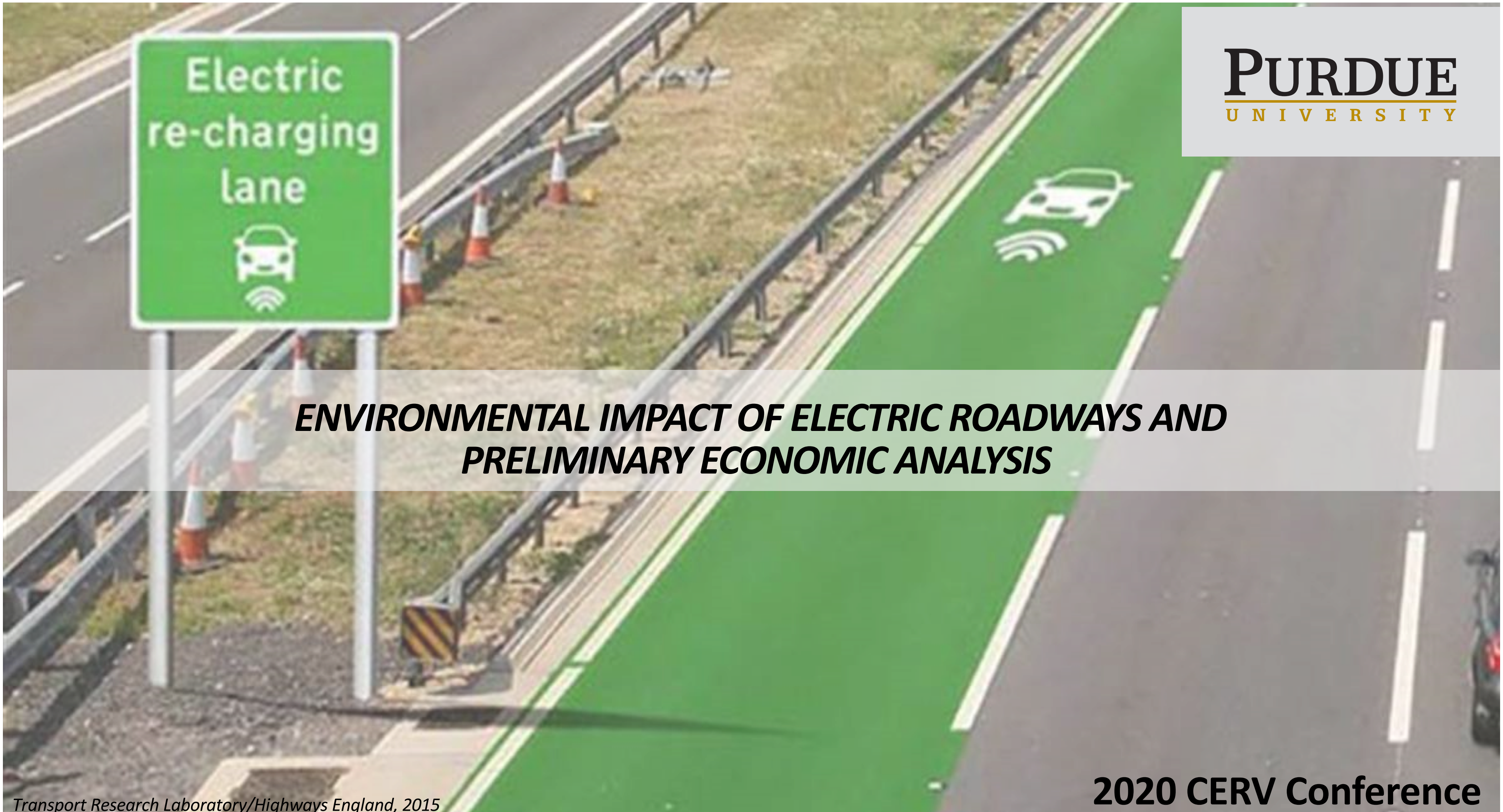


Transport Research Laboratory/Highways England, 2015

ENVIRONMENTAL IMPACT OF ELECTRIC ROADWAYS AND PRELIMINARY ECONOMIC ANALYSIS

2020 CERV Conference

Session 5 - Systems level perspectives on electric roads and corridors: economics and environment

February 10, 2020
Park City, UT, USA

Nadia Gkritza
Professor, Lyles School of Civil Engineering, Purdue University

Director, Sustainable Transportation Systems Research (STSR) group

Outline

Impact on criteria pollutant and greenhouse gas (GHG) emissions

Preliminary economic analysis

Next steps

Impact on Criteria Pollutants and GHG Emissions

DOE APRA-E Feasibility Analysis of Electric Roadways

Theodora Konstantinou, PhD Student, CE
Christos Gkartzonikas, PhD Student, CE

- Project goal: Localized feasibility analysis of electric roadways
- Purdue's Role

✓ Localized market adoption:
  -Survey for general population to identify level of adoption
  -Focus group on stakeholders

✓ **Environmental impact assessment of technology, based on the target corridor and localized data**

Market Adoption

Estimate adoption rates and define market segments

→capture the current trend in the market

Principal Component Analysis (PCA)

- Opinions on ERs
- Environmental consciousness
- Safety concerns on ERs
- Habits towards driving a car

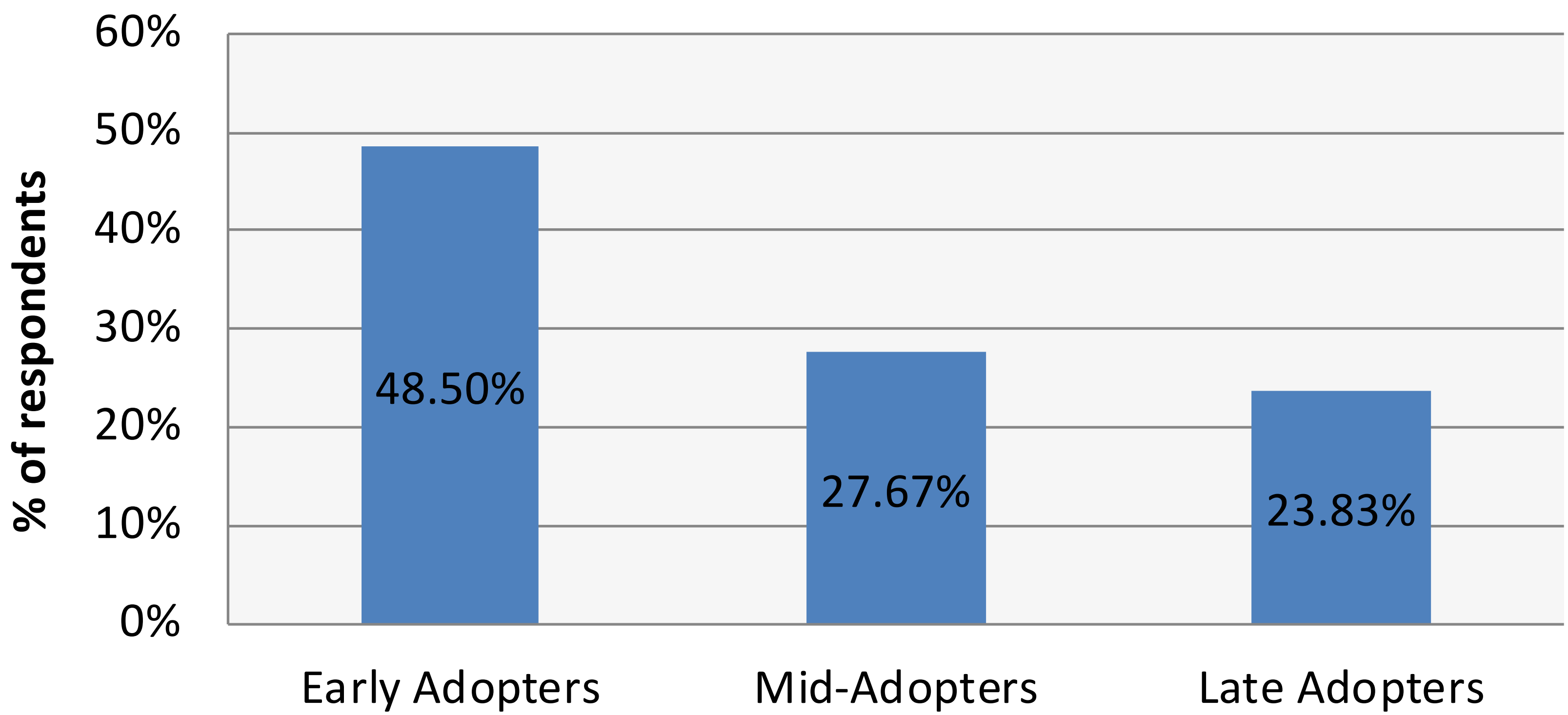
⇒

Cluster Analysis (CA)

k-means algorithm

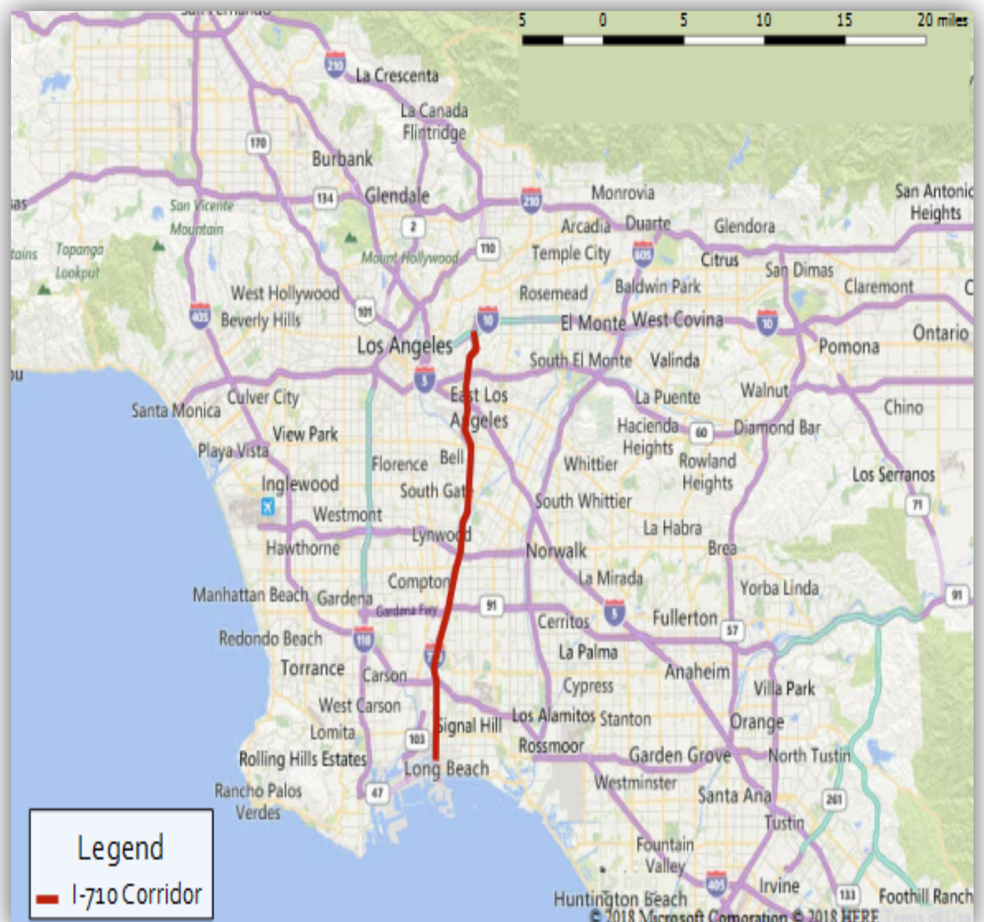
3 clusters

Labeling based on mean scores



Impact on Criteria Pollutants and GHG Emissions

- California Air Resources Board's (CARB) 2017 EMissions FACtor model (**EMFAC**): *Tailpipe emissions/latest and most accurate data*
- Corridor selection and data in Los Angeles, CA



I-710 Corridor (22 mi)

(Bing Maps)

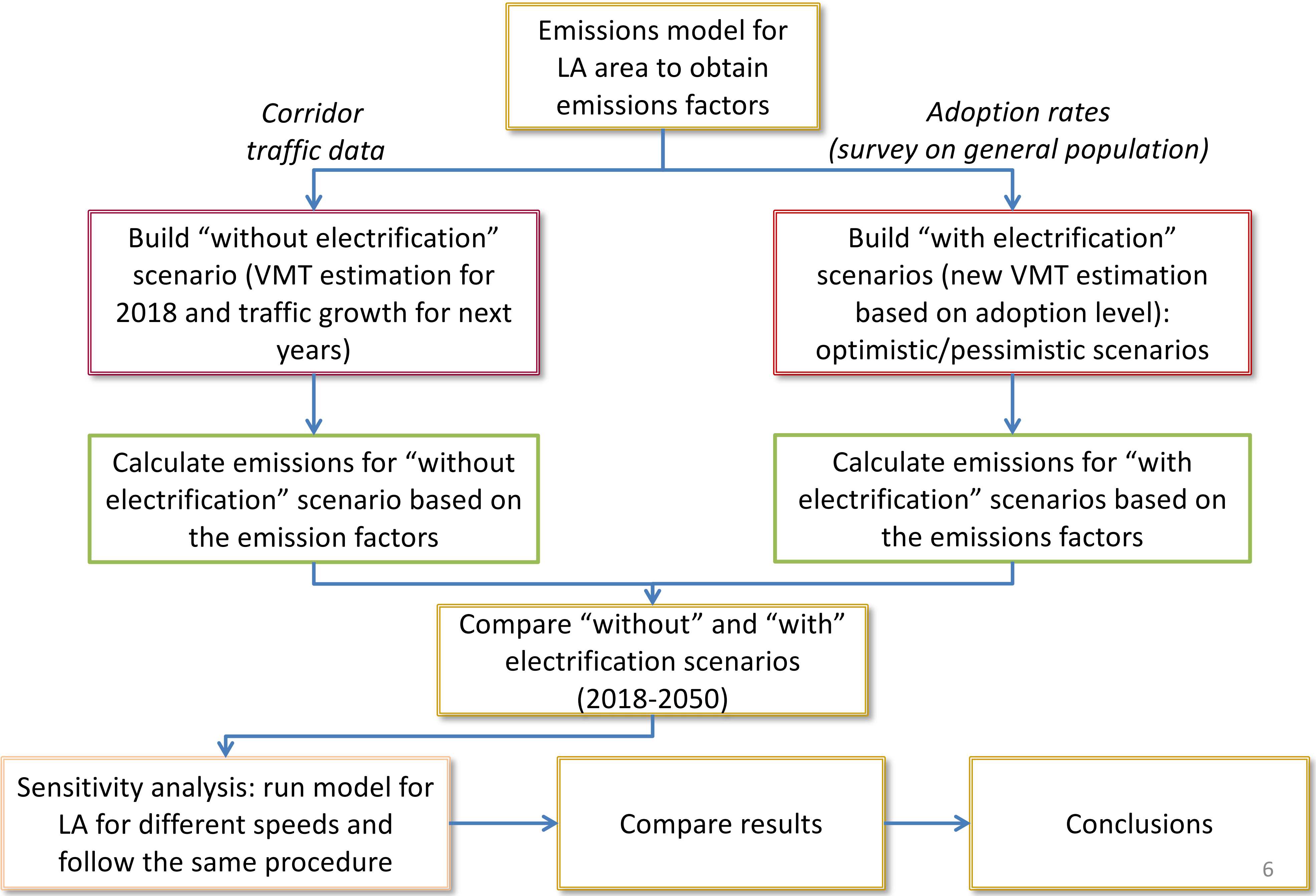
Average annual daily LDV VMT (PeMs)	Diesel/Gas VMT in LA (EMFAC2017)
Average speed (PeMs)	Traffic growth (EMFAC2017)

Traffic data

Adoption Rates: cluster analysis (survey)

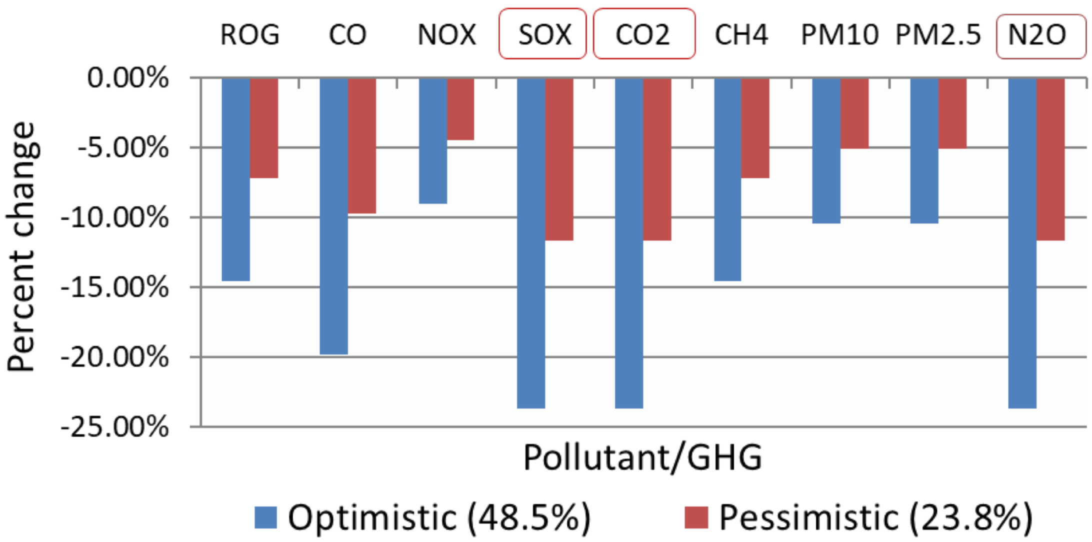
S Curve: 0% in 2018
"optimistic" (48.5% by 2050) and
"pessimistic" (23.8% by 2050)

Impact on Criteria Pollutants and GHG Emissions



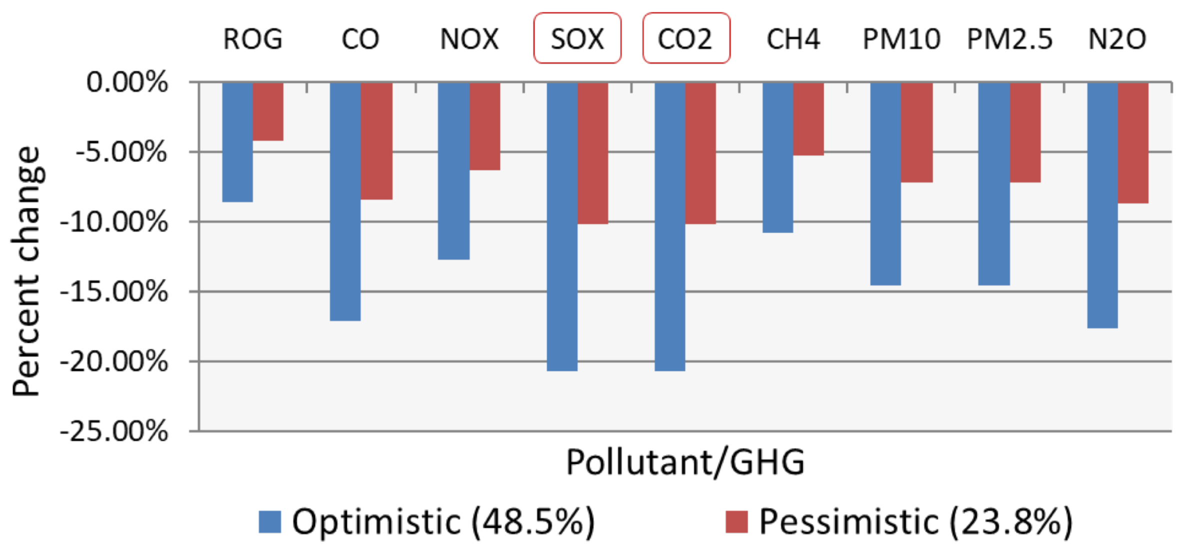
Impact on Criteria Pollutants and GHG Emissions

- Emissions reduction for diesel vehicles ranges from 4.4% (pessimistic scenario) to 23.8% (optimistic scenario), while for gas vehicles varies from 4.21% to 20.68%.
- Greatest reduction for SO_x, CO_2



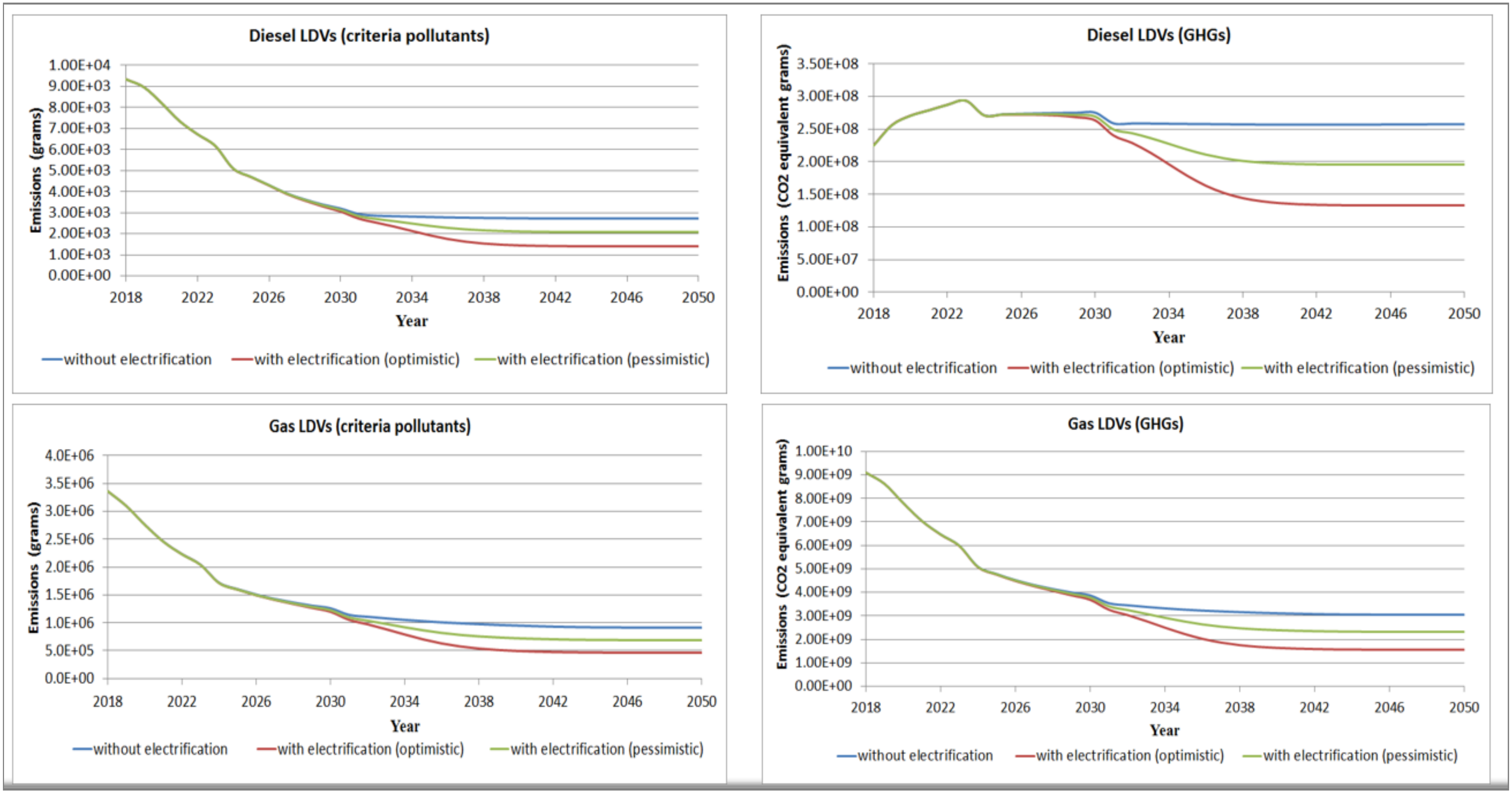
Total emissions change for DIESEL LDVs (65 mph)

Total emissions change for GAS LDVs (65 mph)



Impact on Criteria Pollutants and GHG Emissions

Cumulative reduction in emissions for diesel and gas LDVs from 2018-2050



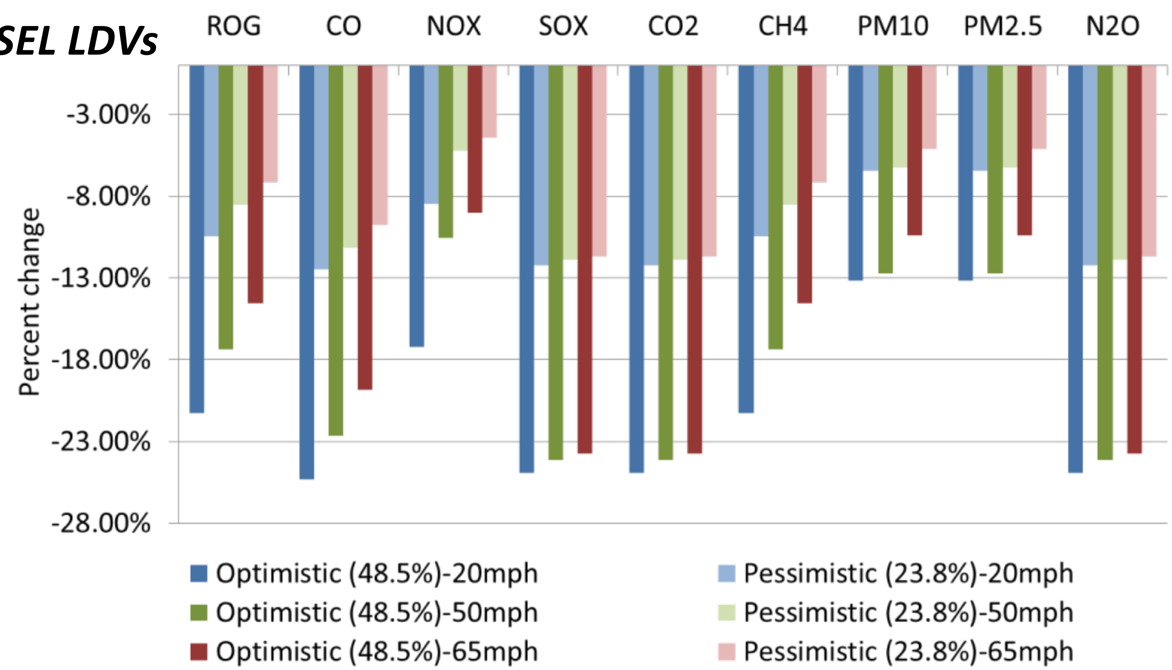
After 2030 emissions reduce at a slower rate (for all speeds and fuel types)

Impact on Criteria Pollutants and GHG Emissions

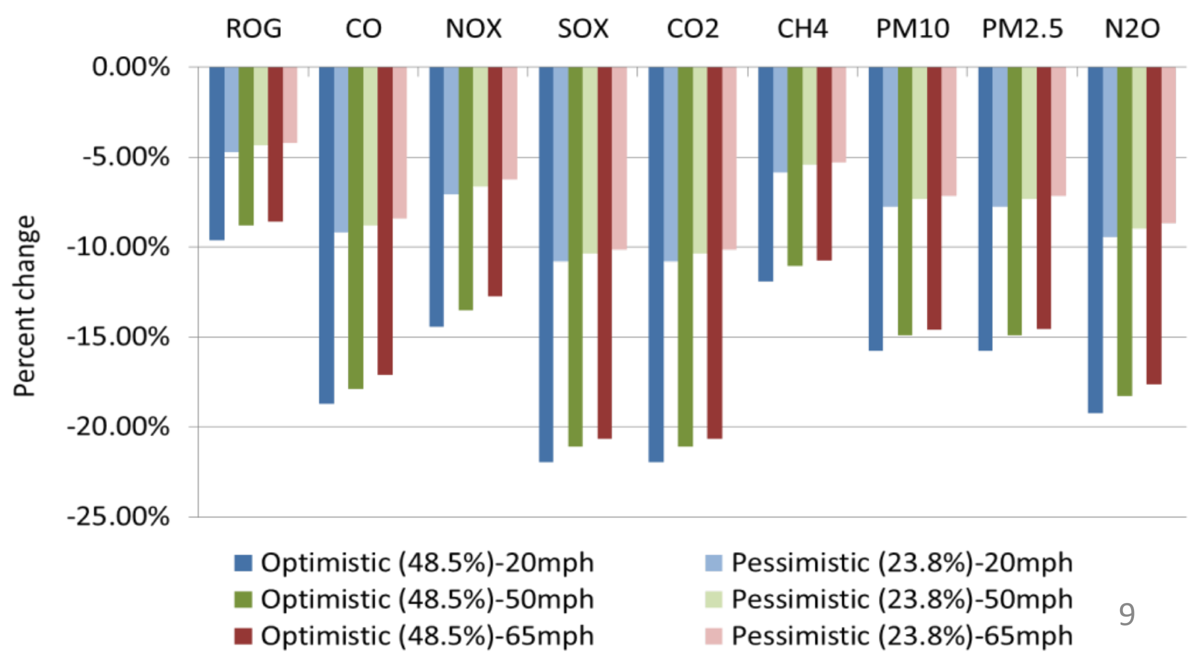
Sensitivity analysis: 50mph, 20mph

- Higher level of emissions change by pollutant for 50 mph and 20 mph
- 20 mph: greatest reduction in CO (diesel)
- 50 mph, 65mph: similar emissions trend

DIESEL LDVs



GAS LDVs



Preliminary Economic Analysis

INDOT Joint Transportation Research Program

SPR4314: Feasibility Study and Design of On-Road Electric Vehicle Charging Technologies for Indiana

Dionysios Aliprantis, Professor of Electrical & Computer Engineering (ECE)

Steve Pekarek, Dr. Edmund O. Schweitzer, III Professor of ECE

John Haddock, CE Professor & LTAP Director

Diala Haddad, PhD Student, ECE

Theodora Konstantinou, PhD Student, CE

Ethan Wright, Undergraduate Student, AAE

Project goals:

- Selection of candidate corridors/locations
- **Localized road construction cost estimation of technology**
- System development and design:

 -Interface with power utility and charging architecture

 -On-board power electronics and system design

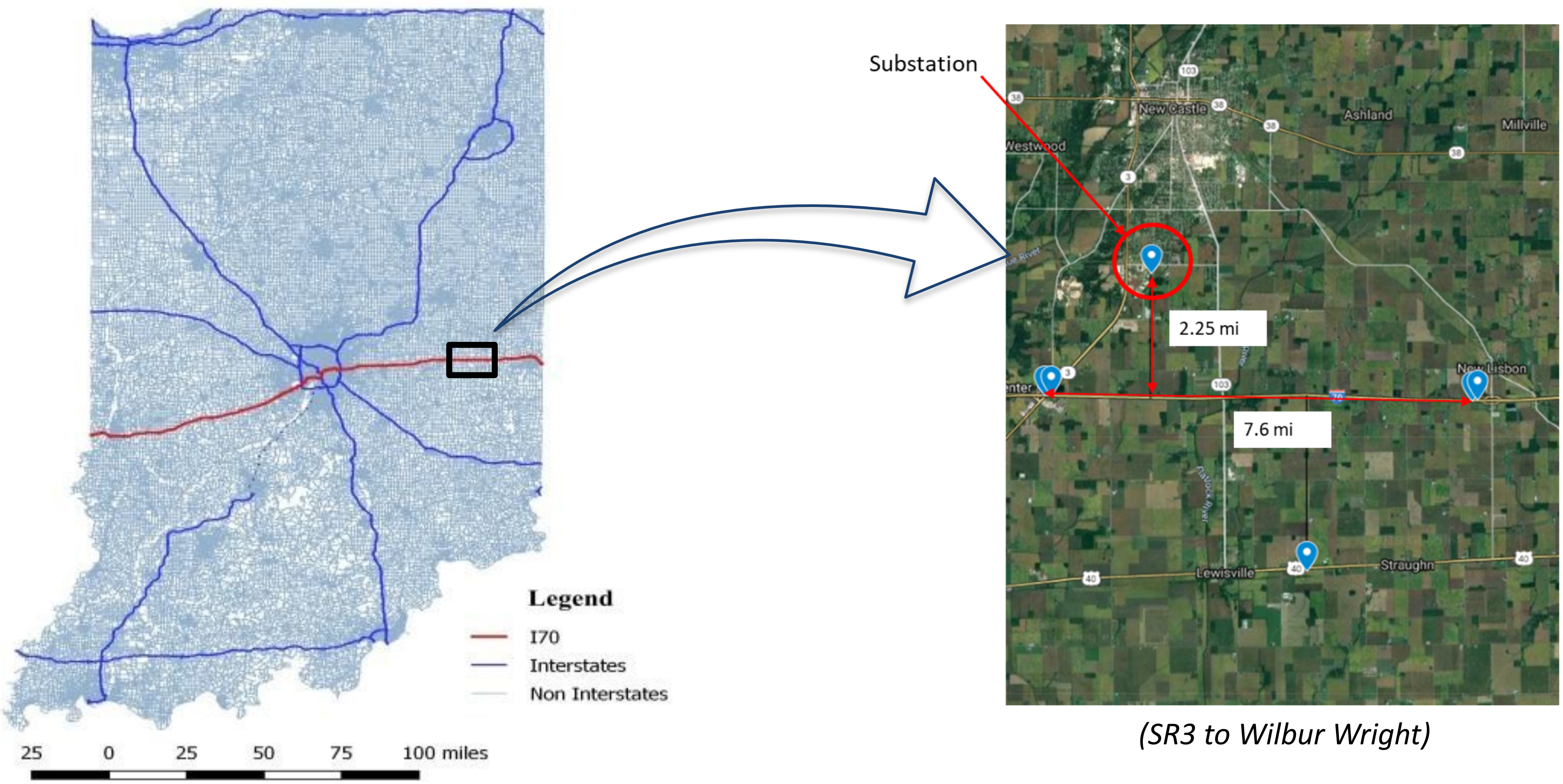
Preliminary Economic Analysis

- Main cost components: construction/pavement and electrical infrastructure

Focus on differential cost:

Cost of construction method (pre-cast panel) + cost of installing the electrical infrastructure

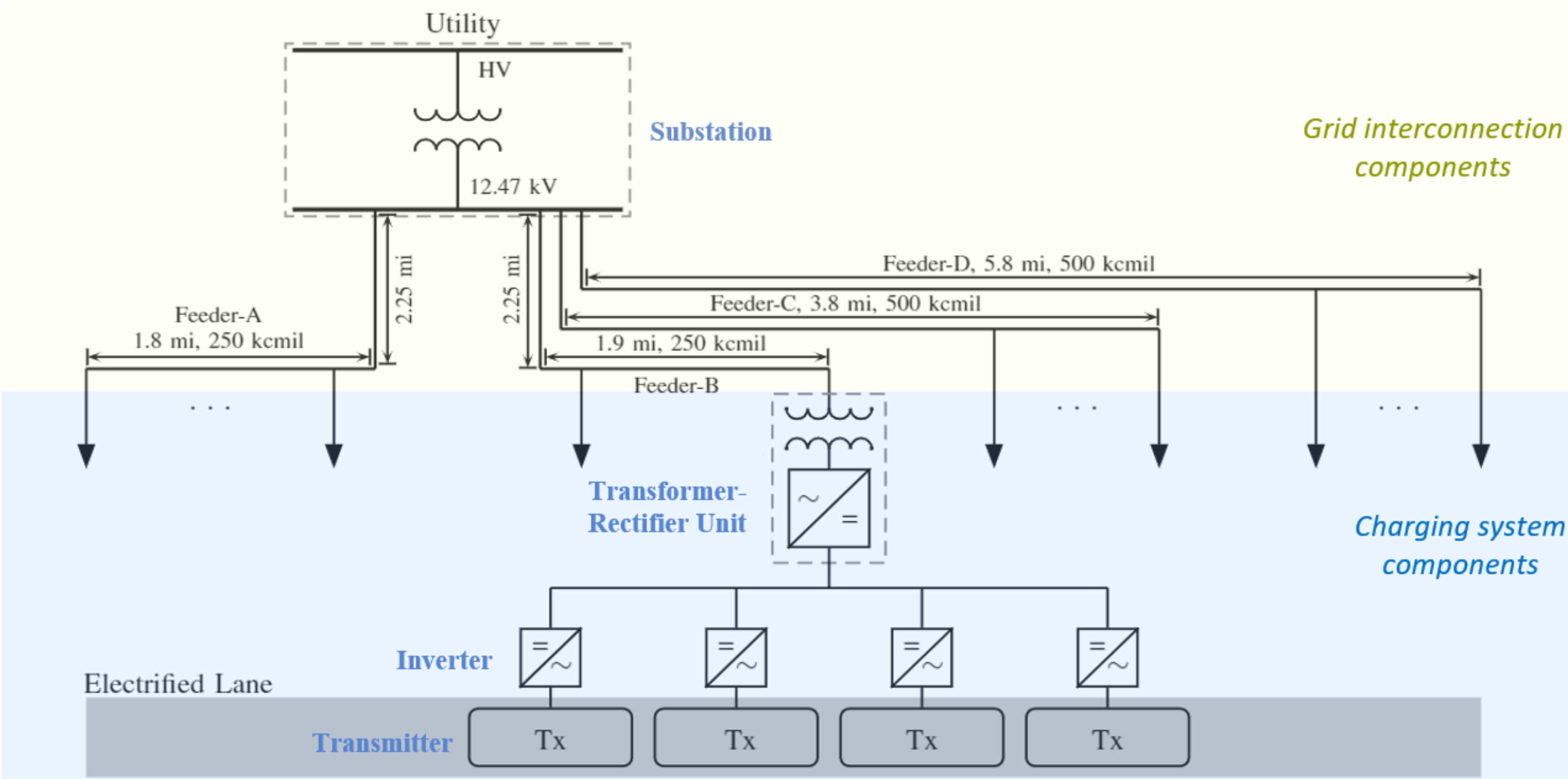
- Selection of one candidate road segment on I-70 in Indiana (high truck traffic)
  Focus on class-9 trucks



(SR3 to Wilbur Wright)

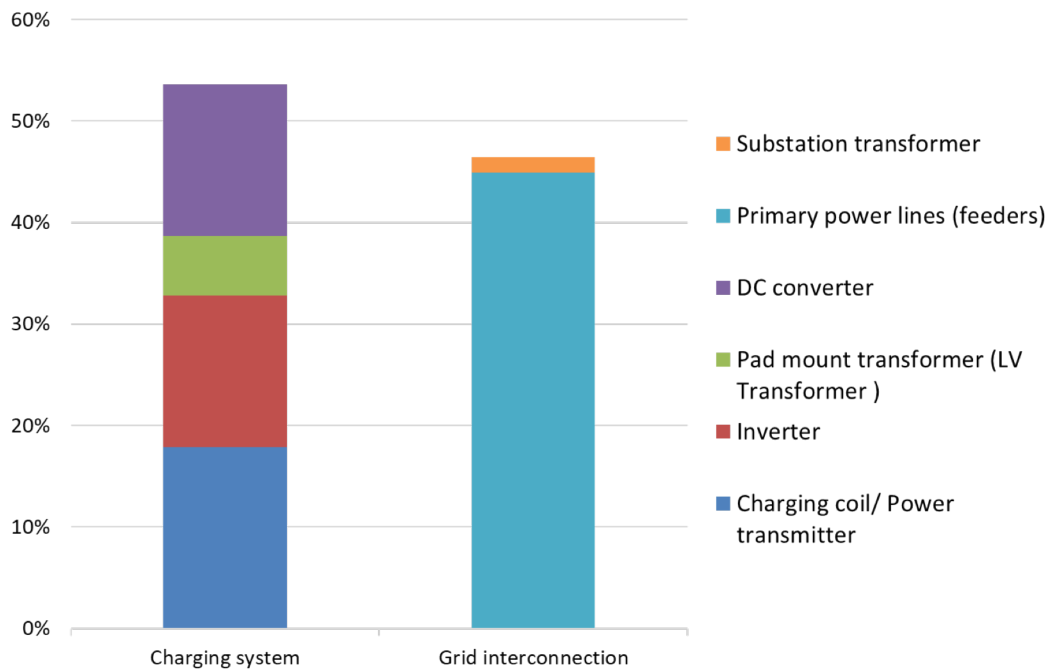
Preliminary Economic Analysis

Electrical Infrastructure Design

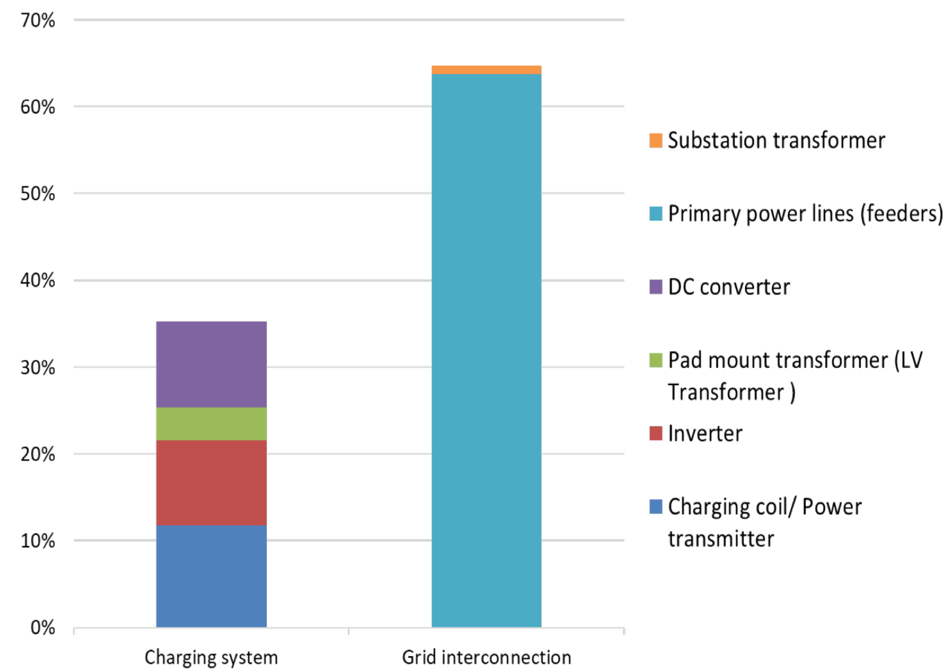


Preliminary Economic Analysis

- Cost shares by component



Underground cable installation



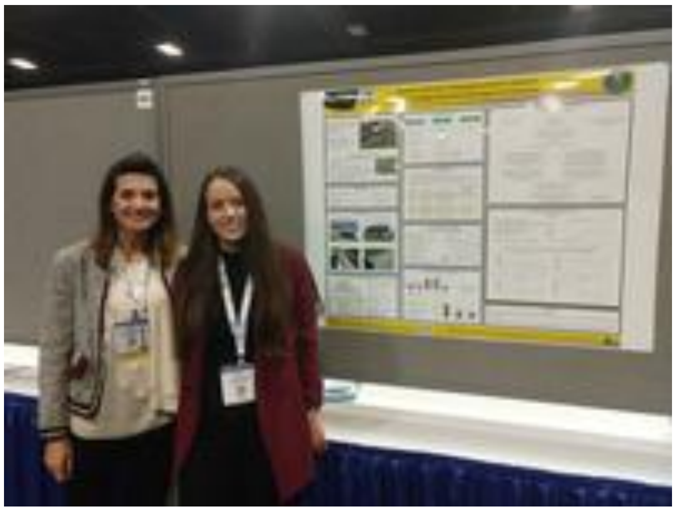
Overhead cable installation

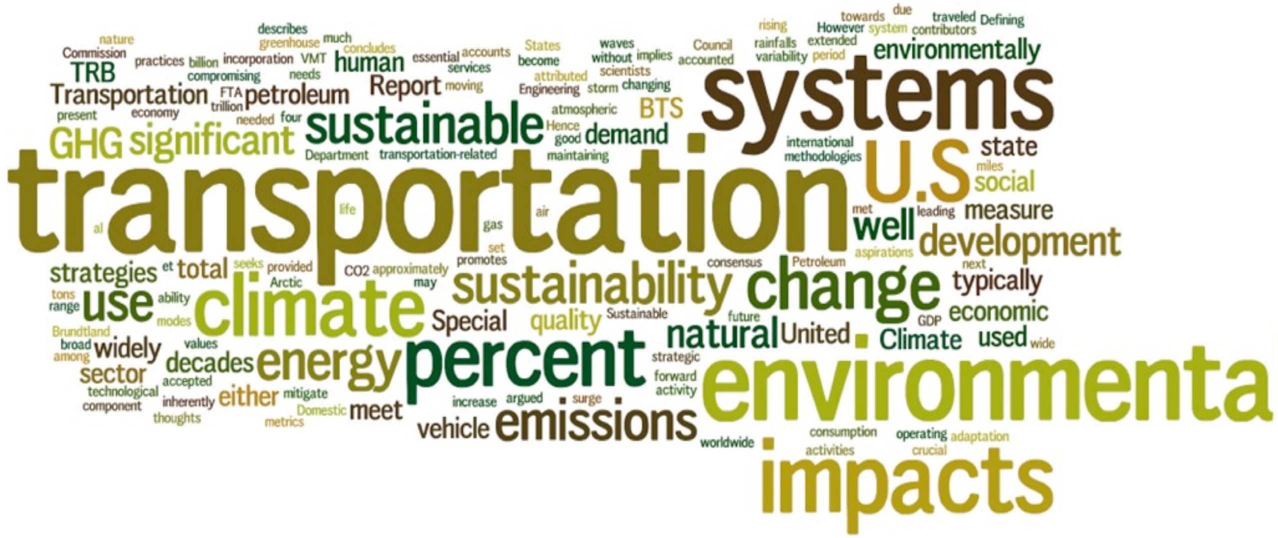
Type of cable installation	Total electrical costs ($ per mile)*
Underground	~4,900,000
Overhead	~3,250,000

**Assuming power of 300 kW for class 9 trucks (worst case), the specific system architecture and design of charging system*

Next Steps

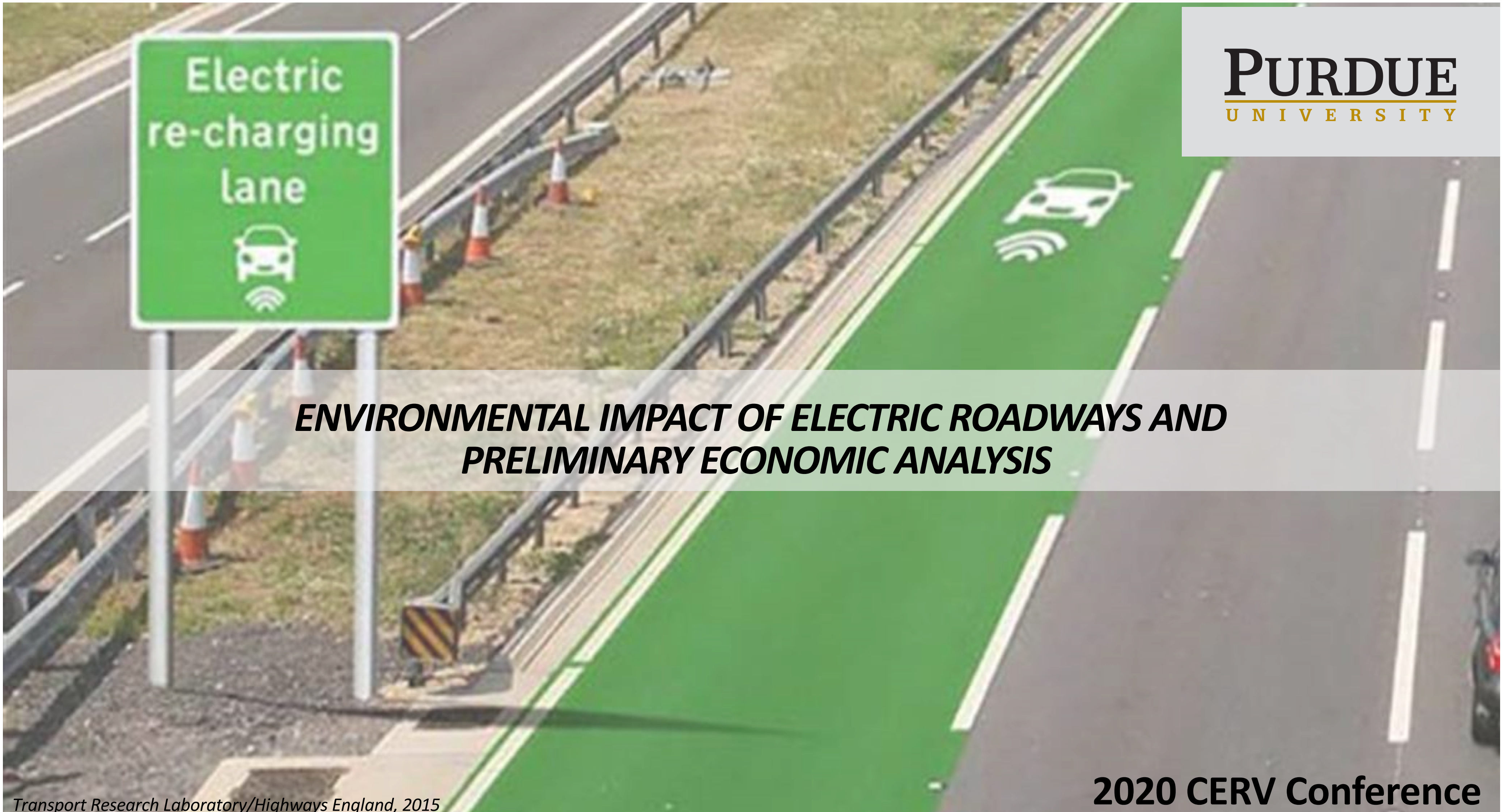
- Develop cost models as a function of ***power level***, ***design architecture***, ***location*** and ***distance from substations.***
- Calculate **project payback period**.
- Estimate conventional versus electric vehicle user **breakeven point**.
- Devise **strategies/policies** required to encourage penetration level to reach at minimum proposed levels.





https://engineering.purdue.edu/STSRG

Thank you!



PURDUE UNIVERSITY

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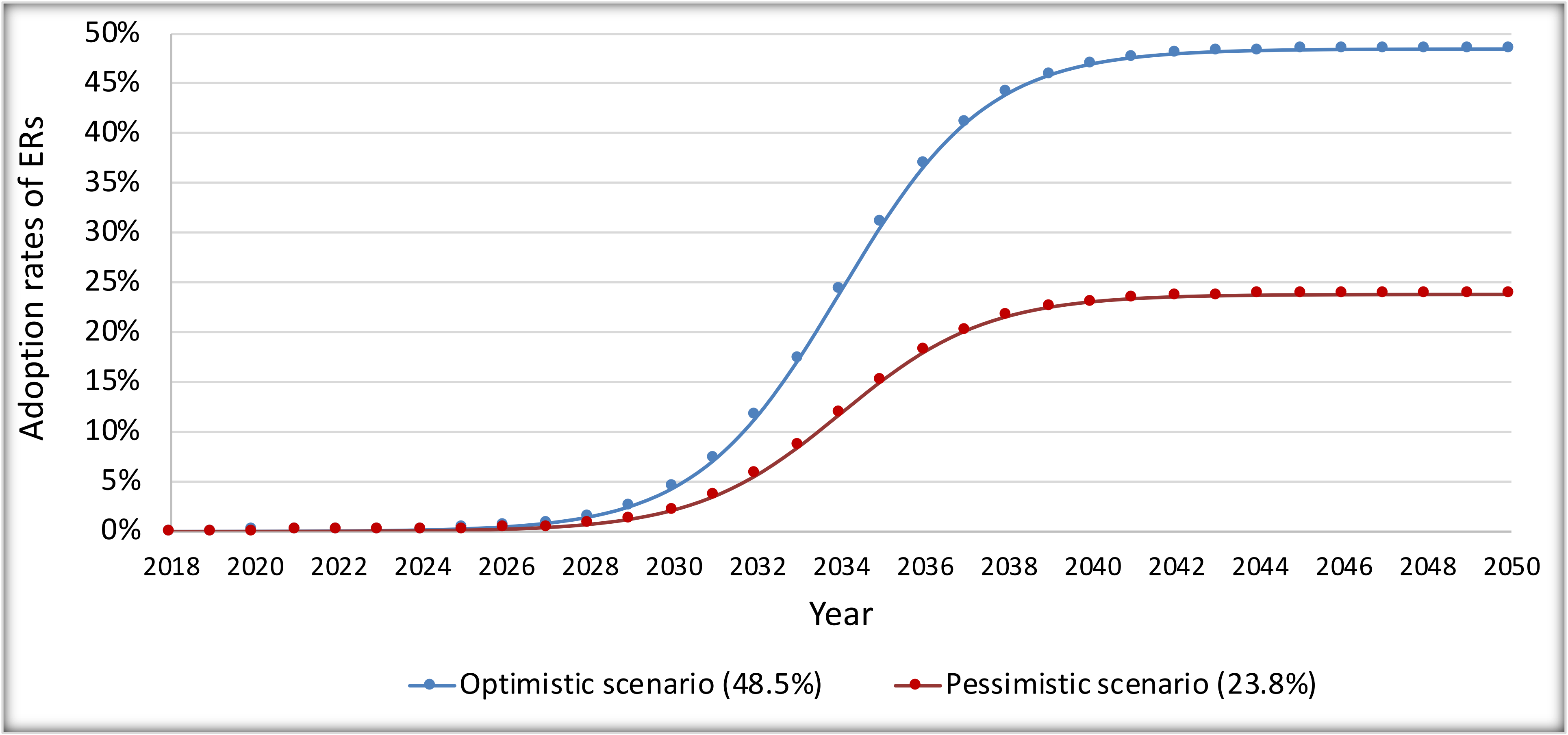
BACK UP SLIDES

Impact on Criteria Pollutants and GHG Emissions

- Adoption rates: cluster analysis

  S-curve



Projected ER penetration under two scenarios: "optimistic" (48.5% by 2050) and "pessimistic" (23.8% by 2050)

Impact on Criteria Pollutants and GHG Emissions

- Assumptions of analysis

Subject	Assumptions
Corridor	Corridor analysis/electrification of both directions
Type of emissions	ER infrastructure or vehicle manufacturing emissions not included Running exhaust emissions
Vehicle types	Light duty vehicles (LDV)/non-truck in EMFAC: -Passenger cars (LDA) -Light-duty vehicles with GVWR<6000 lbs and ETW≤3750 lbs (LDT1) -Light-duty vehicles with GVWR<6000 lbs and ETW 3751-5750 lbs (LDT2)
Pollutants and emissions	CO_2, CO, NO_x, ROG, $PM_{2.5}$, PM_{10}, N_2O, CH_4 and SO_x
Adoption rates	Both EV owners or not Percentage of people who will use ERs: early adopters (optimistic scenario)/late adopters (pessimistic scenario) VMT will be reduced by this percentage
VMT	VMT per capita will remain the same between the “without electrification” and “with electrification” scenarios

Impact on Criteria Pollutants and GHG Emissions

- California Air Resources Board's (CARB) 2017 EMissions FACtor model (**EMFAC**): *Tailpipe emissions/latest and most accurate data*

Data type	Source
Vehicle population	• California Department of Motor Vehicles • International Registration Plan etc.
Vehicle activity	• Metropolitan Planning Organizations • Bureau of Automotive Repair Smog Check Data • 2010-2012 California Household Travel Survey
Emissions factors	• US Environmental Protection Agency's In-Use Vehicle Program • CARB's Vehicle Surveillance Program • US government's source for fuel efficiency information • CARB's Truck and Bus Surveillance Program etc.
Change of sales and VMT	• Regression models (gas price, unemployment rate, disposable income, etc.): *California Department of Finance, US DOE Energy Information Administration, US Bureau of Economic Analysis etc.*
Regulations and policies	• Phase 2 GHG standards • Road Repair and Accountability Act of 2017 (Senate Bill 1) • Advanced Clean Cars

Impact on Criteria Pollutants and GHG Emissions

- "With" and "Without" electrification scenarios: 2018-2050

Subject	Assumptions
Corridor	Corridor analysis/electrification of both directions
Type of emissions	ER infrastructure or vehicle manufacturing emissions not included Running exhaust emissions
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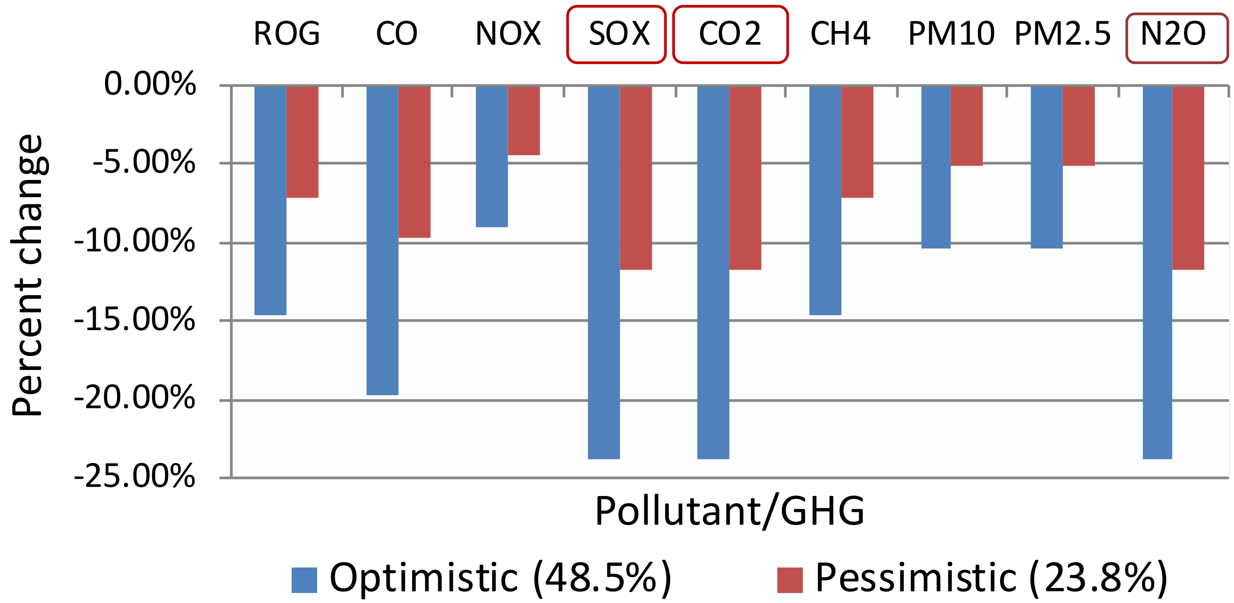
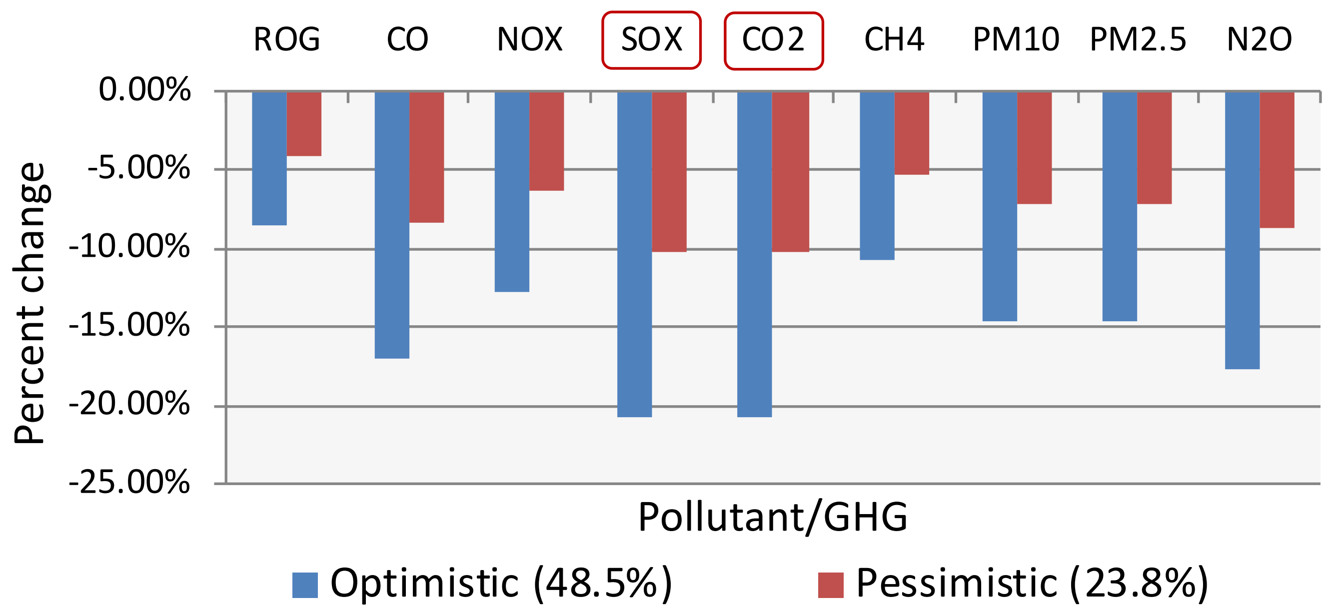
Impact on Criteria Pollutants and GHG Emissions

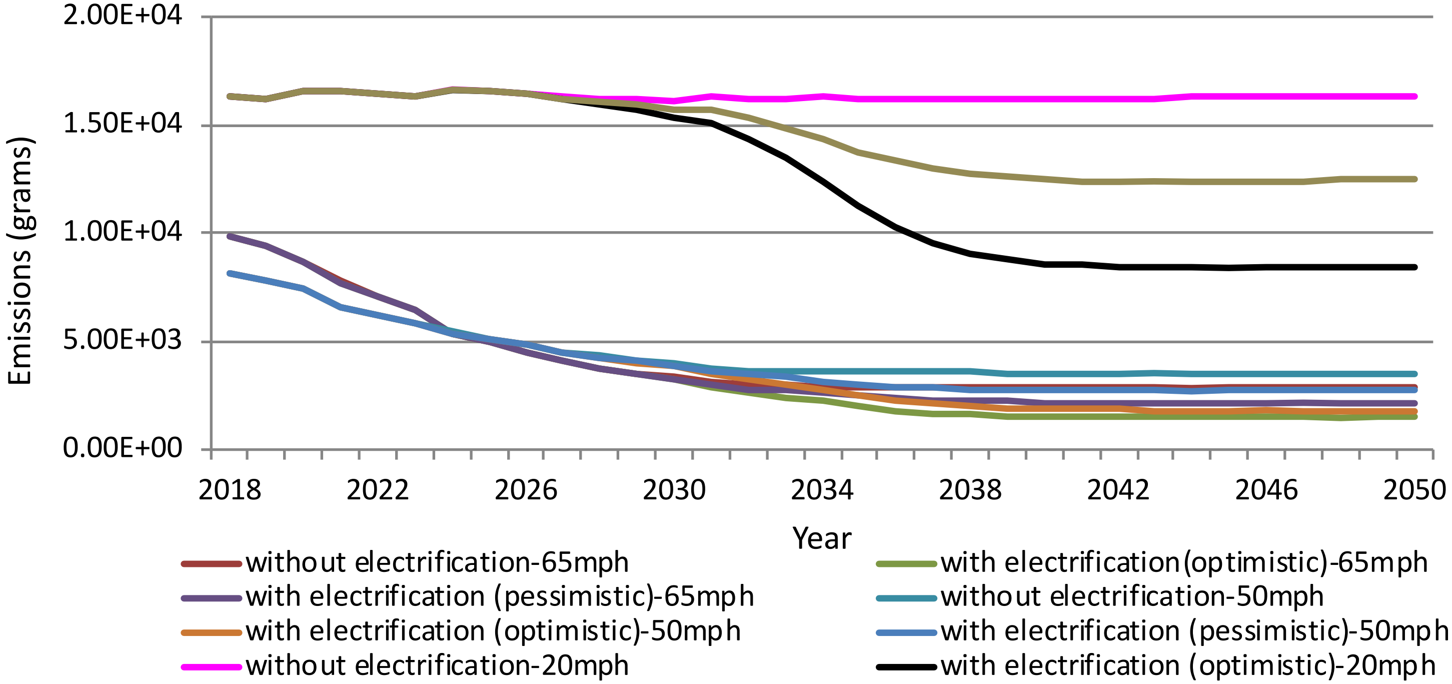


Total emissions change for DIESEL LDVs (65 mph)

Total emissions change for GAS LDVs (65 mph)

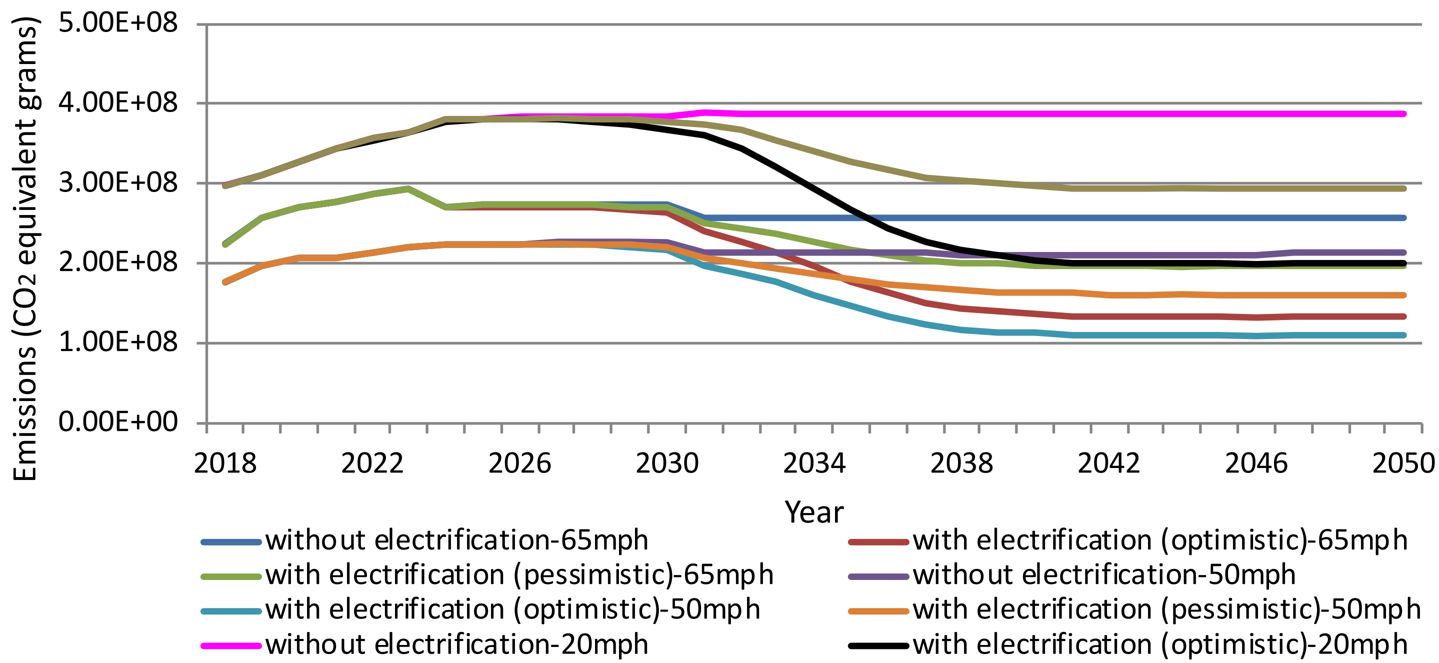


Impact on Criteria Pollutants and GHG Emissions

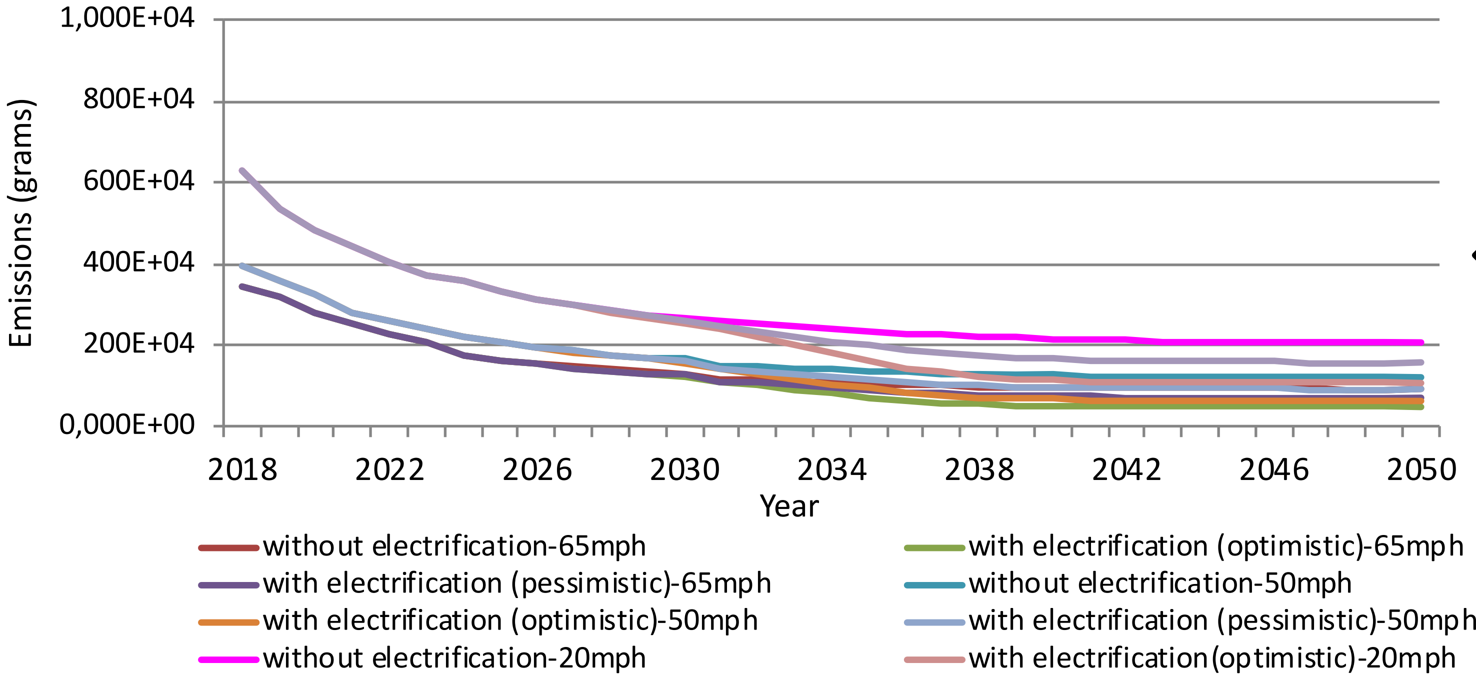


DIESEL criteria pollutants emissions (2018-2050)

DIESEL GHG emissions (2018-2050)

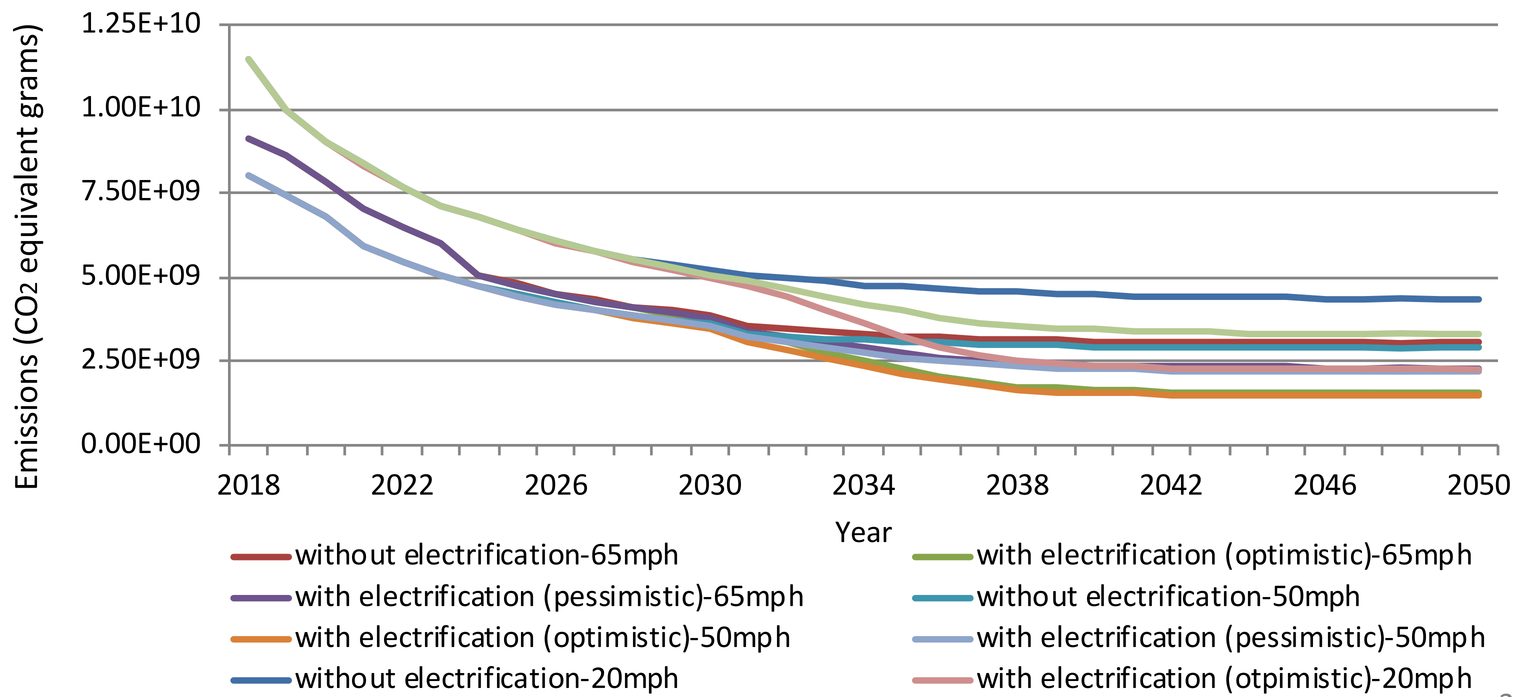


Impact on Criteria Pollutants and GHG Emissions



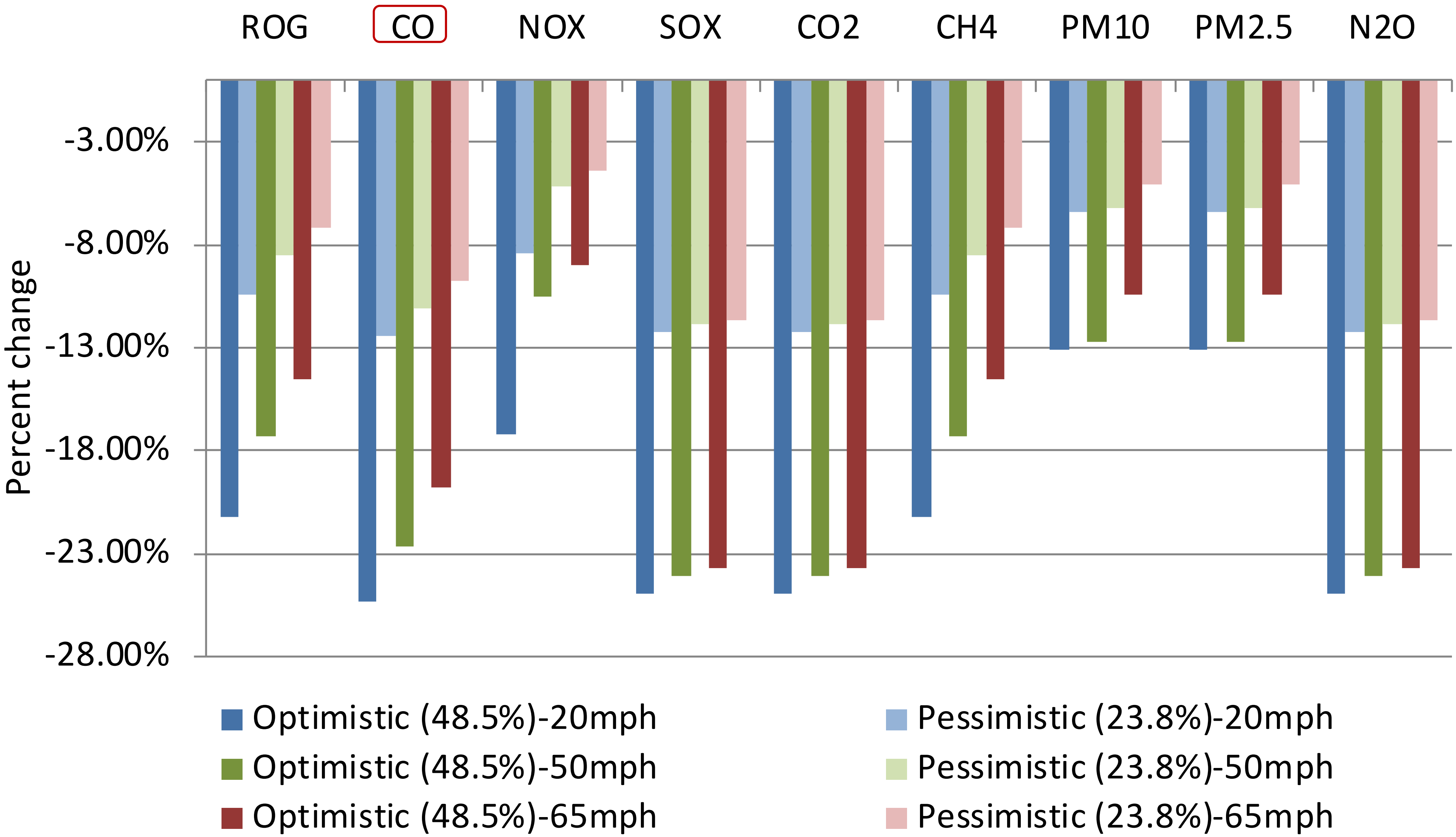
GAS criteria pollutants emissions (2018-2050)

GAS GHG emissions (2018-2050)



Impact on Criteria Pollutants and GHG Emissions

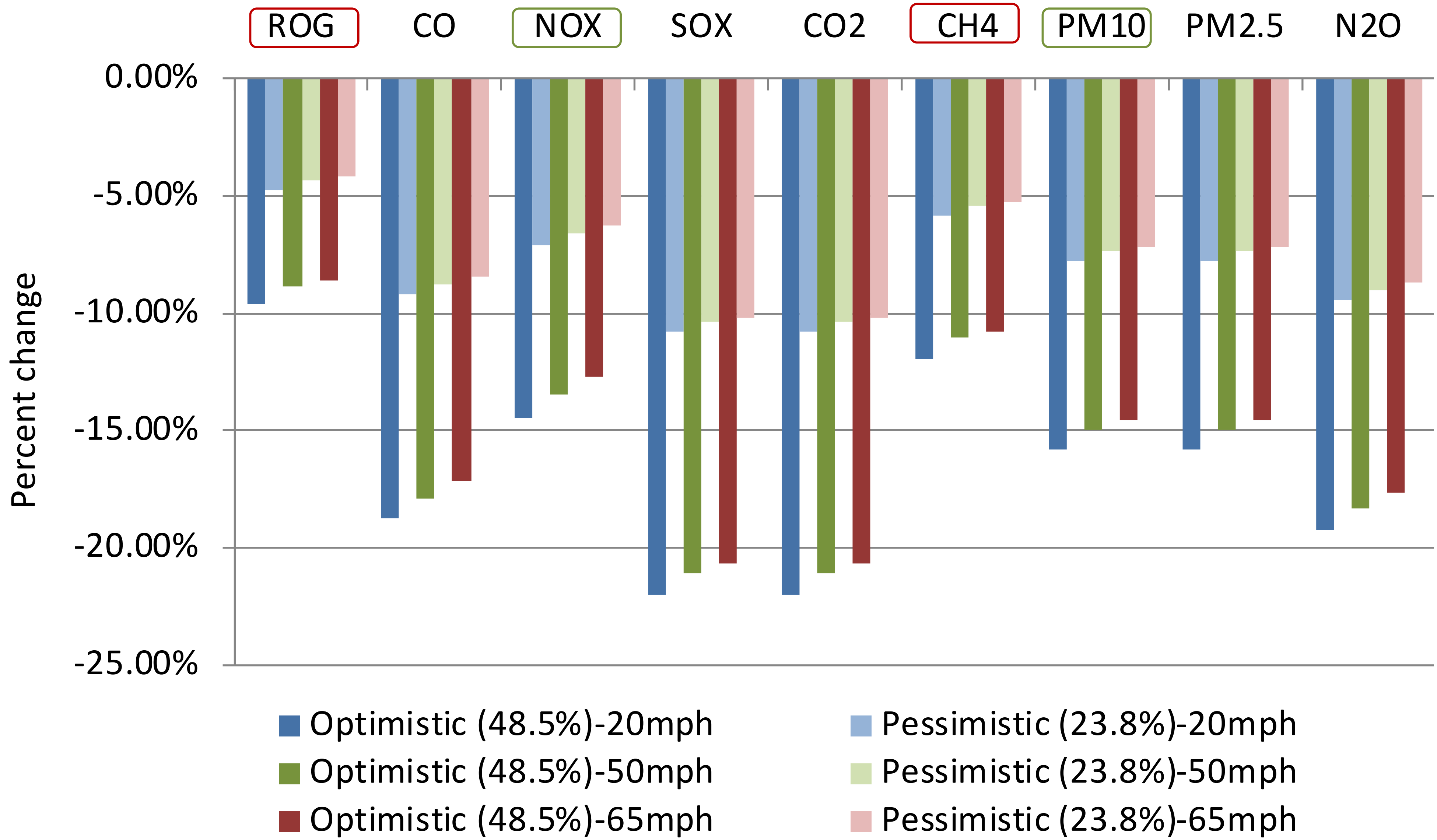
- Sensitivity analysis: 50mph, 20mph



Total emissions reduction in with electrification scenario across speeds for DIESEL LDVs

Impact on Criteria Pollutants and GHG Emissions

- Sensitivity analysis: 50mph, 20mph



Total emissions reduction in with electrification scenario across speeds for GAS LDVs

Market Adoption

- Cluster characteristics

	Early Adopters	Mid-Adopters	Late Adopters
Age	< 34 years old (40%)	35-44 years old (20%)	65 or above years old (24%)
Income	> $75,000 (48%)	$25,000-$50,000 (28%)	< $50,000 (50%)
Employment	53% work full time (8% are currently unemployed)	44% work full time (9% are currently unemployed)	32% work full time (12% are currently unemployed)
Vehicle ownership/annual mileage	45% own one vehicle and 4% do not own a vehicle/ 39% drove > 15,000 miles last year	41% own one vehicle and 11% do not own a vehicle/ 20% drove 5,000-10,000 miles last year	43% own one vehicle and 12% do not own a vehicle/ 19% drove > 15,000 miles and 17% < 5,000 miles last year
Ride-hailing services	34%	17%	4%
EV experience	37%	23%	14%
Charging behavior	Charging their EVs every day/at home	Charging their EVs few times per week/at work	Charging their EVs once per week/at home
Level of awareness on electro-mobility topics	Higher	Average	Lower