Understanding the Health and Climate Change Co-Benefits from Fuel-Vehicle Pathways

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Air emissions impacts

- Road transportation is the largest contributor to CO_2 emissions in the U.S.
- Road transportation accounts for significant fractions of PM and ozone precursor emissions in the U.S. (>50% CO and NO_x; ~25% VOC).
- Annual health and climate change damages caused by on-road vehicles are around $110 billion in year 2005 (National Academy of Sciences, 2010).

Research questions

- What are the **life cycle climate change damages and air pollution damages** from existing and alternative fuel-vehicle pathways for representative light-duty vehicles and heavy-duty vehicles in the U.S.?
- How sensitive are the results to **value of a statistical life (VSL)** and **social cost of carbon (SCC)**?
- Are there **trade-offs** between climate change mitigation and air pollution mitigation from fuel switching strategies?

Research findings

The 'best' fuel-vehicle pathway to reduce climate change damages and air pollution damages varies by county and by vehicle type (Figure 2).

- **Cars, SUVs, and buses**: western U.S. and New England regions: electric vehicles; Atlantic, Midwest, and South regions: hybrid-electric vehicles.
- **Freight trucks**: west coast: CNG or LNG trucks; New England, Midwest, and Atlantic regions: CNG trucks; Rocky Mountains and South: hybrid-electric trucks.

Value of a statistical life (VSL) and social cost of carbon (SCC) have large impacts on the life cycle damages of technology-fuel pathway (Figure 3).

- Both VSL and SCC are highly uncertain and are subject to the stakeholders.
- **Light-duty vehicles (cars and SUVs)** are insensitive.
- **Heavy-duty vehicles (buses and freight trucks**) are very sensitive.

Trade-offs between climate change mitigation and air pollution mitigation due to fuel switching strategies are found for heavy-duty vehicles (Figure 3).

- **Light-duty vehicles** generally see co-benefits – the same fuel-vehicle pathway reduces both climate change damages and air pollution damages.
- **Heavy-duty vehicles** are prone to conflicts between climate change mitigation and air pollution mitigation goals.

Research Methods

Part 1 Bottom-up life cycle emissions inventory

- **Air emissions**
  - Greenhouse gas (GHG): CO_2, CH_4, N_2O.
  - Criteria air pollutant (CAP): $PM_{2.5}$, CO, SO_2, NO_x, VOCs.
- **Fuel-vehicle pathways**
  - Cars and SUVs: gasoline, gasoline hybrid, CNG, and electric vehicles.
  - Transit buses: diesel, diesel hybrid, CNG, and electric vehicles.
  - Heavy-duty trucks: diesel, diesel hybrid, CNG, and LNG .
- **Metrics**
  - Functional unit: vehicle mile travelled (VMT).
  - Reference year: 2014. Monetary unit: $2010.

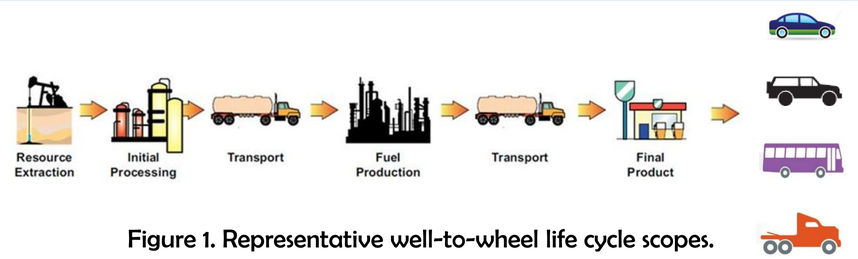

Figure 1. Representative well-to-wheel life cycle scopes.

Part 2 Marginal damages framework

$$\text{Air Pollution Damages (Species, Location, Height)} \simeq \begin{pmatrix}\Delta\text{Mortatlity Rate} \\ \text{by } \Delta PM_{2.5}\end{pmatrix} \times \text{Exposed Population} \times \text{VSL}$$

$$\text{Air Pollution Damages (Fuel - Vehicle Pathway)} = \textit{function}(\text{CAP Emissions} \times \text{Air Pollution Damages, for Species, Location, Height})$$

$$\text{Climate Change Damages (Fuel - Vehicle Pathway)} = \text{GHG Emissions} \times \text{Social Cost of Carbon}$$

- We use EASIUR and AP2 models to estimate marginal damages at county levels.

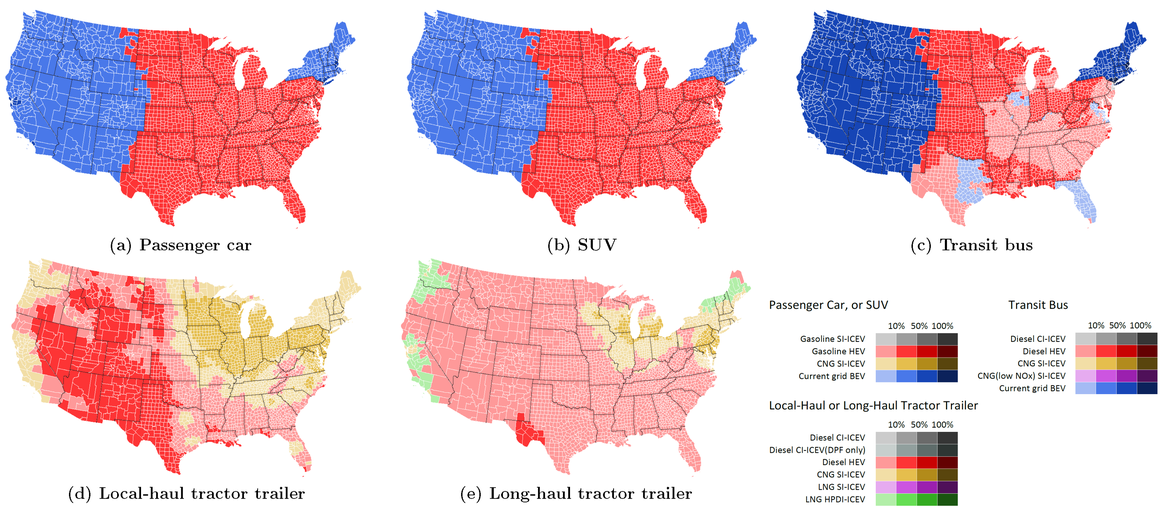

Figure 2. Fuel-vehicle pathways that achieve the lowest climate change damages and air pollution damages in each county. Color shades represent ranges of relative differences between the lowest damages and the 2nd-lowest damages in each county.

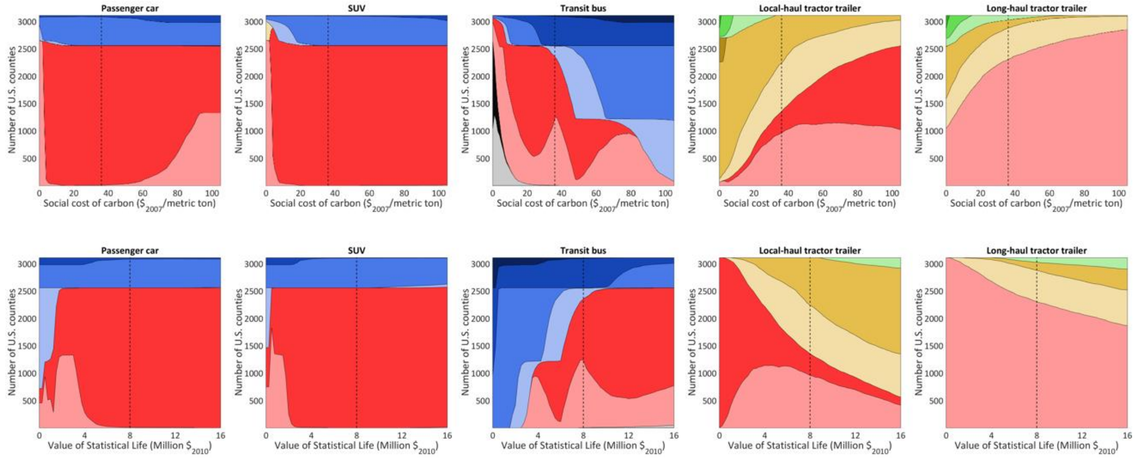

Figure 3. Number of counties in which a fuel-vehicle pathway results in the lowest damages as functions of social cost of carbon (SCC) (top panel) and of value of a statistical life (VSL) (bottom panel).

Significance

- This paper estimates the life cycle climate change damages and air pollution damages of five fuel pathways for five representative light-duty and heavy-duty vehicles in the United States.
- Our results highlight the trade-offs between climate change mitigation and air pollution mitigation in the transportation sector.
- Our results show that social cost of carbon (SCC) and value of a statistical life (VSL) have large impacts on the ranks of fuel-vehicle pathways considered.
- Our results indicate that mitigating climate change and air pollution damages need to take into account vehicle types, fuel-vehicle pathways, and regions.

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