Implications of Policy Interactions for California's Climate Policy

Todd Schatzki
Analysis Group, Inc.

Robert N. Stavins
Harvard University

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Executive Summary

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California's Global Warming Solutions Act of 2006 (AB 32) requires that the State lower its greenhouse gas (GHG) emissions to 1990 levels by the year 2020. To achieve this ambitious goal, California's Air Resources Board (ARB) has developed an AB 32 Scoping Plan that includes multiple policies and programs targeting different sectors and energy uses. Although these diverse policies and programs are typically approached and analyzed as if they were independent of one another, in fact, interactions among these policies and between AB 32 policies and federal policies can have very important consequences for environmental effectiveness as well as economic performance.

Interactions between policies are most problematic when two conditions occur: first, a state policy creates more stringent requirements that overlap with a "broader" state or federal policy ("overlap criteria"); and, second, the broader federal or state policy provides flexibility to meet requirements through adjustments across sectors or states ("flexible policy criteria"). These flexible policies can include quantity-based policies (such as, cap-and-trade) and policies that average performance (such as, renewable portfolio standards or renewable fuel standards.)

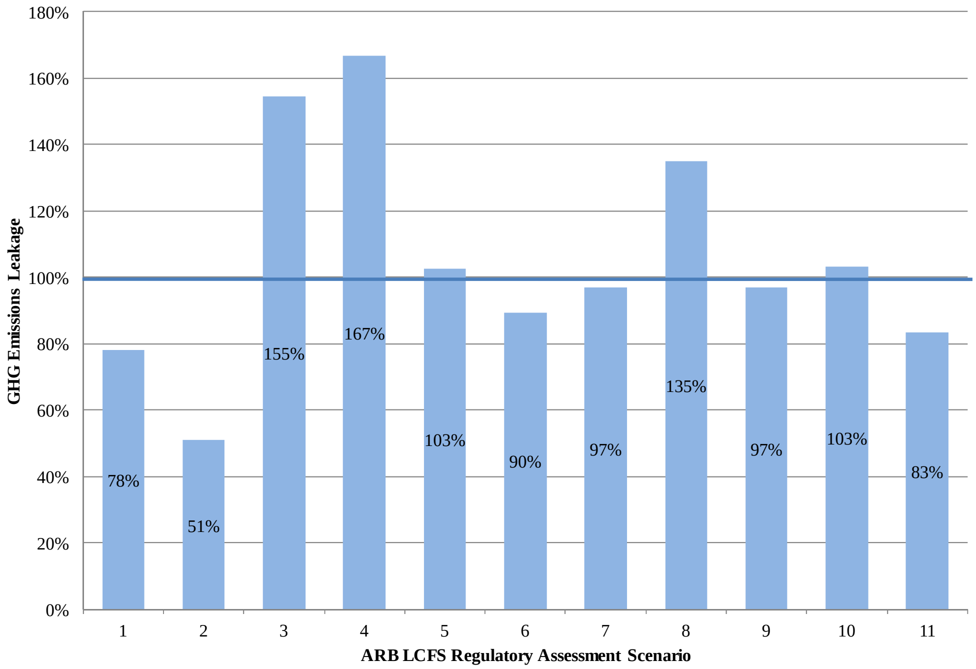
In the context of the AB 32 Scoping Plan, two types of interactions pose the greatest concern. The first is the interaction between the GHG cap-and-trade program and other AB 32 policies that regulate sources covered by the cap-and-trade program. For example, emissions from transportation fuel combustion are regulated by both the cap-and-trade program and by the Low Carbon Fuel Standard (LCFS), which mandates reductions in the GHG-intensity of transportation fuels.

When state-level policies overlap with cap-and-trade, the complementary policies will generally fail to create any additional emission reductions. With a binding cap-and-trade system in place, aggregate emissions will equal the cap whether or not complementary policies are implemented. While complementary policies may shift emissions among sources or sectors covered by the cap, aggregate emissions will remain unchanged.

[1] Schatzki is a Vice President at Analysis Group. Stavins is Albert Pratt Professor of Business and Government, John F. Kennedy School of Government, Harvard University; University Fellow, Resources for the Future; and Research Associate, National Bureau of Economic Research. He is an elected Fellow of the Association of Environmental and Resource Economists, was Chairman of the U.S. Environmental Protection Agency's Environmental Economics Advisory Committee, and served as Lead Author of the Second and Third Assessment Reports and Coordinating Leading Author of the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Institutions listed are for purposes of identification only, implying no endorsement of this work. Support was provided by the Chevron Corporation, but the opinions expressed are exclusively those of the authors. Valuable research assistance was provided by Michael Kincaid, and helpful comments on a previous version of the manuscript were provided by Lawrence Goulder, but the authors are solely responsible for any remaining errors. To request further information or provide comments, Dr. Schatzki can be reached at: tschatzki@analysisgroup.com.

However, complementary policies may increase the cost of meeting emission targets when implemented alongside cap-and-trade. If complementary policies require that more costly emission reductions be undertaken, then the shift from lower-cost to higher-cost reduction activities increases the cost of achieving emission targets. If the complementary policy requires reductions that are cost-effective under cap-and-trade then the reductions occur whether or not the complementary policy is implemented; consequently, costs do not rise, but the policy is irrelevant. A complementary policy can shift emission reductions to *lower*-cost emission reduction activities only if it targets non-GHG market failures, such as information problems or behavioral biases regarding household energy use, or targets sectors not covered by the cap-and-trade system.

Figure ES-1: Emission Leakage from the Low Carbon Fuel Standard



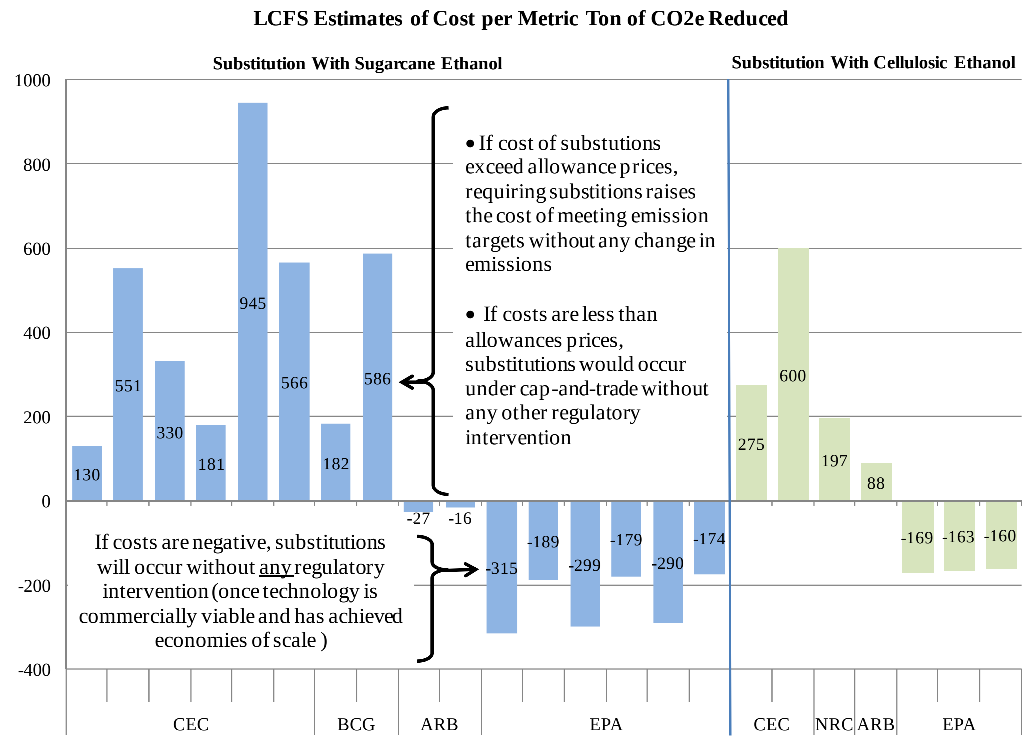
Source: Table 4.

The specific impacts arising from these interactions depend on policy details. With the LCFS, interactions with the GHG cap-and-trade program may partially, fully or more than fully offset reductions required by the LCFS; thus, emissions may decrease, remain unchanged, or even increase. **Figure ES-1** shows estimates of this emission "leakage" for eleven scenarios evaluated in ARB's LCFS regulatory assessment. With the LCFS, leakage may exceed 100% if the LCFS increases the use of renewable fuels that have higher out-of-state up-stream emissions that are not covered by the cap-and-trade program.

The LCFS will also raise the cost of achieving AB 32 emission targets if the GHG reductions arising from fuel substitutions used to comply with the LCFS are more costly than those under cap-and-trade. **Figure ES-2** reports GHG emission reduction costs from fuel substitutions from multiple studies. The figure shows that costs in 2020 may be much higher than likely allowance costs under cap-and-trade. (For comparison, ARB's most conservative scenario in its 2010 economic analysis has allowance prices of $102 per MTCO2e.) However, the figure also shows that costs could be low or even negative if sugarcane ethanol or cellulosic ethanol is less costly than gasoline by 2020. If that is the case, then these substitutions would occur without any policy intervention, including cap-and-trade.

Interactions between federal and California policies can lead to similar outcomes for environmental effectiveness and economic performance. Again, consider the LCFS. The LCFS overlaps with the Federal Renewable Fuels Standard (RFS), which imposes quantity targets for renewable fuels. Under certain conditions, the LCFS simply shifts demand for renewable fuels (and the costs of the RFS) from other states to California without affecting nationwide demand. However, because the LCFS targets carbon-intensity, it could achieve incremental GHG emission reductions by inducing demand for renewable fuels with lower GHG intensity than would be needed to comply with the RFS. These emission reductions would be achieved at an incremental cost that would be borne in California, since the lower-GHG renewable fuels would be more costly than those required to meet the RFS. As with the state-level LCFS interactions, in practice, the outcomes of these federal-state interactions will depend on policy details and the relative costs and emissions intensity of available renewable fuels.

Figure ES-2: Cost of GHG Emission Reduction Through Gasoline Substitution, Alternative Studies (Dollars per MTCO2e)



Source: Table 5

Many elements of the AB 32 Scoping overlap with the GHG cap-and-trade program, and certain policies interact with existing federal policies. The state should carefully consider the implications of these interactions for its climate policies as they evolve both for the benefit of its own citizens and because many states and countries will be drawing lessons about the feasibility of environmentally-effective and cost-effective climate policies from California's experience. Thus, as the cap-and-trade program is implemented, policymakers may want to revisit decisions to pursue other policies that regulate activities covered by cap-and-trade. While some of these policies may address market failures unrelated to GHG emissions, absent such dimensions, these complimentary policies may achieve few emission reductions, while raising climate policy costs.

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Todd Schatzki and Robert N. Stavins[2]

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The California Global Warming Solutions Act of 2006 (AB 32) is a landmark for climate policy. AB 32 established binding targets for greenhouse gas (GHG) emissions from the state of California, requiring that they be lowered to 1990 levels by the year 2020. To achieve this goal, California must reduce emissions from the wide variety of activities that contribute to (or potentially mitigate) atmospheric concentrations of GHGs. The Air Resources Board (ARB) has developed an AB 32 Scoping Plan that identifies multiple policies and programs to achieve AB 32's ambitious goals. Although these diverse policies and programs are typically approached and analyzed as if they were independent of one another, in fact, interactions among these policies and between AB 32 policies and federal policies can have very important consequences for environmental effectiveness as well as economic performance. This paper addresses such interactions and consequences.

1. AB 32 Scoping Plan

A key component of AB 32 is the cap-and-trade system that covers approximately 85% of California's emissions. The cap-and-trade system is uniquely suited to regulating California's diverse GHG sources by creating a uniform price signal for all GHG emissions from covered activities. The program's design provides incentives for emission targets to be met through the least-costly measures regardless of the activities or sectors of the economy from which they originate.

ARB is also implementing a variety of complementary policies to address particular types of emission-generating activities. While some of these policies target emissions not covered by the cap-and-trade program, others target activities already covered by cap-and-trade. In fact, as shown in **Table 1**, ARB is implementing policies to address nearly every major dimension of energy use that contributes to GHG emissions. For example, complementary transportation policies target the GHG content of

[2] Schatzki is a Vice President at Analysis Group. Stavins is Albert Pratt Professor of Business and Government, John F. Kennedy School of Government, Harvard University; University Fellow, Resources for the Future; and Research Associate, National Bureau of Economic Research. He is an elected Fellow of the Association of Environmental and Resource Economists, was Chairman of the U.S. Environmental Protection Agency's Environmental Economics Advisory Committee, and served as Lead Author of the Second and Third Assessment Reports and Coordinating Leading Author of the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Institutions listed are for purposes of identification only, implying no endorsement of this work. Support was provided by the Chevron Corporation, but the opinions expressed are exclusively those of the authors. Valuable research assistance was provided by Michael Kincaid, and helpful comments on a previous version of the manuscript were provided by Lawrence Goulder, but the authors are solely responsible for any remaining errors. To request further information or provide comments, Dr. Schatzki can be reached at: tschatzki@analysisgroup.com.

transportation fuels, vehicle fuel efficiency and local transportation planning and zoning (to reduce vehicle utilization, among other objectives.) Thus, although the cap-and-trade system (by putting a price on emissions) provides a uniform incentive to reduce emissions across all activities covered by the cap, ARB has adopted additional policies affecting nearly every dimension of activity covered by cap-and-trade. This paper addresses the environmental and economic consequences of this "belt and suspenders" approach, due to interactions among components of the AB 32 policy portfolio.

As California implements its climate policy, other policies at the federal level also aim to reduce GHG emissions as one of multiple policy goals. Interactions between these federal policies and policies in the AB 32 Scoping Plan will also have implications for environmental effectiveness and economic performance. A partial list of federal policies affecting GHG emissions include:[3]

- Renewable Fuel Standard (RFS),
- Vehicle fuel efficiency standards (CAFE standards),
- GHG emission standards (under the Clean Air Act),
- Appliance and equipment standards, and
- Tax credits for renewable energy.

These policies reflect a range of mechanisms including technology standards (for example, appliance and equipment standards), price-based instruments (for example, tax credits), and quantity-based instruments (for example, CAFE standards and the RFS).

[3] Other federal policies may create incentives that both complement and work against climate policy goals. For example, Clean Air Act regulations affecting SO_2 and NO_X emissions generally reduce GHG emissions as a co-benefit.

Table 1: Complementary Policies in the AB 32 Scoping Plan

Dimension of Energy Use	Policy	Anticipated Reductions ($MMTCO_2e$)
Capped Activities		
Personal Transportation		
Fuel GHG Content	Low Carbon Fuel Standard	15.0
Driving Behavior and Patterns (Vehicle Miles Travelled)	SB 375	3.0
Vehicle Fuel Efficiency Carbon Emissions Rate	Pavley II Light-Duty Vehicle Standards	29.9
	Vehicle Efficiency Measures	3.7
Other Transportation		
Goods Movement	Shore Power for Ocean-Going Vessels	0.2
Heavy / Medium-Duty Advanced Clean Cars	Medium / Heavy Duty Vehicles	0.5
	Heavy-Duty Vehicle GHG Reduction (Aerodynamic Efficiency)	0.9
Public Transit	High Speed Rail	1.0
Electricity		
Carbon Intensity of Electricity Generation	33% Renewable Portfolio Standard	11.4
	Million Solar Roofs	1.1
	Combined Heat and Power	4.8
Household Energy Efficiency	Utility Energy Efficiency Programs	11.9
Industry		
Production GHG Emissions	Refinery Measures & Energy Efficiency Audits	0.3
Uncapped Activities		
Non-CO2 GHGs	High Global Warming Potential Gases	9.8
	Oil & Gas Sector (methane)	1.1
	Landfill and waste (methane)	1.5
Forestry	Sustainable Forests	5.0

Source: ARB, "Status of Scoping Plan Recommended Measures," July 2011; ARB, "Final Supplement to the AB 32 Scoping Plan Functional Equivalent Document," Attachment D, August 19, 2011.

2. Implications of Climate Policy Interactions for Environmental Effectiveness and Economic Performance

For state-level climate policies, interactions can occur between individual elements of a state policy or between state policy and federal policy. In either case, interaction between policies has potential implications for the cost-effectiveness of actions taken to reduce GHG emissions, and can have implications for aggregate emission reductions as well.[4]

Interactions between policies are most problematic when two conditions are met:[5]

1. When a state policy creates more stringent requirements that overlap with a "broader" state or federal policy ("overlap criteria"); and
2. The broader federal or state policy provides flexibility to meet requirements through adjustments across sectors or states ("flexible policy criteria".)

Not all policies meet these criteria. For example, broader state or federal policies using command and control or price-based instruments have limited interaction with state-level policies. By contrast, policies that trade in quantities (for example, cap-and-trade) and policies that average performance (for example, renewable portfolio standards) provide flexibility that creates interactions between policies.

These conditions encompass two types of interactions of greatest concern. The first is the interaction between either a cap-and-trade program or a quantity-based averaging policy and complementary policies that regulate sources covered by the first policy. This interaction can emerge between two elements of a state climate policy, or between a federal policy and a state-level complementary policy.

The interactions for quantity-based policies can be understood through several examples. Interactions between state policies are illustrated by interactions between the AB 32 GHG cap-and-trade program and complementary policies targeting emission sources under the cap. With a binding cap-and-trade system in place, aggregate emissions will equal the cap whether or not complementary policies are implemented. In this case, complementary policies may shift emissions among sources or sectors covered by the cap, but aggregate emissions will remain unchanged.[6] Thus, complementary policies will not directly result in additional emission reductions.[7]

[4] Goulder, Lawrence and Robert Stavins, "Challenges from State-Federal Interactions in U.S. Climate Change Policy," *American Economic Review Papers and Proceedings*, volume 101, number 3, May 2011, pages 253-257. Goulder, Lawrence and Robert Stavins, "Interactions Between State and Federal Climate Change Policies," *The Design and Implementation of U.S. Climate Policy*, eds. Don Fullerton and Catherine Wolfram. Cambridge: National Bureau of Economic Research, forthcoming.

[5] Goulder and Stavins identify these conditions for interactions between state and federal climate policies. Goulder, Lawrence and Robert Stavins, "Interactions Between State and Federal Climate Change Policies," (forthcoming).

[6] Within a policy such as the AB 32 GHG cap-and-trade program that allows emission offsets, some emission reductions may be achieved by unregulated activities including out-of-state activities.

[7] Out-of-state emissions may indirectly change as a consequence of policy interactions. First, a complementary policy that leads to high-cost emission reductions will reduce allowance prices and thereby lower emission leakage. Consequently, out-of-state emissions will fall. Second, as we illustrate below for the LCFS, substitutions made to

While not affecting emission targets, complementary policies targeting sources under the cap can increase the cost of meeting emission targets. Complementary policies will either be non-binding and irrelevant or will shift emission reductions from lower-cost to higher-cost emission reductions activities, thus increasing the cost of achieving emission targets. A complementary policy is non-binding if its requirements are met through compliance with another regulation or through standard business practices. In this case, a complementary policy will not increase costs, although the policy is also irrelevant. For example, suppose the 33% Renewable Portfolio Standard (RPS) achieves emission reductions at $100 per $MTCO_2e$ and allowances under the cap-and-trade system are priced by the market at $25 per $MTCO_2e$. In this case, if binding, the RPS would shift emission reductions from other activities that have a lower cost ($25 per $MTCO_2e$ on the margin) compared with reductions from renewable energy ($100 per $MTCO_2e$.) Another possible outcome, which we consider below, is that complementary policies lower costs through support of research and development in low-GHG technologies.

These interactions can affect all programs identified in Table 1 that cover capped sources. For example, efforts to reduce GHG emissions through the LCFS will not lead to incremental emission reductions once fuels are added to the cap-and-trade program in 2015. Likewise, any reductions through the "sustainable communities strategy" (SCS) required of every metropolitan area under SB 375 will either relax requirements on other sectors or would have occurred without the SCSs. However, SCSs may address other market failures if, for example, local infrastructure and planning provides public goods that the market may not adequately supply (for example, public transportation.) As with any policy, the efficacy of these policies will depend on whether there are policy mechanisms available to effectively target and mitigate the market failures.

The second interaction of concern arises when a state-level policy regulates activity that is also covered by a federal policy that regulates the activity through a quantity-based or averaging mechanism. For example, suppose there is a federal RPS that overlaps with California's state RPS. In this case, the interactions are similar to those between the state-level RPS and the state-level cap-and-trade system. Because the federal RPS covers renewables from all states, any individual state that imposes a "more stringent" RPS will simply shift renewable energy production from other states to its state.[8] This "leakage" occurs because the greater stringency in one state's activities relaxes constraints on regulated activities in other states. In this case, while the aggregate (national) quantity of renewable energy remains unchanged, the resulting consequences for GHG emissions will be ambiguous because of differences across states in the carbon-intensity of power displaced by renewable energy.[9] However, the state RPS

comply with complementary policies may lead to changes in upstream emissions (from production and transportation) if these activities occur outside California.

[8] In this case, "more stringent" means an RPS that mandates a renewable share that exceeds the cost-effective renewable share that would occur under the federal RPS. However, because renewable shares may vary across states under a federal RPS (given, for example, differences in wind, solar, and geothermal generation potential across states), a state's RPS requirements may actually be higher than the federal standard and yet not require any more renewable power than would occur under the federal requirement.

[9] GHG emissions could increase or decrease depending upon the marginal emission intensity of power generation that is displaced by renewable generation.

would raise the national cost of meeting the federal RPS because it requires renewable power generation to shift from states where it is less costly to those where it is more costly to accomplish.

Not all policies will create these problems. In particular, complementary policies targeting emissions from sources not covered by the cap-and-trade program would not overlap with the cap-and-trade system. Thus, these policies could achieve incremental emission reductions and would not affect the cost-effectiveness of reductions achieved from sources under the cap. Non-overlapping AB 32 policies include policies targeting high global warming potential pollutants (for example, reduced refrigerant leakage), methane emissions from landfills and oil and gas sector operations, and forest programs.

The problems that can arise from overlapping complimentary policies are real. Under some circumstances, overlapping complementary policies can provide policy benefits. In particular, state policies may address *other market failures* affecting decisions with consequences for GHG emissions, such as underinvestment in research and development into low-GHG technologies, and various market failures that affect household energy use (for example, impact of the principal-agent relationship between landlords and tenants regarding investments in energy efficiency, and behavioral biases.) To the extent that federal policies do not address these market failures, state-level policies can – in principle – fill the gap. In some cases, state-level policies may address these market failures more effectively than uniform federal policies if, for example, state regulators have more reliable information to better design and implement policies.

But, when state-level "complementary" policies do not overlap with other state policies (such as the AB 32 such as cap-and-trade system) and do not overlap with Federal policies, then under such circumstances these state-level complementary policies can offer benefits. These may include:[10]

1. *Test-bed for Alternative Policies*. State-level policies may provide an opportunity for policymakers to test alternative policy designs or mechanisms, although such alternatives should provide a reasonable likelihood of creating policy benefits. Consequently, complementary policies that overlap with cap-and-trade offer limited learning opportunities given the greater efficacy of cap-and-trade at the national level. Note that experimentation at the federal level may prove as effective as state-level experimentation. Once effective policies have been identified, these can then be adopted at the national level.

2. *Encourage More Aggressive and/or More Cost-Effective Federal Action.* To the extent that more aggressive action is appropriate at the national level (or internationally), actions at the state level can – again, in principle – encourage political actors to take such steps. However, because complementary policies may not improve environmental effectiveness, complementary policies that overlap with cap-and-trade provide little benefit toward achieving this goal. Likewise, while state policies can help identify more cost-effective ways of achieving climate goals, complementary policies that overlap with cap-and-trade may

[10] Goulder and Stavins identify these conditions for positive interactions between state and federal climate policies. Goulder, Lawrence and Robert Stavins, "Interactions between State and Federal Climate Change Policies," (forthcoming).

actually be detrimental to the goal of demonstrating the efficacy of cost-effective climate policy.

3. *Encourage Adoption of More Stringent Standards by Manufacturers.* Tighter state environmental standards may lead manufacturers to adopt these standards for all units, rather than producing different models meeting different environmental standards for different geographic jurisdictions. California's more stringent auto pollution regulations in the 1970's let to the tightening of federal standards, in part because manufacturers did not want to face different state and federal standards. But the likelihood that state-level policy will lead to industry-wide changes in standards depends greatly on whether there are strong incentives for industry to support such uniformity. Furthermore, adoption of the more stringent state standard does not necessary mean that this standard is socially optimal at a national level. More stringent standards may represent a less cost-effective means of achieving environmental benefits, particularly in the context of climate change, which would be most cost-effectively addressed through cap-and-trade (or another carbon pricing regime), rather than technology-specific standards.

3. Policy Interaction Case Study: California's Low Carbon Fuel Standard

California's Low Carbon Fuel Standard (LCFS) requires reductions of at least 10 percent in the carbon intensity of California's transportation fuels by 2020. The LCFS achieves this goal by imposing increasingly stringent standards for the aggregate carbon intensity (CI) of transportation fuels sold in the state. Compliance with the standard reflects the average CI of all fuel sold. Individual suppliers must comply with the annual standard, but suppliers whose average CI exceeds the standard can purchase credits from suppliers that have over-complied with the standard. The LCFS allows for advanced transportation technologies, such as compressed natural gas, electric vehicles, and hydrogen vehicles, as well as fuels used in traditional combustion engines, such as gasoline, ethanol, and biodiesel.

The LCFS overlaps with both the state-level AB 32 GHG cap-and-trade system and the federal Renewable Fuel Standard (RFS). Both interactions have consequences for emission reductions achieved by the LCFS, and the costs of achieving targets.

a. Interactions with the AB 32 Cap-and-Trade System

Starting in 2015 when transportation fuels are included in the GHG cap-and-trade system, both the LCFS and the cap-and-trade program will cover transportation emissions. As a result of this overlap, emission leakage will occur between the LCFS and cap-and-trade program, diminishing the emission reduction achieved by LCFS. For the LCFS, the extent of emission leakage will depend on differences in how the LCFS and cap-and-trade program account for GHG emissions, as we discuss below.

Table 2 illustrates differences in carbon intensity of transportation fuels covered by the LCFS and cap-and-trade for three fuels: gasoline, Brazilian ethanol, and cellulosic ethanol.[11] The cap-and-trade program covers only emissions from combustion. Because emissions from renewable fuels were offset by carbon sequestered during the growth of biomass feedstock, these fuels are exempt from the cap-and-trade program. In effect, renewable fuels have a zero emission rate for the purposes of cap-and-trade compliance.

By contrast, the LCFS accounts for life-cycle emissions, which include combustion emissions and upstream emissions from production, transport, and indirect land use change that may occur as a consequence of growing crops to produce biomass feedstock. While renewable fuels have no combustion emissions, their production is generally more emission-intensive than fossil fuels.

Table 2: Carbon Intensity of Alternative Transportation Fuels (gCO_2e per MJ)

Life-Cycle Component	Gasoline	Brazilian Ethanol	Cellulosic Ethanol
Production (Total)	21.5	73.4	37.2
Production and Transport	21.5	27.4	37.2
Indirect Land Use Change	0	46	0
Combustion (Cap-and-Trade)	74.4	0	0
Total (Production + Combustion)	95.9	73.4	37.2

Because of this difference in GHG accounting, emission leakage between the LCFS and the cap-and-trade system will depend greatly on which types of substitutions are made to comply with the LCFS. **Table 3** reports net emission reductions as a consequence of the LCFS regulation of gasoline under eleven ARB scenarios. It also reports net LCFS emission reductions from diesel fuels, and the combined effect of both gasoline and diesel LCFS requirements. (Impacts from regulation of diesel fuel are not included.) The net change in emissions reflects emission reductions achieved by the LCFS less the reduction in cap stringency due to leakage. LCFS emission reductions are measured assuming a baseline level of renewable fuel demand set at 2011 consumption levels. Total consumption of each renewable fuel in each year is based on ARB scenarios, and lifecycle emissions per MJ for each fuel in each year are based on ARB data. The reduction in cap stringency is 72.9 g per MJ – that is, every MJ of renewable fuels consumed displaces a MJ of fossil fuel, which has an emission rate of 72.9 g per MJ.

[11] Because energy density (megajoule (MJ) per gallon) is higher for gasoline than ethanol, one gallon of ethanol cannot fully substitute for one gallon of gasoline. To correct for this problem, carbon intensity is compared on an energy basis (i.e., MJ).

Table 3: Net Emission Change from LCFS Requirements under ARB Plausible Compliance Scenarios (MMTCO$_2$e)

LCFS Gasoline Requirements Impact

	Fuels Not In The Cap—No Leakage				Overlap Between LCFS and Cap-and-Trade					
Scenario	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
1	0.0	-0.1	-0.3	-0.6	-1.3	0.4	0.1	-0.1	-0.7	-2.3
2	0.0	-0.1	-0.4	-0.7	-1.1	0.3	-0.6	-1.6	-3.6	-4.8
3	0.0	0.0	0.0	-0.3	1.1	4.3	6.1	5.6	5.5	5.2
4	0.0	-0.1	-0.2	-0.4	0.4	3.4	4.9	6.2	6.6	6.9
5	0.0	0.0	0.0	-0.3	-0.4	1.7	1.5	1.2	0.9	0.3
6	0.0	0.0	0.0	-0.3	-0.7	1.4	1.0	0.5	0.0	-1.1
7	0.0	0.0	0.0	-0.3	-0.4	1.8	1.5	1.0	0.6	-0.3
8	0.0	0.0	0.0	-0.3	0.9	3.1	3.9	3.9	4.0	3.9
9	0.0	0.0	0.0	-0.3	0.0	0.4	0.4	0.2	0.1	-0.3
10	0.0	0.0	0.0	-0.3	0.9	0.9	0.7	0.8	0.6	0.4
11	0.0	0.0	0.0	-0.3	-0.4	-0.9	-0.9	-1.1	-1.4	-1.8

LCFS Diesel Requirements Impact

	Fuels Not In The Cap—No Leakage				Overlap Between LCFS and Cap-and-Trade					
Scenario	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
1	0.0	0.0	-0.2	-0.4	2.4	3.6	4.7	4.1	3.5	2.5
2	0.0	0.0	-0.2	-0.4	2.4	3.7	4.7	4.1	3.5	2.5
3	0.0	0.0	-0.2	-0.4	2.4	3.7	4.7	4.1	3.5	2.5
4	0.0	0.0	-0.2	-0.4	2.4	3.7	4.7	4.1	3.5	2.6

LCFS Gasoline and Diesel Requirements (Combined Effect)

	Fuels Not In The Cap—No Leakage				Overlap Between LCFS and Cap-and-Trade					
Scenario	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
1	0.0	-0.1	-0.5	-1.0	1.1	4.0	4.8	4.0	2.8	0.2
2	0.0	-0.1	-0.6	-1.1	1.3	4.0	4.1	2.5	-0.1	-2.3
3	0.0	0.0	-0.2	-0.7	3.5	7.9	10.8	9.8	9.0	7.8
4	0.0	-0.1	-0.4	-0.8	2.8	7.1	9.6	10.3	10.0	9.4
5	0.0	0.0	-0.2	-0.7	2.0	5.3	6.2	5.3	4.3	2.8
6	0.0	0.0	-0.2	-0.7	1.7	5.1	5.7	4.6	3.5	1.4
7	0.0	0.0	-0.2	-0.7	2.0	5.5	6.2	5.2	4.1	2.2
8	0.0	0.0	-0.2	-0.7	3.3	6.7	8.6	8.0	7.5	6.4
9	0.0	0.0	-0.2	-0.7	2.4	4.1	5.1	4.4	3.5	2.2
10	0.0	0.0	-0.2	-0.7	3.3	4.5	5.4	4.9	4.1	2.9
11	0.0	0.0	-0.2	-0.7	1.9	2.8	3.8	3.0	2.1	0.7

Note: The analysis considers 11 gasoline and 4 diesel scenarios evaluated by ARB that are "illustrations of plausible combinations of fuels that could meet the LCFS targets". (ARB, "Low Carbon Fuel Standard 2011 Program Review Report," Final Draft, December 8, 2011, p. 96.) Combined effects reflect the impact of each gasoline scenario plus the impact of diesel Scenario 1. The estimated change in emissions assumes a counterfactual with renewable fuel use equal to 2011 levels. Thus, the analysis does not assume any adjustment to renewable fuel use from 2011 levels that might occur under a GHG cap-and-trade system. Estimates also do not account for emissions from in-state production that might be covered by cap-and-trade.

Table 4 reports estimated net emission leakage from production and combustion for the same eleven LCFS compliance scenarios evaluated by ARB. The table reports leakage from the LCFS gasoline requirements, the LCFS diesel requirements, and the combined effect of both LCFS requirements. Leakage is measured as the change in emissions from the interaction between the LCFS and the GHG cap-and-trade program divided by emission reductions when the LCFS is implemented alone. As seen from the table, leakage can be partial, complete, or even exceed 100 percent. While the LCFS is intended to control upstream emissions through life-cycle analysis, production emissions outside of California are not covered by cap-and-trade for any product. Hence, as long as AB 32 policies promote product substitutions with large differences in production emissions, aggregate emissions may increase.

An example can illustrate how emissions can increase. Consider the substitution of one megajoule (MJ) of Brazilian ethanol for one MJ of gasoline (using values from Table 1). Based on lifecycle emissions, this substitution reduces GHG emissions by 22.5 gCO_2e per MJ (95.9 minus 73.4 gCO_2e per MJ.) However, this substitution relaxes the cap for non-transportation sources by 74.4 gCO_2e per MJ, the emission rate for gasoline. Consequently, while the LCFS would in this example reduce GHG emissions, leakage with the cap-and-trade system would more than compensate, increasing emissions by 51.9 gCO_2e per MJ (74.4 minus 22.5 gCO_2e per MJ).

This is not the only dynamic that can undo attempts to control upstream emissions beyond California's borders. Fuel reshuffling may limit emission reductions achieved from the LCFS if suppliers shift the distribution of low-CI fuels to California from other regions without actually increasing the supply of these fuels. For example, the CI of Brazilian ethanol depends on the energy-intensity of the process used when producing ethanol. Assuming there is variation in the CI of existing supplies, the LCFS may be met, in part, by shifting the distribution of the lower-CI Brazilian ethanol from Brazil to California, without actually increasing the quantity of low-CI Brazilian ethanol produced. This reshuffling problem arises from incomplete program coverage, and arises in other elements of the AB 32 Scoping Plan, including the regulation of electricity imports under the cap-and-trade system.

Because of these interactions, the LCFS will likely raise the cost of achieving the AB 32 emission targets. The LCFS mandates one particular way of reducing emissions: the substitution of low-CI for high-CI transportation fuels. The cost-effectiveness of GHG emission reductions from such substitution depends on the relative costs and emission rates of these fuel substitutes. **Table 5** reports estimates of the cost of GHG emission reductions for substitutions based on cost estimates from various sources.[12] As the table shows, there is wide variation in the anticipated costs of renewable fuels.

Some studies estimate that the costs of renewable fuels will exceed that of gasoline. In this case, emission reductions incur positive costs. For example, based on estimates from the California Energy Commission, the cost of GHG emission reductions from renewable fuels substitution will range from \$130 to \$945 per $MTCO_2e$. These costs far exceed the cost of emission reductions under the cap-and-trade program. For example, the highest allowance price in scenarios evaluated by ARB in its AB 32 economic analysis was \$102 per $MTCO_2e$.[13]

[12] These estimates assume constant marginal costs, except for CRA, which assumes constant relative costs.

[13] ARB, "Updated Economic Analysis of California's Climate Change Scoping Plan," Staff Report to the Air Resources Board, March 24, 2010, Table 23.

Table 4: Leakage from Interaction between the LCFS and GHG Cap-and-Trade Program Under ARB Plausible Compliance Scenarios

LCFS Gasoline Requirements Impact

Scenario	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
1	—	—	—	—	19%	111%	103%	98%	92%	78%
2	—	—	—	—	30%	110%	87%	72%	57%	51%
3	—	—	—	—	179%	241%	223%	186%	170%	155%
4	—	—	—	—	135%	221%	206%	197%	181%	167%
5	—	—	—	—	75%	157%	130%	118%	111%	103%
6	—	—	—	—	50%	154%	121%	108%	100%	90%
7	—	—	—	—	71%	168%	132%	116%	107%	97%
8	—	—	—	—	162%	216%	183%	160%	147%	135%
9	—	—	—	—	96%	116%	108%	104%	101%	97%
10	—	—	—	—	162%	133%	115%	112%	107%	103%
11	—	—	—	—	37%	67%	80%	83%	83%	83%

LCFS Diesel Requirements Impact

Scenario	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
1	—	—	—	—	377%	373%	329%	246%	196%	154%
2	—	—	—	—	377%	373%	329%	246%	196%	154%
3	—	—	—	—	377%	373%	329%	246%	196%	154%
4	—	—	—	—	378%	374%	329%	246%	196%	154%

LCFS Gasoline and Diesel Requirements (Combined Effect)

Scenario	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
1	—	—	—	—	146%	184%	175%	145%	124%	101%
2	—	—	—	—	154%	185%	163%	128%	99%	84%
3	—	—	—	—	257%	281%	254%	204%	178%	154%
4	—	—	—	—	236%	269%	244%	212%	186%	163%
5	—	—	—	—	188%	225%	189%	157%	137%	119%
6	—	—	—	—	173%	227%	186%	149%	129%	109%
7	—	—	—	—	184%	236%	193%	155%	134%	114%
8	—	—	—	—	242%	268%	228%	186%	162%	141%
9	—	—	—	—	251%	203%	176%	147%	130%	114%
10	—	—	—	—	240%	214%	181%	152%	134%	119%
11	—	—	—	—	225%	171%	157%	132%	117%	105%

Note: Leakage is calculated as the ratio of (1) difference between the emission reductions from the LCFS alone and the LCFS with the GHG cap-and-trade program in place to (2) the emission reductions from the LCFS alone.

By contrast, other studies find that renewable fuels will be less costly than gasoline. In this case, emission reductions have negative costs – that is, savings. For example, based on ARB estimates, substitution of Brazilian sugarcane ethanol will reduce GHG emissions at a savings of $16 to $26 per $MTCO_2e$. This substitution saves money because Brazilian ethanol is less costly to produce than gasoline (2.3 versus 2.4 cents per MJ.) But if this is true, then it is unclear why the LCFS is necessary. Assuming the cost estimates are accurate, competitive producers should be able to enter the market with Brazilian ethanol and underprice existing gasoline suppliers, thus capturing a growing share of the market. Thus, expanded use of renewable fuels would occur without public policy intervention.

Of course, if expanded use of renewable fuels is a costly means of reducing GHG emissions, a cap-and-trade system may not lead to meaningful changes in the carbon intensity of transportation fuels. Some suggest that this is problem with the cap-and-trade system, since they believe that all sectors and all aspects of activities that affect the climate should be simultaneously pursued with equal vigor. Such thinking may be part of the rationale behind the "belt and suspenders" approach that embodies the AB 32 Scoping Plan. While this approach can meet environmental objectives, it does so at excessive cost because it pursues reductions across sectors and activities irrespective of cost, thus requiring that high-cost reductions be pursued at the expense of low-cost reductions. These costs are felt by all households who, in the end, bear the economic burden of climate policy. Thus, pursuing such "distributional equity" across sectors through these means has its social costs.

Moreover, it is important to remember that cap-and-trade will be more cost-effective than any complementary policy alone (such as the LCFS) or any a suite of complementary policies targeting all sources covered by cap-and-trade. Any individual complementary policy will be less cost-effective because standards are based on factors not directly related to GHG emissions (for example, renewable portfolio standards), because requirements target emission rates rather than quantity (for example, the LCFS), and/or because policies allow only very narrow opportunities to reduce emissions.[14] In addition, no suite of policies can provide the uniform incentives to reduce GHG emissions that are provided by cap-and-trade. A suite of policies will be unable to create incentives that equalize marginal abatement costs across policies, thereby achieving cost-effectiveness. Further, cap-and-trade can create incentives to reduce emissions that cannot be easily achieved through complementary policies (for example, incentives to reduce vehicle miles travelled.) Thus, in terms of simple feasibility, the cap-and-trade approach dominates.

b. Interactions with the Federal Renewable Fuel Standard

The carbon-intensity of transportation fuel used in all 50 states is covered by the federal Renewable Fuel Standard (RFS). The RFS specifies quantities of renewable fuel that must be used in each year, with separate targets for non-corn-based biofuels, cellulosic ethanol, and biodiesel. As with the LCFS, the RFS allows trading of renewable fuel obligations among suppliers to help minimize the program's cost.[15] Targets for certain renewable fuels have been set with some flexibility, because current production capability is limited (but there is hope such capacity will develop as a consequence of the standard). Of note, targets for cellulosic ethanol have already been revised downward from initial levels

[14] For an analysis of the LCFS, see Holland, Stephen, Jonathan Hughs, and Christopher Knittel, "Greenhouse Gas Reductions under Low Carbon Fuel Standards?", *American Economic Journal: Economic Policy 2009* 1(1): 106-146.

[15] Fuel producers receive RFS credits, referred to as Renewable Identification Numbers, or RINS, for renewable fuels generated for compliance with the RFS.

due to the slow development of cellulosic ethanol technology. Biodiesel targets are to be determined on a year-by-year basis, depending on the status of market supplies. **Table 6** reports these targets.

Table 6: Fuel Quantity Targets Under the Federal Renewable Fuel Standard (RFS) (Billion Gallons)

	RFS1	RFS2					
				Portion to be from Advanced Biofuels			
Year	Renewable Fuel Target (Total)	Renewable Fuel Target (Total)	Cap on Corn Ethanol	Total Non-Corn	Cellulosic	Biodiesel	Other
2006	4.0	—	—	—	—	—	—
2007	4.7	—	—	—	—	—	—
2008	5.4	9.00	9.0	0.00	0.00	0.00	0.00
2009	6.1	11.10	10.5	0.60	0.00	0.00	0.10
2010	6.8	12.95	12.0	0.95	0.00650	1.15	0.20
2011	7.4	13.95	12.6	1.35	0.00660	0.80	0.30
2012	7.5	15.20	13.2	2.00	0.00865	1.00	0.50
2013	7.6	16.55	13.8	2.75	1.00	1.28	0.75
2014	7.7	18.15	14.4	3.75	1.75	TBD	1.00
2015	7.8	20.50	15.0	5.50	3.00	TBD	1.50
2016	7.9	22.25	15.0	7.25	4.25	TBD	2.00
2017	8.1	24.00	15.0	9.00	5.50	TBD	2.50
2018	8.2	26.00	15.0	11.00	7.00	TBD	3.00
2019	8.3	28.00	15.0	13.00	8.50	TBD	3.50
2020	8.4	30.00	15.0	15.00	10.50	TBD	3.50
2021	8.5	33.00	15.0	18.00	13.50	TBD	3.50
2022	8.6	36.00	15.0	21.00	16.00	TBD	4.00

Note: The Energy Policy Act of 2005 established an initial standard (RFS1), which was subsequently increased (RFS2) by the Energy Independence and Security Act of 2007.

Source: Schnepf, Randy, Brent Yacobucci, "Renewable Fuel Standard (RFS): Overview and Issues," Congressional Research Service, January 23, 2012.

While the LCFS may increase the quantity of renewable fuels used in California, it will not change the aggregate quantity of renewable fuels used in the United States. As the supply of renewable fuels increases in California, the demand for renewable fuels from the federal RFS will be relaxed in the other 49 states, so that any increase in renewable fuels use in California will be fully offset by reduced use outside of California. Consequently, because of this (possibly 100%) leakage between the LCFS and the RFS, the LCFS results in no incremental increase in renewable fuel use. Thus, the primary impact of the LCFS is to shift renewable fuel use from other states to California, increasing costs to California and, in effect, subsidizing other states by relieving their regulatory burden. ARB may recognize this, having stated that advanced fuels will be produced to meet the RFS, "the LCFS merely attracting more than a proportional share to California"[16] These policies may also subsidize production in other states or countries, since much of the fuel supply used to comply with renewable fuel standards would be produced outside California (for example, Brazilian sugar-cane ethanol.)

While the LCFS will not increase the supply of renewable fuels, it could shift the mix of renewable fuels used towards a lower-carbon mix. In this case, emission reductions from the LCFS would reflect the difference in carbon intensity between fuels used to comply with the LCFS and those used to comply with the RFS. Consequently, GHG emissions leakage could be less than 100%.

With the LCFS, such partial leakage may occur because the RFS does not discriminate among renewable fuels, aside from the three categories identified in **Table 4**. Thus, the lowest cost fuel in each category will be used to comply with the RFS. By contrast, the LCFS provides incentives that reflect both cost and carbon intensity. As shown in **Table 7**, when a fuel's carbon intensity is sufficiently low to offset a higher cost, the fuel with a lower CI will be used. In this case, there will be partial leakage, and the LCFS will lower emissions. As the example in **Table 7** shows, when partial leakage occurs, the extent of this leakage will depend upon the difference between the CI of the lowest cost fuel and the CI of the most cost-effective LCFS fuel. In this case, the resulting incremental cost of GHG emissions from the LCFS will reflect both the incremental CI and the incremental cost of the higher-cost, lower-GHG renewable fuel. **Table 5** shows estimates of these emission reduction costs if the LCFS results in the substitution of cellulosic ethanol for Brazilian sugarcane ethanol.

Of course, the RFS and LCFS may induce the same mix of renewable fuels, in which case there will be 100% leakage, and the LCFS will fail to reduce emissions. This will occur when the lowest cost fuel that can comply with the RFS is also the most cost-effective fuel (given carbon intensity) under the LCFS. Even when the LCFS results in the same national mix of renewable fuels, costs could increase because of cost differences arising from a shift from the optimal geographic distribution of renewables fuels. In this case, higher costs may arise due to higher production costs (for example, due to higher biomass production costs) or higher transportation costs (for either biomass inputs or end-product distribution).

c. Other Policy Rationales for the LCFS

While interactions with other state and federal policies will likely raise costs and limit environmental effectiveness, the LCFS could provide other benefits. One question is whether the LCFS addresses market failures other than the failure to internalize GHG impacts. Possible market failures relate to technology adoption and to research and development:

1. *Limits to Technology Adoption.* Use of renewable fuels may face several barriers to greater deployment. First, regulations may pose barriers if the use of fuel blends with higher proportions of ethanol has not been approved. Such regulatory barriers are best addressed by modifying standards. Moreover, the LCFS does not address these barriers.

[16] Air Resources Board, "Low Carbon Fuel Standard 20011 Program Review Report," Final Draft, December 8, 2011 p. 112.

Use of new fuel technologies may be limited by available refueling infrastructure, such as recharging stations for electric vehicles and refueling stations for hydrogen-powered vehicles. Because of network effects, lack of infrastructure can impose a hurdle to widespread technology adoption. The fixed infrastructure costs may pose large economic risks, particularly when there are competing platforms.

2. *Insufficient Research and Development.* Because of information spillovers and the resulting limits on innovator's ability to capture the full value of their innovations, the market may provide insufficient levels of research and development.[17] While the LCFS may provide incentives for some nascent technologies, such as cellulosic ethanol, it provides the same incentives for more mature technologies, such as Brazilian ethanol. Thus, the LCFS does not explicitly distinguish between nascent and mature technologies. In this sense, its impact is similar to the broad incentives for research and development created by cap-and-trade, although opportunities for productive technological development might be greater in fuel technologies than in other activities contributing to GHG emissions. In addition, LCFS targets in later years may exceed the degree of market penetrations needed to move advanced fuels beyond early stages of development. There is also a corresponding risk that technology and markets do not develop sufficiently fast to make compliance feasible, thus requiring on-going adjustments to targets (as with the Federal RFS.)

The LCFS might provide other policy benefits. The LCFS could induce other states to adopt an LCFS or promote a more aggressive federal RFS. Other states are currently considering adoption of state-level LCFS policies. However, in light of the potentially high costs of LCFS policies relative to others (for example, cap-and-trade), wide-spread adoption of LCFS policies may not be the most prudent direction for state-level climate policies. The likelihood that California's LCFS would lead to a more stringent RFS depends, in part, on the degree to which various industries would benefit (or not) from uniform standards. Prior cases in which California policy has helped spur changes in federal policy have involved light-duty vehicle designs, not fuel content standards. While there are many factors that might encourage product uniformity around fuel standards (for example, engine technologies), there are also many differences, particularly since compliance will be tied to fuel use, rather than vehicles sales.

4. Conclusion

ARB has developed a broad suite of policies to achieve AB 32's emission targets. However, because of interactions with policies at the state and federal level, some policies and programs in the AB 32 Scoping Plan may raise the costs of achieving AB 32 targets, without reducing GHG emissions. Given these potential outcomes, ARB should carefully consider whether such policies provide incremental benefits relative to the cap-and-trade policy, which anchors the AB 32 Scoping Plan. While many

[17] See: Jaffe, Adam B., Richard G. Newell, and Robert N. Stavins. "Technological Change and the Environment," *Handbook of Environmental Economics*, Volume I, eds. Karl-Göran Mäler and Jeffrey Vincent, Chapter 11, pp. 461-516. Amsterdam: Elsevier Science, 2003.

policies are already being implemented, these policies should be periodically evaluated over time to ensure they are providing positive net benefits, particularly in light of interactions with other policies.

California's LCFS illustrates the limitations created by policy interactions. The LCFS would raise the cost of achieving the AB 32 emission targets by requiring more costly emission reductions than would otherwise occur with the cap-and-trade system. While raising costs, the LCFS would not achieve meaningful reductions in GHG emissions, and could even increase GHG emissions depending on the types of renewable fuel substitutions used to comply with the LCFS. Moreover, in achieving these outcomes, the LCFS would likely raise costs to Californians, particularly compared to alternative policies that might better target potential market failures addressed by the LCFS.

Table 5: Cost of GHG Emission Reductions From Renewable Fuel Substitutions

Source	**CEC**	**CEC**	**NRC**	**CRA**	**CRA**	**BCG**	**BCG**	**ARB**	**EPA**	**EPA**	**EPA**
	[1]	[1]	[2]	[3]	[3]	[4]	[4]	[5]	[6]	[6]	[6]
Case	**Low Price**	**High Price**		**Optimistic**	**Pessimistic**	**Lower Bound**	**Upper Bound**		**Low Price**	**Mid Price**	**High Price**
Year	2020	2020	2007	2020	2020	2020	2020	2020	2022	2022	2022
Fuel Costs (cents per Gallon)											
Renewable Fuels											
CBI Sugarcane Ethanol	200	320									
Brazilian Sugarcane Ethanol	260	436		323	344	33	106	187	169	172	173
Cellulosic Ethanol	291	548	93	461	492			234	146	149	150
BTL - Gasoline	441	731		684	730						
Gasoline (CARBOB)	238	393		285	285			285	335	335	335
Fuel Costs (cents per MJ)											
Renewable Fuels											
CBI Sugarcane Ethanol	2.48	3.97									
Brazilian Sugarcane Ethanol	3.23	5.41		4.01	4.27	0.41	1.32	2.32	2.10	2.13	2.15
Cellulosic Ethanol	3.61	6.81	1.15	5.72	6.10			2.90	1.81	1.85	1.87
BTL - Gasoline	3.69	6.12		5.72	6.10						
Gasoline (CARBOB)	1.99	3.29		2.38	2.38			2.38	2.80	2.80	2.80
Cost of GHG Emission Reductions ($/MTCO2e)											
CBI Sugarcane Ethanol	130	181									
Brazilian Sugarcane Ethanol	551	945		722	839	182	586	-27	-315	-299	-290
Brazilian Sugarcane Ethanol (Cogen + Mechanized)	330	566		433	503			-16	-189	-179	-174
Cellulosic Ethanol	275	600	197	569	634			88	-169	-163	-160
BTL - Gasoline	289	481		569	634						
Cost of GHG Reductions from Substitutions between Renewable Fuels ($/MTCO2e)											
Braz Sugar Ethanol => Cellulosic Ethanol	104	386		474	507			160	-79	-79	-79
Braz Sugar Ethanol (Cogen + Mech) => Cellulosic Ethanol	178	659		810	866			273	-135	-135	-135

Table 5: Cost of GHG Emission Reductions From Renewable Fuel Substitutions

Note:

Differences in the cost of GHG emission reductions for Brazilian sugarcane ethanol reflects the difference in carbon intensity of alternative production processes, but do not reflect any differences in production costs of these processes.

Sources:

[1] Boston Consulting Group (BCG), "Understanding the impact of AB 32," June 19, 2012. Costs represent incremental cost of Brazilian ethanol relative to gasoline.

[2] California Air Resources Board (ARB), "Proposed Regulation to Implement the Low Carbon Fuel Standard, Volume I: Staff Report: Initial Statement of Reasons." March 2009. Available from http://www.arb.ca.gov/regact/2009/lcfs09/lcfsisor1.pdf. Table V-2, pg V-22.

[3] California Air Resources Board (CEC), "Low Carbon Fuel Standard 2011 Program Review Report." May 2011. Available from http://www.arb.ca.gov/fuels/lcfs/workgroups/advisorypanel/20111208_LCFS%20program%20review%20report_final.pdf. Table VII-1, pg 115, and table VII-9, pg 127.

[4] California Energy Commission (CEC), "Biofuel Values." November 2011. Original version available from http://www.energy.ca.gov/2011_energypolicy/documents/2011-11-14_workshop/2011-11-14_Biofuel_Values.xls. Updated version provided through personal communication.

[5] Charles River Associates (CRA), "Economic and Energy Impacts Resulting from a National Low Carbon Fuel Standard." June 2010. Available from http://www.secureourfuels.org/wp-content/uploads/2010/06/CRA-LCFS-Final-Report-June-14-2010.pdf. Table 4-2.

[6] National Research Council, National Academy of Sciences (NAS), "Renewable Fuel Standard: Potential Economic and Environmental Effects of U.S. Biofuel Policy." 2011. Available from http://www.nap.edu/catalog.php?record_id=13105. Table S-1. Cost reflects incremental costs (price gap between WTA and WTP (cents/gal).)

[7] U.S. Environmental Protection Agency (EPA), "Renewable Fuel Standard Program (RFS2) Regulatory Impact Analysis." February 2010. Available from http://www.epa.gov/oms/renewablefuels/420r10006.pdf. Tables 4.4-4 and 4.4-21.

Table 7: Illustrative Examples of GHG Leakage Between California's LCFS and the Federal RFS

Case A: Cellulosic Ethanol Preferred for LCFS, Brazilian Ethanol Preferred for RFS ==> LCFS Lowers Emissions

				LCFS Compliance			RFS Compliance		
	[A]	[B]	[C]	[D]	[E]	[F]	[G]	[H]	[I]
	Emissions (g CO2e / MJ)	**Fuel Cost (cent / gallon)**	**Fuel Cost (cent / MJ)**	**Substitution Proportions to Comply with LCFS**	**Cost of RF (cents)**	**Emission Reduction (g CO2e / MJ)**	**Mix (Other RFs)**	**Emission Reduction (g CO2e / MJ)**	**Leakage Percent**
Gasoline	95.86	349.70	2.926	1					
Brazilian Ethanol	73.40	387.44	4.811	0.353	1.698	5.86	**0.111**	**2.24**	38%
Cellulosic Ethanol	37.20	487.44	6.053	**0.111**	**0.672**	**5.86**	0	0	

Case B: Brazilian Ethanol Preferred for LCFS, Brazilian Ethanol Preferred for RFS ==> LCFS Has No Effect on Emissions

				LCFS Compliance			RFS Compliance		
	Emissions (g CO2e / MJ)	**Fuel Cost (cent / gallon)**	**Fuel Cost (cent / MJ)**	**Substitution Proportions to Comply with LCFS**	**Cost of RF (cents)**	**Emission Reduction (g CO2e / MJ)**	**Mix (Other RFs)**	**Emissions (g CO2e / MJ)**	**Leakage Percent**
Gasoline	95.86	349.70	2.926	1					
Brazilian Ethanol	58.40	300.00	3.725	**0.185**	**0.691**	**5.86**	**0.185**	**5.86**	100%
Cellulosic Ethanol	37.20	500.00	6.209	0.111	0.689	5.86	0	0	

Assumed LCFS Standard (gCO2e / MJ) = 90

Note: For each potential fuel substitution, the proportion of gasoline to renewable fuel needed to comply with the assumed annual standard (90 $gC0_2e$ / MJ) is calculated (column [E]). Based on this proportion and the fuel cost (column [C]), the cost of renewable fuel (RF) needed to comply with the LCFS is calculated. The lowest compliance cost is identified (as shown by the box) and emission reductions are calculated (column [F]). Leakage (column [I]) reflects the same quantity (MJ) of renewable fuel and carbon intensity of the lowest cost renewable fuel (Brazilian ethanol).

In Case A, a less carbon intensive, but more costly, fuel is most cost-effective for LCFS compliance, thus leakage is partial. In Case B, the most cost-effective and least cost fuels are the same, so leakage is 100%.