Climate and Transportation Solutions:

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Chapter 5:

Role of Low Carbon Fuel Standard in Reducing U.S. Transportation Emissions

by Sonia Yeh and Daniel Sperling

The transportation sector in the United States (U.S.) relies almost exclusively on petroleum fuels, which accounted for over 96 percent of transport greenhouse gas (GHG) emissions in 2009. Policies aimed to reduce transportation emissions have made some progress. These policies include the new Corporate Average Fuel Economy (CAFE) standards and the Renewable Fuel Standards (RFS) established by the Energy Independence and Security Act (EISA). Despite these important policies, future U.S. transportation emissions are projected to continue to rise, although at a slower rate, in the next 20 years (EIA 2009).

To gain large reductions in transport-related GHG emissions, more actions are needed. These actions include improving vehicle technology efficiency, reducing vehicle miles traveled and lowering the GHG intensity of transportation fuels. Many policies have already been adopted to introduce alternative fuels into the transportation sector, with the goals of reducing energy dependence on foreign oil and improving local and regional air quality. These policies have largely failed (McNutt and Rodgers 2004, Sperling and Gordon 2009). The Low Carbon Fuel Standard (LCFS) is a promising approach to reduce GHG emissions by decarbonizing transportation fuels. An LCFS has the following features:

- Is technology neutral
- Uses a lifecycle GHG intensity standard
- Targets a range of transport fuels
- Incorporates market mechanisms by allowing credit trading

This chapter reviews the LCFS standard adopted in California and the European Union (EU) and compares the LCFS policy instrument to other measures. It explores the possibility of a national LCFS in the United States, including key shortcomings and challenges.

The Need for Effective and Performance-Based Policy

Several new policy approaches have been adopted or considered in the past few years to improve energy security and reduce GHG emissions from transportation fuels. These include fuel-specific policies that

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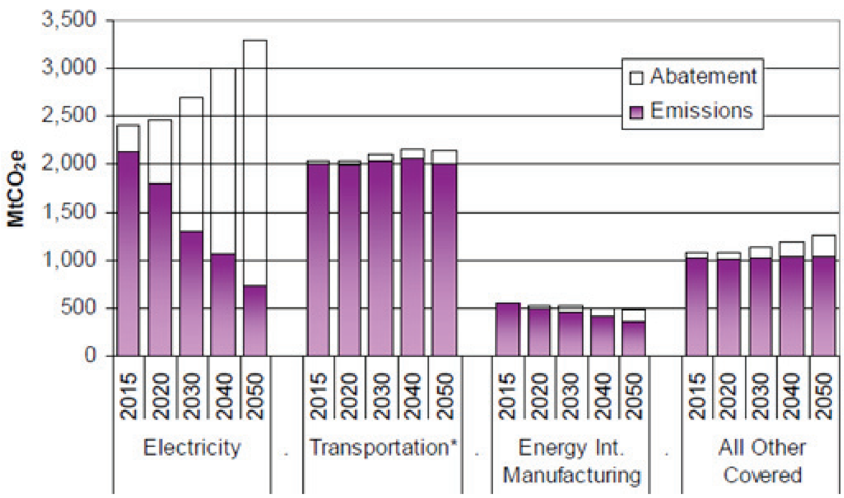
have already been adopted, such as volumetric biofuel mandates (RFS) and fuel subsidies and tax credits for corn ethanol and biodiesels. Market-based policies that have not yet been adopted include carbon taxes, carbon cap and trade, and fuel “feebates.” The RFS, biofuel fuel subsidies, and tax credits have increased domestic U.S. corn ethanol production and biodiesel exports. The actual greenhouse benefits of these policies, however, may be small based on several recent studies (Gibbs et al. 2008; Hertel et al. 2008; Searchinger et al. 2008; Hertel et al. 2010).

Carbon cap-and-trade programs and carbon taxes, at politically acceptable levels, will have little effect on transport emissions. Analyses of proposed cap-and-trade programs suggest that only a very small fraction (less than five percent) of emission reduction will come from the transport sector (EIA 2008; U.S. EPA 2009a). Figure 5-1, for example, shows the limited projected emission reductions in the transportation sector under the cap-and-trade program proposed in 2009 in the federal Waxman-Markey Bill (H.R. 2454). A study by the U.S. Environmental Protection Agency (EPA) estimated that the Waxman-Markey Bill would raise gasoline prices by $0.13 in 2015, $0.25 in 2030 and $0.69 in 2050 (U.S. EPA 2009a). This modest price signal is not likely to be strong enough to induce significant change in consumer behavior in reducing vehicles miles traveled or purchasing low-GHG vehicles or fuels.

Figure 5-1: Projected emission reductions by sector under the proposed cap and trade program: H.R. 2454



Source: U.S. EPA 2009a

More direct policies are likely to be far more effective in reducing transportation fuel use and GHG emissions. The rationales for more direct policy instruments, such as the low carbon fuel standard, are as follows. First, there are significant market barriers that are unique to the transportation sector, including the chicken-and-egg challenge of simultaneously introducing alternative fuels and alternative-fueled vehicles (McNutt and Rodgers 2004), consumers’ inelastic demand for gasoline (Hughes et al. 2008), and the failure of transport fuel prices to incorporate large externalities such as air pollution and energy security in fuel use and vehicle purchase decisions (Delucchi 2008; Lave and Griffin 2008). Second, the cost of doing nothing now and fixing it later will result in very high future costs since the liquid fuel mix is becoming increasingly more GHG intensive as a result of greater use of heavier crude oils and oil sands—with the prospect of even more carbon-intense oil shale and coal-to-liquid fuels being used in the future (EIA 2009). Additional measures beyond cap-and-trade will be necessary to achieve long term reductions in oil use and GHG emissions.

What is the Low Carbon Fuel Standard?

The LCFS is a performance standard that aims to reduce the GHG intensities of transportation fuels. The metric around which the LCFS is designed is total GHGs per unit of fuel energy. The GHGs are measured as carbon-equivalents based on their global warming potential, abbreviated as “carbon” throughout this chapter. The goal is to account for all GHGs emitted in the lifecycle of the fuel, from extraction, cultivation, land use conversion, processing, distribution, and fuel use. Although upstream emissions account for only about 20 percent of total GHG emissions from petroleum, they represent almost the total lifecycle emissions for biofuels, electricity and hydrogen. Upstream emissions from extraction, production and refining also comprise a large percentage of total emissions for the very heavy oils and oil sands that oil companies are increasingly embracing to supplement limited supplies of conventional crude oil. The LCFS is the first major public initiative to codify lifecycle concepts into law, an innovation that will become more widespread as climate policies are pursued more aggressively.

Several countries and states have adopted or are considering adoption of an LCFS. The California LCFS was adopted in April 2009, and took effect in January 2010 (CARB 2009). California’s LCFS applies to onroad transport fuels, but credits can be generated from low-carbon fuels used in off-road vehicles. It excludes the air and maritime transportation activities, where California has limited authority. The standard is imposed on all transport fuel providers, including refiners, blenders, producers and importers. It requires a 10 percent reduction in the GHG intensity in transport fuels by 2020.

To implement the LCFS, each fuel supplier in California must meet a GHG-intensity standard that becomes increasingly stringent over time, ramping up to the 10 percent reduction in 2020. To maximize flexibility and innovation throughout low-carbon technologies, the LCFS allows for trading and banking of emission credits. An oil refiner could, for instance, buy credits, or the fuels themselves from biofuel producers. Alternatively, it could buy credits from an electric utility that sells power for use in electric vehicles. Those companies that are most innovative and best able to produce low-cost, low-carbon alternative fuels would do best. The combination of regulatory and market mechanisms makes the LCFS more robust and durable than a pure regulatory approach and more effective than a pure market approach, given that aggressive carbon caps and taxes are politically unacceptable in the United States and elsewhere.

The European Union first unveiled an LCFS proposal at about the same time as California in early 2007. In December 2008, the European Parliament adopted a revised Fuel Quality Directive (FQD) that incorporated a low carbon fuel standard (EC 2008a). The FQD requires fuel suppliers to reduce lifecycle GHG emissions by up to 10 percent by 2020. The scheme is broader than the California LCFS because it allows credit for upstream reductions in gas flaring and venting and for the use of carbon capture and storage (CCS) technologies. It also allows the purchase of credits under the Clean Development Mechanism (CDM) established by the Kyoto Protocol. Upstream emission reductions, CCS, and the CDM can be used to meet up to four percent of the 10 percent requirement.

Eleven Northeast and Mid-Atlantic states have announced a regional initiative to develop a regional LCFS (NESCCAF 2009). The conceptual construction of the plan is largely based on California’s model, with a major difference being the proposed inclusion of heating fuels for home heating, a significant source of diesel fuel consumption in the Northeast. A national version of the LCFS was considered in the early version of the Waxman-Markey Energy Bill, which required a five percent reduction by 2023 and a 10 percent cut by 2030. The LCFS provision was later dropped from the bill that was passed by the U.S. House of Representatives.

Scenarios to Meet California’s LCFS

California’s LCFS will achieve GHG reductions between 20 and 25 million metric tons (tonnes) of carbon dioxide equivalents (CO_2e) on a lifecycle basis per year by 2020 (CARB 2009; Yeh et al. 2009a). Depending on the particular feedstock and production pathways and the carbon intensity of the fuels used by the regulated parties to meet the standard, it will require between 1.5 and 3.0 billion gallons of ethanol, 0.6 to 0.8 billion gallons of biodiesel or renewable diesel, an additional 1,200 to 16,000 gigawatt hours (GWh) of electricity and from zero to 33 thousand tonnes of hydrogen per year by 2020 (CARB 2009; Yeh et al. 2009a).

California has the potential to supply roughly half of the biofuels needed to meet its LCFS (Yeh et al. 2009a). Biofuels produced in other states to meet the federal U.S. volumetric requirement for renewable fuels will be further incentivized by the prospect of earning LCFS credits when being supplied to the California fuel market. Fuels from other states or countries, such as sugarcane ethanol from Brazil, can also contribute to California's LCFS program.

Figure 5-2: Fuel use change (million gge) between the business-as-usual (BAU) and the portfolio scenario

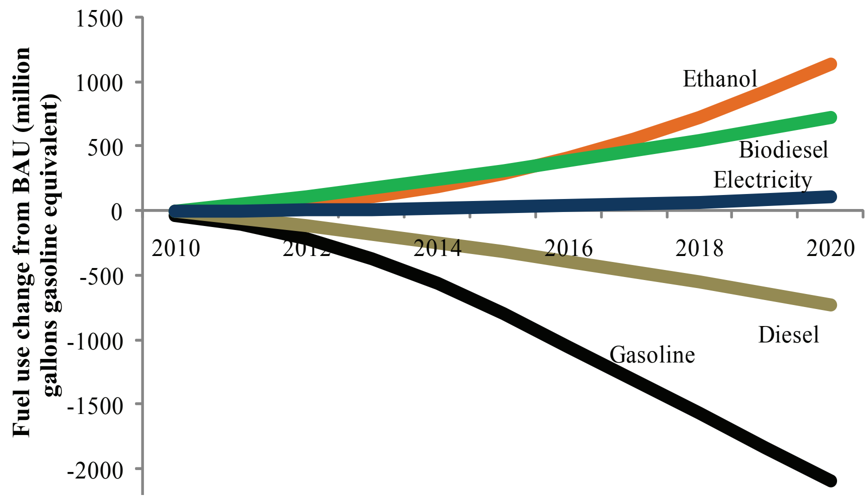
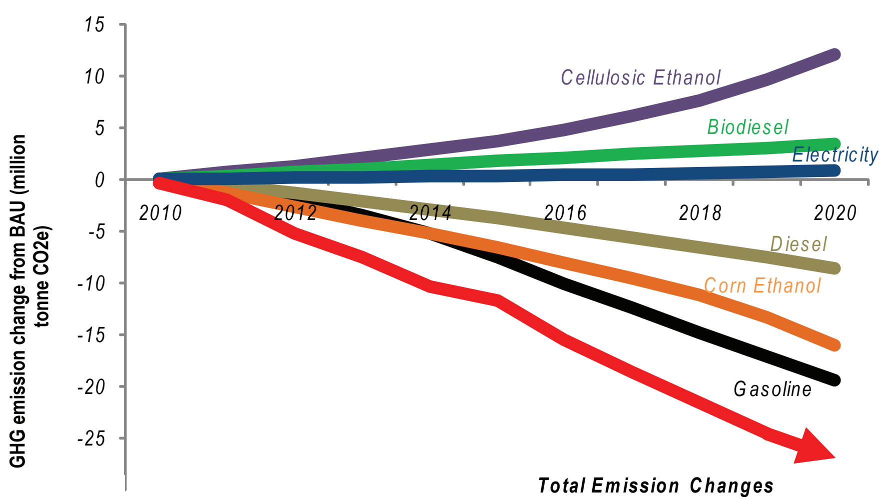


Figure 5-2 shows the fuel use change, measured in million gallons gasoline equivalent (gge), achieved by a portfolio of GHG reduction strategies that achieves the 10 percent reduction target. Figure 5-3 shows the corresponding GHG reduction from the portfolio of GHG reduction strategies relative to the BAU scenario. The portfolio scenario assumes that a mix of second-generation biofuels and advanced electric-vehicle technologies, primarily hybrid electric vehicles, flexible-fuel vehicles capable of burning up to 85 percent ethanol in gasoline, and plug-in hybrid electric vehicles, will be needed by 2020.

Figure 5-3: Greenhouse gas emission reductions (million tonnes CO_{2e}) from BAU in the portfolio scenario

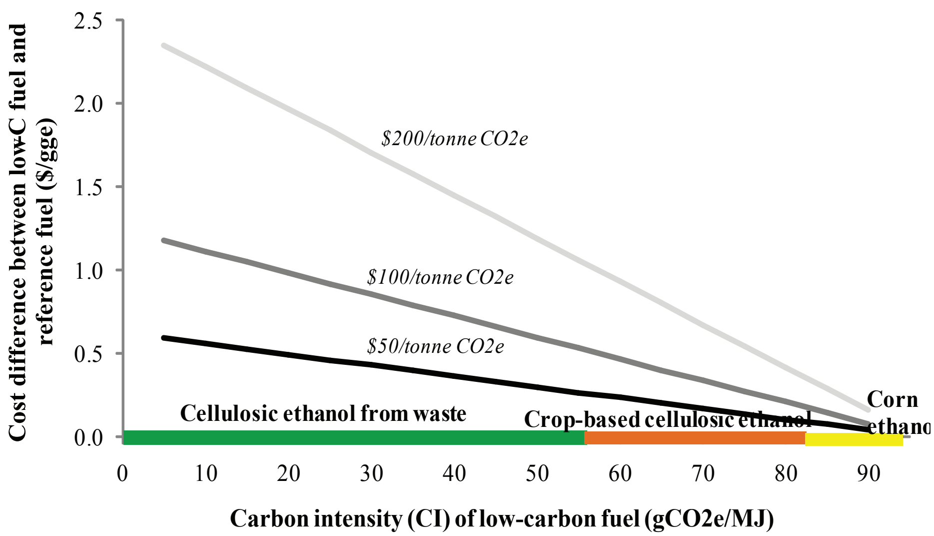


The portfolio scenario estimates that 2.5 billion gge of ethanol, or 3.70 billion gallons, and 0.73 billion gge of biodiesel, or 0.65 billion gallons, will be needed per year by the year 2020 to meet California's LCFS. This is roughly equal to 14 percent of the total biofuels needed to meet the federal RFS of 30 billion gallons in 2020, a ratio slightly higher than California's total transportation fuel demand, which accounted for 11 percent of the U.S. total.

Growth of PHEVs from 2010 to 2020 would be slightly higher than the sales growth of HEVs in California from 2000 to 2010, which was twice the national average, reaching 7.3 percent of new vehicle sales and a total of 0.7 million PHEVs on the road by 2020. The total electric vehicle population would reach 60,000 by 2020. The combined electricity use from PHEVs and electric vehicles would reach 2,280 GWh per year by 2020. These PHEV and electric-vehicle penetration rates represent an optimistic technology deployment scenario. Other policies, such as California's zero emission vehicle program, may provide additional incentives for adoption. In addition to PHEVs and electric vehicles, off-road applications such as forklifts, electrification of truck stops, and marine ports electrification also offer relatively high potential GHG reductions.

Projected low-GHG fuel use will vary because the performance-based LCFS does not specify a minimum amount of fuel volume or energy content for the alternative fuels. The lower the average GHG intensity of the fuels used, the smaller quantity of alternative fuels that would be needed to meet the GHG reduction target. Thus, use of lower carbon fuels will generate more LCFS credits than the same volume of fuel with higher carbon intensity. The price premium can be much higher for low-GHG fuels at a given compliance cost target, as shown in Figure 5-4. In other words, low-GHG fuels incurring higher relative costs of production may still be competitive in the LCFS credit system.

Figure 5-4: Breakeven cost difference between low-carbon fuels and the reference fuel at various levels of compliance cost targets



Note: Color bars shows the range of California default carbon intensity values, including indirect land use changes, for the three major types of biofuel categories: corn ethanol, crop-based cellulosic ethanol and cellulosic ethanol from waste.

Key Challenges of an Expanded LCFS

A national LCFS could be adopted in parallel with, or in place of, the RFS. The RFS mandates 36 billion gallons of biofuels by 2022, of which 21 billion gallons must be advanced biofuel with a minimum GHG reduction of 50 percent compared to 2005 baseline gasoline. Sixteen of the 21 billion gallons must be cellulosic biofuel with a minimum GHG reduction of 60 percent. A national LCFS avoids clumsy categorization of GHG emission accounting, provides additional flexibilities to companies by incorporating market mechanisms, and stimulates innovation and investment in low-carbon fuels.

Some of the challenges associated with the implementation of a national LCFS include the leakage and shuffling of emissions to sources outside the United States, energy security concerns, measurement of indirect land use changes, and sustainability issues. The first two issues are common to carbon policies such as the cap-and-trade program and the LCFS, while the latter two issues are also not LCFS specific, but rather issues associated with biofuels.

Leakage and Shuffling

One potential consequence of the LCFS performance standard is the issue of leakage. In the case of LCFS and cap-and-trade, regulated parties will have incentives to export high-carbon fuels to non-LCFS countries or not import high-carbon fuels (Stavins 2008, Burtraw et al. 2005, and Reilly et al. 2007). Thus, improvement would appear to be made in the United States, but there would still be no net environmental benefit globally. In fact, leakage resulting from a U.S. LCFS may result in higher overall global emissions, due to the added emissions from transportation.

The specific concern in the U.S. is that a national LCFS will limit flow of oil sands to the U.S., but only marginally reduce overall oil sands production, since the majority of the oil sands exports will be diverted to the Pacific market via the Enbridge pipeline to Kitimat (Difiglio 2009). This concern is premised on an assumption that the national LCFS would be implemented in the absence of a national cap-and-trade system or broader global actions to reduce GHG emissions.

More robust assumptions and alternative scenarios will be needed to give a better picture of the impacts of a national LCFS on global oil markets. It is entirely possible, for instance, even likely, that other states and provinces will follow California's lead with the LCFS. A U.S. LCFS must be analyzed in the context of a national cap-and-trade system and a global climate policy regime likely to emerge after 2020. It is unlikely that Canada will do nothing about reducing its emissions from high-carbon oil sands if the United States adopts a national LCFS. If Canada includes oil sands upstream emissions under a cap-and-trade program, then Canadian oil sands would be treated as conventional crude oil under California's LCFS program, since the high-carbon part is only associated with energy-intensive extraction and upgrading (Charpentier et al. 2009). Indeed, a national LCFS may be feasible only if there are well-functioning cap-and-trade programs in both countries (Levi and Rubenstein 2009).

It is important to note that the LCFS does not ban high-carbon fuel, but provides fuel providers with maximum flexibility to use high-carbon fuels as long as carbon liability is managed through improvement in refinery efficiencies, CCS, cogeneration (Jacobs 2009; TIAX 2009), advanced technologies (Ordorica-Garcia et al. 2008), or other low-carbon energy sources, such as nuclear or renewable energy sources. After paying for these offsets, however, it is unclear if Canadian oil sands would still be competitive relative to convention petroleum, especially when oil price could be lowered due to lower demand caused by carbon policies and biofuel programs in the future.

Energy Security

The LCFS helps to achieve climate goals by reducing GHGs, but there are debates about the impacts of the LCFS on energy security. On the one hand, the LCFS encourages the use of alternative fuels and reduces oil consumption. This will lower oil imports and increase energy security. The U.S. Department of Energy's Annual Energy Outlook projects that growth in biofuels for the RFS will lower the prices of transportation fuels and reduce net oil imports from 58 percent of total oil supply in 2007 to 41 percent in 2030 in the reference case (EIA 2009). The increased use of low-carbon fuels, such as biofuels, electricity, landfill gas, and hydrogen, under an LCFS would further decrease imports and strengthen oil independence.

On the other hand, the LCFS discourages production of fuels from oil sands, heavy oil, oil shale and coal. Critics argue that such disincentives would increase the risk of energy dependence on Middle East oil, which is typically less carbon intensive than unconventional oil. This concern is real, but may be overstated according to EIA analyses. Canadian oil sands production currently contributes 1.4 percent of global oil supply. The EIA projects that this figure will increase steadily to 3.5 percent by 2030 (EIA 2009).

There are many ways to define energy security, and a variety of strategies, including reducing imports and diversifying energy type and geographical sources; increasing the portfolio of supplying countries from politically stable regions; and reducing energy prices, can effectively improve energy security (Kruyt 2009). Similarly, to achieve oil independence, the United States must reduce the oil intensity of its economy, increase the economy's ability to substitute energy efficiency and alternative energy sources for oil, and increase domestic production of oil from conventional and unconventional resources (Greene 2010). The LCFS and other policies, such as the CAFE standard, the ZEV mandate and the subsidies for batteries, will directly encourage the first two objectives—reducing oil imports and increasing the economy's ability to substitute energy efficiency and alternative energy sources. A more rigorous analysis of energy security will be needed to compare different carbon policies to reduce transportation emissions.

Indirect Land Use Change

Recent studies have shown that massive consumption of biofuels in the United States could lead to expansion of farm lands throughout the world, at the expense of other crop lands and non-crop lands such as forest and grass lands (Koh and Wilcove 2008; Laurance 2007; Searchinger et al. 2008). When lands with rich soil and biomass carbon deposits are initially converted to agricultural production, a large amount of carbon is emitted. This initial "carbon debt" can take years or even decades of cultivation to pay back (Delucchi 2004; Fargione et al. 2008; Gibbs et al. 2008).

The conversion of land, induced by market-mediated effects, can be direct or indirect. The indirect effect, or indirect land use change (iLUC), represents the overall impact from an increased demand for crop-based biofuel production, leading both to expansion of cultivated land area, called extensification, and increased land inputs to increase yields of agriculture that would not occur in the absence of biofuels production. Extensification modifies the use of global farmland and forests, marginal lands, and their carbon stocks. The iLUC effects cannot be directly observed or easily measured.

A host of models have been applied to estimate the magnitude of indirect land use change. These models include computational general equilibrium (CGE) models, such as the GTAP model (Hertel et al. 2008, 2010) and the miniCAM model (Wise et al. 2009), and partial equilibrium models such as the FASOM and FAPRI models (U.S. EPA 2009b). Reviews of recent model development and model comparison can be found in Chakravorty et al. (2009), Dehue (2009) and Searchinger (2009). The principal building blocks for estimating GHG emissions from indirect land use change and the major uncertainties associated with these steps are shown in Table 5-1.

The LCFS encourages the use of low-GHG biofuels from organic waste or other biomass and cellulosic biofuels from energy crops, crop residues and forest wastes. These biofuels are considered to have substantially lower risk of indirect land use, compete less with food production (FAO 2008; Gibbs et al. 2008; OECD 2008; Searchinger 2009; Tilman et al. 2009), provide higher yields and lower intensity of agricultural inputs including land, fertilizer, irrigation and pesticides, and incur less environmental impacts on soil erosion and loss of biodiversity (Robertson et al. 2008; Tilman et al. 2006). A recent analysis suggests that large quantities of biofuels can be produced in the U.S. from perennials grown on degraded formerly agricultural land, municipal and industrial sold waste, crop and forestry residues, and double or mixed crops produced annually (NAS 2009).

An LCFS without a cap on high-carbon fuels and indirect land use change, as some have proposed, will not be effective in reducing global GHG emissions, but could result in significant leakage, as illustrated in Wise et al. (2009) and Gillingham et al. (2008). An LCFS that covers emissions of high-carbon fuels and direct and indirect emissions will be a more robust and economically efficient policy (Wise et al. 2009, Holland 2009).

Table 5.1 Key components of estimating GHG emissions from ILUC and major uncertainties

Key Component	*Key Uncertainties*
Energy Demand from Biomass	Price of biofuels compared to oil; technology development in biofuel conversion technology
Feedstock Demand	Fuel yield; co-product markets; price elasticity of yield
Trade Balance	Tariffs and trade barriers
Area of Lands Converted	Assumed annual increases in crop yields; productivity of new land; bioenergy-induced additional productivity increase; availability of idle/marginal/degraded/abandoned/ underutilised land; methodology of allocating converted land (e.g. conversion of grassland vs. forests)
Impacts/GHG Emissions	Biofuel cultivation period; carbon stock data; discount rate; Albedo changes (eg, snow on former boreal/temperate forest land); nitrogen cycle; Other greenhouse gases (eg, cattle, rice methane)

Environmental and Social Sustainability

In addition to GHG emissions, concerns for the environmental and social impacts of large-scale biofuel production have also increased (Donner and Kucharik 2008; FAO 2008; Miller et al. 2007; National Research Council 2007; Robertson et al. 2008). As a result, sustainability goals or requirements for biofuel production have been adopted by The Netherlands (Cramer et al. 2007; Cramer et al. 2006; NEN 2009), the United Kingdom (Department for Transport 2008), Germany (BioNachV 2007; WWF 2006), the European Union (EC 2008b), and California (CEC 2008). International organizations, including the United Nations (UN) Food and Agriculture Organization and Environment Programme and the G8's Global Bioenergy Partnership, have led the research, modeling and negotiation efforts among stakeholders at the country level.

There are also more private and public efforts in promoting certifications, facilitating information sharing and sustainability management. Many new commodity-based, biofuel-targeted certifications have recently been or are being established, including by the Roundtable on Sustainable Palm Oil, Roundtable on Responsible Soy, Better Sugarcane Initiative, Council on Sustainable Biomass Production, and Roundtable for Sustainable Biofuels (RSB).

These biofuel schemes often include requirements for sustainable management of agricultural production and seek to avoid environmental damage and long term degradation and improve the socio-economic principles of welfare of local communities, land rights issues and labor welfare. Procedures for certification or verification and requirements to monitor or report progress are key elements of a sustainability scheme. Detailed reviews of these recent sustainability schemes and key challenges can be found elsewhere (Endres 2009; Winrock International 2009; Yeh et al. 2009b).

The most important sustainability criteria for a national LCFS will be to ensure that there are significant GHG reduction benefits from using biofuels. This will be dependent on a credible and consistent carbon accounting scheme that is compatible with international efforts. It is widely accepted that any further expansion of biofuel use should minimize competition between food and fuel (FAO 2008). Using largely non-agricultural land to expand dedicated energy crops would reduce the pressure on food prices and clearing of land, compared to the impacts of first-generation biofuels such as corn ethanol and soybean, but there must be efforts to ensure that unmanaged negative environmental impacts on sensitive areas and biodiversity losses do not occur (OECD 2008). Perennials grown on degraded formerly agricultural land, municipal and industrial solid waste, crop and forestry residues, and double or mixed crops offer great potential for providing significant alternative energy resources, while reducing GHG emissions and with minimal harm to the environment (Tilman et al. 2009).

UC Davis researchers have published a comprehensive review of recent efforts in sustainability standards (Yeh et al. 2009b) and conclude that an LCFS sustainability requirement may be the most effective if it adopts the following principles:

- Stakeholders should collaborate to establish a performance-based sustainability framework that sets reasonable expectations, clear measures of compliance and methods of enforcement; encourages innovation; and rewards practices exceeding a minimum standard.

- The sustainability framework should adopt a lifecycle approach and apply to all fuels, feedstocks, and production and conversion technologies. In the short term, however, the standards may apply only to non-baseline LCFS participating fuels, to address acute concerns for new fuels, reduce administrative burden and recognize existing regulations on baseline fuels.

- Careful coordination and integration among diverse international initiatives is required to improve coherence and efficiency of sustainability standards between countries. Table 5-2 summarizes principles of the RSB sustainability standard.

Table 5-2: Summary of RSB sustainability standard

Category	*Direct*	*Indirect*
National Law (especially concerning land, labor, water rights)	✓	
Community Consultation (especially to determine land rights, social and environmental impact, and idle land and to resolve grievances)	✓	
Social – biofuels should benefit rural communities and workers	✓	
Social – biofuels should not contribute to food insecurity	✓	✓
GHG (biofuels should have significantly positive balance over lifecycle)	✓	✓
Environmental – biofuels should conserve and protect soil, water, air	✓	
Environmental – biofuels should conserve and protect high conservation value areas	✓	✓
Technology and Efficiency – technologies (especially biotech) should be used responsibly and transparently and be economically efficient	✓	

Source: RSB 2009b

Harmonizing LCFS with Cap-and-Trade Programs

LCFS is clearly superior to RFS as a structure to promote the full range of low carbon fuels and to reduce the carbon intensity of fuels in the most cost-effective manner. It is technology neutral and performance based, and accounts for full fuel cycle GHG emissions. A national LCFS should keep these key elements, but need not be identical to the current program designs in California, the Northeast or the European Union. The design details, including compliance schedules; regulated fuel pools that may or may not include jet fuel, maritime fuel and home heating oil; efficiency adjustment factors for diesel and electric fuels; and either a single target or separated gasoline and diesel targets, need to be examined within a national context.

If the LCFS is adopted along with a cap-and-trade program, as would likely be the case in the United States, it would be critical to ensure minimum conflicts with or overlaps between the two programs. In California, the LCFS credits will be allowed to be exported to the cap-and-trade program, but not the other way around. The rationale for this is that the LCFS credits are expected to be of higher value than the cap-and-trade program, at least during the Phase I period from 2010 to 2020. Thus, limiting the flow of the cap-and-trade credits to the LCFS will ensure that the projected reductions under the LCFS program will be achieved.

As the transportation and electricity energy sectors become increasingly coupled due to the development of plug-in hybrid vehicles, battery electric vehicles and off-road electrification applications, issues of double crediting and double counting will become more important. For example, if an independent producer puts up a wind turbine and generates electricity to power a vehicle fleet, there is a possibility to earn credits under both the cap-and-trade program and the LCFS program. Alternatively, if a biorefinery generates electricity that goes into an off-road application, the biorefinery may claim the electricity credits under California's Renewable Portfolio Standard program as well as the LCFS. In these situations, the possibility of double crediting without double counting illustrates the potential overlap between the programs.

In the long term, when costs for low carbon fuels subside and initial market barriers are overcome, it will likely be desirable to phase out the LCFS and allow a full economy-wide credit market to operate under a cap-and-trade program. But that time is far in the future.

Conclusions

The LCFS adopted in California and the EU provide a promising opportunity to drastically reduce fossil fuel use and long-term GHG emissions from the transportation sector that is otherwise unresponsive to other moderate carbon policy initiatives. The LCFS is superior to other alternative fuel policies such as the RFS since it provides additional flexibility, encourages innovation in low-carbon fuels and incorporates market mechanisms. However, as with other policies, the implementation of the LCFS faces several challenges that may reduce its effectiveness. Further understanding of these issues, improvements of the policy design and the adoption of other complementary policies may be needed to overcome these challenges.

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