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Review article

A review of low carbon fuel policies: Principles, program status and future directions

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HIGHLIGHTS

- LCFS is a market-based policy that sets standards for carbon intensity of fuels.
- We compare efficiency, price impacts, GHG emissions, and innovation of C policies.
- In California, reported carbon intensity of alternative fuels declined 21% 2011–2015.
- LCFS credit prices have varied considerably, rising to above $100/credit in the first half of 2016.
- Other LCFS programs share many features with CA's and have distinct provisions.

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ABSTRACT

A low carbon fuel standard (LCFS) is a market-based policy that specifies declining standards for the average lifecycle fuel carbon intensity (AFCI) of transportation fuels sold in a region. This paper: (i) compares transportation fuel carbon policies in terms of their economic efficiency, fuel price impacts, greenhouse gas emission reductions, and incentives for innovation; (ii) discusses key regulatory design features of LCFS policies; and (iii) provides an update on the implementation status of LCFS policies in California, the European Union, British Columbia, and Oregon. The economics literature finds that an intensity standard implicitly taxes emissions and subsidizes output. The output subsidy results in an intensity standard being inferior to a carbon tax in a first-best world, although the inefficiency can be corrected with a properly designed consumption tax (or mitigated by a properly designed carbon tax or cap-and-trade program). In California, from 2011 to 2015 the share of alternative fuels in the regulated transportation fuels pool increased by 30%, and the reported AFCI of all alternative fuels declined 21%. LCFS credit prices have varied considerably, rising to above $100/credit in the first half of 2016. LCFS programs in other jurisdictions share many features with California's, but have distinct provisions as well.

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1. Introduction

Reducing transportation sector emissions will play an important role in any comprehensive carbon reduction strategy. Abatement in the sector will likely be multifaceted, including increasing the efficiency of transportation technologies (vehicles, trucks, trains, planes, etc.), reducing the carbon-intensity of transportation fuels, and travel demand management (Creutzig et al., 2015; IPCC, 2014a). Each of these abatement options may result in significant emissions reductions. The three most common policies enacted or being discussed to reduce the carbon emissions of fuels use, the focus in this paper, are: (i) carbon pricing in the form of carbon cap-and-trade (CAT) programs and carbon taxes; (ii) renewable fuel mandates; and (iii) fuel carbon intensity standards such as California's Low Carbon Fuel Standard (LCFS).[1]

The primary objectives of an LCFS, sometimes referred to as a Clean Fuel Standard, are to: (i) reduce greenhouse gas (GHG) emissions from the transportation sector; (ii) incentivize innovation, technological development, and deployment of low-emission alternative fuels and alternative fuel vehicles; and (iii) provide a framework for regulating transportation sector GHG emissions within a broader portfolio of climate policies (Farrell and Sperling, 2007). In advancing these objectives, an LCFS is notable for its design as a technology-neutral performance standard.[2] The policy does not include mandates for any particular fuel, technology, or compliance strategy. Instead, it defines an average carbon intensity (CI) standard, measured in grams CO_2 equivalent per mega-joule of fuel energy (gCO_2e/MJ), that all regulated parties must achieve across all fuels they provide within the jurisdiction. Many options exist for meeting the standard, and regulated parties may employ any combination of strategies that suits their circumstances, including: (i) producing low carbon fuels; (ii) purchasing low carbon fuels from other producers; (iii) purchasing credits generated by producers of low carbon fuels; or (iv) banking credits across compliance years for future use.

An LCFS is passed by regulators and policymakers with the intention of advancing broad climate objectives within the transportation sector. The policy is technology-forcing, designed on the premise of a need to overcome important market barriers and inefficiencies that might remain unaddressed with other climate policy instruments, and to stimulate innovation in all low-carbon options that might be used for transportation. Options include increasing production of biofuels from low or no-value byproducts and cellulosic materials, electricity used in plug-in vehicles, and hydrogen used in fuel cell vehicles. For a variety of reasons, many promising low carbon fuels currently have high production costs compared to conventional fuels, even after accounting for the social cost of carbon (ARB, 2009b; Sperling and Yeh, 2009). As a result, these fuel options face significant early market hurdles in terms of high initial costs, lack of economies of scale, and inadequate technology know-how beyond laboratory production (NRC, 2004, 2010, 2011; Sperling and Gordon, 2009; Yang and Yeh, 2012).

The LCFS policy has proven to be a popular climate strategy in a number of regions, and its prominence in policy discussions has grown since it was first introduced. In January 2010, California began enforcing an LCFS, requiring sellers of transportation fuels (mainly oil refiners) to reduce the average CI of on-road transportation fuels sold in the state by 10% by 2020 (ARB, 2009b). Variations of an LCFS have also been adopted by the European Union (EC, 2009), British Columbia (British Columbia, 2008), and Oregon (DEQ, 2015). In addition, the State of Washington investigated adoption of a Clean Fuel Standard (WA, 2014) and state and regional initiatives have been considered in the U.S. in Midwestern states (MGA, 2010), northeastern and mid-Atlantic states (NESCAUM, 2011), and discussed at a national scale (Yeh and Sperling, 2013).

This article surveys the literature on the design and economics of low carbon fuel policies, and provides an update on programs currently in place. We begin with a comparison of an LCFS with other policy instruments, and describe common design elements of LCFS policies (Section 1). Section 2 reviews the implementation status of the LCFS in California, where the program is most fully developed and has the highest visibility. We then review LCFS implementation in other jurisdictions in Section 3. We discuss future prospects for the LCFS in Section 4, and conclude in Section 5 with lessons learned, potential policy refinements and improvements, and future research needed.

1.1. LCFS versus other policy instruments

Oil refineries and fuel providers in the U.S. face a number of GHG-related regulations, including renewable fuel mandates, cap-and-trade (CAT) programs, and low carbon fuel standards. For example, all large U.S. oil refiners must comply with the U.S. Environmental Protection Agency's (U.S. EPA) Renewable Fuel Standard (RFS), a biomass-based fuel mandate. In addition, refiners in California must comply with the state's LCFS and CAT programs. All three policies reduce transportation fuel emissions by altering total fuel demand and incentivizing production and consumption of low carbon fuels. The mechanisms by which each policy affects regulated parties, however, are quite different. These differences have important implications for the effects of the policies on consumers, oil refiners, and low carbon fuel producers (Chen et al., 2014; Holland et al., 2009).

[1] Throughout, "carbon" refers to GHGs, with emissions measured in carbon dioxide equivalent (CO_2e).

[2] While all alternative fuels are treated the same under an LCFS, conventional fuels may be differentially treated as discussed in Section 1.2.1.