# SUSTAINABLE TRANSPORTATION ENERGY PATHWAYS

## A Research Summary for Decision Makers

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# Chapter 11: Toward a Universal Low-Carbon Fuel Standard[1]

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Petroleum's dominance as a transportation fuel has never been seriously threatened anywhere—except Brazil, with its sugarcane ethanol—since taking root nearly a century ago. Efforts to replace petroleum, usually for energy security reasons but also to reduce local air pollution, have continued episodically for years—and largely failed. Vehicles, planes, and ships are still almost entirely dependent on petroleum and account for nearly one-third of all greenhouse gas (GHG) emissions in the United States and almost one-fourth of all GHG emissions globally. In the face of this stubborn petroleum lock-in, what is the most effective type of policy to spur technological innovation and investment in alternative fuels?

In this chapter we argue that a new policy instrument known as a low-carbon fuel standard (LCFS) is the most promising approach to getting the carbon out of fuels. We have learned from past failures that to be successful, a policy approach must inspire industry to pursue innovation aggressively; it must be flexible, performance-based, and inclusive so that industry, not government, picks the winners. It should also take account of all greenhouse gas emissions associated with the production, distribution, and use of the fuel, from the source to the vehicle, so that petroleum and alternative fuels such as hydrogen and electricity are compared on a level playing field. (While upstream emissions account for about 20 percent of total GHG emissions from petroleum, they represent almost the total life-cycle emissions for fuels such as electricity and hydrogen; upstream emissions from extraction, production, and refining also comprise a large percentage of total emissions for the very heavy oils and tar sands that oil companies are increasingly embracing to supplement limited supplies of conventional crude oil.) LCFS policies already adopted in California and the European Union fit these requirements and can lead the way toward a harmonized international effort.

## Failed and Ineffective Approaches of the Past

No country other than Brazil has been successful at replacing petroleum fuels in the transport sector. Many countries, especially the United States, have provided policy support for one alternative fuel after another, some gaining more attention than others but each one eventually faltering. The fuels du jour in the 1980s and 1990s were coal liquids, methanol, compressed and liquefied natural gas, and electricity for battery vehicles. Early in the 21st century it was hydrogen, followed by corn ethanol, and now electricity for plug-in hybrid electric vehicles. But worldwide, the only nonpetroleum fuels that have gained significant market share are corn ethanol in the United States and sugarcane ethanol in Brazil.

The fuel du jour phenomenon is fed by oil market failures, overblown promises, the inertia of oil industry investments, and the short attention spans of government, the mass media, and the public.[2] Alternatives emerge when oil prices are high but wither when prices fall. They rise when public attention is focused on the environmental shortcomings of petroleum fuels but dissipate when oil and auto companies marshal their considerable resources to improve their environmental performance. When George H. Bush advocated methanol fuel in 1989 as a way of reducing vehicular pollution, oil companies responded by offering cleaner-burning reformulated gasoline (and later, cleaner diesel). And when air regulators in California and the United States adopted aggressive emission standards for engines, vehicle manufacturers diverted resources to improve combustion and emission control technologies.

One key problem is the ad hoc approach of governments to petroleum substitution. The U.S. government provided loan and purchase guarantees for coal and oil shale "synfuels" in the early 1980s when oil prices were high, passed a law in 1988 offering fuel economy credits for flexible-fuel cars, launched the Advanced Battery Consortium and Partnership for a New Generation of Vehicles in the early 1990s to accelerate development of advanced vehicles, promoted hydrogen cars in the early years of this decade, provided tens of billions of dollars in federal and state subsidies for corn ethanol, and is now providing incentives for plug-in hybrids. State initiatives included California's purchases of methanol cars in the 1980s and its zero-emission vehicle requirement of 1990.

But these various alternative fuel initiatives have failed to move us away from petroleum-based transportation, in part because the government did not adopt supporting incentives and plans. More durable policies are needed—ones that are based on performance, that stimulate innovation, and that reduce consumer and industry risk and uncertainty.

## FUNDAMENTALS OF EFFECTIVE PROGRAMS

Policies and programs that aim to motivate industry to pursue innovations are more likely to be successful if they are flexible, performance-based, and inclusive. Federal fuel economy standards for cars and light trucks, for example, allow industry to determine the best way to achieve the targets, which stimulates innovation. Experiences with fuel economy standards and other programs suggest several principles for policies that promote low-carbon transportation fuels.

**Don't try to pick winners.** Programs are more successful if they focus on the goal and not on the specific means to achieve it. If the goal is to lower GHG emissions from fuels, setting GHG performance standards for transportation fuels motivates companies to find the best approach. Although mandating the use of specific fuels such as natural gas or ethanol may reduce GHG emissions, the market generally will achieve that goal at lower cost if allowed the flexibility to choose from the mix of possible fuels. The market can quickly adapt to changes in technology, allowing the introduction of new fuel pathways with greater emissions reduction or lower cost, or both.

**Assess the full GHG life cycle**. To reduce GHG emissions, all emissions associated with the production, distribution, and use of the fuel must be considered. This well-to-wheels or source-to-wheels life-cycle assessment should include all direct emissions, such as those associated with acquiring, growing, and harvesting the feedstock for biofuels; transporting the feedstock to the fuel-processing facility; turning the feedstock into an acceptable fuel; delivering the fuel to the point of retail sale; and burning the fuel.

Life-cycle analyses should also consider the indirect impacts, which can be large. For biomass-based fuels, for example, indirect emissions are associated with diverting land from food and other uses to energy production; in the case of corn ethanol, additional land is drawn into production to replace the corn diverted to energy use. These effects are controversial because they have never been included in policies or regulations and because the underlying science is still evolving. (See Chapter 12 for more on this.) The indirect land-use effects can be large for food-based feedstocks, which are land-intensive, but small for cellulosic materials, and zero for waste materials.

**Be aware of positive and negative side effects**. Policies and programs promoting fuels with lower GHG emissions may have other consequences, beneficial or harmful. For example, how is the price of food affected by the diversion of food and animal feed, such as corn and soybeans, to biofuel production? And, more positively, how much does greater reliance on biofuels from feedstock grown in the United States reduce expenditures on imported oil and increase farm incomes and jobs? Perhaps more important, some so-called side effects, such as energy security benefits of reducing dependence on petroleum, may be chief reasons for implementing the policies.

**Don't be naïve about real-world responses**. Responses may occur outside the jurisdiction of the entity that establishes a low-carbon fuel program. One response, termed "leakage," occurs when fuel suppliers shift their fuels to avoid compliance with California or federal regulations. For instance, a high-carbon transportation fuel made from oil sands or liquefied coal can be shipped to states or countries with no regulations mandating reduced carbon content. Because GHG buildup is a global problem, the benefits of reduction will be lost if the leakage response becomes rampant. The leakage problem diminishes as more states and nations adopt low-carbon fuel policies.

Another potential response is increased consumption of gasoline and diesel fuels in places without low-carbon fuel policies and biofuel mandates, if reduced consumption in California or the United States reduces world oil prices. This rebound effect would probably be small but would nonetheless offset some of the GHG emissions reductions that the program achieves.

**Recognize infrastructure and economic barriers**. Infrastructure can be slow to change and thus act as a barrier to the widespread introduction of new fuels. For example, ethanol is now used as a blend stock with gasoline. With ethanol use increasing, gasoline in the United States is likely to reach the 10-percent blending limit allowed in vehicles by 2015. Two options exist to expand the use of ethanol. One is to increase the blending limit, but this is opposed by manufacturers of off-road equipment, such as lawnmowers, and cars and light trucks, who are concerned about damage to the engines. The second option is to expand the use of flexible-fueled vehicles, which can use ethanol in concentrations of up to 85 percent in gasoline (E85). Yet the number of filling stations now offering E85 is limited, and adding a pump and storage tank for E85 can cost $100,000 and more.

## The Trouble with Current Mandates and Proposals

What about using a volumetric standard like the Renewable Fuel Standard (RFS) adopted by the U.S. Congress? What about carbon taxes and the cap-and-trade approach? Although these are steps in the right direction, we do not believe they are the most effective policy instruments to move the transport sector away from petroleum dominance.

### Volumetric mandates

Since the start of the 21st century, volumetric mandates have been the preferred policy approach to reduce the use of petroleum fuels. The United States adopted a volumetric mandate for biofuels (the Renewable Fuel Standard or RFS) in 2005 and strengthened it in December 2007 as part of the Energy Independence and Security Act (EISA). RFS2 requires that 36 billion gallons of biofuels be sold annually by 2022; 21 billion gallons of these must be "advanced" biofuels and the other 15 billion gallons can be corn ethanol. To achieve these volumes, the U.S. Environmental Protection Agency (EPA) calculates a percentage-based standard every year. Based on the standard, each refiner, importer, and non-oxygenate blender of gasoline determines the minimum volume of renewable fuel it must use in its transportation fuel mix. The advanced biofuels are required to achieve at least a 50-percent reduction from baseline life-cycle GHG emissions, with a subcategory of cellulosic biofuels required to meet a 60-percent reduction target. These reduction targets are based on life-cycle emissions, including emissions from indirect land-use changes.

Similarly, the United Kingdom's Renewable Transport Fuel Obligation (RTFO) aims to have 3.25 percent of all transport fuel sold in the United Kingdom come from a renewable source by 2009–10 and to reach 5 percent in 2013–14. The European Union's Biofuel Directive (BD) initially set a target of 5.75 percent biofuels by 2010 and 10 percent biofuels by 2020 but has since broadened the target to include all renewable fuels and renamed it the Renewable Energy Directive (RED).

Volumetric biofuel mandates have a number of shortcomings. First, they target only biofuels and not other alternatives. Second, setting GHG reduction targets within the volumetric mandates, as the United States does with its RFS2 program, is a clumsy way to reduce GHGs. It forces biofuels into a small number of fixed categories and thereby stifles innovation. Once the regulatory agency concludes that certain biofuel pathways meet the specified GHG reduction target, there is little incentive for further improvement. As a result, there is less incentive to use very-low-carbon materials, such as waste biomass, or adopt sustainable farming and management practices that reduce direct and indirect land-use emissions.[3] Third, RFS2 exempts existing and planned corn ethanol production plants from the greenhouse gas requirements, essentially mandating a massive unfettered expansion of corn ethanol. Rapid expansion of corn ethanol not only stresses food markets and requires vast amounts of water but also pulls large quantities of prairie lands, pastures, rain forests, and other lands into intensive agricultural production (to replace corn acreage that has been diverted to ethanol production), which means some corn ethanol will likely have higher overall GHG emissions than gasoline or diesel fuels. And fourth, RFS2 could run up against infrastructure barriers. The U.S. EPA estimates that the number of E85 retail facilities may need to expand from approximately 2,000 to between 12,000 and 24,000 nationwide by 2022 if most of the required 36 billion gallons of biofuels are sold as ethanol and the blend limit is not raised. The number of flexible-fueled vehicles on the road capable of using E85 would also need to expand dramatically.

A broader concern is the environmental and social sustainability of biofuels. Unlike the biofuel program in the United States, the European renewable energy mandates are met in large part through imports. In the United Kingdom as of December 2008, 97 percent of the renewable fuels were imports—biodiesel made from American soy, rapeseed from Germany, and palm oil from Malaysia and Indonesia; and ethanol made from Brazilian sugarcane. In the European Union, most of the biofuel imports are ethanol from Brazil and palm oil from Malaysia and Indonesia.[4] Scientists and environmental groups have raised concerns about the local environmental and social impacts of these imported fuels. As a result, the Netherlands, the United Kingdom, and the European Union are adopting sustainability standards for biofuels. These sustainability standards typically address issues of biodiversity, and soil, air, and water quality, as well as social and economic conditions of local communities and workers. They require reporting and documentation but lack real enforcement. The effectiveness of these standards remains uncertain. More science-based research and technical analysis are needed to better quantify the direct effects that the sustainability standards intend to address, as well as the indirect effects and cumulative environmental damages at large scales and over long periods of time that these sustainability standards and certification schemes are ill-equipped to tackle.

## Carbon taxes or cap-and-trade

Many argue that a carbon tax or cap-and-trade program would improve the RFS. Economists argue that carbon taxes—taxes on energy sources that emit carbon dioxide—would be a more economically efficient way to introduce low-carbon alternative fuels. Former Federal Reserve chairman Alan Greenspan, car companies, and economists on the left and the right all have supported carbon and fuel taxes as the principal cure for both oil insecurity and climate change. But carbon taxes have shortcomings. Not only do they attract political opposition and public ire, but they are also of limited effectiveness and work better in some situations than others.

For example, even a modest carbon tax works well to reduce carbon from electricity generation. Electricity suppliers can choose among a wide variety of commercially available low-carbon energy sources, including nuclear power, wind, natural gas, and even coal with carbon capture and sequestration. A tax of as little as $25 per ton of carbon dioxide would increase the retail price of electricity made from coal by about 17 percent (in the United States), which would be enough to motivate electricity producers to seek lower-carbon alternatives. The result would be innovation, change, and decarbonization. Politically plausible carbon taxes promise to be effective in transforming the electricity industry.[5]

But transportation is a different story. A $50-a-ton tax, which would raise gasoline prices about 45 cents per gallon (well above what U.S. politicians have been considering), would motivate very little response from consumers or producers, judging by European experience. (Many European countries have had transport fuel taxes equivalent to $4 per gallon for many years, with virtually no effect in decarbonizing fuels—although the taxes are not based on carbon content.) Oil producers wouldn't respond because they've become almost completely dependent on petroleum to supply transportation fuels and can't easily find or develop low-carbon alternatives within a short time frame. Equally important, a transition away from oil depends on automakers and drivers changing their behavior—and they also would be unmotivated by a carbon tax. A tax of $50 a ton (45 cents per gallon) would barely reduce gas consumption, let alone induce drivers to switch to low-carbon alternative fuels when virtually none are available. As a result, oil industries would simply pay taxes and pass the costs to consumers instead of adopting low-carbon fuels.

Carbon cap-and-trade programs suffer the same shortcomings as carbon taxes. This type of policy as usually conceived involves placing a cap on the carbon dioxide emissions of large industrial sources and granting or selling emission allowances to individual companies for use in meeting their caps. Emission allowances, once awarded, could be bought and sold. In the transportation sector, a cap would be placed on oil refineries' emissions, requiring them to reduce carbon dioxide emissions associated with the fuels they produced. The refineries would be able to trade credits among themselves and with others. As the cap was tightened over time, pressure would build to improve the efficiency of refineries and introduce low-carbon fuels. Refiners would likely increase the prices of gasoline and diesel to subsidize low-carbon fuels—creating a market signal for consumers to drive less and for producers of cars to make them more energy efficient. But if the cap were not very stringent, this signal would likely be relatively weak for the transportation sector.

Carbon taxes and/or cap-and-trade should be central to any regional or national initiative to reduce GHG emissions. It is conceivable that in the long run when advanced biofuels and electric and hydrogen vehicles are commercially viable and overcome the infrastructure hurdle, cap-and-trade and carbon taxes will become effective policies within the transportation sector. But until then, more direct forcing mechanisms, such as a low-carbon fuel standard for refiners, will likely be far more effective at stimulating innovation and overcoming the many barriers to change.

## Emergence of a GHG Performance Standard for Fuels

The ad hoc approach of the past and current limited mandates and proposals needs to be replaced by durable policies that do not depend on the government's picking winners. A new approach is needed that would ideally be fuel-neutral and performance-based and that would harness market forces. Such an approach has emerged in Europe and the United States. It is farthest along in California, where the Low-Carbon Fuel Standard (LCFS) is a performance-based standard that measures $CO_2$-equivalent grams per unit of fuel energy. An important feature of the LCFS is that the performance standard applies to *all* fuels, including not just biofuels but also petroleum-based gasoline and diesel, electricity, hydrogen, and other potential fuels that are likely to play a role in the transportation sector in the future.

The LCFS is the first major public initiative to codify life-cycle concepts into law, an innovation that will become more widespread as climate policies are pursued more aggressively.

The point of regulation can occur anywhere along the energy chain, from the individual user all the way upstream to the fuel producers. To ease administration, it is best placed as far upstream as practical—meaning on oil refiners and importers, and fuel producers. An important feature of the LCFS is the ability to buy and sell credits, which will help reduce the cost of achieving the reductions. A tradable credit market will give companies a strong incentive to invest in new and better ways to produce lower-carbon fuels. An oil refiner could, for instance, buy credits (or the fuels themselves) from biofuel producers or from an electric utility that sells power to electric vehicles. Those companies that are most innovative and best able to produce low-cost, low-carbon alternative fuels will thrive, and overall emissions will be lowered at less cost for everyone.

The concepts underlying the LCFS are not unique, but the intellectual and programmatic antecedents of the LCFS are remarkably sparse. The intellectual origin of the LCFS might be Jonathan Rubin's 1993 PhD dissertation at the University of California, Davis, evaluating the use of tradable credits and emission performance standards in transitioning to alternative transportation fuels. Surprisingly, the scholarly literature is otherwise largely quiet on the concept of carbon standards for fuels. John DeCicco and Jason Mark suggested it in various publications in the 1990s, but not until Bob Epstein, a former Silicon Valley entrepreneur, began promoting the concept in 2005 did it gain prominent attention. He and others, especially Roland Hwang of the Natural Resources Defense Council, an advocacy group, pitched the concept to California governor Arnold Schwarzenegger in the autumn of 2006. In January 2007, Governor Schwarzenegger directed the California Air Resources Board (CARB) to develop and implement a low-carbon fuel standard to spur technological innovation and investment in alternative fuels. CARB adopted the LCFS in concept in June 2007 and began a rulemaking process, with the final rule adopted in April 2009; this rule took effect in January 2010.

The European Union unveiled a similar proposal just two weeks after Governor Schwarzenegger did, and in December 2008 its Parliament adopted an amended Fuel Quality Directive (FQD) [6] that is very similar to the California LCFS—with E.U. leaders publicly indicating it was their intent to closely imitate the California standard. In January 2009, 11 northeastern and mid-Atlantic states signed a letter committing to cooperate in developing a regional LCFS.

Compared to biofuel mandates, an LCFS has three key advantages: it inspires industry to pursue innovation aggressively, it is flexible and performance-based so that industry (not government) picks the winners, and it directly targets actual life-cycle GHG emissions associated with the production, distribution, and use of the fuel from the source to the vehicle. An LCFS is a more robust and ultimately more efficient approach than volumetric mandates. Unlike the RFS and other biofuel programs, an LCFS will encourage oil companies to pursue a fuller set of low-carbon fuel options. It will encourage companies to integrate their R&D portfolios across all energy options, including wind, solar, hydrogen, and natural gas, along with carbon capture and sequestration technologies.

On the other hand, an LCFS faces the same concerns about infrastructure barriers and biofuels sustainability that RFS2 and other biofuels mandates face. And some economists characterize the LCFS approach as second best because it is not as efficient as a carbon tax or cap-and-trade,[7] but given the huge barriers to alternative fuels and the limited impact of increased taxes and prices on transportation fuel demand, an LCFS appears to be the most practical way to begin the transition to alternative fuels. Those more concerned with energy security than with climate change might also be skeptical of the LCFS approach, fearing that it might disadvantage high-carbon alternatives such as tar sands and coal liquids. That concern is valid, but disadvantaging does not mean banning. Tar sands and coal liquids could still be introduced on a large scale with an LCFS. The LCFS would require producers of high-carbon alternatives to be more energy efficient and to reduce carbon emissions associated with production and refining. Producers could do so by using low-carbon energy sources for processing energy and could capture and sequester carbon emissions. They could also opt for ways of converting tar sands and coal resources into fuels that facilitate carbon capture and sequestration. For instance, gasifying coal to produce hydrogen allows for the capture of almost all the carbon, since none remains in the fuel itself. In this way, coal could be a nearly zero-carbon option.

## HOW TO HANDLE UNCERTAINTY AROUND INDIRECT LAND-USE EFFECTS?

One of the key features of the LCFS approach is that its GHG reduction target takes into account all emissions generated during a fuel's life cycle. This means it takes into account even the emissions generated by indirect land-use changes. But it turns out that this is perhaps the most controversial and challenging issue facing the life-cycle accounting approach adopted by the LCFS and RFS2. The problem is that scientific studies have not yet adequately quantified the indirect land-use effects of increased biofuel production. (You can read more about this in Chapter 12.) So how do regulators add in the emissions from indirect land-use effects when they are measuring the life-cycle GHG emissions of a biofuel? It is a classic challenge: how to handle scientific uncertainty in a policy context.

The prudent approach for regulators is to use available science to assign a conservative value to indirect land-use effects and then to provide a mechanism to update these assigned values as the science improves. Meanwhile, producers should focus on biofuels with low GHG emissions and minimal indirect land-use effects—fuels created from wastes and residues and from biomass grown on degraded or marginal land or with very high yields per unit of land (for example, grasses, some tree species, and algae). Those feedstock materials, instead of intensively farmed food crops like corn, should be the heart of a future biofuel industry—and they will be if producers have to meet a low-carbon fuel standard.

## A Closer Look at the LCFS

California's LCFS requires a 10-percent reduction in the greenhouse gas intensity of transport fuels by 2020. The LCFS metric is total carbon and other greenhouse gases emitted per unit of fuel energy. The standard captures all GHGs emitted in the life cycle, from extraction, cultivation, land-use conversion, processing, transport and distribution, and fuel use. The LCFS is imposed on all transport fuel providers, including refiners, blenders, producers, and importers. Aviation and certain maritime fuels are excluded, either because the state does not have authority over them or because including them presents logistical challenges.

To implement the LCFS, each fuel supplier must meet a GHG intensity standard that declines each year, reaching a 10-percent reduction from the baseline year of 2010 by 2020. To maximize flexibility and innovation throughout the energy sector, the LCFS allows for the trading and banking of emission credits. The combination of regulatory and market mechanisms makes the LCFS more robust and durable than a purely regulatory approach and more acceptable and effective than a pure market approach. Companies failing to meet the standard could face monetary penalties and/or legal action via CARB.

There are several ways that regulated parties can comply with the LCFS. Refiners can blend low-GHG fuels, such as biofuels made from cellulose or wastes, into gasoline and diesel. Or they can buy low-GHG fuels such as natural gas, biofuels, electricity, and hydrogen. They can also buy credits from other refiners or use banked credits from previous years. In the EU, producers can also earn credit by improving energy efficiency at oil refineries or by reducing upstream $CO_2$ emissions from petroleum and natural gas production.

The European Union's FQD requires fuel suppliers to reduce life-cycle GHG emissions by up to 10 percent from the 2010 baseline by 2020. The 10-percent reduction is broader than that mandated by the California LCFS in that 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) of the Kyoto Protocol. Upstream emission reductions, CCS, and the CDM can be used to meet up to 4 percent of the 10-percent requirement.

Recent studies suggest that California's LCFS can be met at costs lower than or comparable to oil priced at $60–100 per barrel[8] and that "alternative liquid fuel technology can be deployable and supply a substantial volume of clean fuels for U.S. transportation at a reasonable cost."[9] However, because of market failures, uncertain oil prices, and risk aversion,[10] companies are unlikely to invest in new fuel technologies and infrastructure for alternative fuels. More direct, performance-based policy instruments are needed to overcome carbon lock-in.[11]

A major challenge for the LCFS is avoiding "shuffling," which is similar to leakage but refers specifically to the actions of producers to shift production elsewhere outside of the regulated market. Companies will seek the easiest way of responding to the new requirements, which might involve shuffling production and sales in ways that meet requirements without actually creating a net change in emissions. For instance, a producer in Iowa could divert its low-GHG cellulosic biofuels to California markets and send its high-carbon corn ethanol elsewhere. The same could happen with gasoline made from tar sands and conventional oil. Environmental regulators will need to account for shuffling in their rules. This problem will eventually disappear as more states and nations adopt the same regulatory standards and requirements.

## Going National and International with the LCFS Approach

The principle of performance-based standards lends itself to adoption nationally and even internationally. The California program is designed to be compatible with a broader program and in fact will be much more effective if the entire United States as well as other countries also adopt it. Existing volumetric biofuel requirements could be readily converted into an LCFS by converting them to greenhouse gas requirements. In the United States that would not be difficult, since GHG requirements are already imposed on required biofuels. The E.U. biofuel programs could also be converted similarly. Indeed, the evolving carbon and sustainability reporting and certification schemes of the European Union and the U.K. Renewable Transport Fuel Obligation (RTFO) are already gravitating away from a pure volumetric requirement and toward an LCFS.

An important innovation of the California LCFS is its embrace of all transportation fuels. The U.S. RFS2 and E.U. programs, in contrast, include only biofuels, not gaseous fuels or electricity (although biogas is eligible for credits in the European Union, and the December 2008 revisions of the E.U. Fuel Quality Directive envision a future role for electric vehicles). While it is desirable to cast the net as wide as possible, there is no reason why all states and nations must target identical fuels.

Broader LCFS programs are attractive for three reasons. First, it would be easier to include fuels used in international transport modes, especially fuels used in jets and ships. California is excluding these fuels initially because it has only limited jurisdiction over international modes of travel. Second, a broader LCFS would facilitate standardization of measurement protocols. California is currently working with fuel-exporting nations to develop common GHG emissions specifications for their fuels. And third, the broader the pool, the more options are available to regulated entities. More choice means lower overall cost, since there will be a greater chance of finding low-cost options to meet targets.

## KEY ELEMENTS OF SUSTAINABILITY STANDARDS FOR FUTURE TRANSPORTATION FUELS

To ensure sustainable development of future transportation fuels, governments—including the Netherlands, the United Kingdom, the European Union, and to some extent the United States with its Renewable Fuel Standard (so called RFS2) program—have begun to impose a variety of sustainability goals and requirements for biofuel production. These sustainability initiatives often include requirements for sustainable management of agricultural production, reduced environmental damage and degradation, and considerations of local community welfare, land rights, and labor welfare. Procedures for certification and verification of sustainability reports, plus requirements to monitor or report progress, are also key elements of sustainability schemes.

California will develop sustainability standards for its low-carbon fuel standard (LCFS). UC researchers have developed a list of recommendations for the implementation of sustainability standards for the LCFS.[12] They assert in their report that a sustainability scheme can be effective only if the proposed framework

- is a multi-stakeholder process,
- is robust but not excessively complicated and acknowledges the limitations of resources, politics, and California's legal jurisdiction,
- sets measurable and verifiable criteria and standards,
- defines methods of enforcement, and
- is consistent with international efforts in sustainability criteria.

Further, the report suggests that government assistance in facilitating information sharing, certification, and capacity building will be crucial for the development of the sustainability criteria. Governments should design incentive mechanisms to encourage the practice of sustainable management and reward practices exceeding minimum standards.

## Summary and Conclusions

- The ad hoc policy approach to alternative fuels has largely failed. A more durable and comprehensive approach is needed that encourages innovation and lets industry and consumers pick winners. The LCFS approach does that. It provides a single GHG performance standard for all transport fuel providers and all transport fuels, and it uses credit trading to ensure that the transition is accomplished in a more economically efficient manner.

- Although one might prefer more pure market instruments, such as carbon taxes and cap-and-trade, those instruments are not likely to be effective in the foreseeable future with transport fuels. The envisioned (and politically plausible) price and cap levels would not motivate large investments in electric vehicles, plug-in hybrids, hydrogen fuel cell vehicles, and advanced biofuels. More direct policies, such as an LCFS, are needed to stimulate innovations in low-GHG alternative fuels.

- While an LCFS would be highly effective on its own, to be most effective it must be coupled with other policies—those that address the amount of fuel consumed (since the LCFS is an intensity standard), accelerate the initial provision of infrastructure to supply low-carbon fuels, and assure vehicles are available to use the low-carbon fuels. The LCFS and RFS2 programs are important steps forward. Continued progress will require the concerted efforts of scientists, investors, producers, and elected officials to ensure that wise choices are made in the transition to a different transportation energy future.

## Notes

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