Costs & Emissions Implications of Controlled EV Charging

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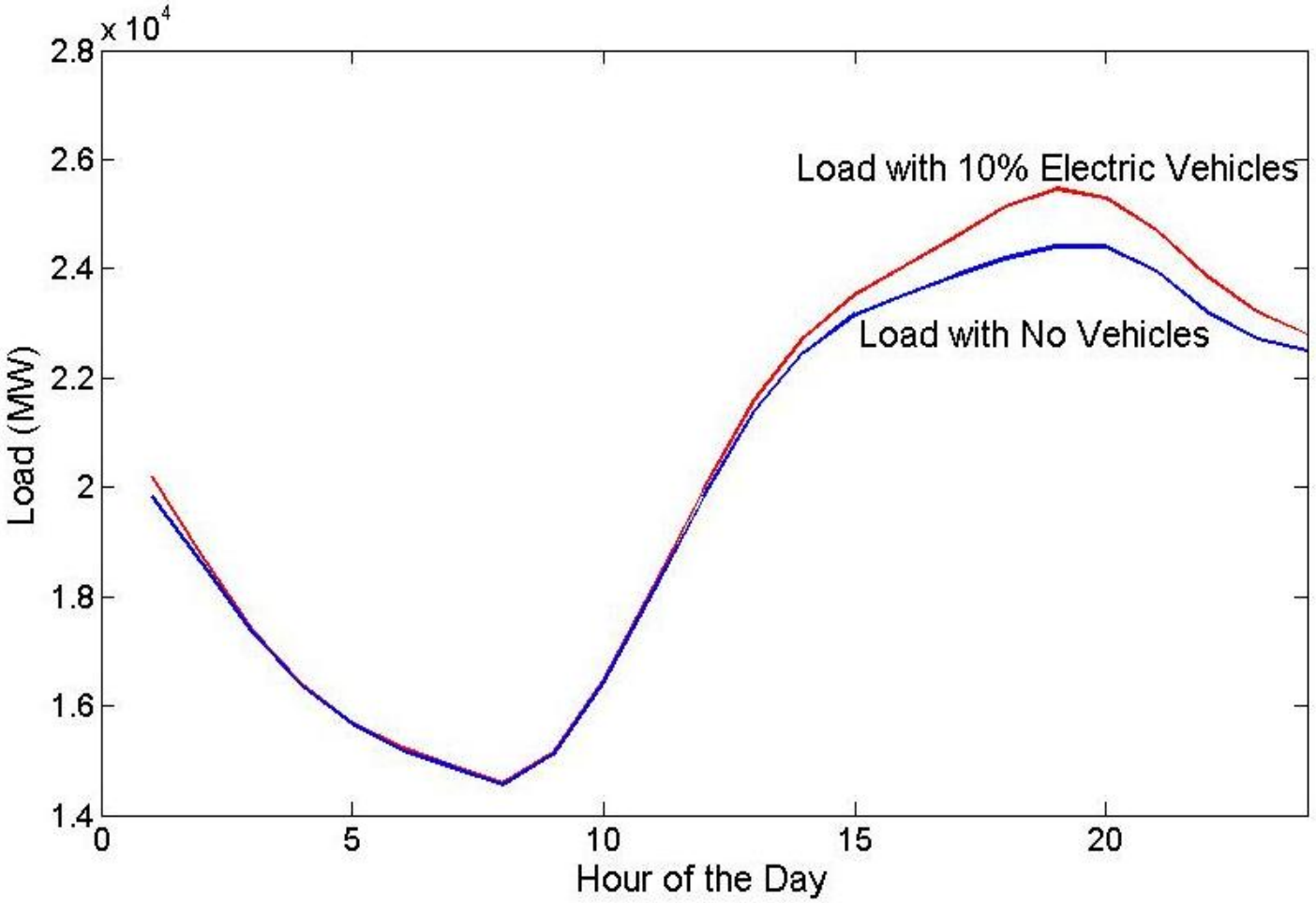
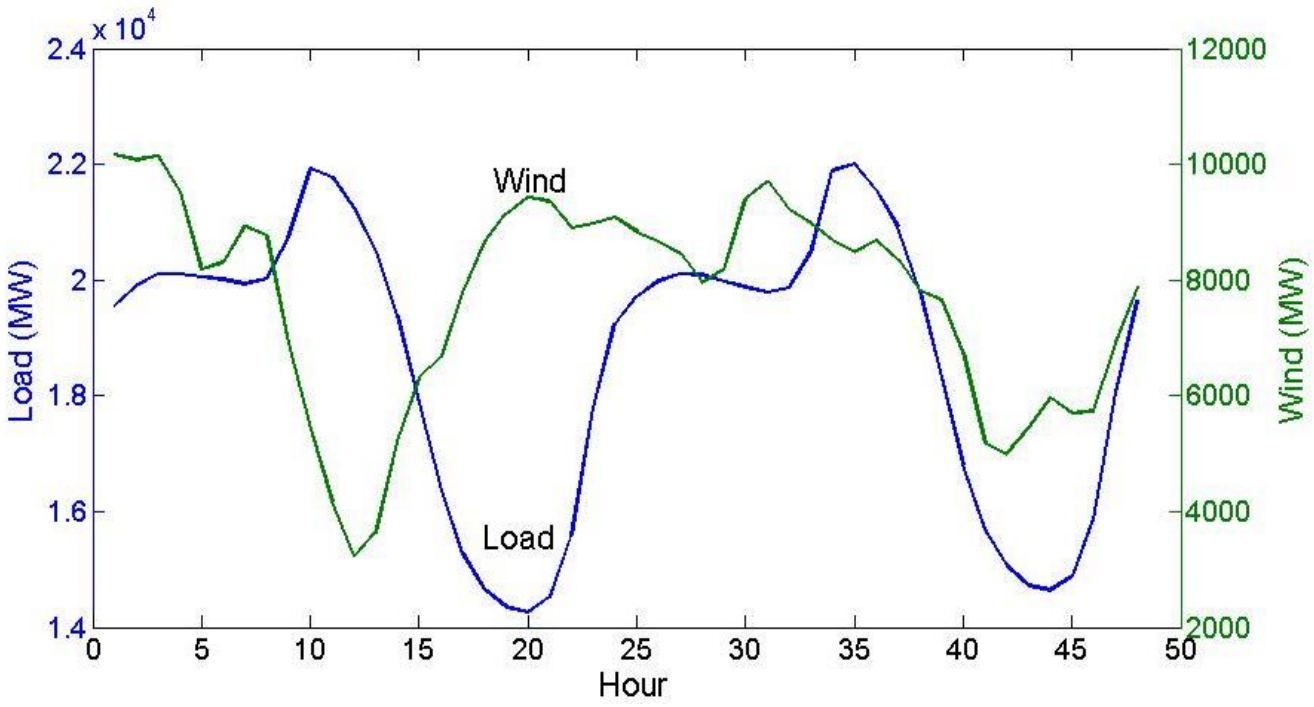
Motivation

- Electric vehicles are predicted to make up 2%-15% of the light-duty vehicle fleet by 2025 (EIA)



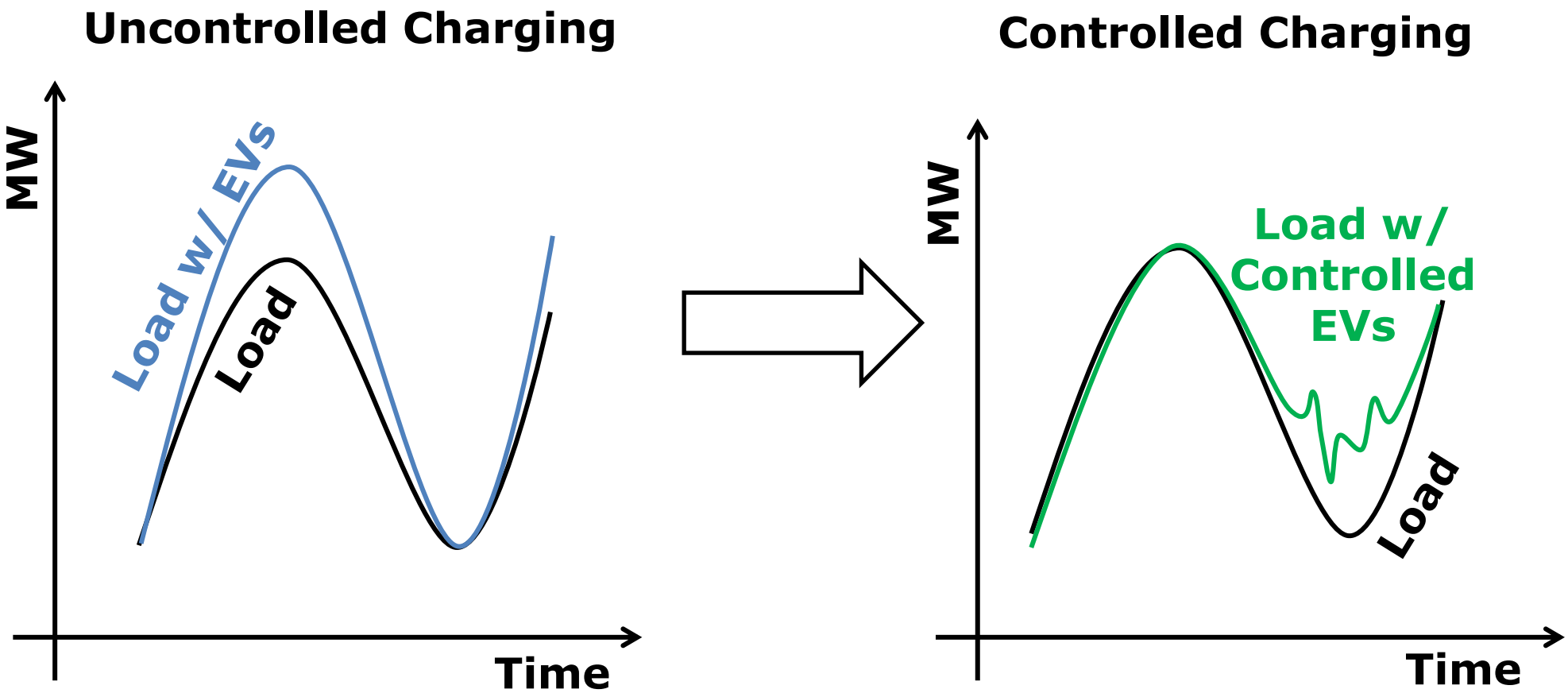
Motivation

- Electric vehicles are predicted to make up 2%-15% of the light-duty vehicle fleet by 2025 (EIA)
- Significant wind generation expected in states with Renewable Portfolio Standards
  - Fluctuations in wind generation will require additional grid flexibility



Controlled Charging of EVs

- Allow grid operator to modulate EV charging power to
  - Shift load
  - Modulate load (e.g.: to follow wind generation)



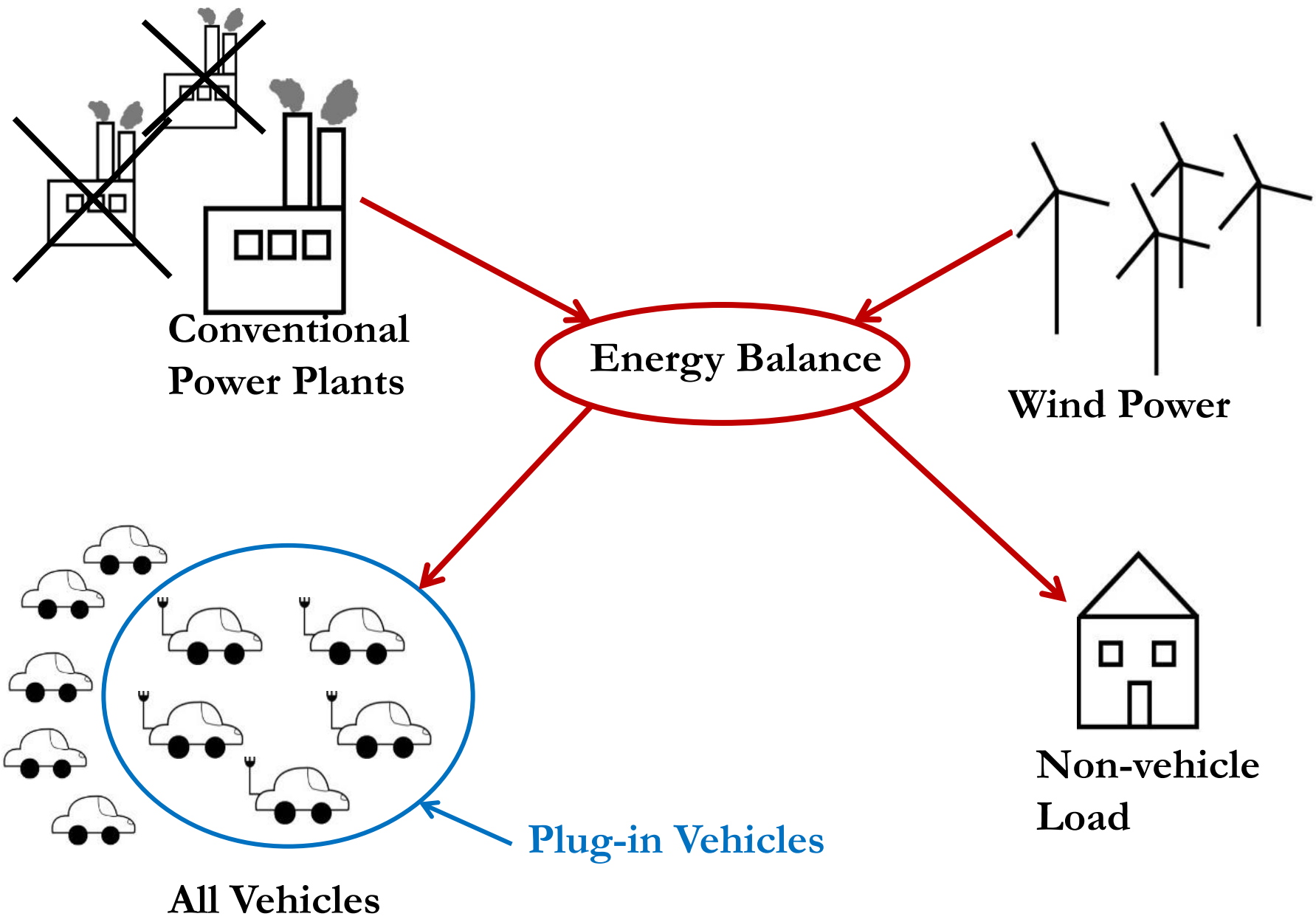
Research Question

- Can controlled charging reduce the impact of EV charging?
  - Operational costs
  - Emissions damages

Related Work

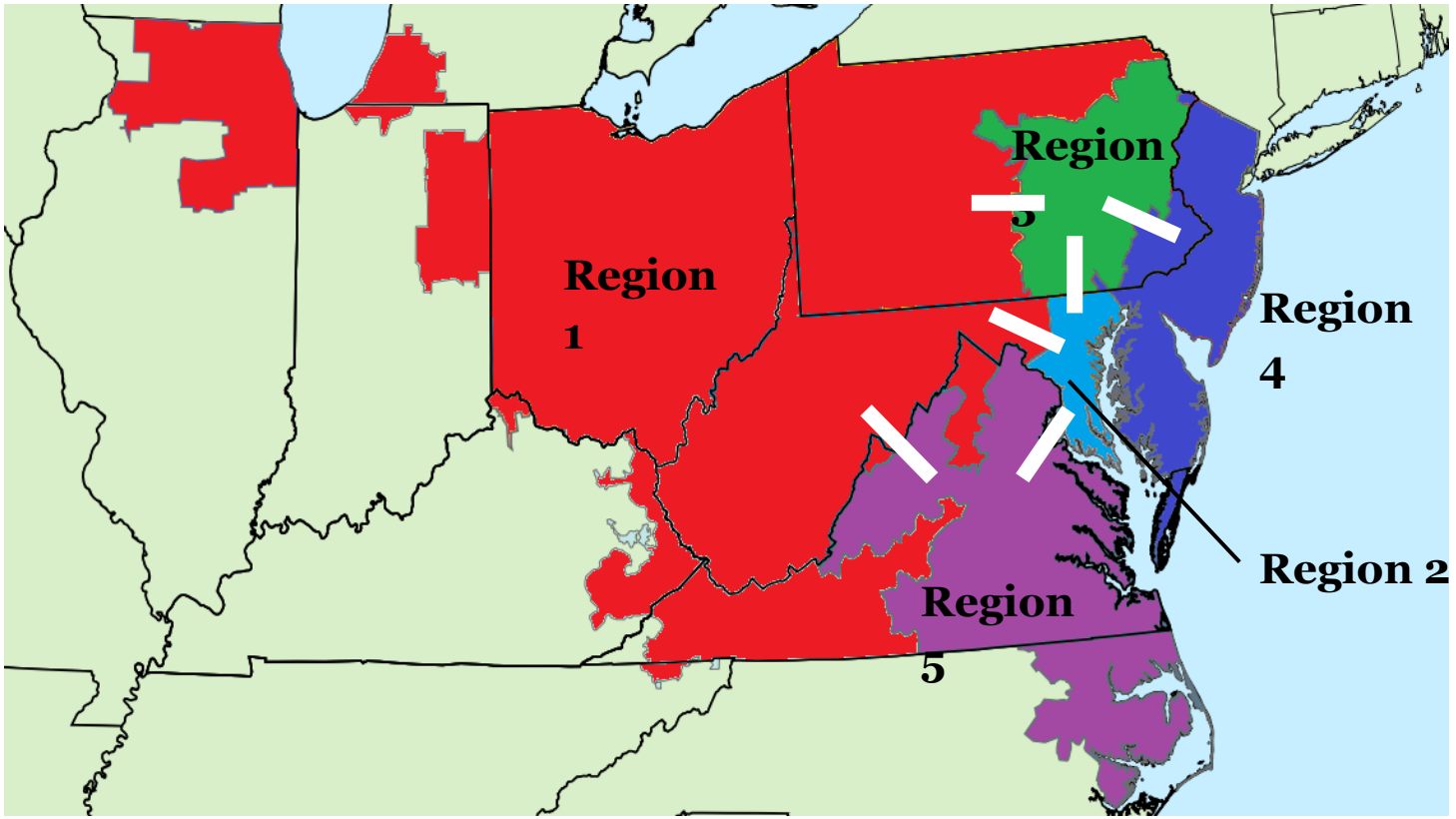
Author	Year	Power System	Scope	Power System Model	High Wind Scenario?	Emissions Considered	Calculation of damages?
Lund and Kempton	2008	Denmark	Charging emissions	Supply curve with min gen	Yes	CO_2	No
McCarthy and Yang	2010	California	Charging emissions	Supply curve	No	CO_2	No
Peterson et. al.	2011	PJM and NYISO	Charging emissions	Supply curve	No	CO_2, SO_2, NO_X	No
Choi et. al	2013	Eastern Interconnect	Life cycle emissions	Unit commitment & capacity expansion	Yes	CO_2	No
Weis et. al.		PJM	Charging emissions	**Unit commitment**	Yes	**CO_2, SO_2, $PM_{2.5}$, NH_3, NO_X, VOCs**	**Yes**

System Overview



Power System: PJM

- 2010 PJM power plants and 2010 fuel prices
- 5 transmission regions with power limited connections



Electric Vehicles

Vehicle	Battery Size
2012 Prius PHEV	4.4 kWh
GREET PHEV-35	16 kWh
2012 Tesla Model S	85 kWh

- National Household Travel Survey trip data
  - Uncontrolled charging based on all passenger vehicles
  - Controlled charging based on 20 representative profiles
- Drive as many miles as possible in electric mode
- Charge at home at the end of the day
- Full charge for the first trip of the next day

Model

- MILP: Minimize system cost with a unit commitment and economic dispatch model (perfect information)

$$\text{minimize} \sum_{\text{time}} \sum_{\text{plants}} (\text{Fuel Costs} + \text{Startup Costs} + \text{Shutdown Costs})$$

Subject to:

- Generation = Load
- Spinning and non-spinning reserves
- Power plant constraints
  - Minimum and maximum generations levels
  - Ramp-rate limits
  - Minimum runtime and downtime
- Vehicle battery charging
  - Battery state of charge
  - Charge rate limits
- Transmissions constraints

Air Pollutant Damages

- APEEP2 model used to estimate & monetize air pollutant damages

Pollutants Considered

- SO_2
- NO_X
- VOCs
- PM 2.5

Damages Considered

- Health problems
- Reduced agricultural yields
- Reduced visibility
- Lost recreational services
- Depreciation of man-made materials

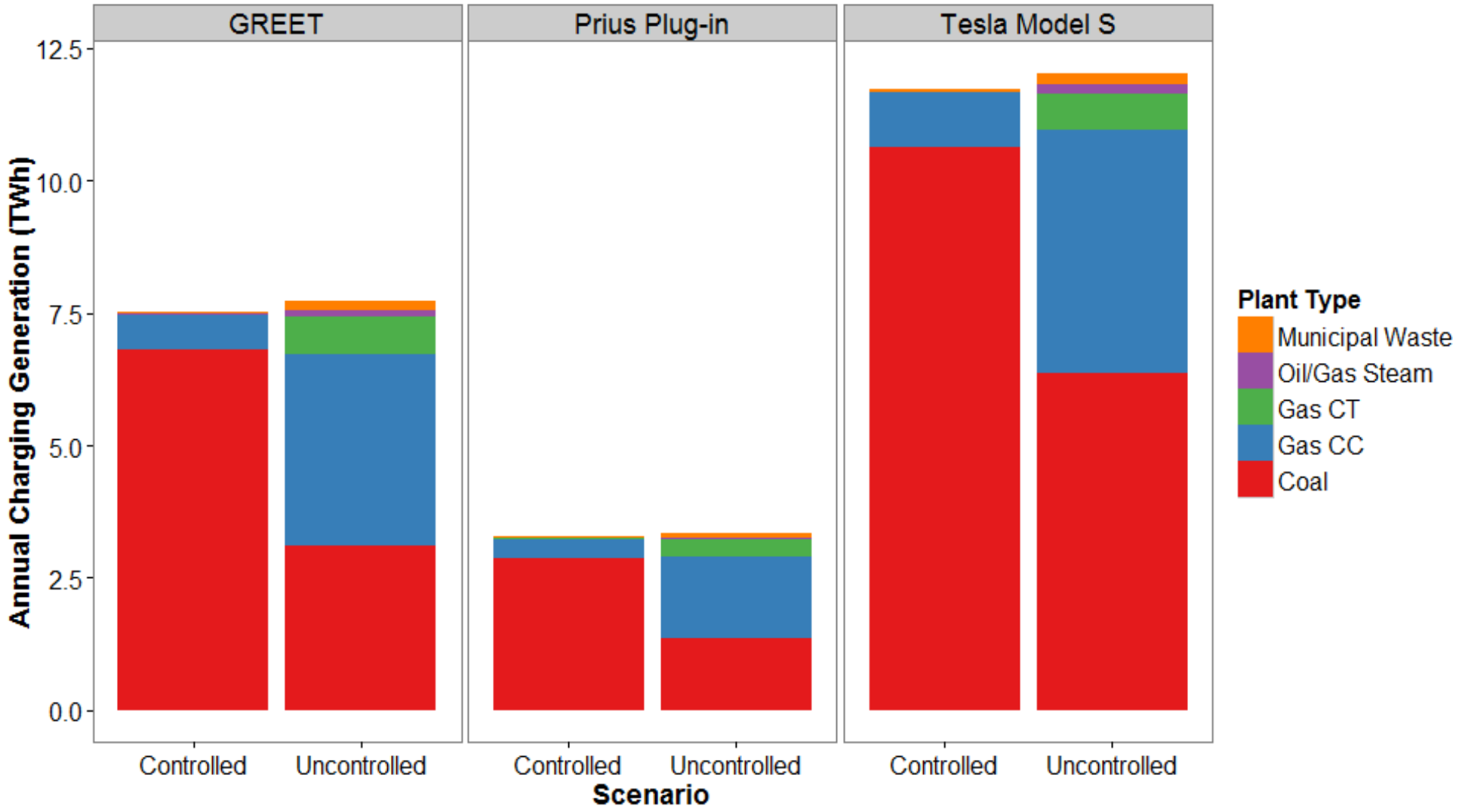
Cntrl Chrg: Cuts EV charging cost

- Results:

Reduction in Annual Power System Generation Costs due to Controlled Charging

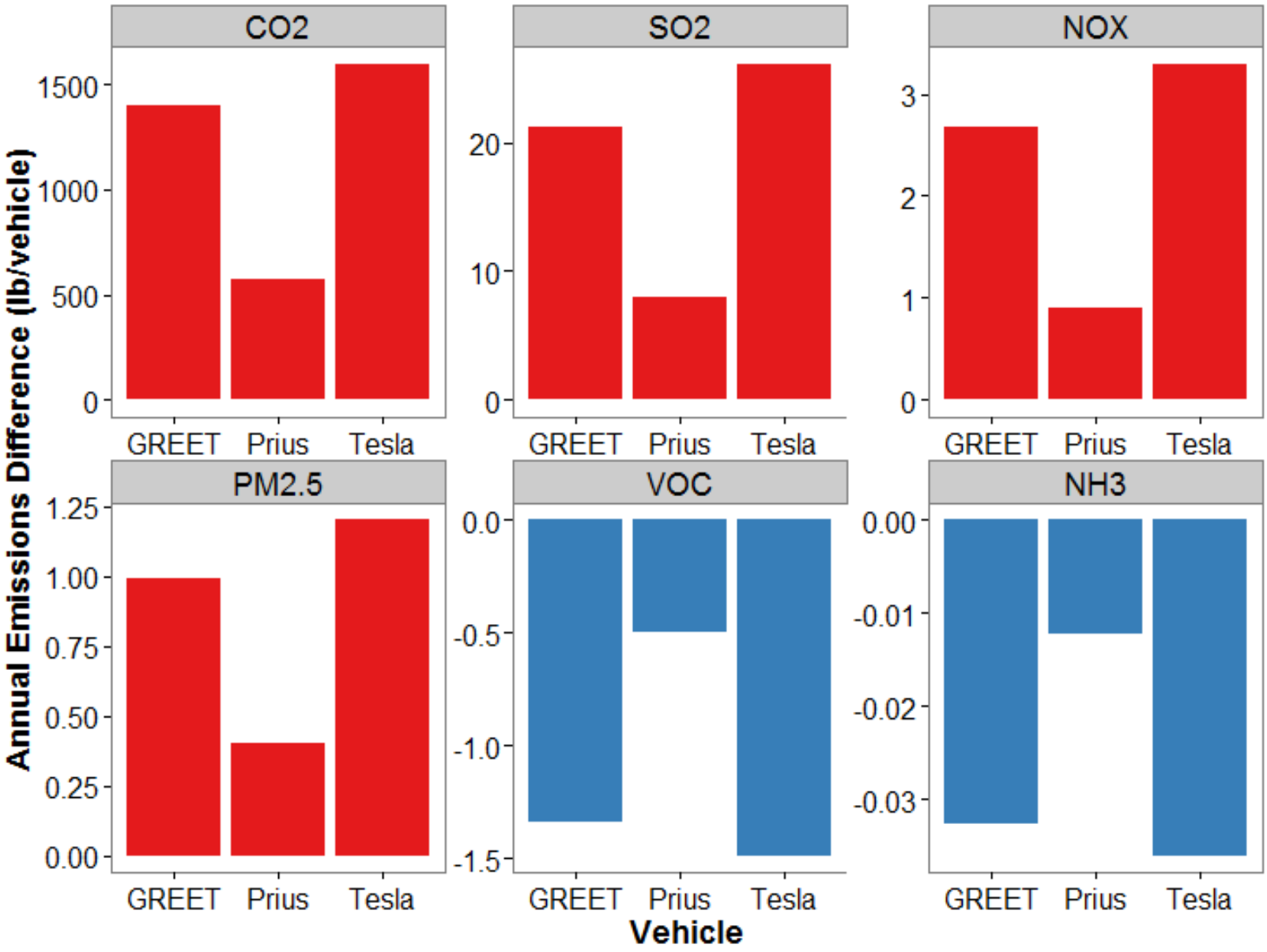
	$ Per Vehicle Per Year	% of Electricity Generation Cost
Prius PHEV	$22	30%
GREET PHEV35	$54	32%
Tesla Model S	$58	24%

Cntrl Chrg: More coal, less gas



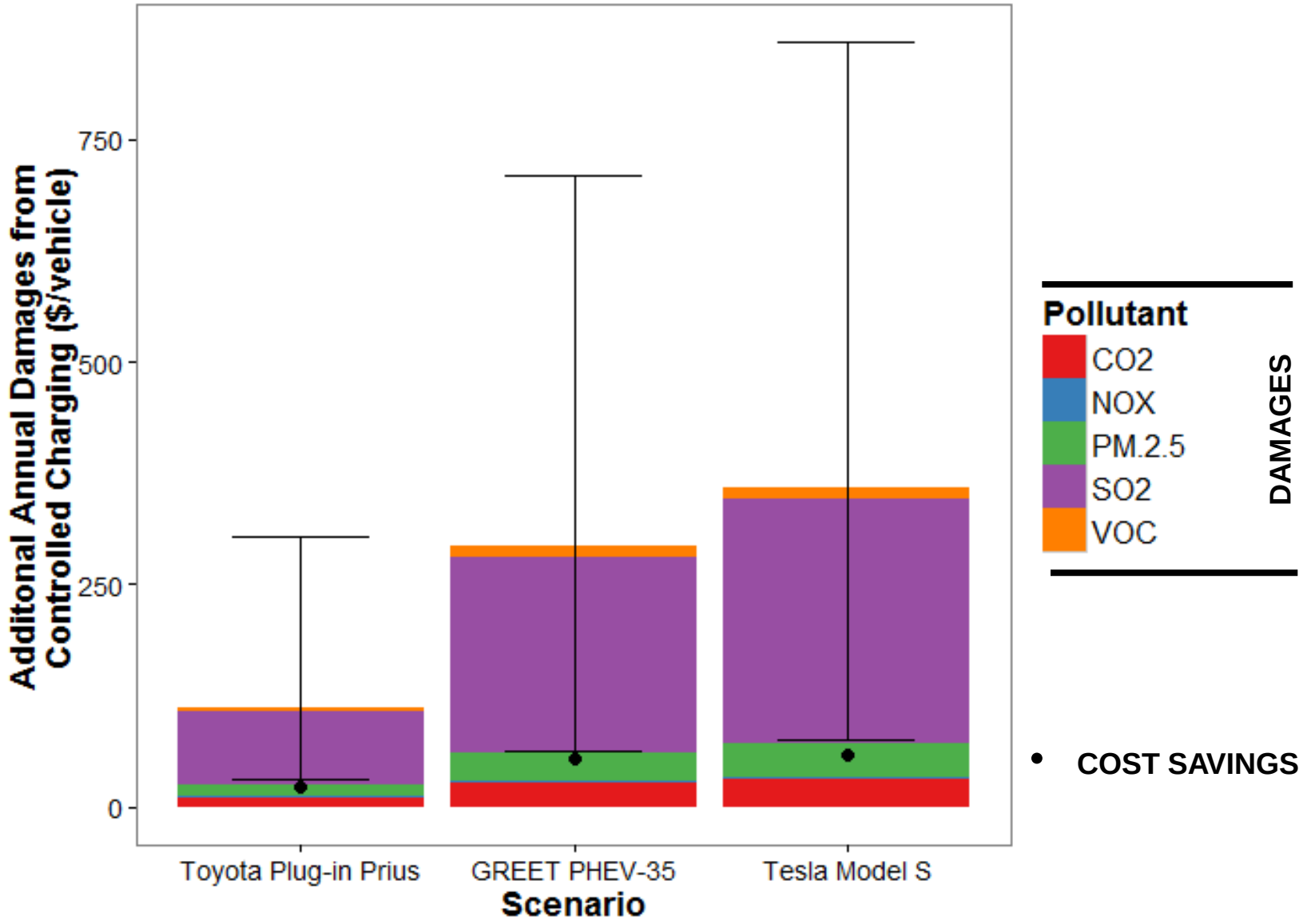
Cntrl Chrg: Increases most pollutants

Change in emissions due to controlled charging (vs. uncontrolled charging)



Damages are larger than cost savings

Change in damages due to controlled charging (vs. uncontrolled charging)



Key Findings – PJM

- Controlled charging cuts the costs of generating electricity to charge EVs by 20%-30%
- But, controlled charging changes the emissions resulting from vehicle charging
  - Increases CO_2, SO_2, PM, NO_X
  - Decreases VOC, NH_3
- And the resulting emissions damages are larger than cost savings
  - Suggests policy should not encourage controlled charging in PJM
  - This could change with a cleaner grid (ongoing work)

Acknowledgements

Funding by:

- Doris Duke Charitable Foundation
- Richard King Mellon Foundation
- Electric Power Research Institute
- Heinz Endowment
- National Science Foundation CAREER Award #0747911
- Toyota Motor Corporation
- National Science Foundation Graduate Research Fellowship Program
- Carnegie Mellon Electricity Industry Center through the RenewElec project