Feasibility of Roadway Electrification Using Wireless Power Transfer

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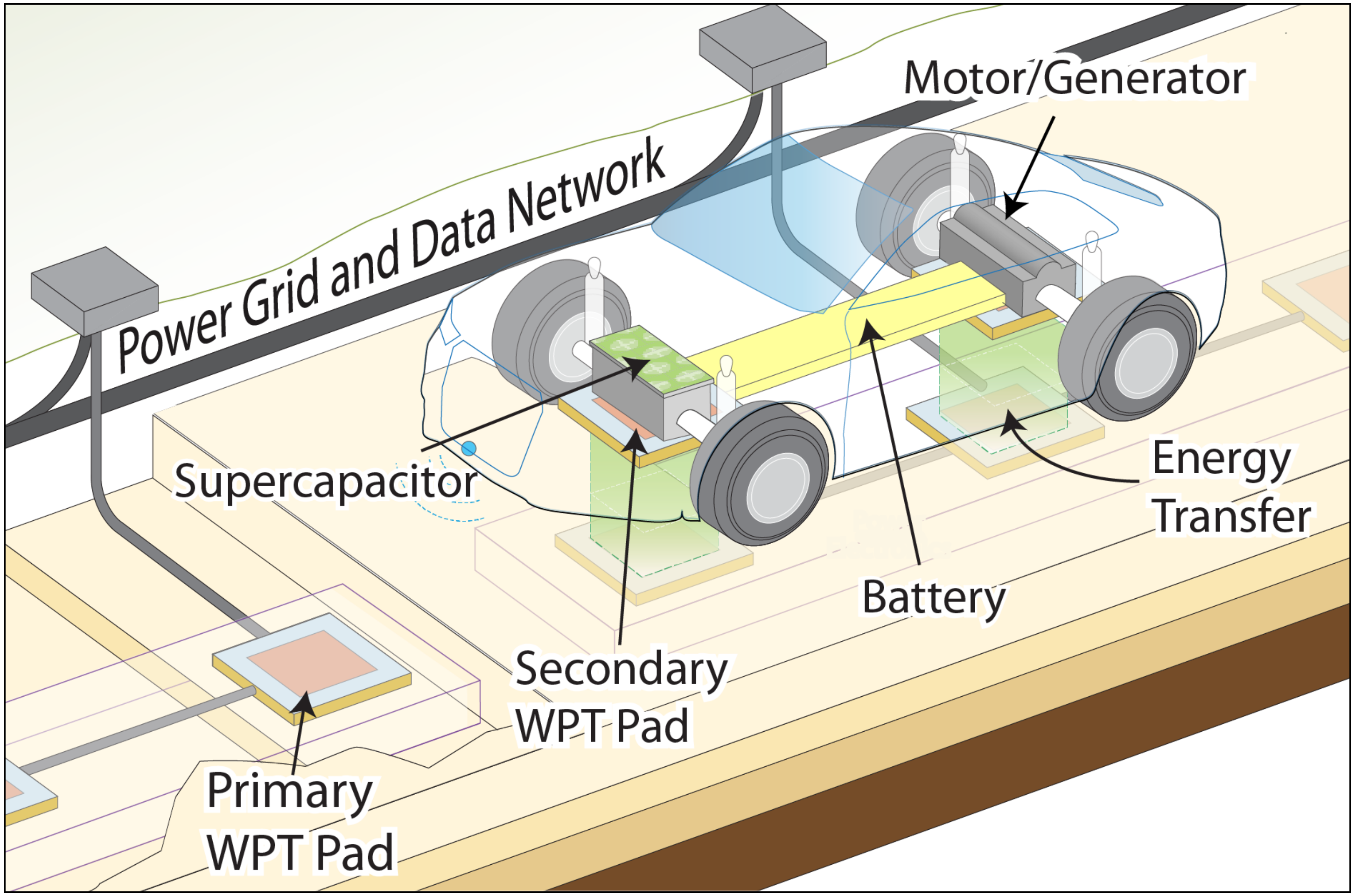
Utah State University

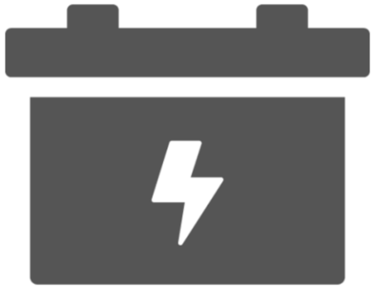
SELECT
Sustainable Electrified Transportation Center
A transformational, holistic approach to transportation electrification.

Electric Vehicle & Roadway Research Group

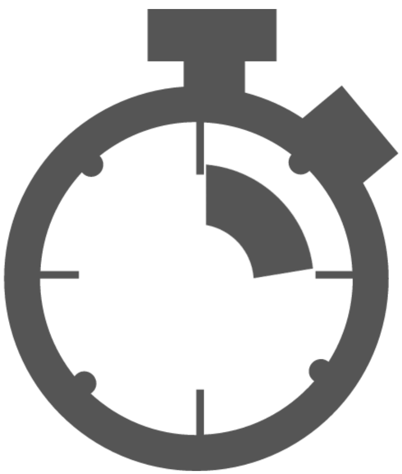
Roadway Electrification Using WPT



Current Electric Vehicle Limitations



Heavy Batteries with Low Range



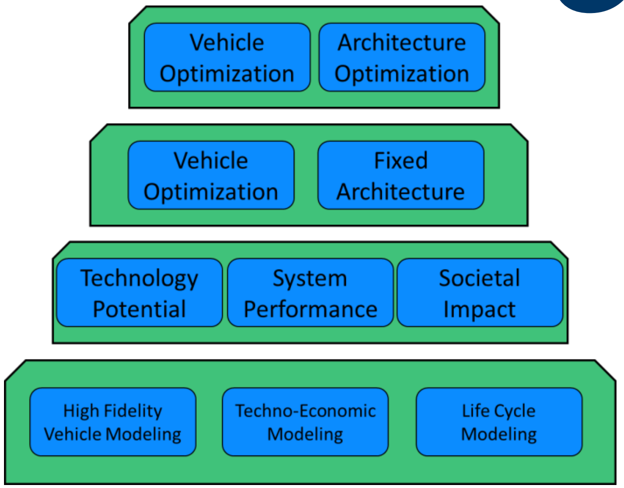
Long Charge Times
Limited Charging Locations

WPT Electric Vehicles

Cheaper Vehicle
Smaller on Board Energy Storage

Unlimited Range

OUTLINE



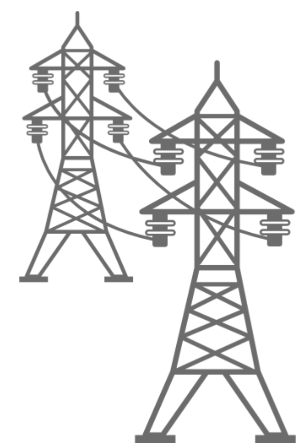
System Modeling

Feasibility Results

Economic

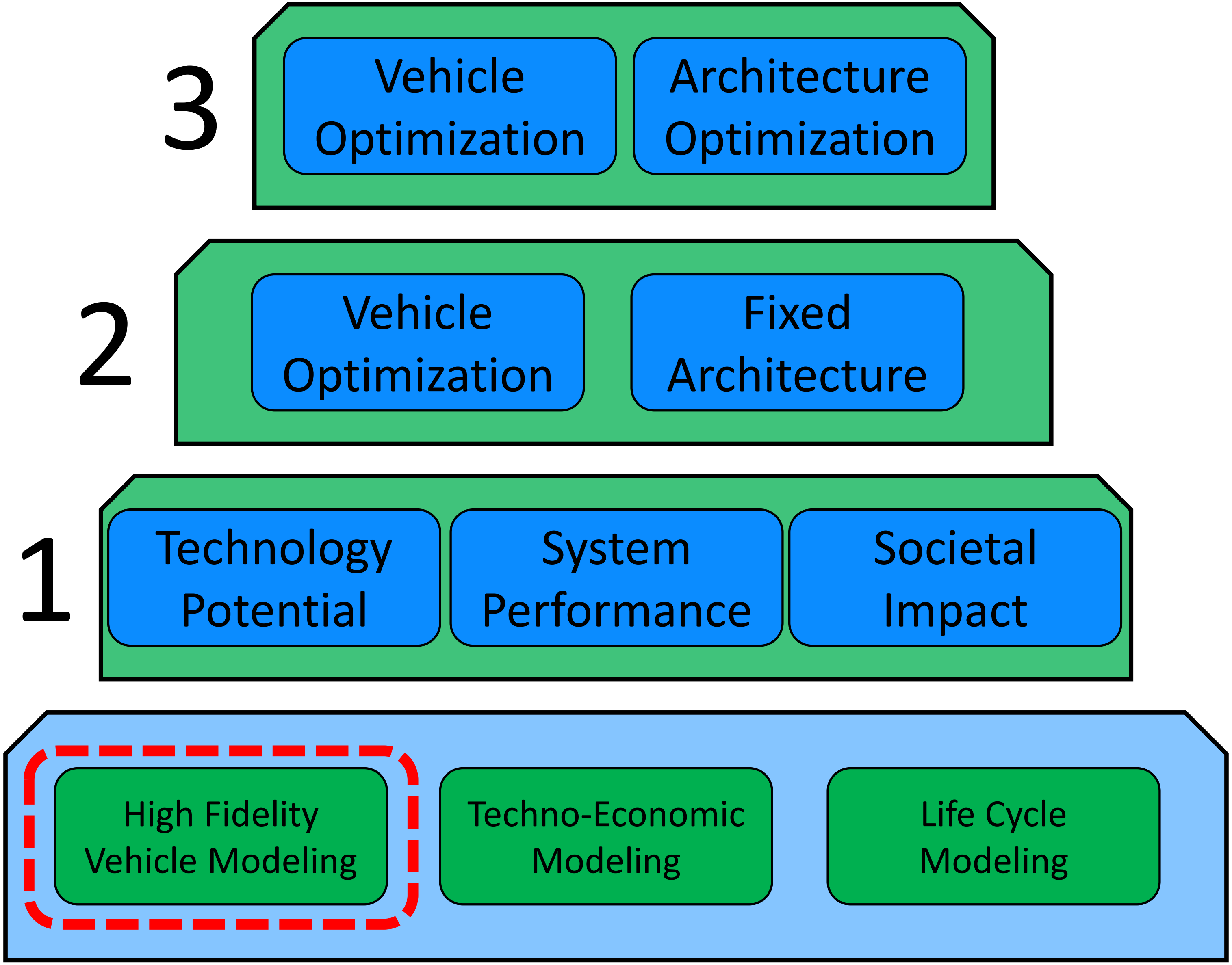
Environmental

Optimization

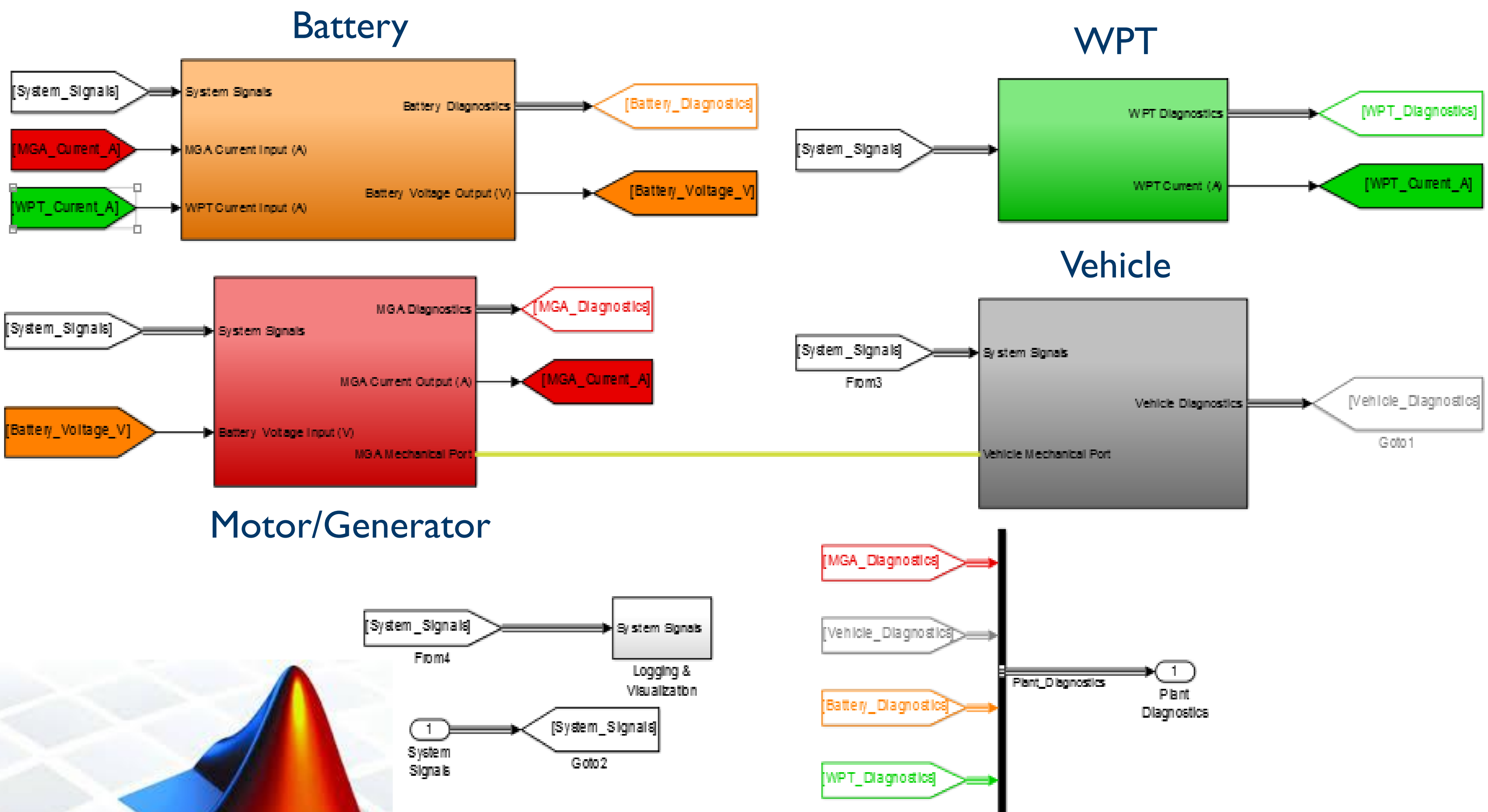


Grid Impact

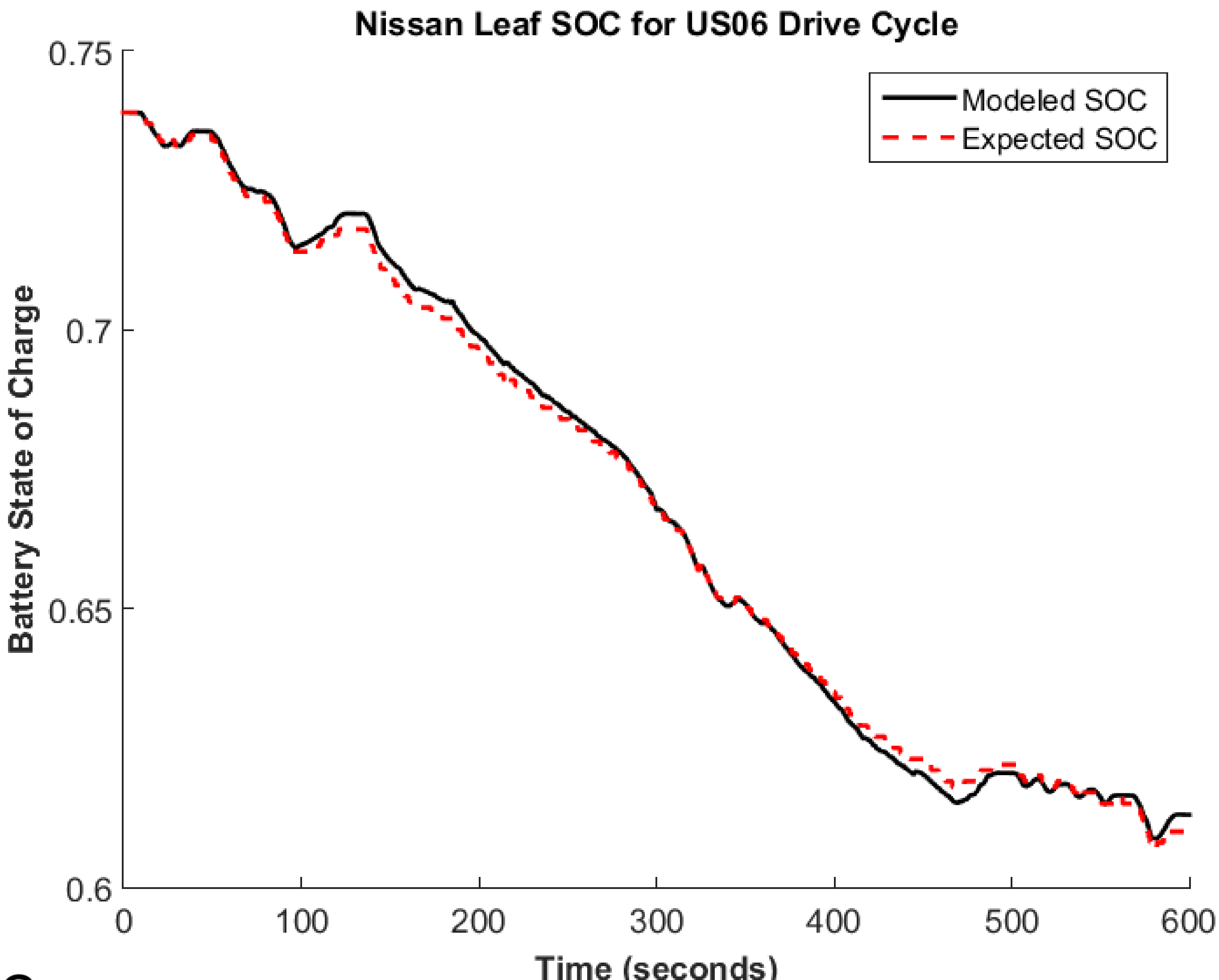
Model Path


3
Vehicle Optimization
Architecture Optimization
2
Vehicle Optimization
Fixed Architecture
1
Technology Potential
System Performance
Societal Impact
High Fidelity Vehicle Modeling
Techno-Economic Modeling
Life Cycle Modeling

Dynamic Vehicle Modeling



Vehicle Model Validation



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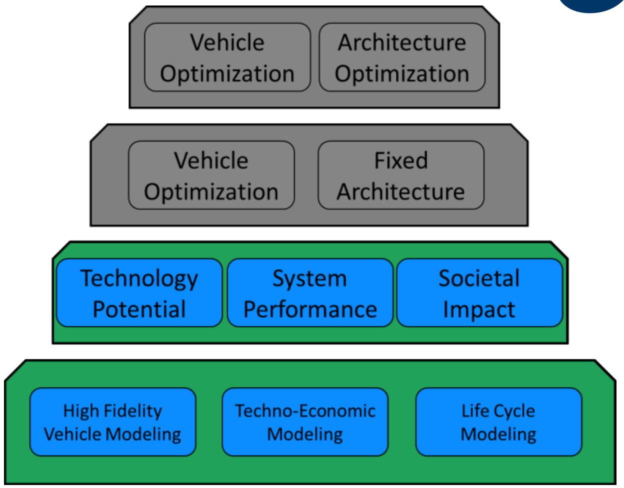
Downloadable Dynamometer Database (D^3)

OUTLINE



System Modeling

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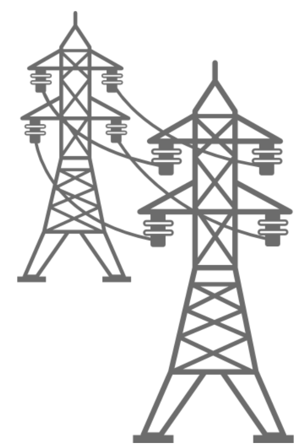
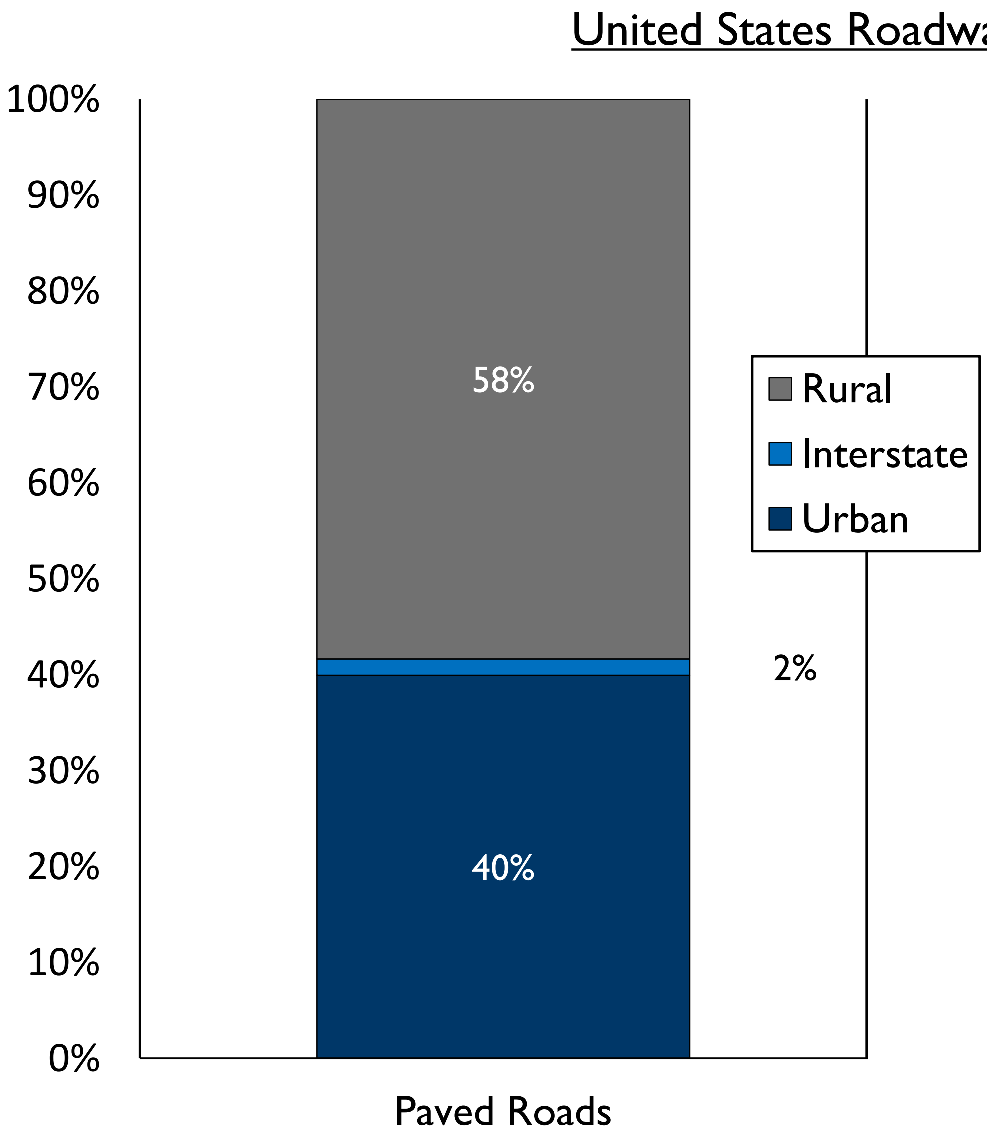
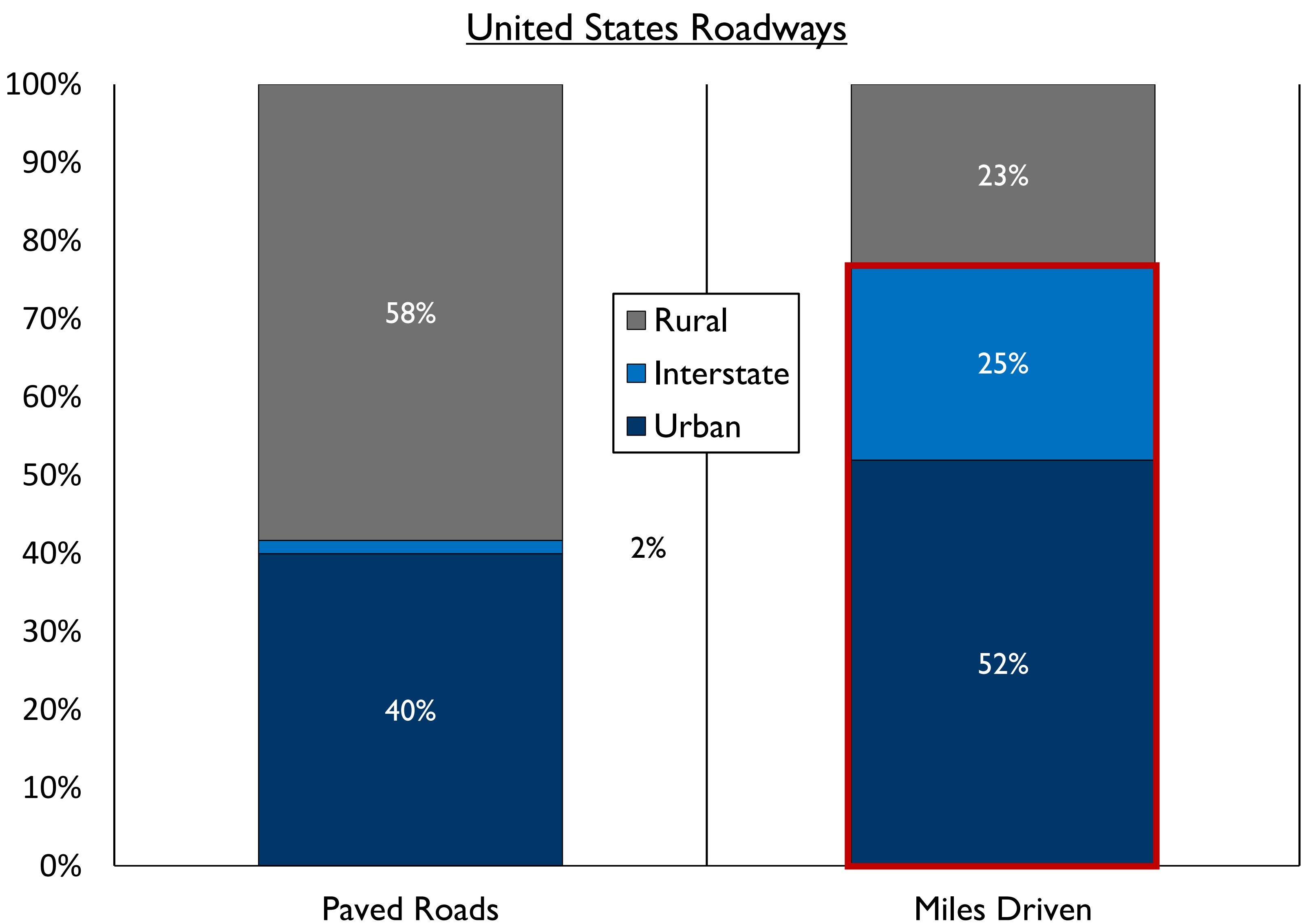


Grid Impact

Roadway Modeling

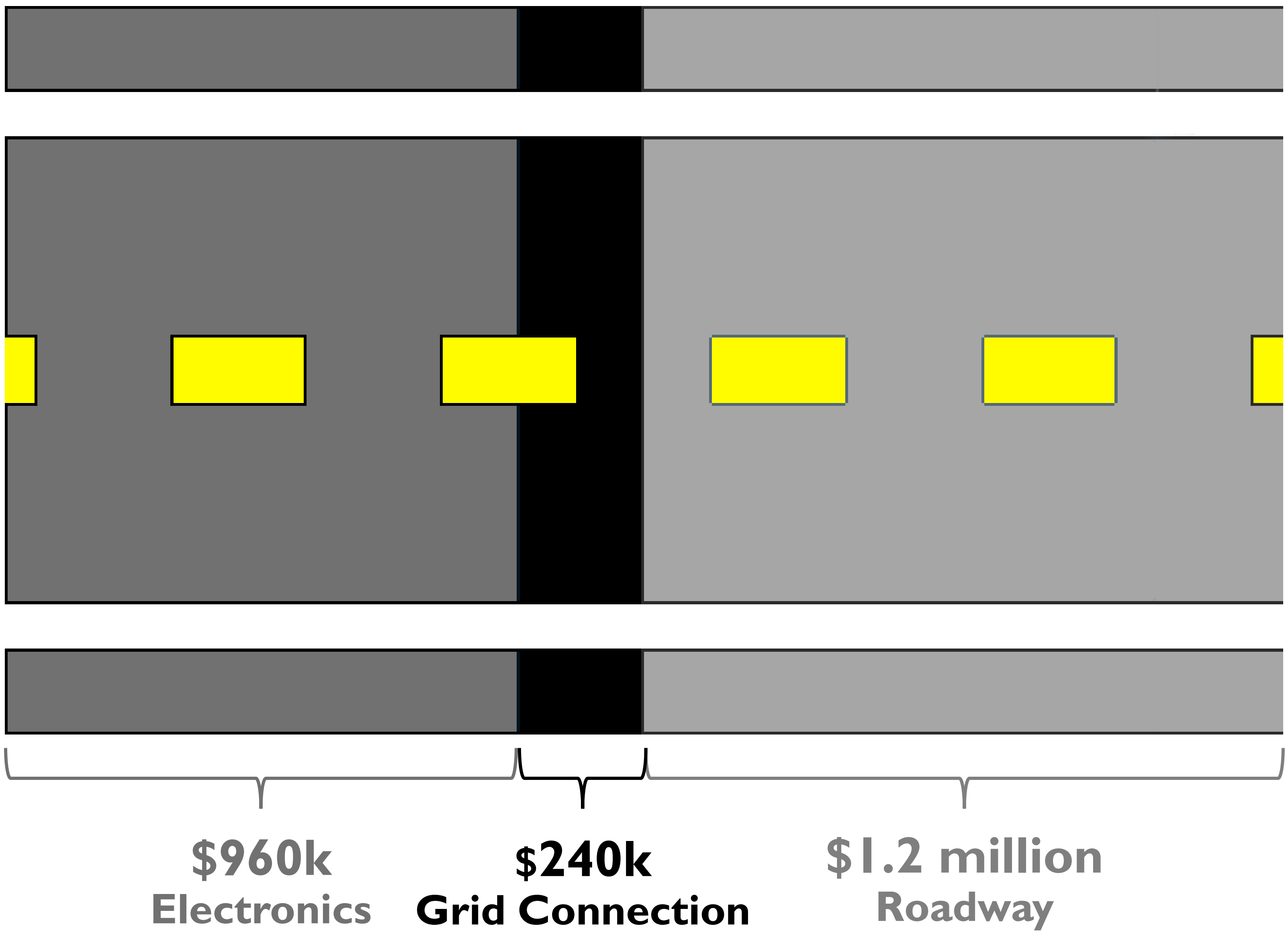


Roadway Modeling



Modeled System Covers 77% of Miles Driven

Roadway Cost: $2.4 million per mile



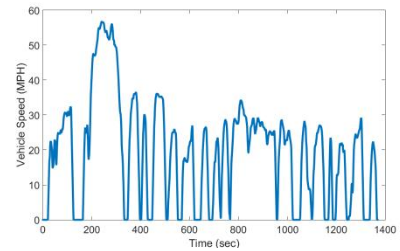
Vehicle Energy Consumption

Vehicle Models

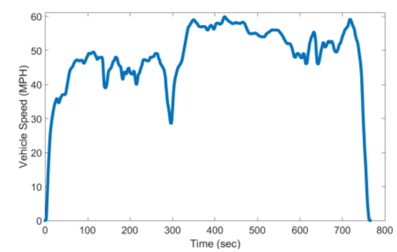
Light Duty

Class 8 Trucks

Drive Cycles



Urban: UDDS

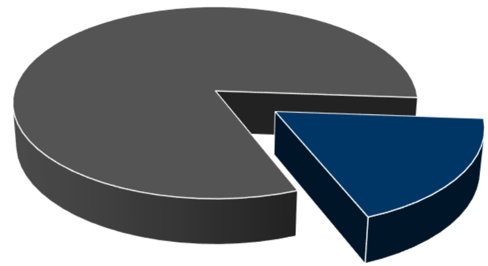


Interstate: HWFET

	ICE (Whr mi^{-1})	WPT (Whr mi^{-1})	Energy Savings (%)
Light Duty Interstate	1,375	336	**76**
Light Duty Urban	1,807	294	**84**
Truck Interstate	4,958	1,617	**67**
Truck Urban	8,005	850	**89**

Electrified Roadway Coverage

25 KW Power Transfer

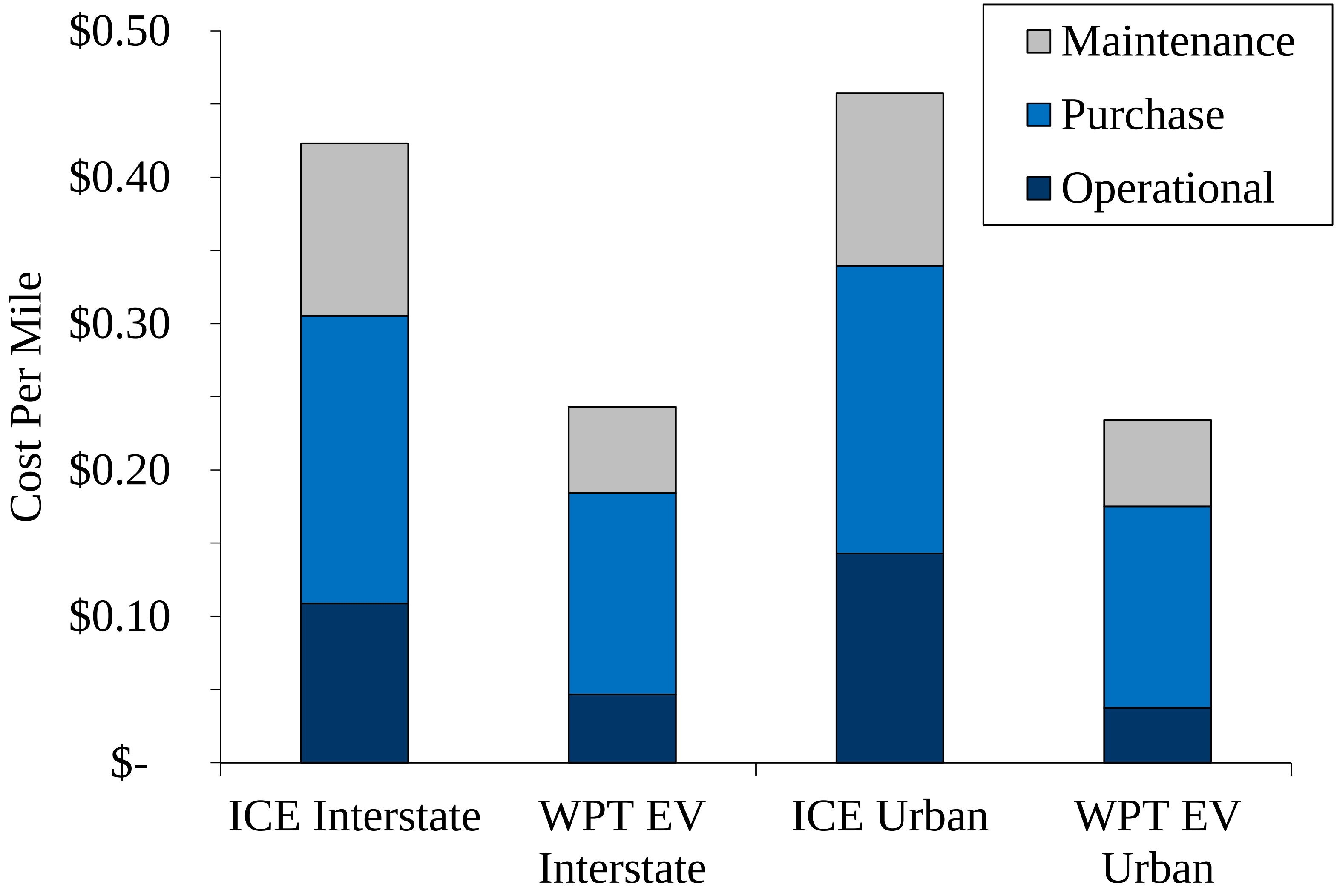


82% Transfer Efficiency

Interstate
17.6 KW Average
85% Charge Time
83.5% Coverage

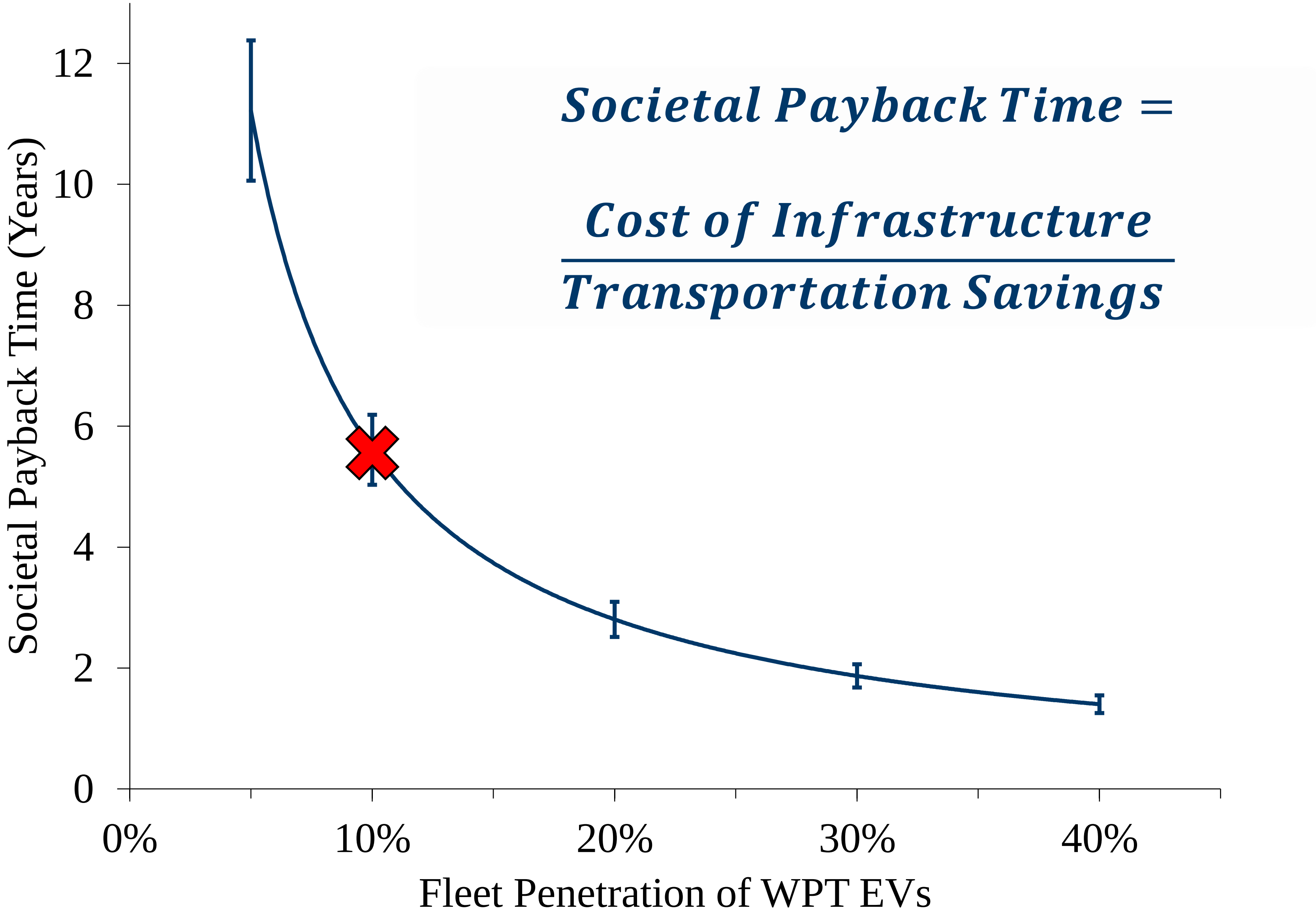
Urban
5.76 KW Average
28% Charge Time
2.6% Coverage

Vehicle Level Results



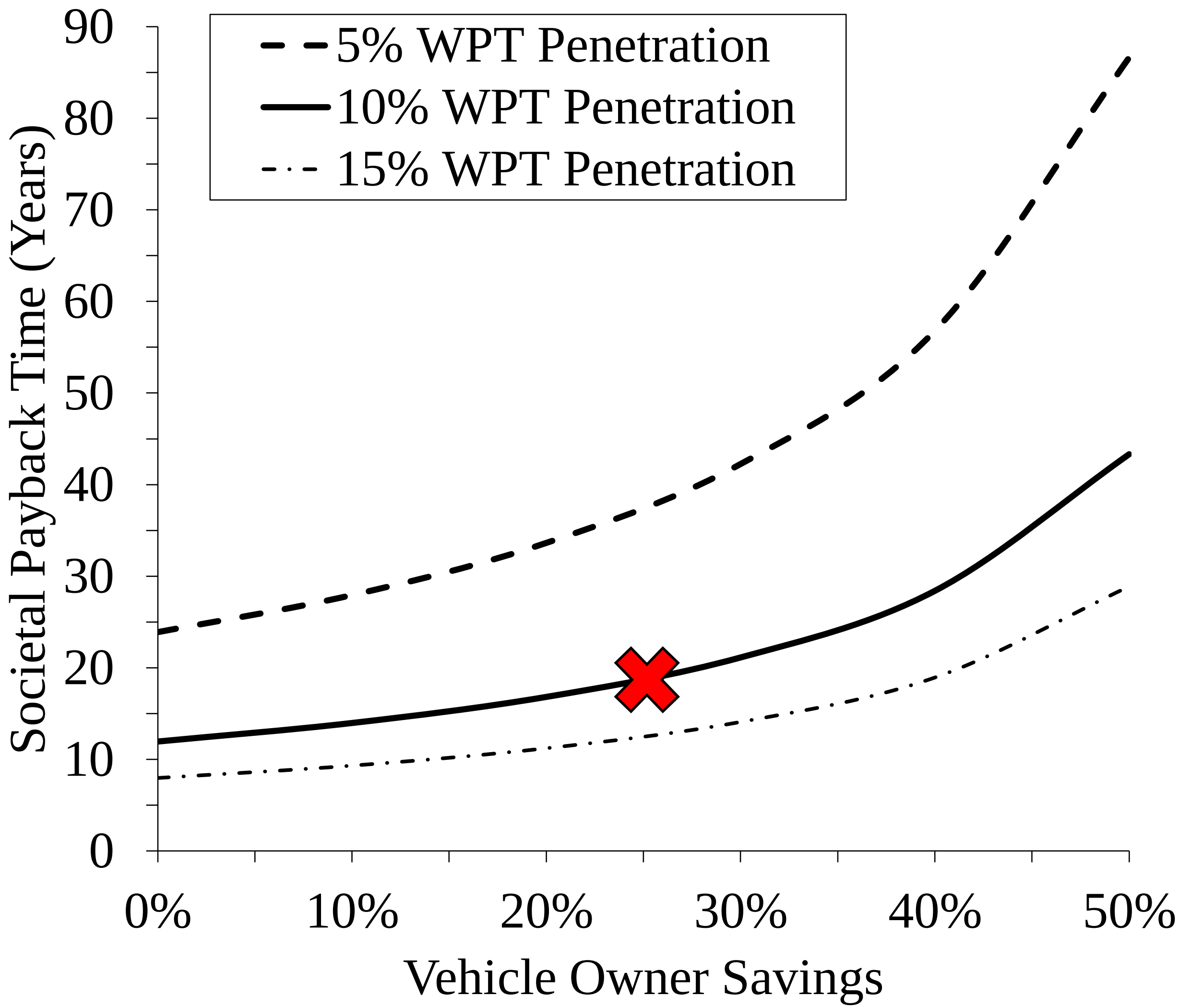
44% Reduction in Total Costs

Societal ROI



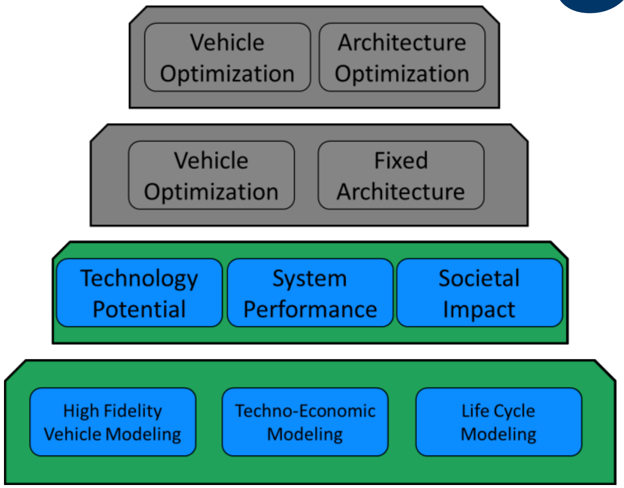
5.9 Year Payback Time for 10% Fleet Penetration

Societal ROI w/ Reimbursement Plan



18.7 Year Payback Time for 10% Fleet Penetration

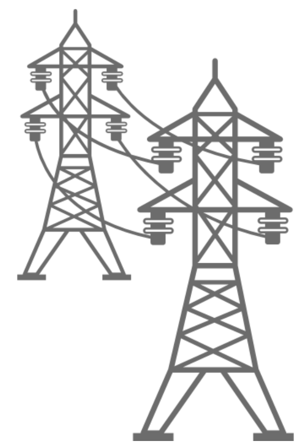
OUTLINE



System Modeling

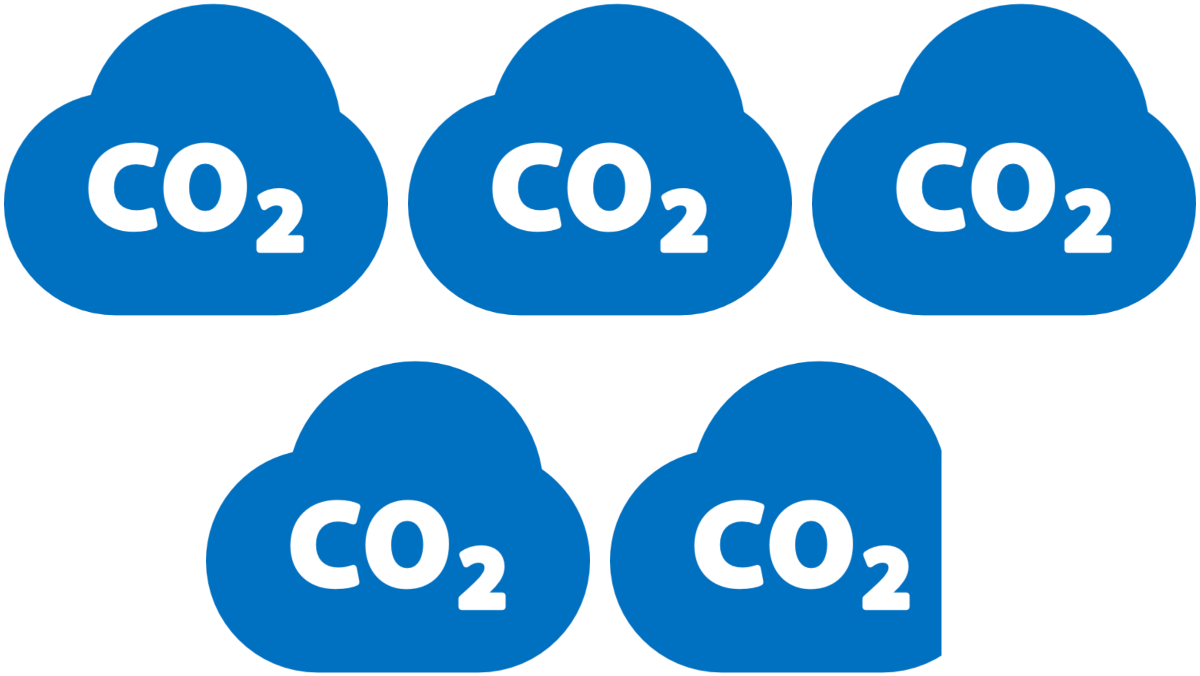
Feasibility Results



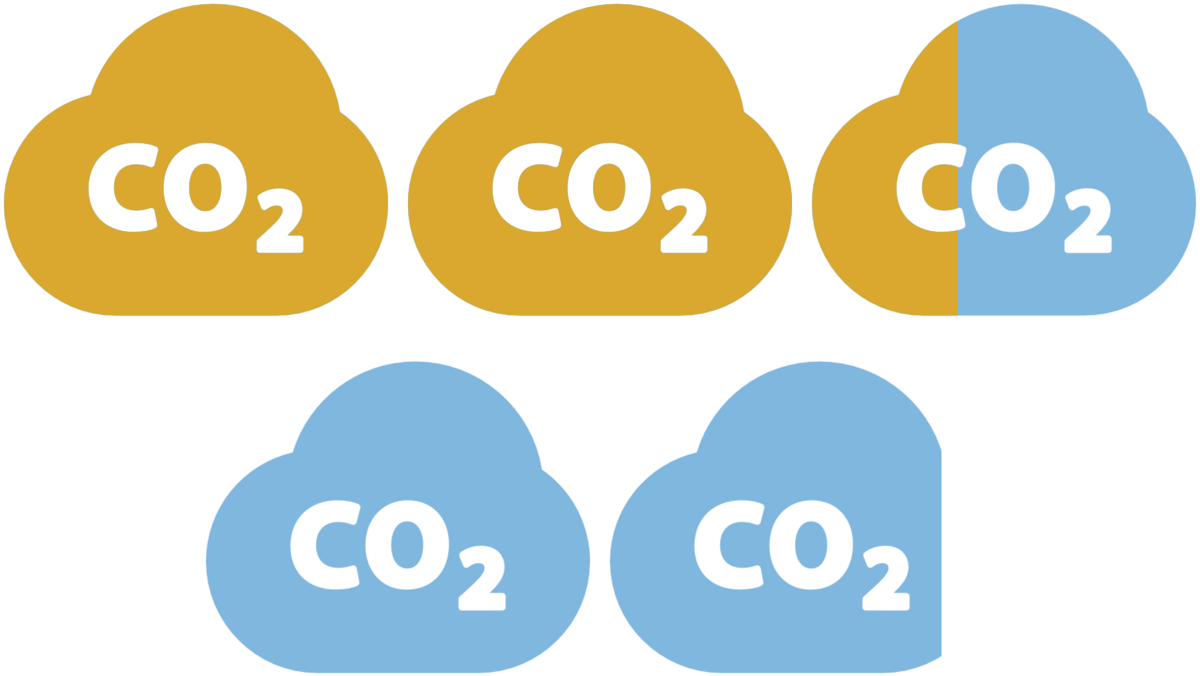
Economic Environmental Optimization Grid Impact

Environmental Impact - GHGs



Conventional Vehicle: 486 g-CO_2 mi^{-1}

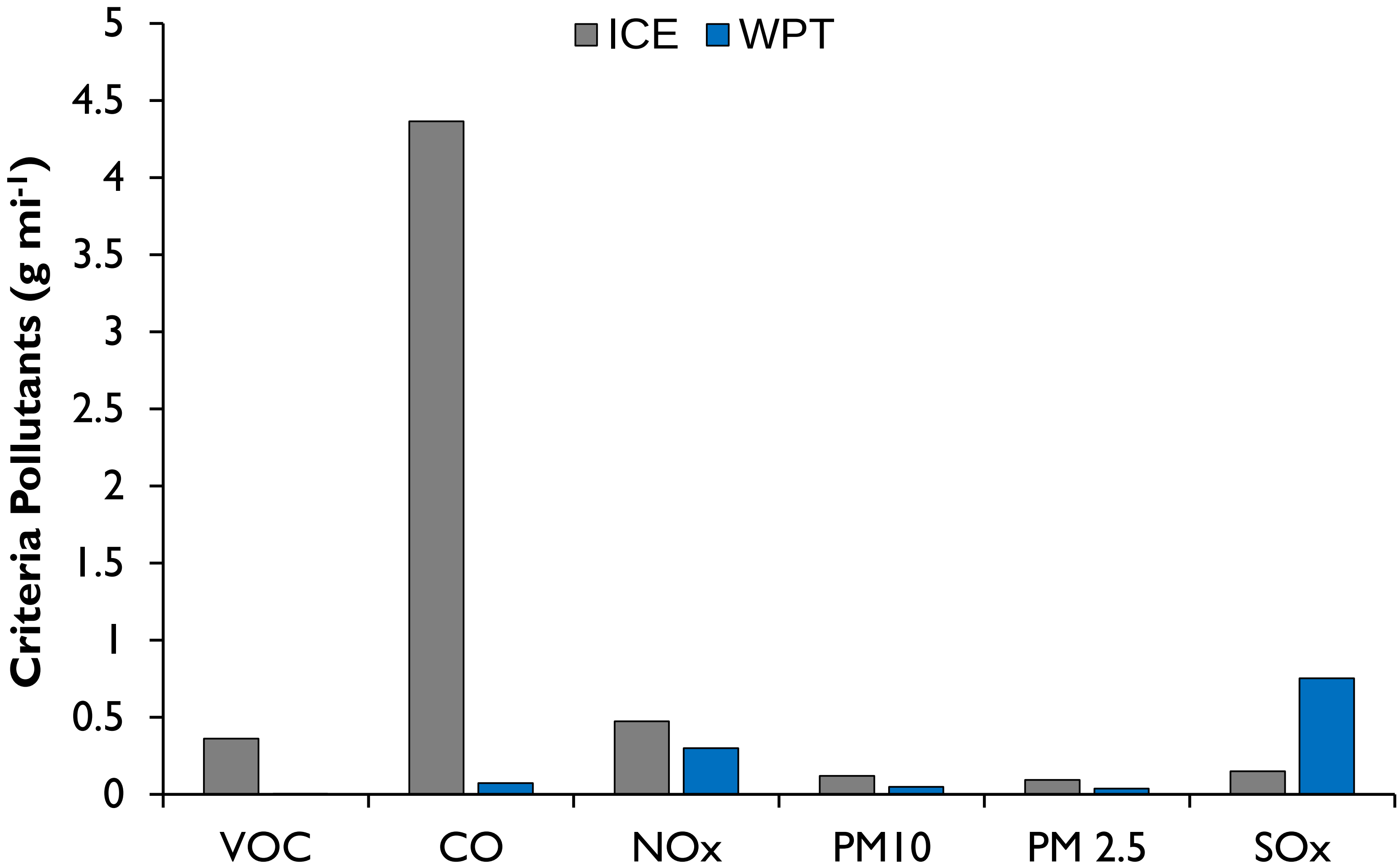
Environmental Impact - GHGs



Electric Vehicle: 238 g-CO_2 mi^{-1}

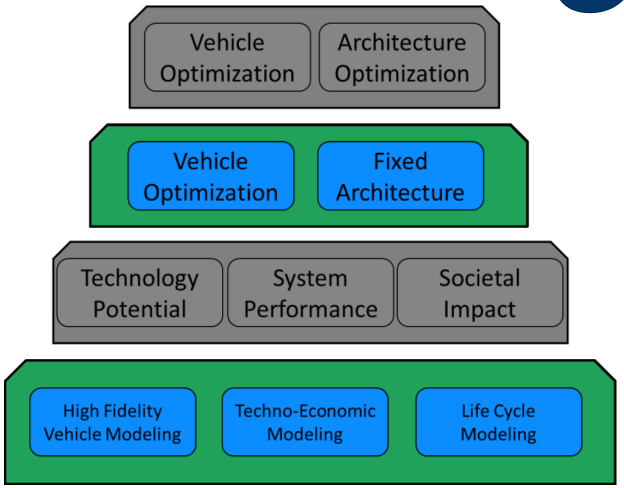
51% Reduction

Environmental Impact – Criteria Pollutants



Up to 99% Reduction in Criteria Pollutants

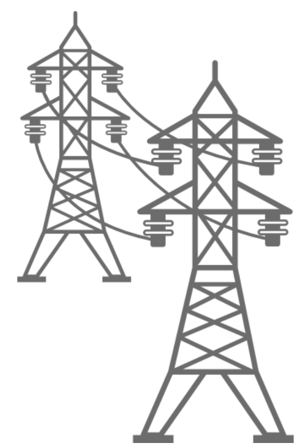
OUTLINE



System Modeling

Feasibility Results

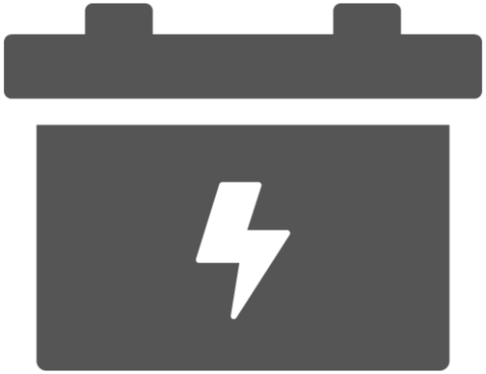


Economic Environmental Optimization Grid Impact

Optimization

Vehicle Weight



Vehicle Range

WPT Power Requirements

WPT Pad Placement

Real World Drive Cycles

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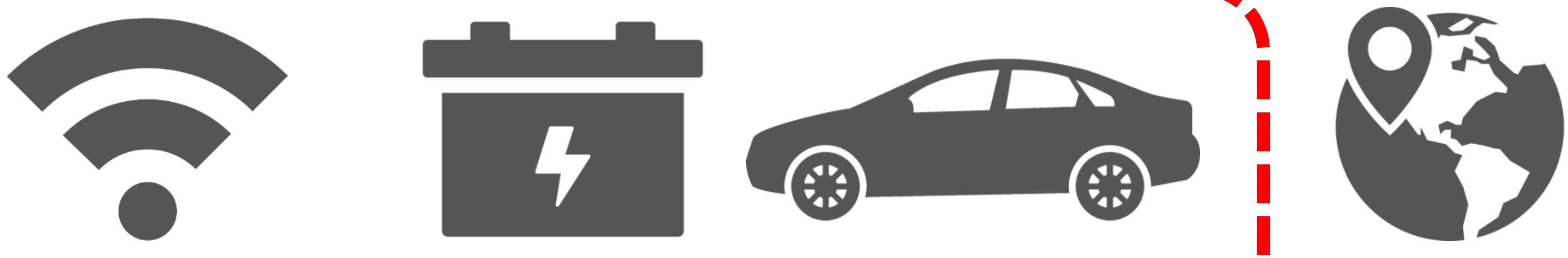
“Millions of second by second real world drive cycle data.”

WPT Vehicle Optimization



50kW WPT Power

25 Mile Range

Nissan Leaf w/ Supercapacitor

"Interstate" Only WPT Coverage

~12,000 Real World Drive Cycles

Optimization Results

Battery Range	WPT	Supercaps	Satisfied
25	0	0	79.8%
25	25	7	91.0%
25	25	10	94.5%
25	25	13	96.0%
25	50	13	97.8%
25	50	20	99.0%
25	100	50	98.6%
30	25	13	97.3%
30	0	0	83.7%
30	50	17	99.3%
30	50	13	99.0%
20	25	13	91.4%
20	0	0	73.6%
35	0	0	87.1%
35	50	10	98.8%
35	25	13	97.7%

Optimization Results

Battery Range	WPT	Supercaps	Satisfied
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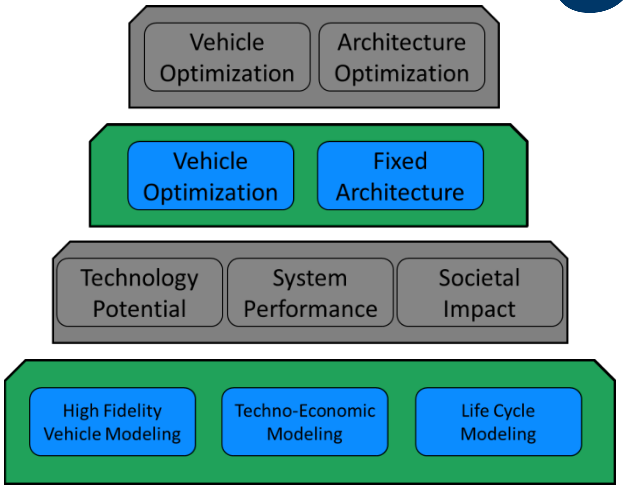
25	100	50	98.6%
30	25	13	97.3%
30	0	0	83.7%
30	50	17	99.3%
30	50	13	99.0%
20	25	13	91.4%
20	0	0	73.6%
35	0	0	87.1%
35	50	10	98.8%
35	25	13	97.7%

OUTLINE



System Modeling

<u>Feasibility Results</u>

Economic

Environmental

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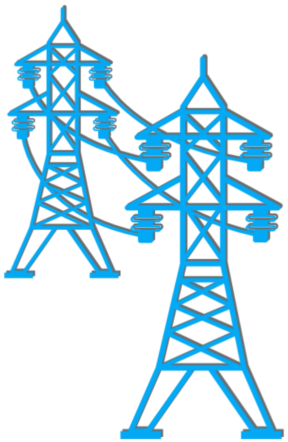
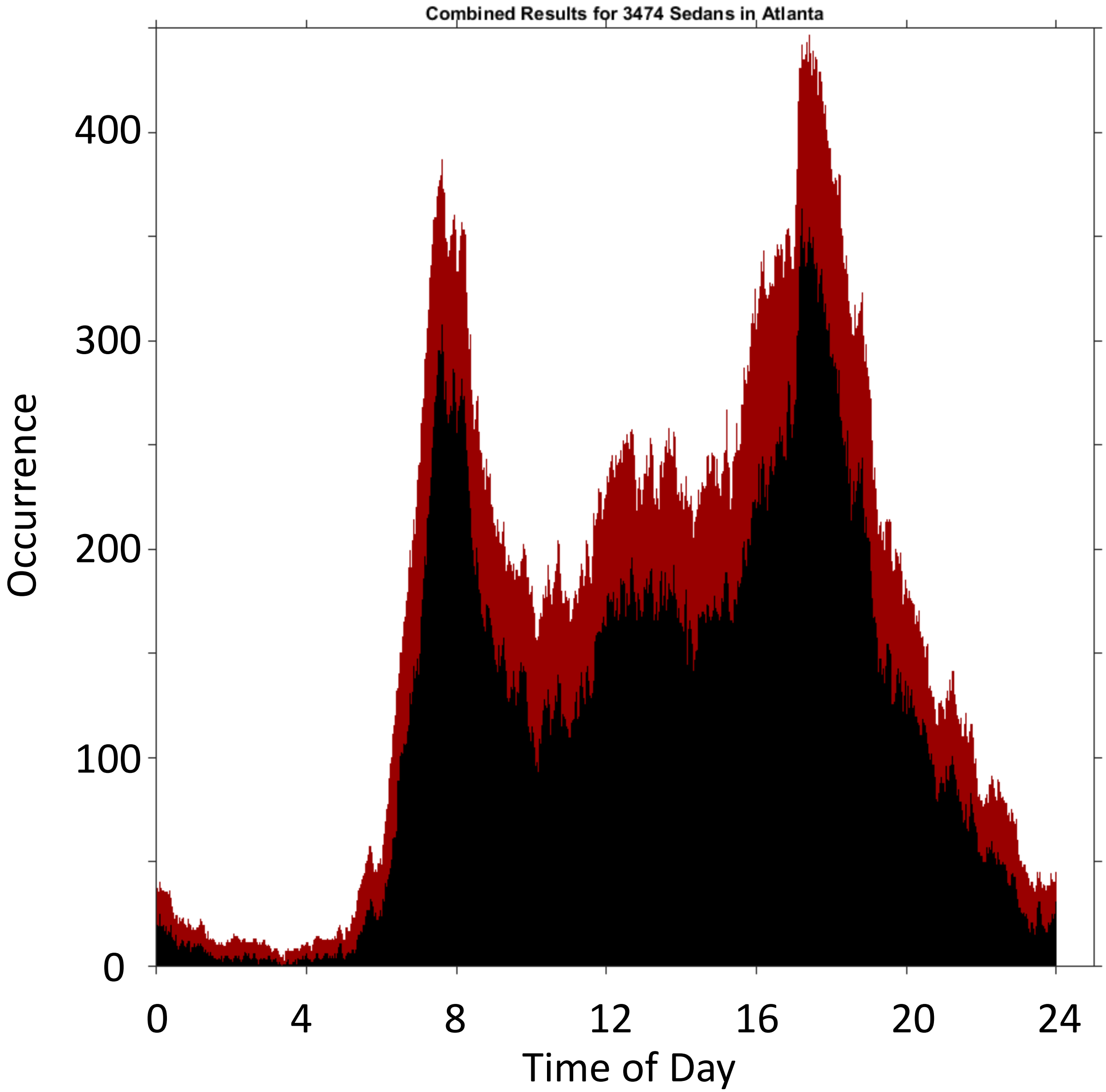


Grid Impact

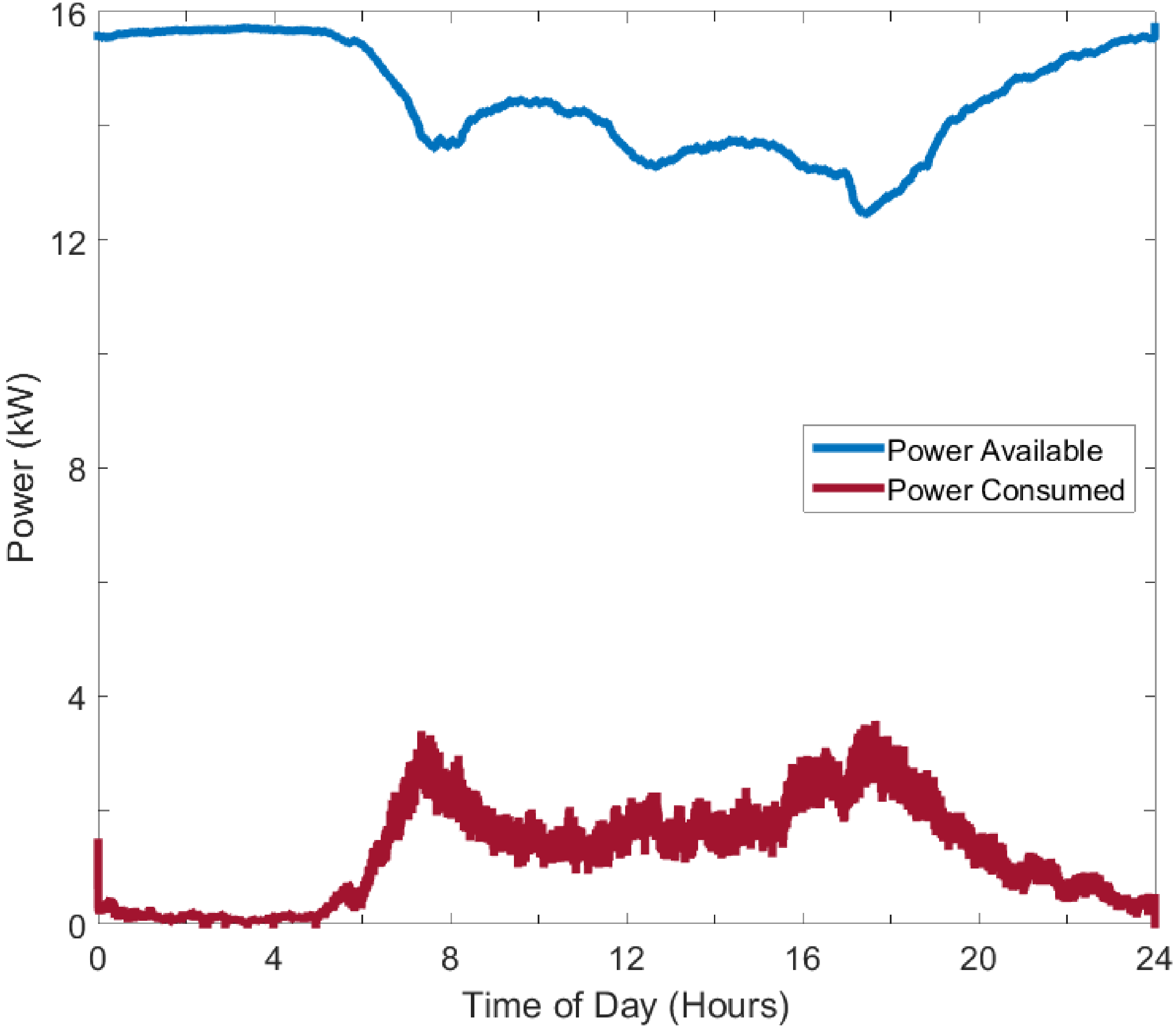
Vehicle Load Distribution

Maximum: 12.8% of vehicles on road at a time, 87.2% available for V2G



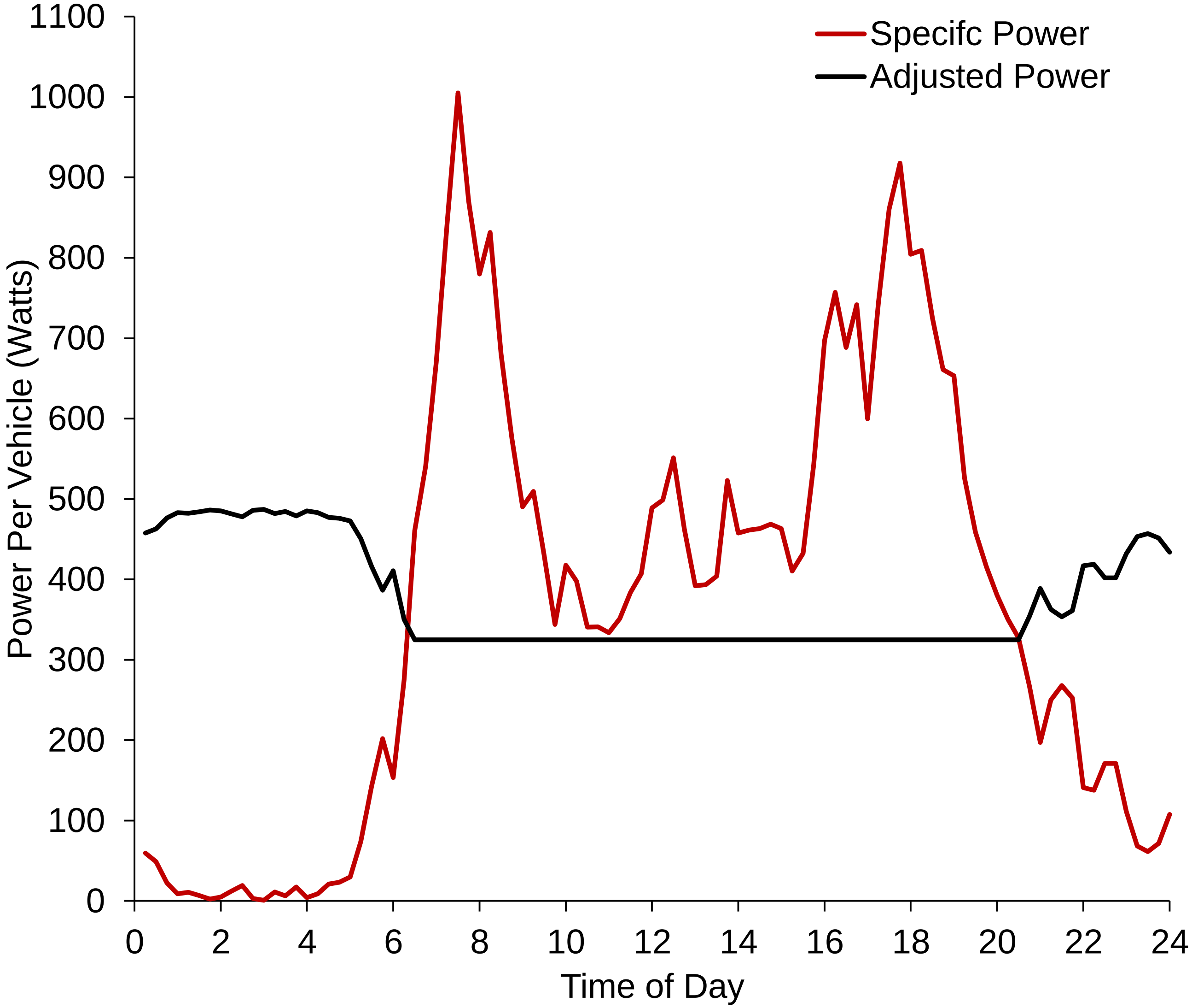
Available Power

Power available is 3.5X greater than power consumed.

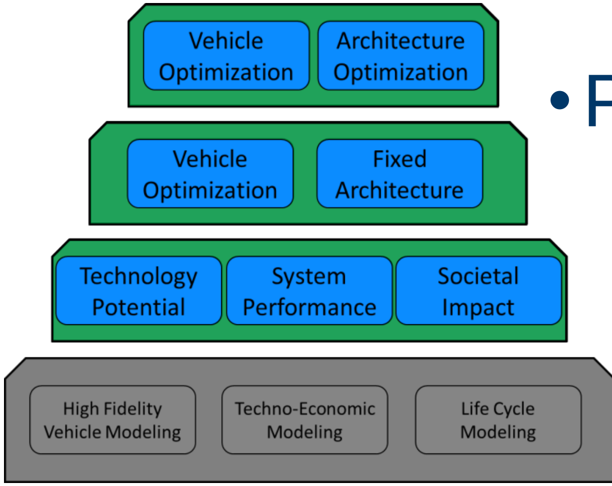


Load Shifting

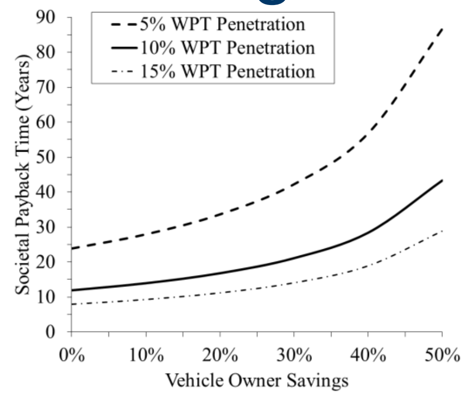
Constant 325 W per vehicle during peak demands satisfies energy consumption

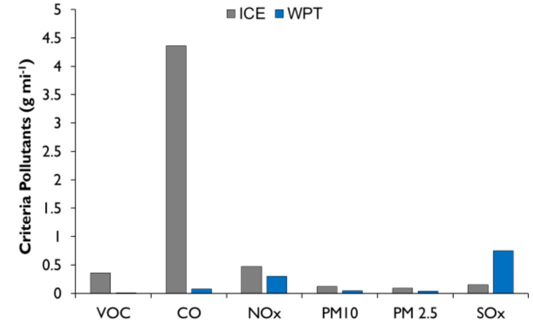


Summary

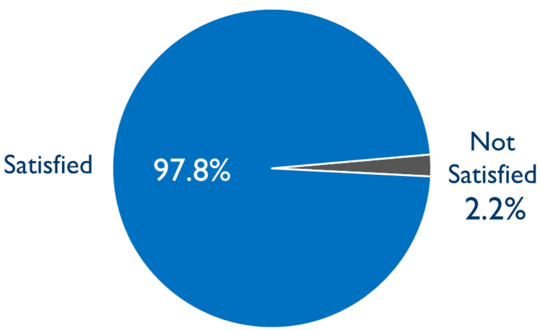


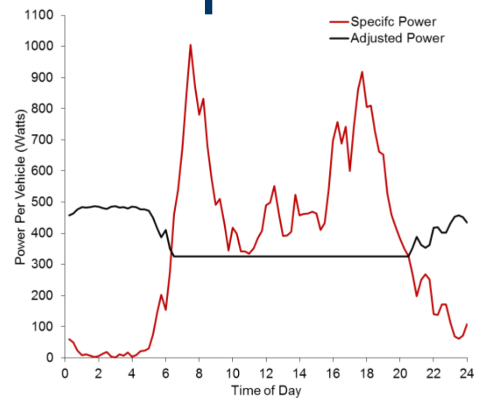
- Promising ROI & GHG emissions





- Satisfies consumers & Minimal impact on grid





- Need to advance modeling

Current and Future Research

- Concurrent Vehicle and Architecture Optimization (GPS enabled drive cycle data)
  - Preliminary results: Increased roadway coverage required

- Economic Impact of Environmental Benefits
  - Improved health from metropolitan air quality change

- Micro/Macro Grid Modeling
  - Economic value of energy storage

- Case Studies
  - Network Modeling
  - Closed campus impact
  - Dedicate route deployment

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