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Achieving reductions in greenhouse gases in the US road transportation sector

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HIGHLIGHTS

- Travel elasticities are calculated for policy scenarios using an activity-based travel model.
- These elasticities are used to estimate changes in total life-cycle greenhouse gas emissions.
- Current technology and fuel policy and the strongest behavioral policy will not meet targets.
- Heavy and medium-duty trucks need more aggressive technology and fuel options.

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ABSTRACT

It is well established that GHG emissions must be reduced 50 to 80% by 2050 in order to limit global temperature increase to 2 °C. Achieving reductions of this magnitude in the transportation sector is a challenge and requires a multitude of policies and technology options. The research presented here analyzes three scenarios: changes in the perceived price of travel, land use intensification, and increases in transit. Elasticity estimates are derived using an activity-based travel model for the state of California and broadly representative of the US. The VISION model is used to forecast changes in technology and fuel options that are currently forecast to occur in the US for the period 2000–2040, providing a life-cycle GHG forecast for the road transportation sector. Results suggest that aggressive policy action is required, especially pricing policies, but also more on the technology side, especially increases in the carbon efficiency of medium and heavy-duty vehicles.

1. Introduction

In 2010, greenhouse gas (GHG) emissions in the United States totaled nearly 6.8 billion MT of CO_2 equivalents. Of this total, the transportation sector was responsible for more than 1.8 billion MT of emissions, or 27.1% of total GHG emissions. While the industrial sector emits a larger share of total GHGs (29.8%), the transportation sector is the single greatest contributor of CO_2 to the earth's atmosphere in the U.S. and accounts for about 31.1% of all CO_2 emissions (Davis et al., 2012). Within the transportation sector, on-road sources account for about 86% of all emissions, of which light-duty passenger vehicles account for about three-quarters (United States Environmental Protection Agency, 2011). Climate Change experts have urged that keeping global mean temperature rise at 2 °C relative to pre-industrial averages is necessary to avoid heightened risk to human and natural systems. This would require reducing emissions by 50 to 85% by 2050 from 1990 levels, and a peak in emissions by the middle of the 2010's (IPCC, 2007).

In order to reach these climate policy objectives, each sector of the economy must contribute reductions. The level of responsibility borne by each sector is partly a matter of policy, and partly a matter of varying abatement costs between sectors. One recent study analyzing deep-reduction scenarios found that each of six different economy-wide models forecasted a greater share of emission reductions in the electricity sector compared with the transportation sector (Fawcett et al., 2009). However, it is of interest to transportation planners, engineers, and economists whether the transportation sector could possibly shoulder an equal burden of emissions reductions, particularly those emissions generated by road transportation. Therefore, the objective of this

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research is to evaluate what mix of policies and technology options are needed to achieve aggressive reductions in life-cycle GHG emissions from the road transportation sector.

GHG emissions from transportation are the result of the dynamic interactions between human behavior, vehicle technology, and fuel technology. The total level of GHG-emissions from transportation in the U.S. depends on four factors: travel demand, what modes of transport are used to travel and how far, the fuel economy of those vehicles, and the carbon-intensity of fuels. The latter requires a full assessment of life-cycle GHG emissions, as the process of producing fuels, especially biofuels, may be quite energy intensive and also result in other GHG emissions (including carbon releases from the soil and methane and nitrous emissions from agricultural production). A full assessment would also require an analysis of the life-cycle emissions of vehicle manufacture and infrastructure construction, however that is beyond the scope of this analysis.

The analysis presented here seeks to examine the impact of various policies to reduce the demand for vehicle travel, namely increases in transit capacity, road pricing, and the concentration of housing and commercial development; these are evaluated in the context of existing policies to reduce carbon fuel intensity and increase vehicle efficiency. Due to our models, the current study examines the potential for reaching a goal of a 50 or 80% reduction of GHG emissions from the road transportation sector in the planning horizon of 2040, relative to 2000 levels. We use an activity-based travel demand model as the basis for developing vehicle-kilometer of travel (VKT) elasticity estimates. The results provide policy guidance on what policies are most effective and which are critical to closing the gap to meet carbon reduction targets in the US.

2. Previous research

Outside of investments in infrastructure that may induce or reduce vehicle travel and taxes on transportation fuels, federal and state authorities in the U.S. have limited direct influence on travel demand. The national agenda for reducing GHG emissions from transportation falls into two general regulatory frameworks: corporate average fuel economy (CAFE) standards and GHG standards, jointly set by the National Highway Transportation Safety Administration (NHTSA) and the U.S. Environmental Protection Agency (EPA), and Renewable Fuel Standards, which are set by the EPA and are intended to regulate the carbon intensity of the fuel supply. In addition to these regulations, various federal incentive programs have been established, for both the supply and demand of the light duty vehicle market. These incentives seek to ensure that the future composition of the light duty vehicle fleet will include higher shares of more efficient vehicles.

While gains in vehicle efficiency are mandated by regulations, resulting reductions in per-mile GHG emissions in the U.S. will be partially offset by increased demand for vehicle travel. Estimates of total VKT for light duty vehicles in 2010 range from about 4.26 to 4.55 billion VKT per year, equivalent to 2.65 to 2.83 billion miles (Davis et al., 2012; McCollum and Yang, 2009; Cambridge Systematics, 2009). The Annual Energy Outlook (AEO) forecasts that, between 2010 and 2035, VKT from LDVs will grow at an average rate of 1.2% annually (EIA, 2013). The *Moving Cooler* report forecast growth in VKT from LDVs at 1.4% annually from 2010 to 2050, and the authors used 1.0 and 1.6% growth rates to test the sensitivity of their projections to increased or decreased fuel costs (Cambridge Systematics, 2009). Extrapolating from trends in the 2008 AEO, McCollum and Yang decomposed LDV VKT into a function of population and travel demand per capita for light duty vehicles, with population growing a total of 69% between 1990 and 2050 and LDV VKT per capita growing by 71%, assuming vehicle load factors remain constant. The combined increases in population and transportation intensity approximate a 2.1% average annual growth rate over a 60 year period (McCollum and Yang, 2009). Although a variety of assumptions drive these forecasts, population growth alone may cause VKT to grow significantly between 2010 and 2050. Total VKT for LDVs could perhaps double, highlighting the need to aggressively pursue increases in fuel efficiency and decreases in the carbon intensity of fuels.

More recently there has been a reduction in VKT, both in total and per capita (Millard-Ball and Schipper, 2011). However, the causes of the leveling off of travel growth are not yet fully understood. Declines in youth licensing for a variety of reasons—including the affordability of driving; increased reliance on communications-technology for interpersonal contact; cultural shifts that deemphasize the importance of auto-mobility; and the revitalization of less auto-dependent urban cores in the United States have all been cited as important factors (Puentes, 2012; Sivak and Schoettle, 2011; Schoettle and Sivak, 2014). In contrast, other researchers argue that economic-factors such as increased unemployment prevail, and growth in VKT may resume once the lingering effects of the Great Recession have passed (Taylor et al., 2013). The uncertainty of future travel-demand growth trends complicates transportation policy analysis, and in the present study we will rely on forecasts from the Annual Energy Outlook to remain consistent with other studies using federal data.

A recent review of strategies to achieve significant reductions in the GHG impact of transportation is the *Moving Cooler* report, prepared by Cambridge Systematics. Rather than developing models, *Moving Cooler* relied on existing data and estimates of changes to VKT, fuel consumption, and emissions in response to various bundles of strategies. *Moving Cooler* evaluated combinations of nearly 50 separate strategies, falling into nine major categories (Cambridge Systematics, 2009). Various sensitivity tests were conducted with alternative scenarios, including scenarios with then-proposed 6.6 L/100 km (35.5 mpg) CAFE standards and varying projections for fuel-prices, VKT, and the rate of technology advancement. Without economy-wide pricing measures, such as a carbon or VKT tax, the report's authors found that reductions of 4 to 18% compared to the 2005 baseline were possible using "aggressive" deployment of strategies including local and regional pricing, smart growth, encouraging eco-driving, and other measures. Bundles that included economy-wide pricing were found to lead to much greater reductions in emissions: a bundle including a fee equivalent to a tax of $0.63/L ($2.40/gal) on fuel in 2015, increasing to $5.00/gal in 2050, was found to result in an additional 28% reduction in GHG emissions (Cambridge Systematics, 2009). The Special Report, *Driving and the Built Environment*, also examined the possibility of achieving GHG emission reductions through more compact development (National Research Council, 2009). The report used forecasts based on elasticity estimates found in the literature to examine the impact of building 25 to 75% of new residential development at twice the average density in the U.S, and found that smart-growth strategies could reduce emissions by between 1 and 11% by 2050.

Only one other study was reviewed that utilized an activity-based model (Brisson et al., 2012). This study examined several options for reducing GHG emissions in San Francisco, California. Scenarios included a 20% increase in transit service, a $3 cordon charge for entering the central business district, and a doubling in costs of driving throughout the region from $0.15 to $0.30/km (either through a VKT tax, increased fuel tax, or pay-as-you-drive insurance). Advancements in vehicles and fuels were represented by an increased penetration of electric-drive vehicles, making up as much as 25% of the private vehicle fleet by 2035, and continuation of the California Low-Carbon Fuel Standard and