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Fuel carbon intensity standards may not mitigate climate change

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ABSTRACT

To mitigate the climate change effects of transportation, the US states of California and Oregon, the Canadian province of British Columbia, and the European Union have implemented regulations to reduce the life cycle greenhouse gas (GHG) emissions intensity of transport fuel, commonly referred to as "carbon intensity", or CI. In this article, we unpack the theory and practice of fuel CI standards, examining claims regarding climate-change mitigation. We show that these standards do not reliably mitigate climate change because estimates of GHG reductions rely primarily on models that are not designed to estimate changes in emissions and climate impacts. Some regulations incorporate models that estimate a subset of changes in emissions, but the models must project changes in global markets over decades, and there is little agreement about the best model structure or parameter values. Since multiple models and projections may be equally plausible, fuel CI is inevitably subjective and unverifiable. We conclude that regulating or taxing observable emissions would more reliably achieve emission reduction.

1. Introduction

Petroleum-based fuels provided 94% of global transportation energy in 2010 (Sims et al., 2014), and over 91% of US transportation energy in 2014 (Davis et al., 2015). The climate change effects of transportation can be mitigated by reducing the quantity of petroleum-based fuels combusted, which can be accomplished by reducing distances traveled, shifting travel to more efficient modes, improving vehicle fuel efficiency, and by substituting fuels whose use results in less warming than does petroleum (Sims et al., 2014). Fuel GHG CI[1] standards are meant to address this final option.

The CI standards implemented in the US states of California (CARB, 2009) and Oregon (Oregon Legislative Assembly, 2015), the Canadian province of British Columbia (BC Laws, 2011), and the European Union (European Parliament, 2009a) share the following attributes:

- Each fuel "pathway" (feedstock and production process) is assigned a GHG CI rating (e.g., in g CO_2e/MJ.)
- The energy-weighted average CI of fuels in use prior to the regulation serves as a baseline.
- An CI target below the baseline is calculated (e.g., requiring a 10% reduction in CI.)
- The regulation requires that the energy-weighted average CI of fuel sold by regulated parties (e.g., fuel blenders and importers) meet the target CI, either directly or (in the California, Oregon, and British Columbia cases) through trading of credits.

The four CI standards noted above use *life cycle assessment* (LCA) to assign CI ratings, recognizing that the GHGs associated with transport fuels are not all released at the tailpipe. For example, electric vehicles (EV) based on batteries and fuel cells emit no fuel-related GHGs during vehicle use, but relevant emissions occur during hydrogen or electricity production and distribution. Other fuels entail emissions from feedstock production, distribution, and refining. LCA looks "upstream" of fuel end-use to count the GHG emissions released by all processes in the supply chain.

Because the complexity of supply chains makes it difficult to directly measure the GHG emissions from all the associated processes, fuels-oriented LCA is generally conducted by modeling. Notably, the four standards use different LCA models and methods, resulting in ratings that produce different rankings in terms of CI. The unobservable nature of life cycle CI makes it impossible to know which, if any, of these ratings best represents environmental outcomes.

In this article, we examine the challenges of using LCA-based CI ratings, showing that fuel CI standards suffer from several flaws that

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[1] CI: carbon intensity; LCA: life cycle assessment; ALCA: attributional LCA; CLCA: consequential LCA; PBR: performance-based regulation; ARP: acid rain program; LCFS: low-carbon fuel standard; RFS: renewable fuel standard; LEV: low-emission vehicle; LUC: land-use change; ILUC: indirect LUC.

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make it difficult or impossible to know whether CI-based regulations mitigate or exacerbate climate change.

2. Performance-based regulation

Fuel CI standards are a type of performance-based regulation (PBR) where "performance" is modeled using LCA (Sperling and Yeh, 2010). PBRs allow regulated parties to use a variety of behaviors that achieve an intended goal in different ways, including ways not anticipated by the regulator (Coglianese et al., 2003). PBRs provide flexibility to the regulated entity by specifying desired outcomes rather than prescribing means of achieving them (Napolitano et al., 2007). When coupled with trading, PBRs can allow regulated parties to minimize compliance costs (May, 2011; Stavins, 1998).

2.1. Generalizing from successful PBRs

Successful PBRs such as the US Acid Rain Program (ARP) and the California Low Emission Vehicle (LEV) program have been cited in support of fuel CI regulation (Office of the Governor, 2007). However, the success of these programs depended in part on attributes that are absent in the fuel CI case. In particular, these policies regulated measurable emissions of regional pollutants for which the regulation covered a high percentage of sources. In the ARP case, for example, the regulation covered all domestic power plants, which accounted for about 70% of national SO_X emissions (Ellerman et al., 2000).

The regulation of life cycle GHG emissions differs from the policies above in several important ways. First, life cycle emissions are unobservable; they must be estimated through modeling. LCA is well-known to produce a wide range of results for ostensibly similar analyses, owing to subjective choices regarding a range of implementation details (Plevin et al., 2014). The differing modeling approaches adopted in the aforementioned regulations demonstrate a lack of agreement on how to operationalize the concept of "life cycle GHG emissions". Second, the primary GHGs – CO_2, CH_4, and N_2O – are global rather than regional in effect (Myhre et al., 2013): reducing emissions in the regulated region merely by moving emissions elsewhere does nothing to solve even the *local* problem. Third, GHGs emissions are ubiquitous: virtually every industrial and natural process produces them. Because of these last two factors, production and consumption changes that are transmitted through global markets can affect policy outcomes.

Fourth, while the APR and LEV policies attempt to regulate all known acid-forming emissions and harmful vehicle tailpipe emissions, respectively, fuel CI policies neglect important non-GHG factors affecting climate, such as biogeophysical effects, which we discuss further below. These fundamental differences suggest caution when generalizing from the ARP and LEV cases to fuel GHG emissions programs (Ellerman et al., 2000).

A more subtle difference between the acid rain and LEV programs and fuel CI standards is how and where emission reductions are achieved. In the LEV and ARP cases, all relevant emissions reductions are directly measurable at the smokestack or tailpipe. In the fuel CI case, some compliance actions—such as improving energy efficiency in a fuel ethanol plant—have directly measurable emission reductions, but blending a biofuel does not in itself reduce GHG emissions: combustion of biofuels produces tailpipe CO_2 emissions per unit energy nearly equal to those of petroleum-based fuels (Wang, 2015). Achieving GHG reductions (which in any case does not necessarily translate into reduced climate change impacts, because of the non-GHG drivers of climate change) requires that the global economy—net of all market interactions—use less petroleum-based fuel and/or sequester enough additional atmospheric carbon to offset biofuel production and combustion emissions (DeCicco, 2013; Searchinger, 2010). Unfortunately, we cannot—and for reasons described below, should not expect to—reliably model these effects.

2.2. Performance metrics must reflect policy goals

By definition, a PBR regulates some measure of performance relative to a desired policy outcome. Performance metrics inconsistent with policy goals can create perverse incentives. Consider, for example, the common goal of reducing a region's GHG emissions as computed by a regional inventory. If a PBR intended to support this goal uses a performance metric that ignores emission increases or reductions outside the region, the PBR could incentivize activities that increase emissions despite a decrease in the scored inventory.

If the goal of a PBR is to mitigate harm from climate change, the performance metric must account for net global changes (i.e., net of market-mediated effects) in *all* non-negligible factors that contribute to climate change, including but not limited to changes in GHG emissions. For example, while some fuel CI polices include GHG emissions from biofuel-induced land-use changes (LUC), none includes the corresponding changes in radiative forcing resulting from changes in albedo, which can substantially alter the estimated climate effects of some fuels (Caiazzo et al., 2014; Delucchi, 2010). Including albedo change, however, poses several challenges including its conversion to CO_2-equivalents (Jones et al., 2013), dependence on cloud cover, which is also influenced by land-use changes (Spracklen et al., 2008), and dependence on estimates of the location, magnitude, and type of LUC, all of which are uncertain.

If the CI rating assigned to each fuel does not reflect the net global climate-change effects of using that fuel to comply with the regulation—that is, if the actual effects of compliance actions differ from the effects implied by the fuel ratings—then the actual outcome of the policy will differ from the average rating of fuels used to comply with the regulation, and the overall effect of the policy is unknown.

Another commonly stated goal for fuel CI standards is to spur technology innovation (Farrell et al., 2007; Holland et al., 2015; Lade and Lin Lawell, 2015; Sperling and Eggert, 2014). However, innovation is a means to an end: the goal is presumably to mitigate harm from climate change. The greatest innovation incentives will flow to fuels assigned the lowest CI ratings, regardless of their actual environmental performance. Thus the innovation "goal" also requires meaningful CI ratings.

3. Estimating policy benefits

Elsewhere, we have argued that climate benefits cannot be assessed of a fuel narrowly (as with what is known as "attributional" LCA, or ALCA) or even using broader models (Plevin et al., 2014). Rather, analyses of climate benefits should focus on policy choices and the anticipated behavioral changes by the various actors affected by potential policies. The correct approach to estimate the climate benefits of a policy requires a comparison of the climate effects in scenarios with and without the policy (Bento and Klotz, 2014; Parson and Fisher-Vanden, 1997). The projected difference in climate effects can be said to be the effect of the policy, *ceteris paribus* (Khanna and Crago, 2012). Regulatory evaluations of the fuel CI standards in California, Oregon, British Columbia (BC), and European Union (EU) use a much simpler approach to estimate policy benefits: they simply multiply the average carbon intensity (e.g., $g\ CO_2\ MJ^{-1}$) by the quantity (e.g., MJ) of fuel used in the baseline and compliance scenarios and subtract the latter product from the former to compute the mass of CO_2 assumed to be avoided by the policy (BC Ministry of Energy and Mines, 2012; European Parliament, 2009b). As we have argued above, this approach does not accurately represent the actual climate effects of these policies.

In California and Oregon, fuel ratings are based primarily on emissions of CO_2, CH_4, and N_2O from the production and use of fuels, but also include estimates of CO_2 emissions from soil and biomass carbon disturbed by what has become to be known as "indirect" land use change (ILUC) (CARB, 2009). However, these regulations omit