominator of the % Roads metrics
    - Can have significant impact if comparisons are not made appropriately (used to normalize across regions)
- **Vehicle Drivetrain**
  - How does vehicle interact with infrastructure
    - Hybrid: Accept charge or direct power to the motor
    - Electric: Accept charge
  - Charging efficiencies at high speed
  - Metrics that can optimize for EVs
- **Exploration into suitability modeling to better assess costs and generalize fuel savings using capacity, speed, grade, flow, etc..**

- **Expand HPC Implementation**
  - After first segment placed re-run simulation to place the second, and third