GHG Cap-and-Trade: Implications for Effective and Efficient Climate Policy In Oregon

Todd Schatzki, Ph.D.
Analysis Group, Inc.

Prof. Robert N. Stavins
Harvard University

November 2018

GHG Cap-and-Trade: Implications for Effective and Efficient Climate Policy In Oregon

Executive Summary

Todd Schatzki and Robert N. Stavins[1]

November 2018

Like many other states, Oregon has begun to pursue climate policies to attempt to fill the gap created by the lack of effective climate policy at the Federal level. After adopting a variety of policies to address climate change and other environmental impacts from energy use, Oregon is now contemplating the adoption of a greenhouse gas (GHG) cap-and-trade system. However, interactions between policies can have important consequences for environmental and economic outcomes. Thus, as Oregon considers taking this step, reconsidering the efficacy of its other current climate policies may better position the state to achieve long-run emission reductions at sustainable economic costs.

1. A Well-Designed GHG Cap-and-Trade Program is a Better Approach to Regulating GHG Emissions Than Alternatives

A GHG cap-and-trade system offers many advantages compared with other approaches to reducing GHG emissions. By capping total emissions, a cap-and-trade system provides a high level of emissions certainty. By comparison, policies that target particular activities through standards do not achieve any particular emission target with certainty.

In addition, c**ap-and-trade systems achieve emission reductions at a lower cost than other regulatory approaches by creating a uniform incentive that encourages emission reductions through the least-costly approach.** Thus, cap-and-trade creates incentives for sources to undertake the least-costly emission reductions, while forgoing more costly options.

Development of a well-designed cap-and-trade system requires careful attention to the details. Prior legislative proposals in Oregon have included elements of a well-designed GHG cap-and-trade system, such as btiol- TDisl5lem

are dramatic; while GHG cap-and-trade allowance prices have been below $16 per $MTCO_2e$, LCFS program credit prices have risen to nearly $180 per $MTCO_2e$, more than a 11-fold difference.

Figure ES-1. Aggregate Change in Emissions from California's LCFS

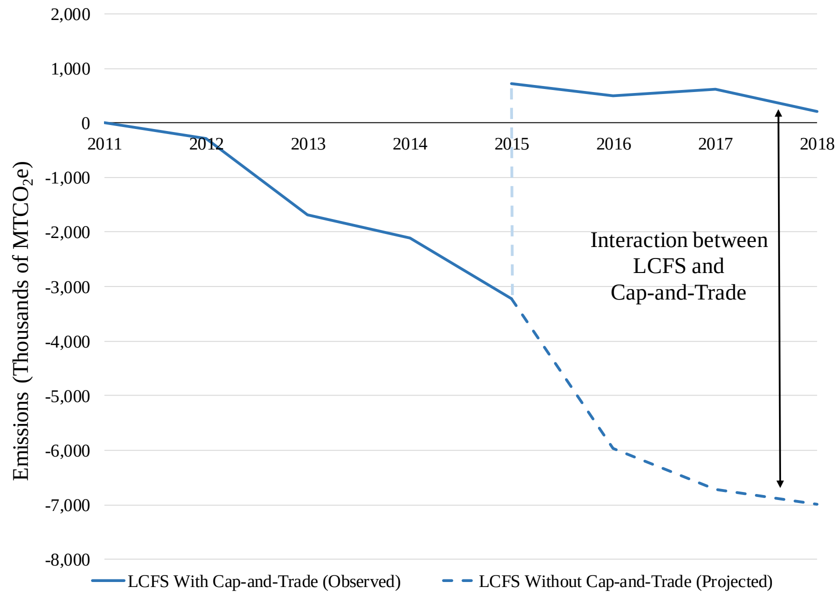
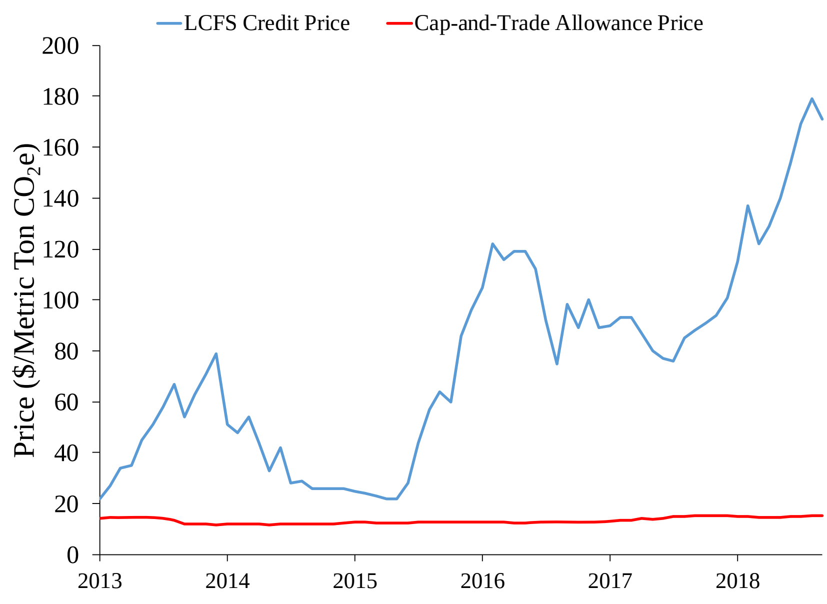


Figure ES-2. California's LCFS Credit Prices vs. Cap-and-Trade Allowance Prices



Some have tried to justify these high costs and negligible environmental impacts by claiming that the LCFS is a "technology" policy aimed at "spurring innovation." While measuring innovation is complex, it should be noted that compliance with the LCFS has largely been achieved through pre-existing technologies. It is unclear to what degree, if any, improved efficiencies ("learning by doing") have been achieved through the demand for renewable fuels created by the LCFS. Moreover, LCFS costs are comparable to all federal spending on renewable energy, raising the question of whether the LCFS is the best use of society's resources from the standpoint of investment in promoting energy technology innovation.

4. Next Steps for Oregon Climate Policy

As Oregon contemplates the adoption of cap-and-trade, it has several options for its suite of climate policies. One approach maintains all policies, as currently designed. Our analysis shows that, due to interactions among overlapping climate policies, retaining certain complementary policies could be very costly without achieving any incremental environmental benefits.

A second option would be to develop a GHG cap-and-trade program of sufficient stringency to achieve targeted emissions or allow prices to rise to the social cost of carbon, and end complementary policies that do not produce incremental benefits by addressing market failures unrelated to the GHG emission externality or regulating sources not covered by the cap. This approach could begin by undertaking a thorough assessment of the likely interactions among overlapping climate policies and the extent to which policies address market failures unrelated to GHG emissions. The feasibility of this approach will depend on how aggressively Oregon can pursue carbon pricing.

A third approach is a hybrid of these approaches. While economic analysis unambiguously shows that policies relying on GHG emission pricing, such as GHG cap-and-trade, are the most cost-effective approach to achieving emission targets, political realities may not support the immediate adoption of climate policies relying largely (if not solely) on carbon pricing. But the costs of pursuing aggressive GHG emission reductions goals through more-costly complementary policies will grow over time, which makes that path not only costly but politically risky. The hybrid option involves a transition to increased reliance on GHG cap-and-trade by diminishing the reliance (i.e., stringency) of some complementary policies and gradually (or even quickly) shifting to the uniform-price incentives created by cap-and-trade.

I. BENEFITS OF GHG CAP-AND-TRADE SYSTEMS

A cap-and-trade system limits (caps) the total emissions permitted from a designated set of sources. By reducing the cap over time, emissions are reduced from current levels to meet policy objectives. Cap-and-trade systems have been widely applied to GHG emissions. At present, there are approximately 21 systems covering emissions at the state, provincial, national, or regional level.[5] A cap-and-trade system can cover a large fraction of economy-wide emissions, because the energy sources that account for most emissions can be regulated through a relatively small number of sources. For example, California's GHG cap-and-trade system covers approximately 85% of state-wide GHG emissions by regulating emissions from electric power generators, large industrial facilities, and suppliers of natural gas and other fuels.[6]

By capping total emissions, a cap-and-trade system provides a high level of emission certainty. By comparison, policies that target particular activities through standards do not achieve any particular emission target with certainty. For example, a low carbon fuel standard may reduce fuel carbon-intensity, but it does not affect the number of miles driven or vehicle fuel efficiency. Thus, total emissions may increase even if carbon-intensity is falling.

Cap-and-trade systems achieve emission reductions at a lower cost than other regulatory approaches. By imposing a cost on activities that generate emissions, cap-and-trade creates a uniform incentive that encourages emission reductions through the least-costly approach. Sources that can reduce emissions at a cost less than the cost of emission permits (allowance prices) will take steps to reduce emissions, while sources that can only reduce emissions at a cost greater than allowance prices will not take such action. Because allowances used to comply with the cap-and-trade system are tradeable among regulated sources, allowances can flow to sources as needed to cover emissions.

Legislative proposals in Oregon (e.g., HB 4001, SB 1507) specify many elements of the GHG cap-and-trade design, but also leave many features for the regulator, the Oregon Environmental Quality Commission (EQC), to determine. These proposals include features of a well-designed GHG cap-and-trade system, and, when providing the EQC with rule-making discretion, do not preclude potentially valuable design features. But, as with any complex regulation, the design details that need to be worked out during this rulemaking process would be critical to determining the eventual effectiveness of the policy.

In these proposals, the program would cover all sectors of the economy that are easily regulated through a GHG cap-and-trade system, including large point sources and fuels, such as natural gas, gasoline and diesel. Sources outside the proposed program are generally more difficult to monitor and enforce, thus making regulation through other measures more promising.

Proposed legislation can accommodate key design features to take advantage of "when" and "where" flexibility, although such features must be developed during the rulemaking process. Because GHG emissions are long-lived "stock" pollutants, the timing of emissions is less critical to the damages they create than is the case with many other pollutants (e.g., criteria air pollutants). Thus, well-designed cap-and-trade systems include banking and multi-year compliance periods to allow sources

[5] ICAP. (2018). Emissions Trading Worldwide: Status Report 2018. Berlin: ICAP.

[6] Center for Climate and Energy Solutions, "California Cap and Trade," March 16, 2018.

flexibility over when emission reductions are made.[7] Further, because the impact of GHG emissions is independent of where emissions occur, systems that include linking and offsets can lower the total costs of achieving emission goals. The legislation includes specific provisions that permit the EQC to link Oregon's programs with other systems and allow sources to use offsets to fulfill up to 8% of their compliance obligation.[8]

The proposed system includes an Allowance Price Containment Reserve, designed to help contain the costs of compliance. The Reserve holds a finite quantity of allowances that are released only when prices rise to a predetermined "trigger" price level. **The Reserve can help mitigate costs and allowance price volatility in the event that there is a sudden increase in demand that would lead to a spike in allowance prices.**

However, the proposed cap-and-trade system does not include an explicit price cap that could provide a "safety valve" in the event that demand for allowances suddenly increases. By itself, the Reserve will not limit prices from rising to economically (and politically) unacceptable levels. Because the Reserve holds a finite quantity of allowances, once the Reserve is exhausted, allowance prices can continue to rise unabated.

A price cap has many benefits.[9] A price cap sends a clear signal to the market about the range of prices that could prevail in the future. It also provides market stability, because absent a price cap, there is a risk that a sudden increase in prices undermines political support for the policy. In the past, the failure of policies to include a safety valve has led to the suspension of emission trading programs when prices suddenly rose to high levels, such as occurred in the RECLAIM program in California's South Coast Air Quality Management District.[10]

California recently adopted a price cap. In its draft rulemaking, the California Air Resources Board (CARB) has set the price cap at $65 per MTCO$_2$e in 2021. The price cap would rise at a rate of 5% plus inflation. It is anticipated that CARB will finalize these rules this year.

In many respects, the GHG cap-and-trade proposals mirror systems already in place in California

esign of GHG cap-and-trade systems in California. If sufficiently similar, Oregon could link its system to the California system and other systems (e.g., Quebec), if desired. Linkage can lower the total economic cost of achieving emission targets by expanding the geographic scope of emission reductions opportunities.[11]

[7] SB 1507 does not specify the length of compliance periods and does not explicitly allow allowance banking.

[8] SB 1507, Section 17. Offset Projects; SB 1507, Section 19. Linkage w ma rket-based compliance mechanisms in other jurisdictions.

[9] SB 200. *See* Schatzki and Stavins, 2018.

[10]

The compliance instruments -- allowances -- used by sources to comply with a cap-and-trade system have substantial economic value.[12] Thus, a key decision for legislators in developing a cap-and-trade system is determining how these allowances will be allocated. This can affect both the aggregate economic impact of the cap-and-trade program, as well as the distribution of its economic outcomes across businesses and consumers.

Legislators have two basic options: freely allocating allowances to particular entities, or selling allowances through auction. HB 4001 / SB 1507 proposes to allocate allowances through both of these mechanisms. Some allowances would be allocated directly to electric and natural gas utilities and emission-intensive, trade-exposed industries. These direct allocations have two distinct purposes. **Direct allocations to emission-intensive, trade-exposed industries through an updating, output-based** aimed at achieving the bill's objectives, and transitioning workers in affected communities.[15] Road and educational spending reflects requirements in the Oregon Constitution given the nature of the revenues being collected.

Like Oregon's proposal, many cap-and-trade programs use auction revenues to support projects aimed at reducing GHG emissions. Such spending may seem natural given the goals of climate policy. However, care is needed when selecting projects and activities to achieve environmental and economic benefits. To achieve reductions in GHG emissions, such spending should target sources outside the cap or programs that address market failures unrelated to GHG emissions. Below, we elaborate on these conditions, as they pertain to complementary policies. But the same logic holds for revenue spending: spending to reduce emissions from sources covered by the cap will not reduce total emissions because the cap remains unchanged. Instead, such spending shifts where emissions occur under the cap and subsidizes spending on emission reductions activities that otherwise would be made solely due to the cap-and-trade price signals.

II. STATE CLIMATE POLICIES

In the wake of a lack of Federal leadership on climate policy, some states have sought to develop their own policies, often in coordination with other states (and provinces). These state climate initiatives often take a "belt and suspenders" approach that includes a suite of policies targeting different activities that generate GHG emissions. This approach can aim to address each activity that produces GHG scenario planning guidelines; and tools that suppora07 Tc2.021 Tw[(t)5.38678[(t)5.34io pl2.74

benchmark, used by many other regulators, including CARB.

Information Problems. When market participants fail to have accurate information about a product's attributes, they can make decisions that do not account for the true costs and benefits of alternative choices. Two types of information problems are of particular concern.[23] The *principal-agent problem* arises when one party makes decisions with financial implications for another party. For example, building owners may not make investments in energy efficiency if they lease may be impractical because of technical challenges. As a result, certain public policies may target these externalities, such as subsidies for public transportation.

Network Externalities. Many energy systems include distribution networks that deliver fuel to individual consumers. For a given technology or fuel type, the availability and reliability of the network used to delivery energy is an important dimension of consumer technology choices. Network externalities potentially affect these technology choices. Several examples from the transportation sector illustrate network externalities.

Hydrocarbons, electricity and hydrogen are three important transportation fuel technologies that each require distinct refueling infrastructure. At present, the ubiquity of gasoline service stations creates a positive network externality -- the benefits of owning a traditional gasoline powered vehicle increase with a more-developed refueling network. Due to these positive network externalities, the incentives favor owning a gasoline-powered vehicle relative to, for example, an electric vehicle, which depends on a less-developed network of electric charging stations. While a more developed network of charging stations would increase the benefits of owning an electric vehicle, without sufficient numbers of electric vehicles on the road, incentives to invest in charging stations may be inadequate (Li et al, 2017). The resulting "chicken-and-egg" problem may prevent the efficient market developments.

Another example of a network externality is hydrocarbon standards. Combustion and diesel engines are designed to accept fuels meeting particular fuel specifications. For example, most gasoline-powered vehicles rely on E10, which includes up to 10% ethanol, but cannot operate on higher fractions of ethanol without creating risks of engine damage and voiding of warranties. As a result, these technical engine standards may create a "blend wall" that limits the ability to blend renewable fuels.

Policies aligned with the underlying market failure will address most efficiently and effectively these market failures. For example, network externalities associated with refilling/recharging station networks suggest subsidization of refilling/recharging networks.[26] By contrast, while some other policies substantial technological innovation or simply lead to widespread deployment of pre-existing

2. The broader federal or state policy provides flexibility to meet requirements through adjustments across sectors or states, i.e. averaging ("flexible policy criteria".)

Not all policies meet these conditions. 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 and fleet vehicle efficiency standards) provide flexibility that creates perverse interactions between policies.

In the context of Oregon's climate policies, the interaction of greatest concern is between the GHG cap-and-trade program and other climate policies that regulate sources covered by the cap-and-trade program.[31]

Oregon’s CFP required reductions in carbon intensity of 0.5% (relative to a 2015 baseline), while

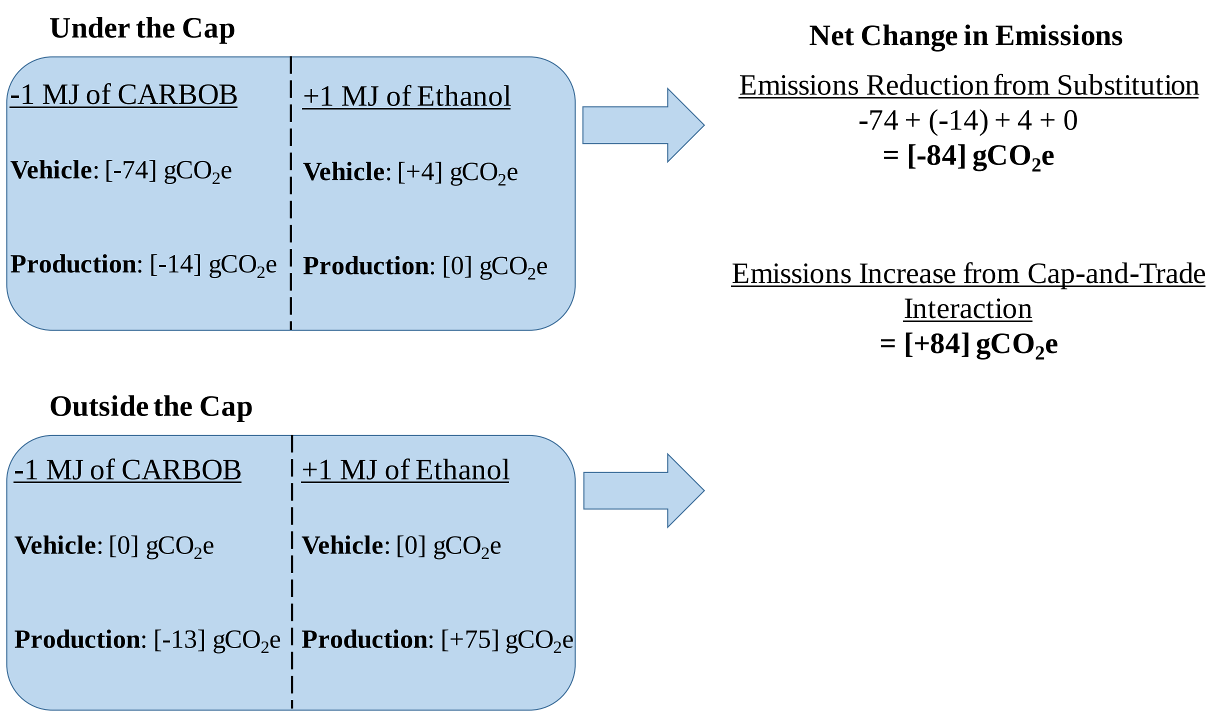
Figure 3. Annual Incremental Costs, California's LCFS

Note: We distinguish in our calculations between expenditures by reducing entities and economic cost of emission reductions. Expenditures associated with emission reductions are simply (annual emission reductions [MT]) × (average annual credit price [$/MT]), where the average annual credit price represents the average of the 12 monthly CARB reported average credit prices. Costs of emission reductions can be represented by the area under an emissions reduction supply curve between the origin and market ethanol produces very little net vehicle emissions because carbon sequestered in the process of growing corn to produce ethanol offsets tailpipe emissions.

Absent the GHG cap-and-trade system, switching from gasoline to ethanol results in a carbon reduction of 22 gCO_2e (that is, 101 gCO_2e - 79 gCO_2e). However, with the GHG cap-and-trade system in place, the impact needs to account for the interaction of the switch to ethanol proscribed by the LCFS program with the GHG cap-and-trade system. Accounting for this impact requires a separate analysis of changes in emissions from sources covered by the cap-and-trade system and those outside the cap.

Start with emissions under the cap. For gasoline, 88 gCO_2e of lifecycle emissions are covered by the cap (74 gCO_2e of vehicle emissions + 14 gCO_2e from in-state refining), whereas only 4 gCO_2e of ethanol lifecycle emissions would be covered by the cap. Thus, substituting ethanol for gasoline reduces GHG emissions under the cap by 84 gCO_2e (that is, 88 gCO_2e - 4 gCO_2e). However, because total emissions under the cap is fixed, there is actually no change in emissions under the cap; instead, other sources under the cap will increase their emissions by 84 gCO_2e given the slack in emission created by substitution.

Figure 4. Illustration of Change in Emissions due to Substituting Ethanol for Gasoline under the LCFS



Note: [1] We assume that the cap binds; thus any reduction in emissions covered by the cap will be replaced by emissions from another sector or source covered by the cap. This accounts for the increase in emissions due to interaction with the GHG cap-and-trade system. [2] Assumptions regarding what is under the cap and outside the cap are made for illustrative purposes.
Source: [1] CARB.

Outside the cap, production of 1 MJ of ethanol increases GHG emissions by 75 gCO_2e, while production of 1 MJ less of gasoline decreases GHG emissions by 13 gCO_2e. As a result, substitution of ethanol for gasoline *increases* emissions outside the cap by 62 gCO_2e (that is, 75 gCO_2e - 13 gCO_2e).

Figure 7. LCFS Direct Emission Change Relative to California Aggregate Emissions

Source: California Greenhouse Gas Emission Inventory.

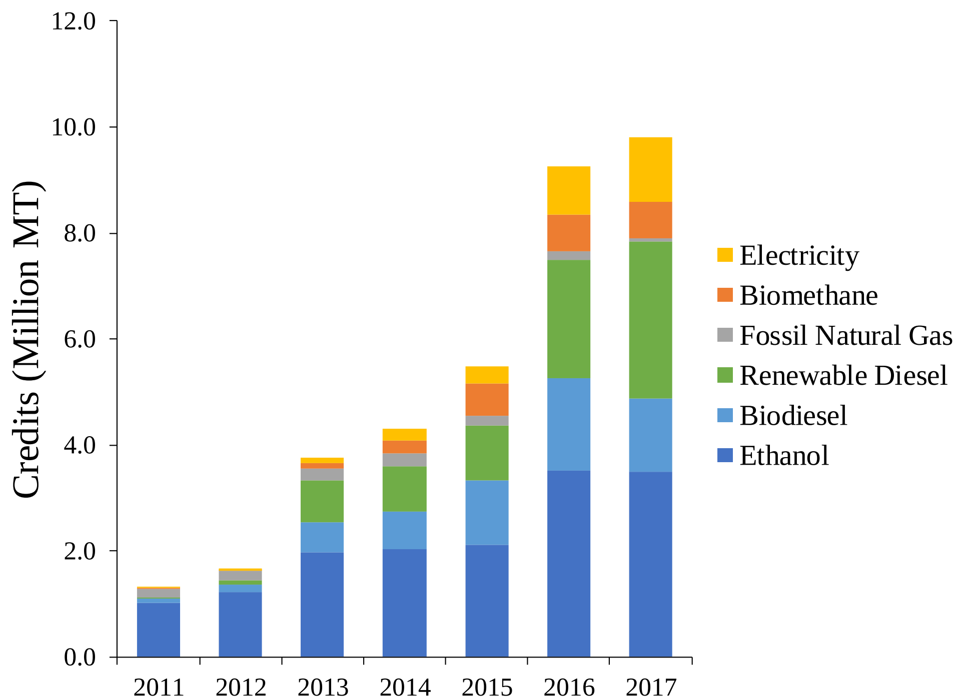
On average, fuel substitution required to comply with the LCFS has led to an increase in emissions from fuel production outside California not covered by the state's GHG cap-and-trade system. Thus, in aggregate, the LCFS has *increased* total GHG emissions. Figure 8 shows estimated changes in total GHG emissions from the LCFS over the period 2012 to 2015. Starting in 2015 when the GHG cap-and-trade system was expanded to include fuels, Figure 8 shows the actual change in emissions given the interaction between the LCFS and the GHG cap-and-trade system (the solid blue line) and the emissions reductions the LCFS would have achieved state's GHG cap-and-trade system) have increased in each

Table 2. California Overall Net Change in GHG Emissions (MTCO$_2$e)

Note: [1] For 2012-2017, the estimated change in emissions assumes a counterfactual with renewable fuel use equal to 2011 levels. For 2018 (Q1), the estimate change emissions assumes a counterfactual of one fourth of renewable fuel use from 2011. 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 th too early for private sector investment. In 2016, the budget for ARPA-E was $294 million, less than half of the LCFS's incremental cost in the same year.

Second, **compliance with the LCFS has been achieved through fuel technologies which have been commercially available prior to the LCFS, but have generally been too costly compared with alternatives without the LCFS subsidy. Figure 9 and 10** illustrate the mix of fuels used to comply with the LCFS in terms of number of credits (Figure 9) and percentage of credits (Figure 10). To date, LCFS compliance has been achieved primarily through ethanol, biodiesel, and renewable diesel, accounting for over 80% of credits each year. These fuels were commercially available prior to the LCFS. **Thus, to date, LCFS compliance has largely been achieved through the deployment of existing, rather than innovative technology.** The LCFS program has expanded the market for these fuels, potentially providing producers of these fuels or suppliers of the underlying feedstock with windfalls (economic rents).[38]

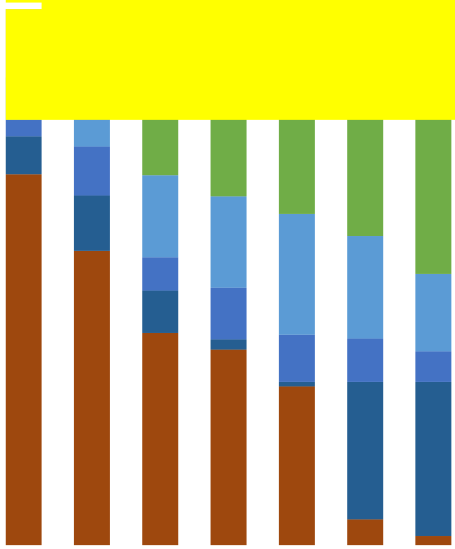
Figure 9. Mix of Fuels Used to Comply with the LCFS, MMT Credits



Source: CARB.

[38] The increase in LCFS credit prices increases the value of the underlying feedstock and means of production. In some cases, some production may be held by companies with proprietary technologies although, as we describe below, the fundamental chemical processes used in current renewable production are fairly well understood scientifically.

Figure 10. Mix of



Source: CARB.

Ethanol has been the largest source of credits since the inception of the LCFS, while biodiesel has been the third largest source of credits. Both ethanol and biodiesel have been widely produced in the United States for decades, in part due to subsidies from the Federal Renewable Fuel Standard. Ethanol use to comply with the LCFS also includes sugar cane ethanol produced in Brazil, where the sugar cane industry was well-established prior to the LCFS, having produced significant quantities of fuel for decades.

Some ethanol and biodiesel credits have also been created through "fuel shuffling," which occurs when low-carbon intensity ethanol is directed to California (because of the higher price), while high-carbon intensity ethanol is directed to other parts of the county. Fuel shuffling creates "paper" emission reductions in California without actually creating any change in the ethanol fuel stock.

The second largest source of credits is renewable diesel. Renewable diesel is a "drop in" replacement for diesel that does not require any blending. Use of renewable diesel in California has grown in recent years as credit prices have increased. But, renewable diesel was in production long before the LCFS was established. California's renewable diesel is supplied primarily by two producers, Neste (Singapore) and Diamond Green Diesel (Louisiana).[39] Neste has four plants, all of which have been operational since 2011. Thus, renewable diesel is not a novel technology.

% has 0..447c.02 0 3 % has 0..44 31.262[(403.72(% has)]T[4503.72(% has)]T[4603.72(% has)]T[47).72(% has 0..447c.02 0 8).72(

[39] Neste produces renewable diesel at facilities in Finland, Rotterdam and Singapore in facilities that were operational in 2007/2009, 2010 and 2011, respectively.

The share of credits from electric powered vehicles (EVs) has grown in each year. In 2017, EVs accounted for over 10% of credits. Electric vehicles have been growing slowly in share, and face significant technical hurdles to broad commercial acceptance (including battery life and cost, and necessary recharging infrastructure). EVs also benefit from multiple state and federal subsidies, including federal tax deductions, rebates and incentives and requirements related to EV charging stations. The extent to which the LCFS materially increases these incentives is unclear.

D. Implications for Oregon

California's experience with its LCFS has important implications for Oregon.

First, the GHG cap-and-trade system will achieve emission reductions at a lower cost than other (complementary) policies that Oregon has already adopted to address climate change and other environmental impacts. At present, credit prices for the CFP program are approximately $80 per $MTCO_2e$, which is significantly above likely GHG cap-and-trade allowance prices. At present, emission reduction costs from the RPS appear comparable (but subject to uncertainty due to limited information).[40] These costs may rise as the stringency of Oregon's CFP standard increases.

Second, Oregon should expect the adoption of a GHG cap-and-trade system will have consequences for the effectiveness of the CFP in producing incremental emission reductions. Like California's LCFS, the CFP will lead to no (or little) emission reductions, and potentially even increase emissions as has been the experience in California. As with California, actual emission outcomes will depend on the particular fuel substitutions used to comply with the CFP. However, differences between the state's programs and markets will lead to differences in emission outcomes. While nearly all of California's fossil fuel refining occurs in-state and is thus under the cap, none of Oregon's fuel is refined in-state, and so all reductions in refining emissions are outside the cap. All else equal, this will increase the emission reductions achieved by the CFP (compared to California's LCFS) because reduced gasoline and diesel consumption will reduce out-of-state refinery emissions. In addition, details of the policies, notably the carbon-intensities, differ between the states.

fuels (including biodiesel, renewable diesel and forms of CNG) of 746 Million MJ. This shift in the composition of non-traditional fuels may be the result of CFP incentives, or it may be the result of other market factors.

IV. NEXT STEPS FOR OREGON CLIMATE POLICY

As Oregon contemplates the adoption of a GHG cap-and-trade system, it has several options for its suite of climate policies. **One approach maintains all policies, as currently proposed, with a new** cap-and-trade system revenue neutral may address concerns that the policy is a new tax. Making the use of revenues transparent may also reduce political opposition.

In the interim, there are several important considerations for decisions regarding complementary policies. First, policies that meet the criteria identified above, such as addressing market-failures unrelated to the GHG emission externality or targeting emission sources outside the emission cap, will continue to provide economic, and potentially environmental, benefits. Second, complementary policies that achieve emission reductions at a lower cost than alternatives will be more economically efficient. Finally, complementary policies that include mechanisms to reduce their stringency over time may better allow carbon pricing to achieve a growing share of emission reductions. In this regard, subsidies are problematic, as they create a constituency that inevitably lobbies for their preservation.

Technical Appendix

Our analysis assesses the change in lifecycle emissions achieved by the LCFS. In particular, for fuels covered by both the LCFS and GHG cap-and-t1(g g1)cle emi

- Production of electricity used to power electric vehicles is covered entirely by the GHG cap-and-trade system, consistent with the program design.
- Production of remaining fuels (bio-CNG, bio-LNG, fossil CNG, fossil LNG, and hydrogen) occur within California.

The lifecycle emissions change (in grams of CO_2e per MJ) implied by the model are captured in the table below:

California Change in GHG (gCO_2e/MJ)

	LCFS Without Cap-And-Trade - No Leakage				LCFS With Cap-and-Trade - Leakage			
	2011	2012	2013	2014	2015	2016	2017	2018 (Q1)
Bio-CNG	-	-	-81	-76	-8	-8	-8	-8
Bio-LNG	-78	-78	-72	-59	-8	-8	-8	-8
Fossil CNG	-27	-27	-27	-26	-8	-8	-8	-8
Fossil LNG	-19	-19	-19	-19	-8	-8	-8	-8
Hydrogen	-	-	-	-	-8	-8	-8	-8
Electricity - Onroad	-57	-57	-69	-69	-8	-8	-8	-8
Electricity - Offroad	-	-	-	-	-	-8	-8	-8
Ethanol <65	-41	-48	-41	-40	45	44	39	43
Ethanol 65-75	-30	-30	-30	-28	51	53	53	53
Ethanol >75	-12	-13	-16	-16	64	60	59	59
Biodiesel	-61	-67	-78	-85	5	1	10	9
Renewable Diesel	-81	-72	-57	-63	41	27	22	21

Source: [1] Carbon intensities are calculated based on fuel volumes and credits from ARB LCFS Quarterly Data spreadsheet as of 7/3/2018.

Annual Direct Emission Reductions and Incremental Costs, California's LCFS

Year	Observed Emission Reductions (MT) [A]	Average Credit Price ($ / MT) [B]	Estimated Incremental Cost of Reducing Emissions [C] = ([A] * [B]) / 2
2013	1,683,674	50.5	$42,512,760
2014	2,105,268	36.1	$37,982,546
2015	3,225,935	45.9	$74,062,084
2016	5,969,891	103.0	$307,548,894
2017	6,723,286	87.9	$295,544,445
2018Q1	1,749,576	124.7	$109,056,884

Note: We distinguish in our calculations between expenditures by reducing entities and economic cost of emission reductions. Expenditures associated with emission reductions are simply (annual emission reductions [MT]) × (average annual credit price [$/MT]), where the average annual credit price represents the average of the 12 monthly CARB reported average credit prices. Costs of emission reductions can be represented by the area under an emissions reduction supply curve between the origin and market clearing price, here represented by the average annual price. If we make the simplifying assumption of a linear supply curve, costs will equal half of the expenditures, since the area of a triangle is one half the area of a rectangle with same base and height.

Source: CARB.