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California's Low Carbon Fuel Standard: Modeling financial least-cost pathways to compliance in Northwest California

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ABSTRACT

The transition to low-carbon transportation fuels plays a key role in ongoing efforts to combat climate change. This analysis seeks to optimize potential alternative fuel portfolios that would lead to a 10% reduction in fuel carbon intensity by 2020 as required under California's Low Carbon Fuel Standard (LCFS).

We present a novel, probabilistic modeling approach for evaluating alternative fuel portfolios based on their marginal greenhouse gas (GHG) abatement costs. Applied to a case study region in Northwest California, our model enables us to quantify the financial cost of GHG reduction via each fuel pathway, as well as for a portfolio deployed to meet the LCFS target. It also enables us to explore the sensitivity of the alternative fuel portfolio, evaluating the impact of fluctuating prices, fuel carbon intensities, and technology penetrations on the makeup of the portfolio and on the average cost of GHG abatement.

We find that battery electric vehicles play a critical role, as they offer the lowest-financial-cost significant abatement in almost all plausible scenarios. However, electric vehicles alone will not be sufficient to reach the target; low-carbon biofuels can be expected to play a role in the achievement of 2020 Low Carbon Fuel Standard targets.

1. Introduction

Transportation accounts for almost 23% of all energy-related greenhouse gas (GHG) emissions globally. Increasing economic development, especially in non-OECD Asia, is expected to cause transport sector emissions to rise faster than those of any other sector (U.S. Energy Information Administration, 2016), increasing more than 70% by 2050 barring major coordinated action on transport emissions (Sims et al., 2014).

Mitigation of the increasingly significant emissions from this sector will require aggressive policy action. However, emissions from transport are among the most difficult to reduce. Necessary change in this sector is inhibited by market barriers such as technology lock-in, the low price elasticity of fuel demand and vehicle choice (Greene et al., 2008; Small and Van Dender, 2007; US Congressional Budget Office, 2012), the entrenched interests of the petroleum industry, the fickle history of alternative fuel policy and investment (Melton et al., 2016), and the need for coordination among fuel producers, distributors, and consumers (Sperling and Gordon, 2009; Yeh and Sperling, 2010). Furthermore, while an economy-wide carbon price is widely considered the most economically efficient approach to emission abatement, it is improbable that such a policy will achieve significant near-term reductions

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from transport at politically-acceptable carbon prices, due to the higher abatement costs in transportation compared to other areas of the economy (Lutsey and Sperling, 2009; Morrow et al., 2010; Rhodes et al., 2015; van der Zwaan et al., 2013). U.S. government analysis of the American Clean Energy and Security Act of 2009 determined that its proposed nationwide GHG emissions trading scheme would generate almost no emission abatement from the transport sector, leading transport to account for over 50% of total emissions nationwide in 2050 (U.S. EPA, 2010; Yeh and Sperling, 2010).

Given the large and increasing role of transportation as a driver of global climate change, reduction in these emissions is critical to achieving climate goals (Williams et al., 2012). Since conventional carbon pricing mechanisms are not expected to generate much near-term emission reduction in transport, policymakers have turned to sector-specific instruments to reduce emissions from the sector.

While this may be considered a sub-optimal approach from an economic standpoint, some researchers have observed that given the market failures present and the scale of the emissions involved, sectoral action in this case is appropriate (Azar and Sandén, 2011; Bennear and Stavins, 2007; Vogt-Schilb and Hallegatte, 2014; Yeh and Sperling, 2010). Such policies enable the commencement of developments that will ultimately be necessary for deep emissions cuts to be achieved, and can stimulate cost reductions to the point that sectoral policies are no longer needed. One key element in the pursuit of deep emissions cuts from transportation will be the deployment of low-carbon alternative fuels. California's Low Carbon Fuel Standard (LCFS) is a policy tool targeting fuel carbon intensity directly.

1.1. California's Low Carbon Fuel Standard

In the state of California, transportation accounts for 37% of total GHG emissions – more than any other single sector (California Air Resources Board, 2016). One key tool in mitigating these emissions is the state's Low Carbon Fuel Standard (LCFS). Pursuant to the 2006 "Global Warming Solutions Act," the California LCFS seeks to reduce the average life-cycle carbon intensity (CI) of transportation fuels used in the state, setting a target of 10% reduction in average fuel carbon intensity (AFCI) below a fossil fuel baseline by 2020. The LCFS differs in important ways from the approach applied by the US federal Renewable Fuel Standard and the E.U. Renewable Energy Directive. Where those policies set targets for specific technologies and create CI thresholds for inclusion, an LCFS is designed to be technology-neutral across alternative fuel pathways and to incentivize transport fuels proportional to the relative carbon intensity of each specific fuel pathway. For detailed discussion of the design, current status, and impacts of LCFS policies see Lade and Lawell (2015) and Yeh et al. (2016). While California was the first jurisdiction to implement an LCFS in 2010, similar policies are currently in place in Oregon, British Columbia, and the European Union, and are in various stages of development elsewhere (Yeh et al., 2016). Lessons learned in California will prove critical to the success of these other policy frameworks.

It should be noted that there are legitimate critiques of the LCFS, its calculated CI values, and the use of this type of life cycle GHG accounting in policy (see e.g. Lemoine, 2017; Plevin et al., 2017, 2014). The LCFS does little to characterize or mitigate uncertainty in its calculated CI values – especially as it relates to market-mediated land use change, leakage, and possible rebound effects. As such, the true impact of the LCFS remains uncertain. However, as this paper investigates compliance with the policy itself, this uncertainty is outside the bounds of our study.

1.2. Evaluating decarbonization of energy in California

Many studies have investigated pathways for deep decarbonization of California's energy sector. Some (e.g. Long et al., 2011; Wei et al., 2013; Williams et al., 2012) use scenario analysis or energy-economic models to explore the roles of different sectors in reaching carbon reduction targets but don't specifically focus on transportation or robustly account for costs. Yang et al. (2015) applied the CA-TIMES model – an energy economic systems optimization model – to evaluate scenarios for deep decarbonization in California through 2050. They showed significant savings in the transportation sector, but given the broad scale of their analysis did not aim to characterize the implementation and impacts of specific policy mechanisms. A more recent iteration of the CA-TIMES model (Yang et al., 2016) investigates the LCFS directly, but with a focus on the presence/absence of this policy in conjunction with other policies impacting California energy use and GHG emission reduction.

Some studies have also focused on pathways to GHG abatement in the transportation sector specifically. Morrow et al (2010) used the NEMS model to evaluate policies aimed at reducing oil consumption and GHG emissions in the U.S. transportation sector. However, their investigation of sector-specific policies focused on vehicle fuel efficiency policies rather than those targeting fuel carbon intensity. Others have investigated pathways to reduced emissions from transport in California from both vehicle efficiency and fuel carbon intensity (Leighty et al., 2012; Yang et al., 2009). These studies lay important groundwork in exploring the technology pathways that could lead to deep decarbonization of the California transportation sector by 2050. However, they do not explicitly evaluate the cost-effectiveness of the different portfolios they discuss, do not focus on the LCFS, and do not evaluate nearer-term priorities.

Morrison et al (2015) offer a comprehensive investigation of California energy system models, identifying commonalities and differences among these models in their methods and projections. As these are broader energy system models, this inter-comparison paper, and the models it draws on, offers a relatively coarse treatment of transportation fuel carbon intensity and of the vehicle and infrastructure costs associated with some alternative fuel pathways. The authors do not investigate pathways to compliance with specific policies such as the LCFS, instead focusing on system-wide achievement of GHG reduction goals. In discussing their findings, Morrison et al (2015) indicate that there is interest among policy makers for analyses that investigate the effects of individual policies, that treat sensitive inputs as distributions rather than point estimates, and that evaluate performance on policy-relevant