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Summary Report on Low Carbon Fuel-Related Standards

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INTRODUCTION

This paper provides a summary of low carbon fuel-related standards that are in various stages of development and implementation emphasizing the key features of each type of standard. These standards represent an important step in curbing GHG emissions from the transportation sector, which contributes 13% of GHG emissions worldwide (Pew Center on Global Climate Change, 2004). There are five main low carbon fuel-related standards in existence or near to implementation in the US and Europe:

- US Federal Renewable Fuel Standard (US-RFS2)
- California Low Carbon Fuel Standard (CA-LCFS)
- European Renewable Energy Directive
- European Fuel Quality Directive, and
- The UK Renewable Transport Fuel Obligation (RTFO).

Canada is also pursuing standards similar to California's LCFS. US-RFS2 and CA-LCFS have not been officially implemented yet. Although the underlying objective of the low carbon fuel-related standards in different countries and regions is the same (i.e., to diversify fuel sources and reduce GHG emissions), there are differences in GHG reduction targets and mechanisms for achieving the targets.

Table 1 summarizes the key elements that are taken into consideration while developing different low carbon fuel-related standards in the US and Europe. As shown in Table 1, biofuels constitute an important component of low carbon fuel related-standards to achieve the desired reductions in GHG emissions. Carbon neutrality of the tailpipe emissions is what makes biofuels a preferred choice, since tailpipe CO_2 emissions are counterbalanced by CO_2 sequestered during the plant growth. It should be noted that the question of whether biofuels can reduce GHG emissions relative to fossil liquid fuels may ultimately depend on whether or not indirect land use changes (ILUC) are included in the scope of the life cycle studies. For example, preliminary estimates indicate that corn ethanol may emit more GHG emissions than gasoline if GHG emissions from ILUC are considered as part of the life cycle (US EPA, 2009a).

Table 1. Salient features of low carbon fuel-related standards for transportation sector

Features	US-RFS2	CA- LCFS	The Fuel Quality Directive (EU)	The Renewable Energy Directive (EU)	UK (Renewable Transport Fuel Obligation (RTFO)
Baseline fuels	Diesel and gasoline	Reformulated gasoline and 10% corn ethanol, diesel	Diesel and gasoline	Diesel and gasoline	Diesel and gasoline
Targets	36 billion gallons of biofuels by 2022, GHG emission reduction of 6.5%	10% reduction in GHG emissions by 2020	10% reduction in GHG emissions by 2020 (6% mandatory)	10% of biofuels (energy content)	5% of biofuels (energy content) by 2010/2011, GHG emission reduction of 1.9%
Compliance pathways	Cellulosic ethanol, advanced biofuel, renewable biofuel	Biofuels, LPG, NG, electricity, H2	Biofuels, reductions in flaring and venting, carbon sequestration and capture	Biofuels	Sustainable biofuels
Market mechanisms	None	Credit trading	Credits can be purchased from CDM to meet 2% optional target	None	Tradable Renewable Transportation Certificates (RTFCs), buy-out option
GHG emissions from ILUC	Proposed but uncertain	Included	TBD (proposal by Dec. 2010)		None
Sustainability criteria	Included	To be included by 2011	Included	Included	Included
Status	Rule making stage	Rule making stage	Implemented	Implemented	Implemented

US-RFS2 and CA-LCFS envision that starch-based ethanol would dominate in the early part of the program implementation, with advanced biofuels such as cellulosic ethanol expected to gain a larger share of biofuel content in the latter part of the program. Fossil-based fuels such as LPG, natural gas, and hydrogen and electricity from fossil fuels and biomass also offer the possibility of GHG reductions and hence qualify as low carbon fuels under California's LCFS and Europe's Fuel Quality Directive. The US federal RFS2, the UK RTFO and the European Renewable Energy Directive, as the names indicate, do not deal with fossil-based low carbon fuels. Reductions in flaring and venting activities are explicitly recognized by the European Fuel Quality Directive as carbon mitigation measures that may contribute towards achieving the optional 2% reduction target by 2020. CA-LCFS and the RTFO have market-based mechanisms to achieve the GHG reduction targets. Sustainability, which can be broadly defined as the continuation of well-being of humans and the environment and responsible utilization of natural resources, is taken into consideration while developing low carbon fuel-related standards. Sustainability measures included in low carbon fuel-related standards deal with environmental and social aspects of biomass production and its impacts. The rest of the report includes a brief analysis of the various low carbon fuel-related standards highlighting their key features and differences.

LOW CARBON FUEL-RELATED STANDARDS

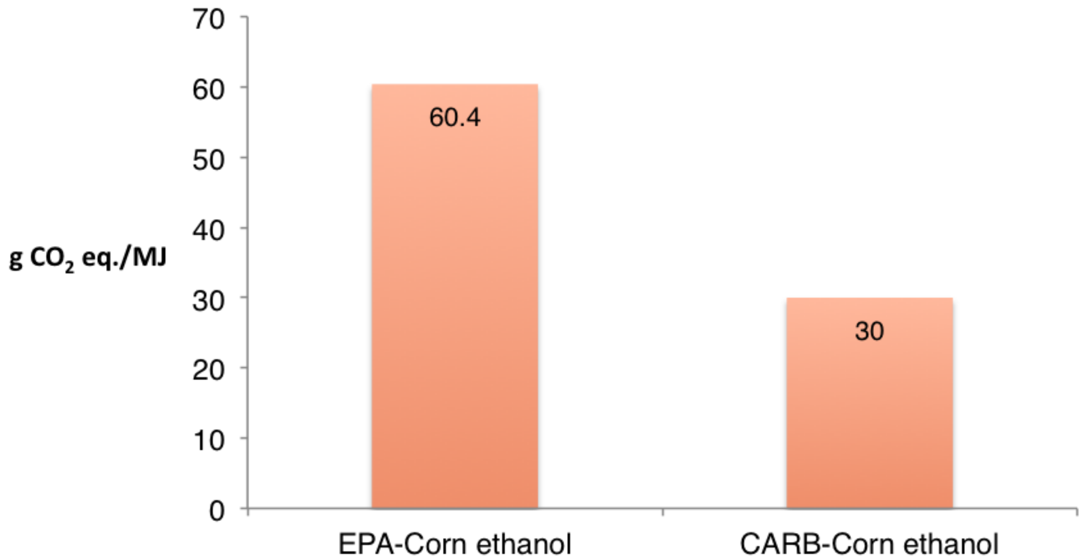
Low carbon fuel standard (LCFS), California

On April 23, 2009, the California Air Resources Board (CARB) approved for adoption a low carbon fuel standard. The standard is expected to become final by the end of 2009. The overall goal of CA-LCFS is to achieve 10% reduction in GHG emissions from the transportation sector in California by 2020; this amounts to a reduction of 16 million metric tons (CO_2 eq.). The salient features of California's LCFS are as follows (CARB, 2009a):

- The two baseline fuels against which other fuels are measured are California reformulated gasoline mixed with corn-derived ethanol at 10 percent by volume, and low sulfur diesel fuel.
- Potential low carbon fuels include biofuels, natural gas, LPG, hydrogen and electric-drive vehicles (hybrid, plug-in-hybrid, and battery-electric vehicles).
- Credits and deficits for fuels are generally determined based on the amount of fuel sold, the carbon intensity of the fuel, and the efficiency with which a vehicle converts the fuel into useable energy.
- Providers of transportation fuels must report all fuels provided and track the fuels' carbon intensity through a system of "credits" and "deficits." They must demonstrate that the mix of fuels they supply meets the LCFS carbon intensity standards for each annual compliance period between 2011 and 2020. Credits may be banked and traded within the LCFS market to meet obligations.
- The LCFS requires the use of life cycle analysis (LCA) as a tool to quantify GHG emission reductions from alternative fuels on a well to wheels basis.
- It is proposed that emissions associated with direct and indirect land use changes, principally for biofuel feedstocks, be included in the carbon intensity values assigned to those fuels in the regulation. Preliminary estimates show that GHG emissions from indirect land use changes can be appreciable (Fig. 1). Large uncertainties exist in the estimates of GHG emissions from ILUC.
- The proposed standard does not allow carbon trading outside the California transportation sector.
- Sustainability criteria will be included in LCFS by 2011.

Following in the footsteps of California, a regional consortium of eleven Northeastern and Mid-Atlantic States has shown a strong interest in developing LCFS similar to that of California's. The members of the consortium agreed to draft a Memorandum of Understanding with regard to LCFS. The Memorandum of Understanding will be sent to governors for further consideration. In Canada, the province of British Columbia published a paper in August 2009 that proposes LCFS regulations based on California's, except that there is a single baseline fuel – gasoline with no ethanol content.

Fig. 1. Estimates of GHG emissions from indirect land use change for corn ethanol (30 years 0 % discount)



Source: Air Improvement Resource, Inc., 2009

Note: The large difference in the estimates of the US EPA and CARB for ILUC GHG emissions is attributed to utilization of different land use models, and assumptions with regard to land use change and GHG emissions from converted forests.

US Renewable Fuel Standard (US-RFS2)

Serious efforts to promote low carbon fuels at the federal level began with promulgation of a renewable fuel standard (RFS) in 2005. The RFS mandated that 7.5 billion gallons (Bgal) of ethanol and biodiesel fuels be sold in the US market by 2012. The RFS is currently being augmented as directed by the Energy Independence and Security Act of 2007 (EISA) and is known as US-RFS2.

There are two important features of US-RFS2: (1) It specifies the volumetric requirements for renewable fuels through 2022, and (2) it sets GHG emission thresholds for four biofuel types: advanced biofuel, cellulosic biofuel, biomass-based diesel, and other renewable fuels. US-RFS2 requires that the total volume of renewable fuels used in the US should be 36 Bgal by 2022, of which 16 Bgal should be cellulosic biofuel (US EPA, 2009a). For the purpose of quantifying GHG reductions, US-RFS2 incorporates LCA as a tool to measure the net reductions in life cycle GHG emissions compared to gasoline and diesel. It is also required that LCA consider both direct and indirect GHG emissions from land use change.

US-RFS2 classifies biofuels into four categories.

1) Advanced biofuel is defined as a renewable fuel other than corn ethanol that reduces life cycle GHG emissions by 50% as compared to gasoline or diesel that it replaces.

2) Cellulosic biofuel is defined as a renewable fuel obtained from cellulose, hemicelluose and lignin that decreases life cycle GHG emissions by 60% as compared to gasoline and diesel it replaces. All cellulosic biofuels are advanced biofuels but not all advanced biofuels are cellulosic biofuels.

3) Biomass-based diesel refers to biodiesel, non-ester renewable diesel and other diesel derived from biomass. Biomass-based diesel must reduce life cycle GHG emissions by at least 50%.

4) Other renewable fuels include any renewable fuels used in a motor vehicle that reduce the quantity

of fossil fuel used in a fuel mixture used to drive a vehicle. Conventional ethanol derived from starch sources qualifies as renewable fuel under this category. Other renewable fuels are required to meet a 20% reduction in life cycle GHG emissions.

Biofuel facilities built before December, 2007 are exempt from the 20% reduction requirement (US EPA, 2009a). The US EPA expects that at least 15 Bgal will be grandfathered, including all current corn-ethanol and biodiesel production volume. In sum, US-RFS2 seeks to move beyond corn-based ethanol to cellulosic ethanol and advanced biofuels.

The scale of the US-RFS2 program is sufficiently large that the ethanol targets are too large to be met solely through gasoline blending up to 10% by volume. The additional ethanol could be accommodated either by a large-scale program to implement E-85 refueling and flexible fuel vehicles, or by raising the ethanol blending limit in gasoline. Both of these strategies have their challenges.

As mandated by the Energy Independence and Security Act (EISA) of 2007, US-RFS2 needs to address the longer-term environmental impacts of large-scale biofuel production. In order to be eligible for renewable identification numbers (RINs) under US-RFS2, biofuel producers need to demonstrate that the feedstock used for biofuel production is renewable and grown in cleared or cultivated lands that are either fallow or actively managed prior to the enactment of EISA through a system of record keeping, reporting and verification. Forest slash and thinnings from non-federal forest lands also qualify as renewable biomass for the purpose generating RINs. EISA directs the US EPA to assess the potential impacts on air quality, water quality, soil erosion and biodiversity of US-RFS2 biofuel volumes and take appropriate measures to the extent possible to mitigate these impacts. In this regard, the US EPA has begun to evaluate potential impacts associated with large-scale biofuel production.

Low carbon fuel–related standards in Europe

The European Parliament approved a package of measures for GHG mitigation in 2008. One of the measures relates to the Fuel Quality Directive which requires that fuel suppliers should reduce life cycle GHG emissions by up to 10% by 2020. Only 6% of the 10% reduction is binding, with a further 2% reduction that can be achieved using technologies like carbon sequestration and storage; another 2% can be attained through CDM projects such as prevention of natural gas flaring and venting (EurActiv.com, 2008). The Renewable Energy Directive is another measure to reduce GHG emissions from the transportation sector. This directive stipulates that the share of biofuels in the transportation sector should be 10% (by energy content) for each member country by 2020. Some important features of the Renewable Energy Directive are (EuroParl, 2008):

- It requires the European Commission to develop a methodology by December 2010 to account for GHG emissions from indirect land use change.
- It includes provisions that ensure that biofuel production is sustainable. For example, biofuel should not be derived from biomass grown on land with rich biodiversity and high carbon stock. It also sets a minimum GHG reduction threshold of 35% for biofuels, which would increase to 50% in 2017.
- It is incumbent upon fuel suppliers to verify that all sustainability criteria for raw materials used in biofuel production have been met using a mass balance system. Fuel suppliers are required to submit information on the measures taken to protect air, water and soil.
- It sets up standard methods for creating, reporting and verifying the data (EuroParl, 2008).

Fuel suppliers need to comply with environmental sustainability criteria under the Fuel Quality Directive and Renewable Energy Directive. There is mandatory reporting on social sustainability criteria but proof of compliance is not required.

The United Kingdom implemented the Renewable Transport Fuel Obligation (RTFO) in April, 2008. The concept of the RTFO is similar to that of US-RFS2. It aims to reduce the GHG emissions from the transportation sector by requiring that 5% of fuels used (about 2.5 billion liters per year) are from sustainable sources by 2010/2011. This can be achieved by blending fossil fuels with bioethanol, biomethanol, biodiesel and biogas. From April 2008 to January 2009, 987 million liters of biofuels were used by the transportation sector under the RTFO. During this period more biodiesel (84%) was used than bioethanol (20%). It is expected that 50% of biofuels would be bioethanol by 2010/2011.

The RTFO imposes a legal obligation on suppliers of fossil transportation fuels, also known as obligated suppliers, to obtain Renewable Transport Fuel Certificates (RTFCs). Biofuel suppliers are not obligated to obtain RTFCs but may wish to apply for RTFCs. RTFCs can be used to meet the compliance targets and any extra RTFCs can be traded in the market. If the obligated suppliers fall short of the required RTFCs at the end of a compliance period, they have to buy out the balance by paying a buy-out price.

Obligated suppliers are required to submit a carbon and sustainability report each month. However, they are not required to comply with sustainability criteria. For the purpose of reporting, the RTFO includes two types of standards related to sustainability: (1) RTFO Sustainable Biofuel Meta-Standard and (2) Qualifying Standard. The RTFO Sustainable Biofuel Meta-Standard protects the environment by requiring that production of biomass does not deplete carbon stock, does not damage biodiversity, and does not cause air pollution, soil erosion and contamination of water. It also addresses the societal aspect of biomass production by ensuring that biomass production does not adversely impact workers' rights, labor conditions, land rights and community relations. The standards that are already in place and meet most of the sustainability criteria of the Sustainable Biofuel Meta-Standard are known as Qualifying Standards. Qualifying Standards can also be used to provide evidence of an acceptable level of sustainability. The carbon and sustainability reporting scheme is working well and companies are reporting significant carbon reductions. The sustainability criteria in the RTFO are progressive compared to other low carbon fuel-related standards.

Low carbon fuel –related standards in Canada

Two Canadian Provinces, Ontario and British Columbia, signed a Memorandum of Understanding with California in 2007 to implement standards similar to CA-LCFS that would reduce GHG emissions from the transportation sector by 10% by 2020 (COG, 2007). The federal government has an RFS that applies to road fuels and heating fuels, with a target of 5% volume replacement in gasoline by 2010 and 2% biodiesel use by 2012; three provinces have similar renewable fuels policies in place. Ethanol is currently manufactured from corn and wheat; it is expected that cellulosic ethanol will make important contributions within the next few years.

COMPLIANCE PATHWAYS FOR CA-LCFS AND US-RFS2

According to ICCT estimates, implementation of the US-RFS2 standard may reduce GHG emissions of the transportation sector by 6.5% by 2022. To achieve this goal, US-RFS2 specifies the volumes for each type of renewable fuel that should be used in the transportation sector in a given year starting from 2010. Volumetric requirements for biofuels for the period 2010-2022 are given in Figure 2. The important contribution of cellulosic ethanol to the overall target is clearly shown by the blue bar in Figure 2.

CA-LCFS does not put emphasis on volumes of biofuels used. Rather it requires that the overall carbon intensity of fuels used for transportation decrease by a certain percentage each year compared to the baseline fuels. The prescribed carbon intensity for a given year can be achieved by using a combination of fuel blends, alternative fuels, and credits. The composition of the fuel mix to meet the target in a given year for CARB's scenario 1 is provided in Figure 3 (CARB, 2009a). CARB projects that mid-west corn ethanol will be the major fuel in the early part of the program with cellulosic and advanced renewable fuels dominating in the latter part of the program. Hydrogen and electricity use in alternative fuel vehicles (AFVs) such as fuel cell vehicles (FCVs), plug-in-hybrid electric vehicles (PHEVs), and battery-electric vehicles (BEVs) is expected to increase gradually. The projected vehicle composition under scenario 1 for CA-LCFS is provided in Figure 4. Since biofuels will be the major alternative fuels, CARB estimates that the largest number of AFVs would be flex-fuel vehicles (FFVs) followed by PHEVs.

Fig. 2. Compliance pathway for US-RFS2

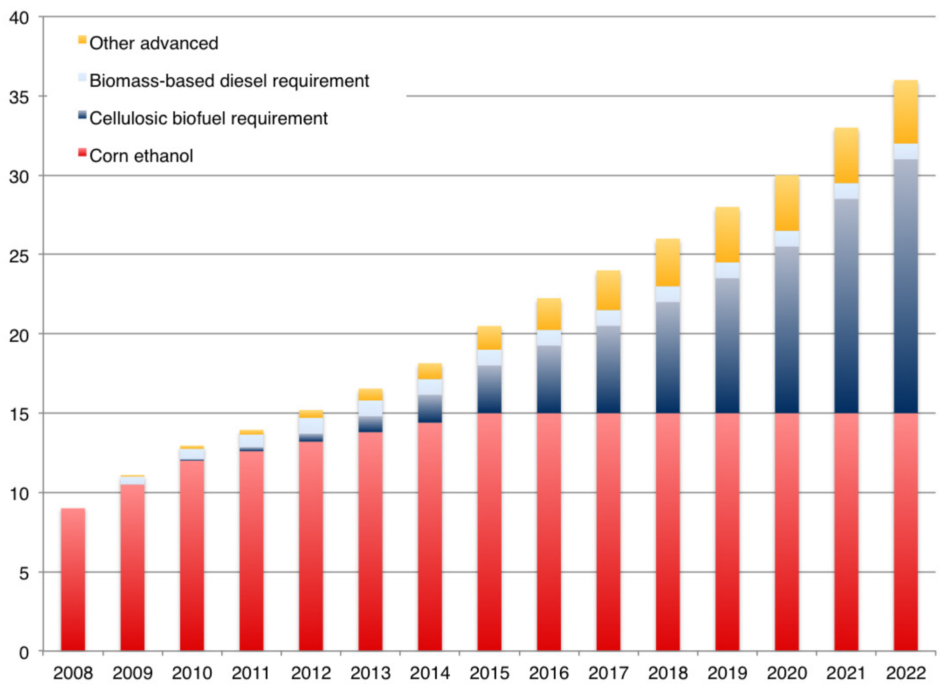
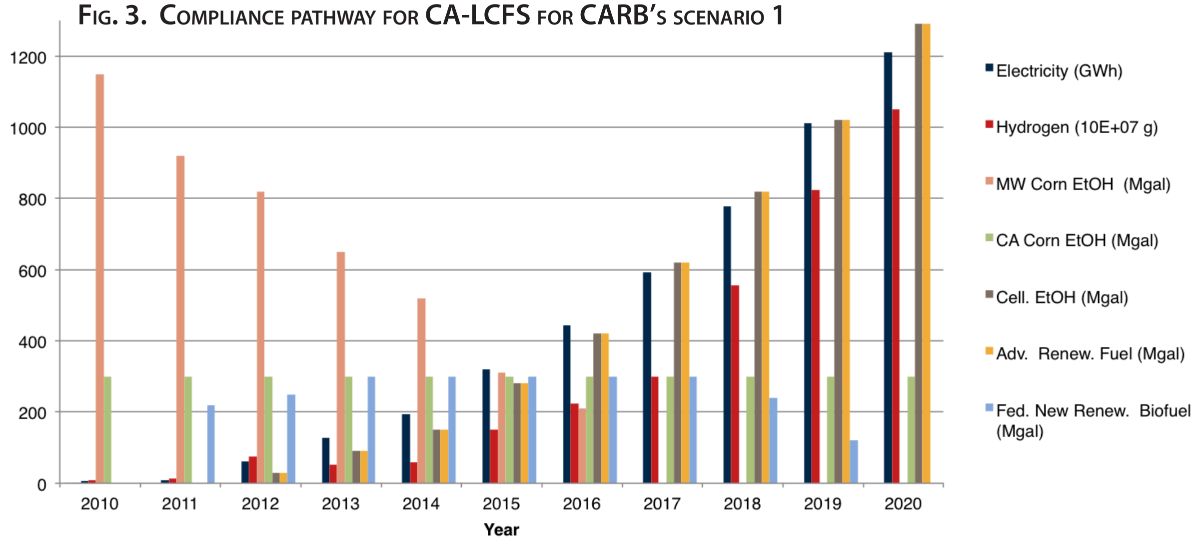
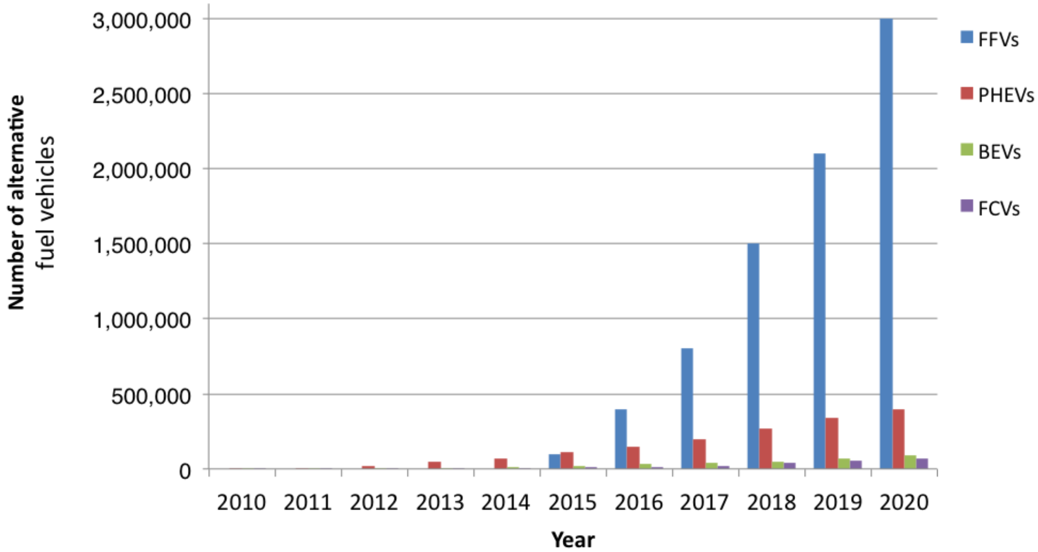


Fig. 3. Compliance pathway for CA-LCFS for CARB's scenario 1



Units: g-grams, Mgal-million gallons, GWh- giga watt hours
Source: CARB, 2009a

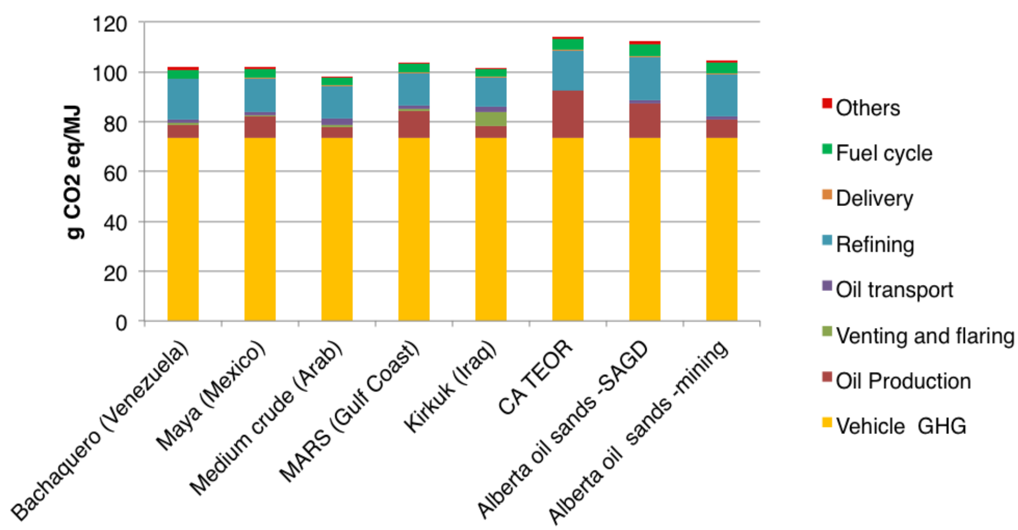
Fig. 4. Vehicle composition of the California transportation sector for CARB's scenario 1



Source: Derived from CARB, 2009b

Since crude oil extraction and refining varies by regions, processes and feedstocks, gasoline and diesel produced from efficient extraction and refining processes may meet the carbon intensity reduction targets when mixed with smaller volumes of biofuels. For example, life cycle studies of gasoline show a variation in well-to-wheel GHG emissions depending on the feedstock types, as well as extraction and refining methods (Fig. 5). As shown in Figure 5, gasoline obtained from a tertiary enhanced oil recovery (TEOR) process has the highest life cycle GHG emissions, whereas gasoline obtained from medium crude from the Middle East has the lowest life cycle GHG emissions. The higher GHG emissions of gasoline obtained from TEOR is due to significant fossil fuel use in crude oil extraction. The opposite is true for gasoline obtained from the Middle East.

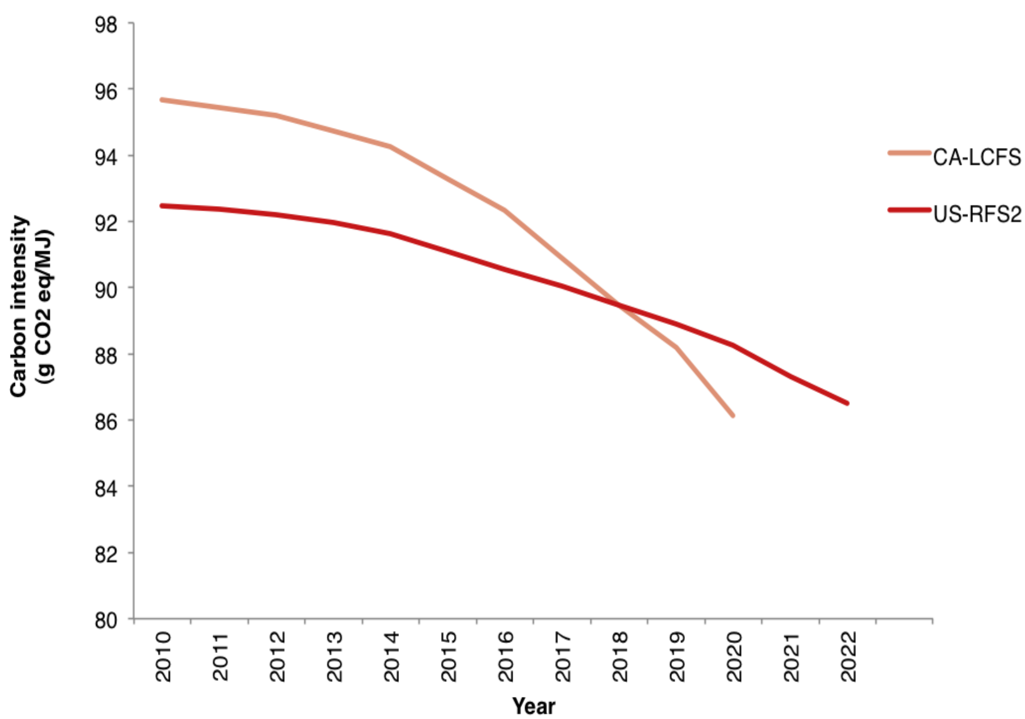
Fig. 5. Well-to-wheel life cycle analysis of reformulated gasoline blendstock for oxygen blending (RBOB) from various crude oil blends and oil sands



Note: The first bar at the left is Venezuelan heavy oil; the next four bars are conventional crude oil from Mexico, the Middle East, the Gulf coast, and Iraq. The sixth bar from the left shows California oil using Tertiary Enhanced Oil Recovery (TEOR). The two bars to the right are Canadian oil-sands extracted using mining and Steam Assisted Gravity Drainage In–Situ Recovery (SAGD) (Jacob's Consultancy, 2009).

Since US-RFS2 and CA-LCFS use different metrics for regulation, it is useful to convert US-RFS2 volumetric requirements into carbon intensity to properly compare the carbon mitigation benefits of US-RFS2 and CA-LCFS. In Figure 6, projected volumes of biofuels and petroleum fuels were converted to corresponding GHG emissions (g CO_2 eq.) per MJ. The figure shows that US-RFS2 may achieve an emission reduction of about 6.5% by 2022 which is lower than the CA-LCFS target of 10% reduction by 2020. This figure was derived by the ICCT based on the projected liquid fuel volumes obtained from EIA's Annual Energy Outlook 2009 with Projections to 2030 (EIA, 2009). The EIA's projected values were adjusted according to volumetric requirements for biofuels under RFS2. This is because EIA projections are based on pre-RFS2 requirements that entail smaller volumes of biofuels. The reduction of 6.5% is largely due to a significant increase in the volume of cellulosic ethanol, which has lower life cycle GHG emissions. For diesel and its substitutes, emissions would remain flat due to: (1) lower projected volume of biodiesel use, and (2) higher GHG emissions of soy biodiesel (95.5 g CO_2/MJ) which would be a major component of the biodiesel mix.[1]

Fig. 6. Comparative analysis of carbon intensity of CA-LCFS and US-RFS2



Source: CARB, 2009a for LCFS, ICCT estimates for RFS2

MAJOR DISTINGUISHING FEATURES OF VARIOUS LOW CARBON FUEL-RELATED STANDARDS

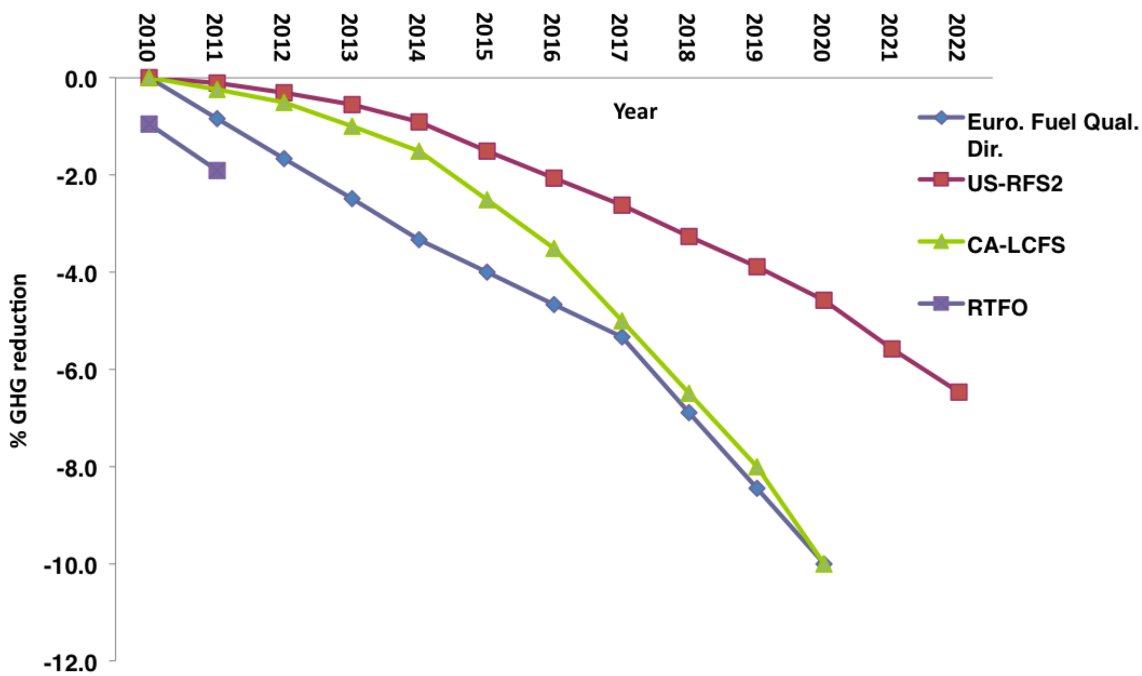
One major difference between CA-LCFS and US-RFS2 is that the baseline fuel for quantifying life cycle GHG emission reductions is federal reformulated gasoline (RFG) for US-RFS2, whereas for the CA-LCFS it is E10 blended in California RFG. As far as GHG reduction is concerned, US-RFS2 is less aggressive than CA-LCFS (Fig. 7) which aims to achieve 10% reduction by 2020 as compared to a probable 6.5% reduction by 2022 for US-RFS2. Although the European Fuel Quality Directive intends to achieve a 10%

1 Due to two areas of correction, the GHG emissions of soy biodiesel are likely to be adjusted downwards after the end-September comment period for US- RFS2.

reduction, 4% of the reduction is optional. The RTFO may reduce GHG emissions by 1.1-1.9% (European Commission, 2006). Since CA-LCFS is performance based, all fuels are treated as the same and there are no exemptions for existing biofuel production facilities. Unlike US-RFS2, CA-LCFS includes non-liquid fuels such as hydrogen, natural gas, methane, etc. As a result the overall potential of CA-LCFS for GHG reductions is higher.

Another difference lies in the use of indirect land use change (ILUC) models for estimating GHG emissions. The Global Trade Analysis Project (GTAP) was used for estimating GHG emissions from ILUC as part of CA-LCFS. The Forest and Agricultural Sector Optimization Model (FASOM), and the Food and Agricultural Policy Research Institute (FAPRI) model were used for developing US-RFS2. As a result GHG estimates for biofuels are different for CA-LCFS and RFS2. GTAP models 57 sectors, including agriculture, of the US economy and takes into account international trade. GTAP classifies land use by agro-ecological zone. FAPRI is an agriculture sector model and takes into account demand and supply of agriculture commodities. It uses price effects to estimate land conversions and considers the effects outside of the US. FASOM models the equilibrium between forest and agriculture land in the US. FASOM does not include the effects outside of the US.

Fig. 7. Comparison of GHG emission reductions for various low carbon fuel-related standards



Source: CARB, 2009a, European Commission, 2006

Note: US-RFS2 estimate was calculated by the ICCT. Reductions for the European Fuel Quality Directive and The RTFO do not include GHG emissions from ILUC.

To meet the GHG reduction targets for the transportation sector, the European Fuel Quality Directive provides an incentive to utilize the natural gas produced in oil extraction for useful purposes. According to the World Bank, over 100 billion cubic meters of natural gas are either flared or vented from oil fields around the globe (The World Bank, 2004). This amount is equivalent to the amount of natural gas consumed by Germany and France in a year. Reducing natural gas flaring and venting would also lower life cycle GHG emissions of gasoline and diesel which will assist the fuel suppliers to meet the GHG reduction targets as required by CA-LCFS and the European Fuel Quality Directive. For example, flaring and venting contributes about 6% of the life cycle GHG emissions of gasoline derived from the Kirkuk oil blend (Iraq) (Fig. 5).

When it comes to sustainability criteria, low carbon fuel-related standards of Europe are more progressive than those of the US since they include both environmental and social sustainable criteria. However, proof of compliance with social criteria is not mandatory. US-RFS2 does have a few provisions for sustainable renewable fuel production. By specifying the types of feedstocks and lands that can be used for renewable fuel production in order to qualify for a Renewable Identification Number (RIN), it addresses the issue of sustainability to some extent. CARB estimates that there will be limited air and water quality impacts from the implementation of CA-LCFS. CA-LCFS does not have sustainability metrics yet. CARB is expecting to develop sustainability criteria and a certification process for verification by the end of 2011.

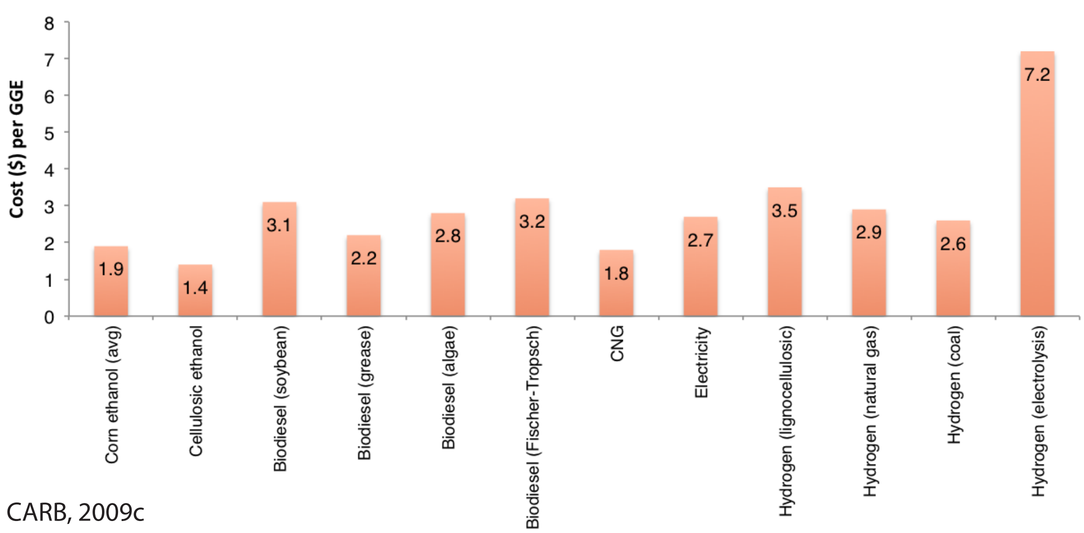
ECONOMIC AND ENVIRONMENTAL IMPLICATIONS OF US-RFS2 AND CA-LCFS

Economic costs

According to the US EPA estimates, US food prices may increase by $10 per year per person by 2022 when US-RFS2 is implemented. The US farm sector may see its income grow by $7.1 billion dollars (US EPA, 2009b). Due to higher commodity prices, exports of crops would fall by 10% and exports of soy bean would fall by 9.3%. Due to the increasing use of biofuels as mandated by US-RFS2, the value of petroleum imports would decline by $16 billion by 2022. US-RFS2 standards could increase the cost of gasoline by $4 billion and $18 billion in 2022 at crude oil prices of $92/barrel and $53/barrel, respectively (US EPA, 2009b).

The total costs including production, storage, transport, and dispensing for various alternative fuels under CA-LCFS are shown in Figure 8. Costs can be as low as $1.4 for cellulosic ethanol and as high as $7.2 for hydrogen produced by electrolysis per gallon of gasoline equivalent (GGE) (CARB, 2009c). CARB estimates that implementing CA-LCFS would reduce imports of crude oil, which would result in savings of $10 billion in California. These savings are realized as profits for biofuel producers or passed on to consumers. Nonetheless, the increasing use of biofuels may lead to lower revenues for the State due to lost transportation fuel taxes. The potential loss in revenues would be $80-370 million in 2020 (CARB, 2009a).

FIG. 8. TOTAL COSTS OF ALTERNATIVE FUELS INCLUDING PRODUCTION, STORAGE, TRANSPORT AND DISPENSING



Source: CARB, 2009c

Environmental benefits and impacts

It is expected that the implementation of low carbon fuel-related standards would reduce the global warming potential of the transportation sector. However, there are significant uncertainties in GHG estimates of biofuels. Not only is it difficult to model direct GHG emissions from the agriculture sector, but there can also be GHG emissions resulting from ILUC induced by change in demand and price of foods and fuels. The latter has become a thorny issue in policy debates due to lack of a standardized model and sufficient data for estimating GHG emissions. For example, corn ethanol can have lower net GHG emissions without including GHG emissions from ILUC but higher net GHG emissions when including ILUC relative to gasoline. GTAP has been used for CA-LCFS whereas FASOM and FAPRI have been used for US-RFS2. As a result estimates of GHG emissions from ILUC are different for CA-LCFS and US-RFS2. While there is an emerging consensus on the need for incorporating ILUC in life cycle studies, disagreements exist on assumptions, parameters and methodologies for estimating ILUC. A standard protocol for estimating GHG emissions from ILUC is needed that is based on sound science and the best available data. This task could take several years to achieve as the subject is complex.

There are few air emissions that are expected to increase from the implementation of low carbon fuel standards. An increase in the use of ethanol would lead to slightly higher NOx, hydrocarbon, acetaldehyde, and ethanol emissions. In contrast ammonia and CO emissions are expected to decrease. With expected increases in fertilizer and pesticide use, impacts on water quality are likely to get worse without intervention measures. Soil erosion and water consumption would also increase.

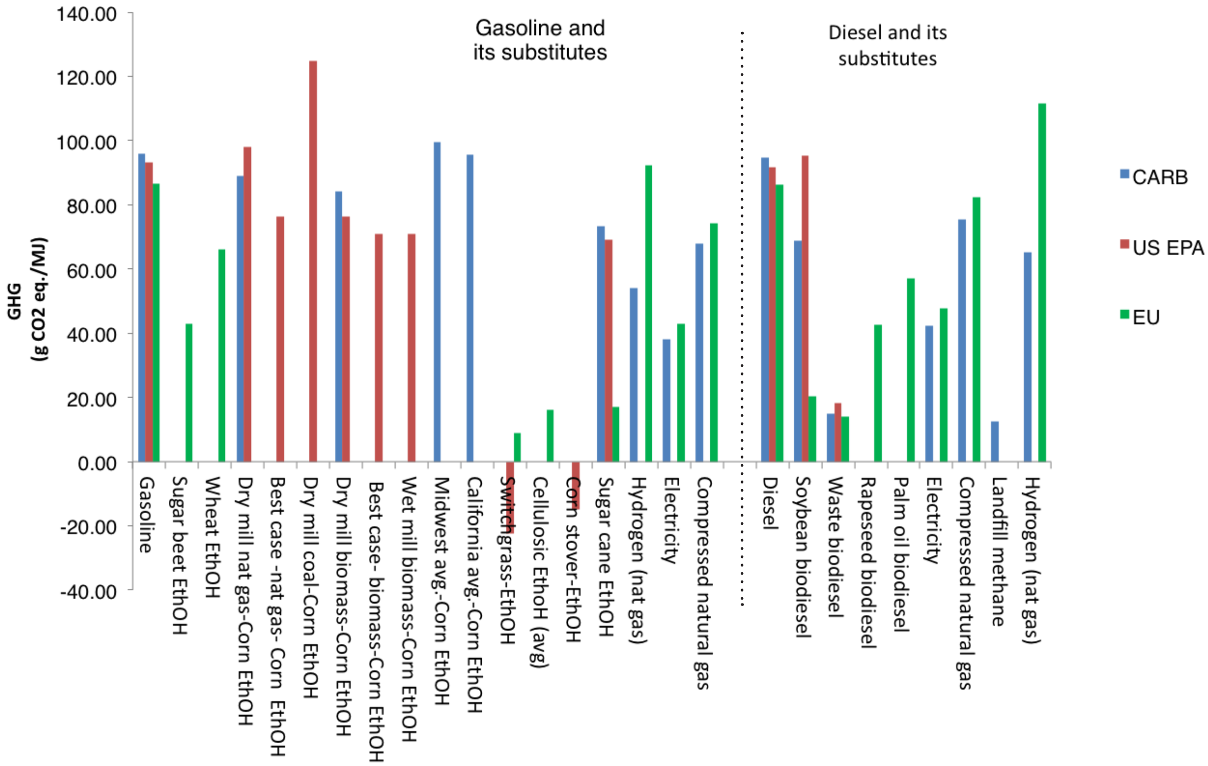
CONCLUSIONS

Based on the review of low carbon fuel related-standards, the following points can be deduced.

- Of all the standards discussed here, California's CA-LCFS is the most aggressive standard to reduce GHG emissions from the transportation sector followed by the European Fuel Quality Directive. CA-LCFS aims to achieve a 10% GHG emission reduction from the transportation sector by 2020. Although CA-LCFS sets rigid timelines for reducing the carbon intensity of transportation fuels, it offers flexible market mechanisms for achieving the required carbon intensity through credit trading. The RTFO also has market-based mechanisms for achieving the compliance but may provide GHG emission reductions of 1.1-1.9% by 2011 (European Commission, 2006). These reductions do not take into account GHG emissions from ILUC.
- Both CA-LCFS and US-RFS2 have provisions for GHG emissions from indirect land use change (ILUC), and ILUC is likely to be included in the European Renewable Energy Directive in the near future. While there is a growing recognition that GHG emissions from indirect land use change should be included in GHG accounting, there are concerns that existing models and available data are not robust enough to estimate indirect land use change with reasonable accuracy. This may create a hurdle for the regulated parties to comply with CA-LCFS and US-RFS2 standards.

  Recognizing this constraint, the European Union is taking a more cautious approach. It is currently evaluating all the available models for land use change to make an informed decision and account for ILUC. Likewise, the UK government is trying to extend the deadline for achieving 5% blending to 2013/14 to buy more time to study the indirect effects of biofuel production on food prices and land conversion.
- Since the European Fuel Directive does not consider ILUC at present (Fig. 9), meeting the 10% reduction by 2020 would not be as hard as in the case of CA-LCFS.
- GHG emissions from cellulosic ethanol can be negative meaning that it avoids more GHG emissions than it releases (Fig. 9). As a result it holds a superior promise for reducing GHG emissions via low-carbon fuel related standards.

Fig. 9. Estimated WTW GHG emissions of baseline fuels vs. alternative fuels by CARB, US EPA and EU



Source: US EPA, 2009a, CARB, 2009a, RFA, 2009

Note: European estimates do not include GHG emissions from ILUC.

- Low carbon fuel-related standards of Europe are more progressive in terms of sustainability requirements that lay out detailed provisions for environmental and social sustainability.
- Use of biofuels as low carbon fuels has the potential to reduce GHG emissions from the transportation sector but may create other environmental impacts such as eutrophication, acidification, soil erosion, and increased demand on water and land.
- While ILUC is very important for current biofuels, it is anticipated that some second and third generation biofuels will have much reduced land use impacts and that a gradual transition to these fuels could lead to a much lower carbon fuel future.

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ACRONYMS

AFVs	Alternative Fuel Vehicles
BEVs	Battery-Electric Vehicles
CA-LCFS	California-Low Carbon Fuel Standard
CDM	Clean Development Mechanism
CARB	California Air Resources Board
FAPRI	Food and Agricultural Policy Research Institute
FASOM	Forest and Agricultural Sector Optimization Model
FCVs	Fuel Cell Vehicles
FFVs	Flex-Fuel Vehicles
GHG	Greenhouse Gas
GTAP	Global Trade Analysis Project
ILUC	Indirect Land Use Change
PHEVs	Plug-in-Hybrid Electric Vehicles
RFG	Reformulated Gasoline
RTFO	Renewable Transport Fuel Obligation
SAGD	Steam Assisted Gravity Drainage In–Situ Recovery
TEOR	Tertiary Enhanced Oil Recovery
US EPA	United States Environmental Protection Agency
US–RFS2	Unites States-Renewable Fuel Standard 2

About the Author

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Baral works with regulators in the US and Europe assisting the formulation and effective implementation of low carbon fuel policies, and conducts research on LCA and low carbon fuels.

About the International Council on Clean Transportation
The International Council on Clean Transportation (ICCT), a nonprofit organization, is a central actor in efforts to reduce the negative impacts from all transportation sectors. Our goal is to protect public health, minimize climate change and improve quality of life for billions of people as the world's transportation infrastructure grows. Our work, focused in the top ten largest motor vehicle markets globally, falls into four general categories: (1) producing reports that identify international best practices, (2) working with consultants and organizations to lay the technical groundwork for future regulations, (3) working with government agencies directly to provide technical assistance in the drafting of regulatory documents and data collection and analysis, (4) holding public workshops as well as invite-only meetings among key regulators.

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