Implications of the Low Carbon Fuel Standard for State and National Ethanol Use

James Kaufman

Wyatt Thompson

and

Seth Meyer

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The Department of Agricultural Economics is a part of the Division of Applied Social Sciences of the
College of Agriculture, Food and Natural Resources at the University of Missouri-Columbia
200 Mumford Hall, Columbia, MO 65211 USA
Phone: 573-882-3545 • Fax: 573-882-3958 • http://dass.missouri.edu/agecon

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Highlights

The following is a partial analysis of the Low Carbon Fuel Standard (LCFS) setting out carbon emission reduction targets for California. We use emission estimates of the California Air Resources Board (CARB) in a two-step analysis that (1) sets out various fuel mixes that could satisfy the LCFS targets based on fixed fuel costs and (2) test the implications of these fuel mixes for national markets relative to existing national mandates. We explore the implications if the LCFS is applied in California alone or if it is adopted more widely.

This analysis does not consider all the possible questions and does not tally up all the implementation costs, including distributional effects. Our focus is on the implications of the LCFS given the CARB estimates of emissions for fuel mixes, more specifically on ethanol, and on national biofuel and agricultural markets. We do not provide competing estimates of fuel emissions or define the full benefits and costs on consumers and taxpayers in states that adopt the LCFS or in states that do not.

Critical assumptions, apart from using CARB emission estimates, are as follows. We assume that national biofuel policies continue into the near term future, of which the most relevant are the biofuel use mandates defined by the Renewable Fuel Standard (RFS) as defined by the Energy Independence and Security Act (EISA) of 2007. Cellulosic biofuel expansion is a matter of assumption in this analysis, so we do not estimate the exact costs required to produce these cellulosic biofuel volumes. In the base case, we assume that the cellulosic mandate of the RFS is waived and a lower level is used. We assume a particular path for petroleum prices that implies that national mandates are mostly binding in the near-term future.

Key findings regarding the fuel mix in states that adopt the LCFS are as follows.

- Consumption will shift to fuels with lower carbon intensity that are (at least currently) understood to often be associated with higher costs in order to meet the targets.
- The LCFS will tend to cause lower total fuel consumption by increasing overall fuel costs.
- The fuel mix to meet the target is likely to include sugar-based ethanol imports from Brazil.
- The indirect land use change (ILUC) estimated by CARB has a major role in the impact of the LCFS.
- If adopted by California alone, the LCFS can be met with a combination of alternative vehicles, less fuel use, more imported ethanol, and the majority of cellulosic ethanol likely to be available nationally.
- A larger multistate LCFS tests the limits of feasibility if the vehicle fleets in adopting states cannot change quickly or if sufficient volumes of low-emission cellulosic biofuels cannot be found.

Our findings regarding the effects of the LCFS on national biofuel and agricultural markets follow.

- The national RFS likely spans the LCFS if it is adopted by California alone. California rules are unlikely to add additional requirements beyond those necessary to meet national mandates.
- Widespread adoption of the LCFS is likely at some point to affect the national fuel mix. Results suggest more imports of sugar-based ethanol or more cellulosic ethanol than we assume is produced under the waived national mandate.
- Results depend on whether or not supplies of these fuels can expand and at what costs. We assume Brazilian ethanol imports can expand substantially. We ignore the potential that greater cellulosic biofuel could compete with other agricultural commodities for land or other inputs.
- The LCFS could have large distributional impacts by shifting much of the burden of meeting certain parts of the RFS to states that adopt the LCFS.

Background

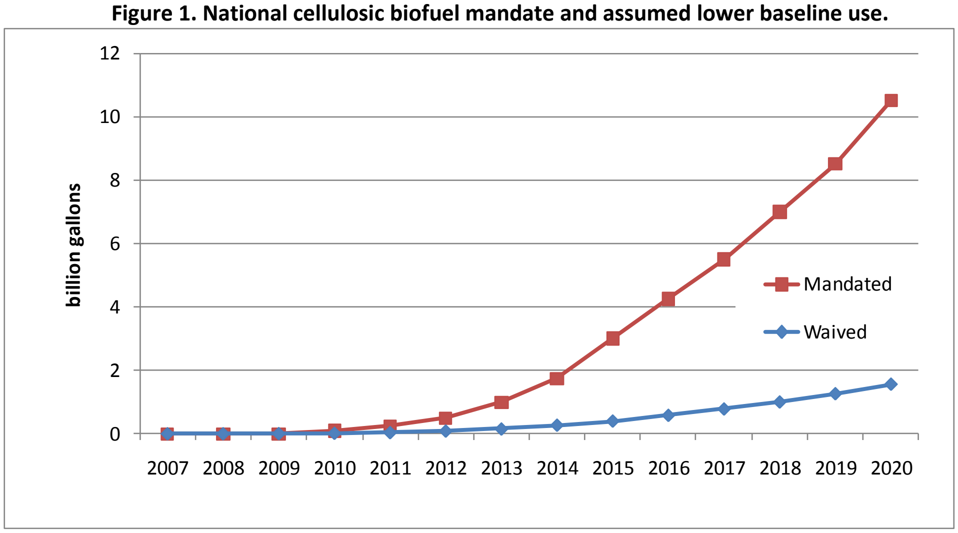
This is a partial analysis of the Low Carbon Fuel Standard (LCFS) of the California Air Resources Board (CARB). This partial analysis is supported by the National Corn Growers Association, but the work is the authors' own and we are responsible for any errors.

The LCFS is intended to reduce greenhouse gas (GHG) emissions caused by vehicle use in that state. In its preliminary rule-making, the CARB set out their estimates of GHG emissions for different fuels that must be used alongside alternative vehicles, such as electric cars, to achieve the targeted GHG emission reduction. This policy is not expected to exist in isolation. Nationwide, fuel blenders will also be required to meet the mandated levels of biofuel use defined by the Renewable Fuel Standard (RFS) of the Energy Independence and Security Act (EISA) of 2007.

The focus of this paper is two-fold. First, the CARB rates of GHG emissions are used to trace out different scenarios of ethanol use in fuel mixes that could achieve the targeted reduction. This part of the analysis also goes further by investigating the consequences if the LCFS is adopted by other states. Second, the ethanol use implied by these scenarios is compared to national ethanol use under the RFS. In some scenarios, the LCFS could imply more ethanol use or trade, leading to effects on agricultural markets.

The partial study omits certain questions or considerations. We do not take full account of the costs of meeting the LCFS. We do not tally up transportation costs of redistributing fuels available nationally which may occur in order to meet the LCFS, nor any additional transaction costs necessary to prove that both LCFS and RFS are met. We do not take full account of the competing effects of higher costs for car drivers in California and other states that adopt the LCFS versus the possibly lower costs to car drivers elsewhere. We do not assess the impacts of more biofuel use on energy prices. In some cases these omitted cost could be significant for adopting states.

Figure 1. National cellulosic biofuel mandate and assumed lower baseline use.



Our analysis is based on a certain understanding of biofuel policies and markets. Biofuel markets have been characterized by large structural changes as production and use rose rapidly. Potential further changes are likely as new biofuels are introduced and increasing numbers of consumers choose to adopt them. There is uncertainty about national biofuel policies because the regulations to implement the mandates outlined in the EISA of 2007 are not yet final. What is clear in the legislation is that the mandates can be waived, and in the analysis that follows we assume the mandate relating to national use of cellulosic mandate will be waived and a lower level used (Figure 1). The cellulosic biofuel production potential is unknown in terms of its costs and its effects on agricultural markets particularly through competition for inputs such as land. We omit these potential effects, but we do represent the impacts of changing cellulosic ethanol use on US biofuel markets.

This partial analysis gives an objective view of some of the costs of the LCFS and how the LCFS could affect national markets under certain conditions. We do not study all the effects of the LCFS nor do we make any comparison of these effects to societal goals; we take no position on the LCFS itself.

State Level Policies

As the most populous state in the US, California is an important component of the national fuel market. In 2008 California used over 15 billion gallons of reformulated gasoline according to DOT[1]. California recently mandated a 10% ethanol blend to facilitate its low carbon fuel standard suggesting that Californians could consume in excess of 1.5 billion gallons of ethanol per year.

In order to reduce further its environmental impact California is considering the implementation of policy to limit the greenhouse gas emissions of all motor fuel used in the state. This policy, commonly referred to as the LCFS, sets a schedule for emission reductions (Table 1). The first two years (starting in 2011) only require a 0.25% annual reduction which grows to .5% in the following two years, again increasing to a 1%, then 1.5%. By 2020 the LCFS calls for a 10% reduction in GHGs associated with motor fuel.

Table 1. California GHG emission reduction schedule[2].

Year	% Reduction	Gasoline: Carbon Intensity (gCO2e/MJ)
Baseline		*95.85*
2011	0.25%	95.61
2012	0.50%	95.37
2013	1.00%	94.89
2014	1.50%	94.41
2015	2.50%	93.45
2016	3.50%	92.5
2017	5.00%	91.06
2018	6.50%	89.62
2019	8.00%	88.18
2020	10.00%	86.27

Based on prevailing prices and availability, the Californian motor fuel industry must select a mix of fuels that will meet the LCFS based on their unique carbon intensities (CI). CARB finds that gasoline

[1] Federal Highway Administration, U.S. Department of Transportation. "Monthly Motor Fuel Reported By States" http://www.fhwa.dot.gov/ohim/mmfr/jan09/index.cfm

[2] CARB, "Proposed Regulation to Implement the Low Carbon Fuel Standard" March 5, 2009. http://www.arb.ca.gov/fuels/lcfs/lcfs.htm

emits 95.86 gCO2e/MJ which becomes the benchmark value from which reductions are calculated (Table 2). CARB analysis finds that conventional corn-based ethanol produced in the Midwest, that is most often used in California at present, emits 69.4 gCO2e/MJ on average for a -28% reduction relative to the neat gasoline benchmark. If all fuel sold in California were blended at a 10% ethanol level (as in E10), at this CI, fuel emissions would be reduced by 2.76% allowing California to comply with the CARB schedule through 2015. However, CARB further includes indirect land use changes (ILUC) into California's calculation of ethanol's carbon intensity, raising the value to 99.4 gCO2/MJ on average, or 4% above that of conventional gasoline. Motor fuel blenders would look to different fuels in order to meet the LCFS targets if Midwestern ethanol did not have lower emissions than gasoline.

Table 2. California CARB fuel emissions[2].

`	CA-GREET *(gCO2e/MJ)*	ILUC *(gCO2e/MJ)*	Total *(gCO2e/MJ)*	Change from Neat Gasoline
Neat gasoline	**95.86**		**95.86**	**0%**
Ethanol Blends				
Gasoline 10% etoh (80% midwest avg, 20% CA wet)			95.85	-0.01%
Gasoline 10% ethanol (100% midwest avg)			96.09	0.20%
Gasoline 10% ethanol (Brazilian sugar)			93.61	-2.30%
Corn Ethanol				
Midwest average: 80% dry, 20% wet, dry DDGS	69.4	30	99.4	4%
Midwest Dry Mill, Dry DDGS	68.4	30	98.4	3%
Midwest Dry Mill, Wet DDGS	60.1	30	90.1	-6%
Midwest Wet Mill	75.1	30	105.1	10%
CA Dry Mill Dry DDGS	58.9	30	88.9	-7%
CA Dry Mill Wet DDGS	50.7	30	80.7	-16%
Advanced Biofuel Ethanol				
Brazilian Sugar Cane	27.4	46	73.4	-23%
Cellulosic from Poplars	2.4	18	20.4	-79%

The inclusion of ILUC might not preclude the use of corn ethanol in California altogether. Corn ethanol can be produced in a number of pathways yielding unique CIs. Under a system where the CI of a fuel is valued and a system for accounting for those differences (i.e. RINs defined below) is in place, it is likely that fuels will be sold in a way that captures their different values. For example, CARB assumes ethanol made in Midwestern drymills that sell wet distillers dried grains with solubles (DDGS) yield an ethanol with a CI of 90.1 (gCO2e/MJ) which may be a plentiful and viable fuel for complying with the LCFS, particularly in the early years. Further, the CARB has found that producing ethanol in California can lead to lower emissions, most notably where DDGS are sold wet, resulting in a CI of 80.7. At a 10% blend this fuel would reduce emissions by 1.6%.

Ethanol can also come from sources other than corn. The CI associated with Brazilian ethanol made from sugar cane could lower emissions by almost 2.5% as E10. Cellulosic ethanol may offer further reductions although its full scale viability and cost has not yet been demonstrated. CARB anticipates that cellulosics (made from poplars here) could reduce carbon emissions by as much as 79%, or 8% as E10. Alternative energy sources for vehicles such as electricity and hydrogen may also play an important role in meeting the LCFS requirements.

State Markets Effects

The California LCFS sets a minimum target for carbon emissions and lets the market decide what portfolio of fuels to use to satisfy that limit. While this provides flexibility it also makes anticipating the market impacts of the policy more complicated. As such, we explore several scenarios to test the feasibility of various fuel mixes that could meet the LCFS targets.

Scenarios of the state fuel market were generated to be an optimal mix of fuels to meet exactly the regulated LCFS at a minimum of cost. Fuel prices are held constant over the duration of the scenarios.[3] These fuel price relationships, while based on general expectations, are used to order the fuel choice and not represent actual price forecasts. This ordering generally results in low cost high carbon intensity fuels being selected in early years, and high cost low carbon intensity fuels are consumed when the emission reduction target is more stringent. The following table (Table 3) shows the difference in CI and cost of the various fuels as compared to neat gasoline.

Table 3. Key fuels and assumed price differences from neat gasoline.

	Change in CI (gCO2e/MJ)	Change in Cost ($/gal)[4]
Midwest Dry Mill, Dry DDGS	2.54	0.175
Midwest Dry Mill, Wet DDGS	-5.76	0.20
Midwest Wet Mill	9.24	0.175
CA Dry Mill Dry DDGS	-6.96	0.21
CA Dry Mill Wet DDGS	-15.16	0.21
Brazilian Sugar Cane	-22.46	0.40
Cellulosic (Poplars)	-75.46	2.15
Electricity	-60.96	1.00
Hydrogen	-62.77	1.00
Advanced Renewable ethanol (Forest waste)	-73.66	2.15

We also make certain assumptions about the volume of fuels consumed based on capacity growth constraints (Table 4). The growth path of Californian ethanol production capacity takes into consideration the time and resource constraints needed to build new capacity. Likewise, E85 growth is similarly constrained to reflect adoption of flexible fuel vehicles. These assumptions disallow certain mixes of fuels that could meet the LCFS in the absence of restrictions. For example, widespread use of E85 with imported ethanol may meet a LCFS target mathematically, but was judged to be out of the realm of likely outcomes and disallowed. In principle, such limits to vehicle type and fuel use are sensitive to many factors, but we assume that there is limited flexibility. Fuel demand is based on a study from the California Energy Commission[5] forecasting on-road gasoline demand with and without CARB policy to reduce GHG emissions.

[3] Constant fuel prices used here risk some contradiction with the results of national market analysis below in those cases that the LCFS leads to greater use of a fuel at a national level and its price is bid higher.

[4] Cost differences are based on the presumed cost of producing and adopting the particular fuel. Production costs, obtained from available literature are the basis of these costs. However, production costs must also be adjusted for supply conditions, subsidizations, taxes, necessary infrastructural investments and value to the end user. For example, hydrogen and electric fuels may be inexpensive to produce but requires additional investment in infrastructure and some degree of sacrifice on the part of the end user during this 10 year period.

[5] California Energy Commission (Sept 2007) "Transportation Energy Forecasts for the 2007 Integrated Energy Policy Report" http://www.energy.ca.gov/2007publications/CEC-600-2007-009/CEC-600-2007-009-SF.PDF

Table 4. Californian fuel market assumptions.

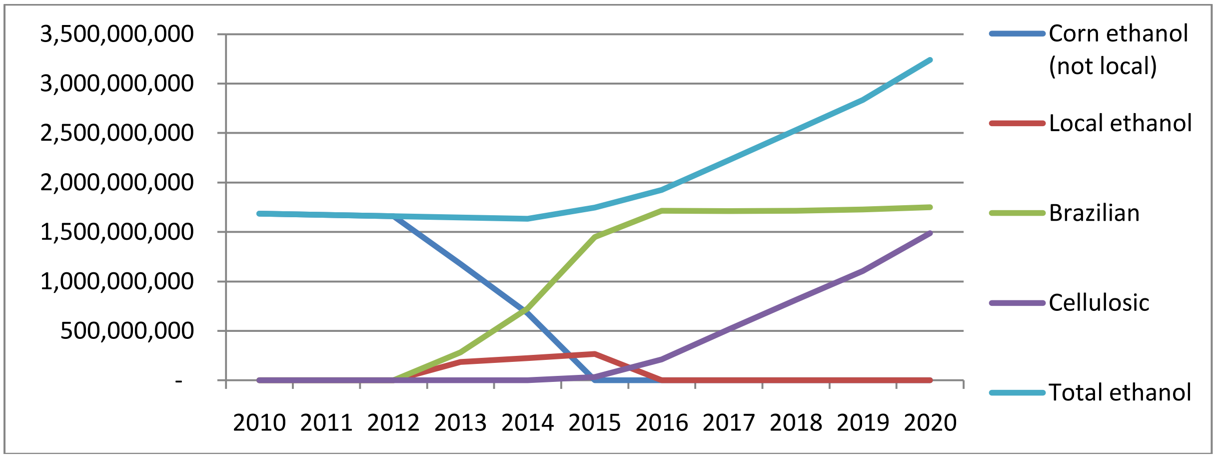
	Maximum E85 allowed[6]	CA ethanol production capacity (gal)	CA fuel demand (gal)
2010	0.10%	65,000,000	16,840,000,000
2011	1.30%	105,000,000	16,709,000,000
2012	2.60%	145,000,000	16,578,000,000
2013	3.90%	185,000,000	16,447,000,000
2014	5.20%	225,000,000	16,316,000,000
2015	6.50%	265,000,000	16,185,000,000
2016	7.80%	305,000,000	16,054,000,000
2017	9.10%	345,000,000	15,923,000,000
2018	10.40%	385,000,000	15,792,000,000
2019	11.70%	425,000,000	15,661,000,000
2020	13.00%	465,000,000	15,530,000,000

Given these assumptions Figure 2 shows the primary scenario where the amount of cellulosic ethanol available to California is limited to the lower (waived) path (in Figure 1) and alternative vehicles are not considered. In this scenario, within the first 3 years California gets all of its LCF blendstock as conventional corn ethanol. Initially, the predominant value of this fuel is to meet the 10% blend mandate but is quickly needed to satisfy the LCFS. By the 4th year the CI of conventional ethanol becomes insufficient to meet the LCFS and lower CI fuels are needed. The first fuels to be chosen are imported Brazilian ethanol and ethanol produced in-state. Since imported Brazilian ethanol has a significantly lower CI (than conventional and local ethanol) it is the primary replacement for conventional ethanol as the LCFS tightens. By year 2015 conventional corn ethanol is no longer used and by 2016 locally produced ethanol is abandoned despite its relatively low cost.[7] During this period cellulosic ethanol comes into use, despite its higher cost, as it has the lowest CI. As cellulosics enter the market, Brazilian ethanol growth is curtailed, with the volume staying at a constant 1.7bgy. In the last two years of the scenario, cellulosic fuels in California begin to track closely the waived national level of cellulosic ethanol, implying that California uses most of the cellulosic ethanol available in the U.S.

[6] Based on an average inclusion rate used in the compliance scenarios of CARB "Proposed Regulation to Implement the LCFS".

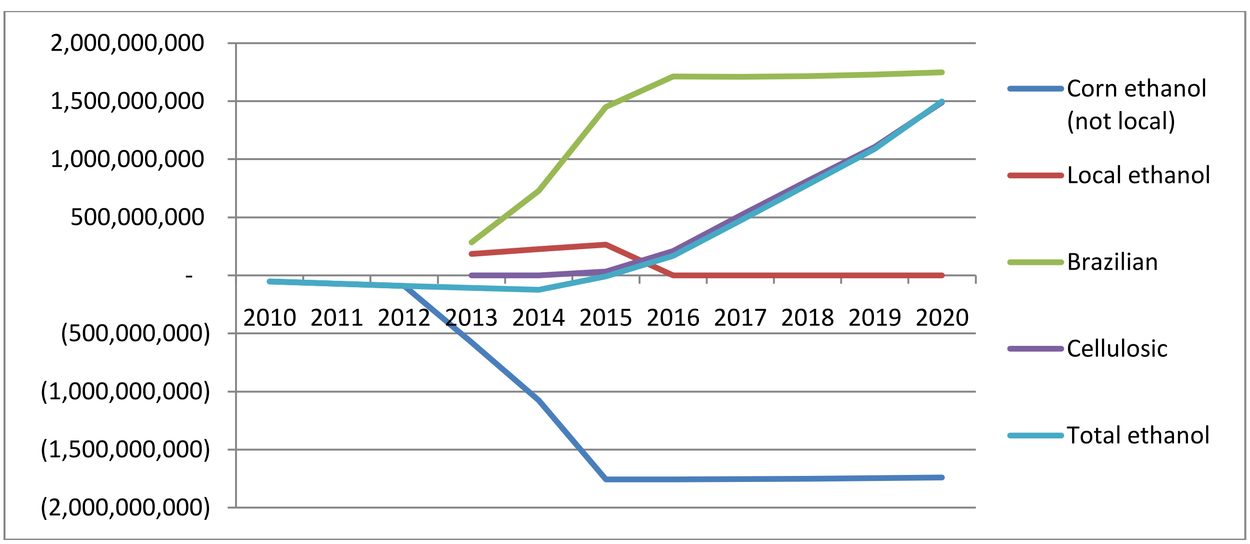
[7] By largely disregarding the risk associated with large capital investments, the constant prices used in this study likely over-estimate the willingness of California ethanol facilities both to enter and exit the market. Regardless, the relatively short optimal production period might suggest that significant market risk awaits California corn ethanol producers considering investments.

Figure 2. Primary CA LCFS fuel consumption scenario (gal)



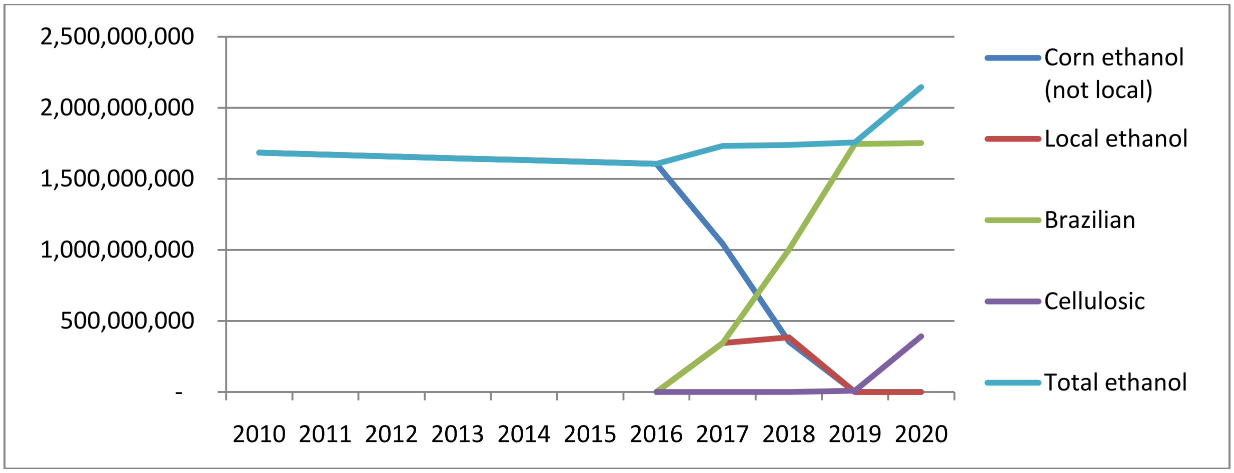
This first LCFS scenario clearly differs from the status quo. Figure 3 compares this case to a baseline fuel consumption forecast**Error! Bookmark not defined.** where a 10% conventional ethanol blend is in wide use but there is no LCFS. Total fuel consumption is lower under the LCFS, presumably due to higher fuel prices and in early years this equates to slightly lower ethanol consumption. However, as the LCFS tightens ethanol consumption rises significantly – by as much as 1.5bg in 2020. This increase in fuel consumption above the 10% blend level is facilitated by an increasing number of flexible fuel vehicles that can utilize E85 up to the limit show in Table 4. Much of this additional consumption comes from cellulosic and imported Brazilian ethanol which grows by as much as 1.5bg and 1.75bg in 2020, respectively. In comparison, low cost corn ethanol from the Midwest, which is assumed to supply the status quo E10 blend, falls by as much as 1.7bgy in between 2015-2020.

Figure 3. Net effects of baseline LCFS on CA ethanol consumption as compared to the status quo (gal)



Considerable debate has emerged on what constitutes an accurate value for a fuel's relative CI to gasoline. Nowhere has the debate been as heated as on the issue of indirect land use changes (ILUC).[8] As such it is instructive to consider a scenario of the California LCFS where land use changes are not included in the calculation of ethanol CI (Figure 4).

Figure 4. LCFS scenario where indirect land use change (ILUC) is not considered (gal)

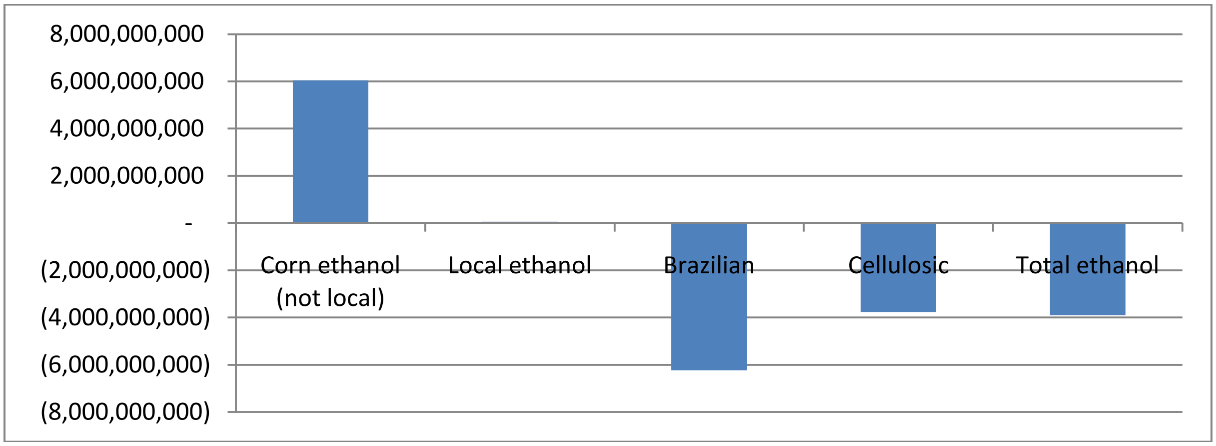


In the initial years there is little difference from the status quo without a LCFS. Conventional ethanol sources are able to meet the LCFS to 2016 and remain at a 10% blend. At this point however, corn ethanol is rapidly replaced by Brazilian ethanol. Without its relatively high ILUC value, Brazilian ethanol is able to cover the LCFS to 2019 when the lower CI cellulosic fuels are needed. This scenario has a very moderate impact on total ethanol consumption as compared to the status quo staying near a 10% blend through 2019.

The differences between LCFSs that do and do not include ILUC show more marked differences. Over the course of the 10 year period from 2010 to 2020, not including ILUC in the calculation of fuel carbon intensity would result in 6 billion more gallons of domestic ethanol being utilized in CA and 6 billion fewer gallons of Brazilian ethanol being imported (Figure 5). Nearly 4 billion gallons less cellulosic fuel would be required, leading to a total reduction of 4 billion gallons in the volume of ethanol needed to meet the LCFS.

[8] At issue is the indirect effect of greater biofuel output on land use caused by price interactions in national or international markets.

Figure 5. Total 10 year change from baseline by not including ILUC (gal)



There are a number of other situations that could arise to complicate the above comparison. For example, Brazilian ethanol supply to California may be limited, leading to a higher price. In this case, California might have a difficult time meeting the LCFS. Given the lower (waived) ethanol production path, there could be inadequate cellulosic ethanol to meet the LCFS past 2016. Either a significant addition of cellulosic fuel would be needed or another source of fuel would need to be made available, such as alternative vehicles.

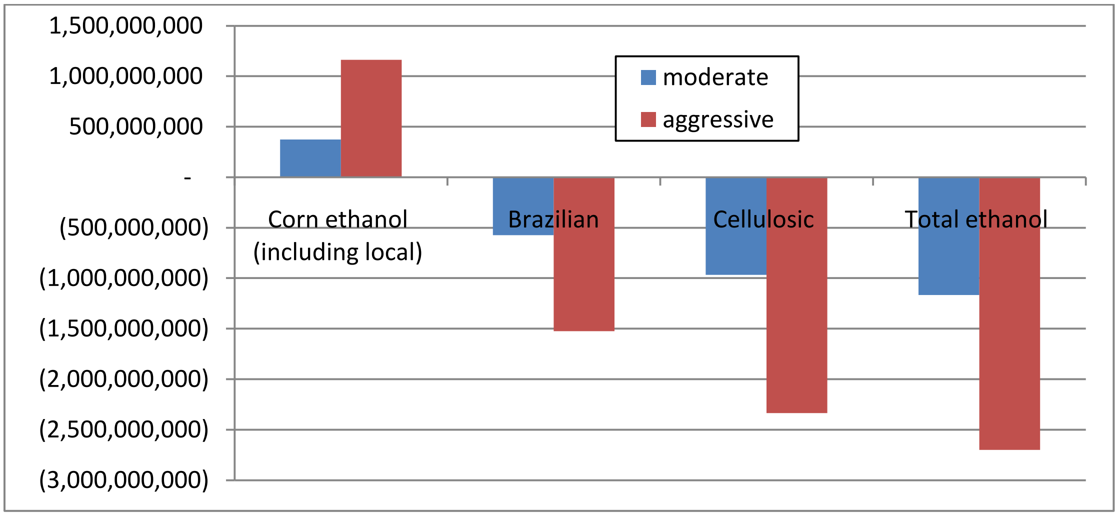
Alternative vehicles could play an important role meeting LCFS depending on the level of adoption (Table 5). Alternative vehicles effectively serve to lower the CI requirement of gasoline blends. This allows higher CI fuels, like conventional ethanol, to be used at a higher rate and for a longer amount of time and a significant drop in the total ethanol demand, often coming from the most costly sources – cellulosics. In so doing it also has the effect of reducing demand for E85.

As shown in Figure 6, over the entire 10 year period this could lead to an increase of between 400 and 1200 million gallons of conventional ethanol used. It could also reduce the use of Brazilian ethanol by between 500 and 1500 million gallons and displace between 1 and 2.3 billion gallons of cellulosics.

Table 5. Considered Alternative Vehicle Adoption Paths

	Moderate Alternative Vehicle Use	Aggressive Alternative Vehicle Use
2010	0.01%	0.01%
2011	0.02%	0.04%
2012	0.10%	0.14%
2013	0.21%	0.26%
2014	0.32%	0.48%
2015	0.54%	1.11%
2016	0.75%	1.74%
2017	1.01%	2.48%
2018	1.38%	3.28%
2019	1.83%	4.58%
2020	2.22%	5.96%

Figure 6. Comparison of Alternative Vehicle Use to Baseline LCFS Scenario: 20 Year Summary (gal)



Key points – California LCFS

The above discussion suggests a few key points.

1) The implementation of the LCFS, as it is currently understood, will likely increase ethanol demand in California gradually over the next 20 years. Very little of this ethanol, especially after 2012, will come from current sources, but instead will require large volumes of lower CI sources.
    a. A key uncertainty is fuel availability. California must be able to access sufficient amounts of low CI fuel. This could mean initially, choosing low CI ethanol (e.g. ethanol from Midwestern drymills that sell wet DDGS) but later will mean finding plentiful sources of lower CI fuels such as cellulosics which are not yet available in such quantities.
        i. To exemplify the dependence on cellulosic and Brazilian biofuels it is instructive to consider a scenario where one is withheld and alternative vehicles are not expanded. Assuming that cellulosic ethanol is held to the lower base level (ending with 1.6 billion gallons in 2020) and no Brazilian ethanol available, California would cease to be able to meet its LCFS after 2016.
2) Alternative vehicles can lower the demand for these fuels but only up to a point, barring much more rapid expansion than seems likely at present. Total ethanol demand in 2020 could be reduced by as much as 10% in a moderate case (of 2.2% alternative vehicle adoption in 2020) and 27% in an aggressive case (of 6% adoption in 2020).
3) If ILUC was not factored into the calculation of the carbon intensity of ethanol, the LCFS would vary only moderately from the current status quo, until 2016, when lower CI fuels would need to come into play, but at lower volumes as compared to the case of the LCFS with indirect land use change calculations as estimated by the CARB.

Northeast and Mid-Atlantic Consortium

Although California is furthest along in its efforts to implement a LCFS it is not alone. For example, eleven Northeast/Mid-Atlantic States have signed a letter of intent to begin the process of instituting a LCFS Program.[9] A number of other states have also shown varying levels of commitment to adopting a

[9] see http://www.mass.gov/Eoeea/docs/pr_lcfs_attach.pdf

LCFS, including Minnesota, Wisconsin, Illinois and Michigan. While California accounts for 11% of national fuel consumption adding Northeast and Mid-Atlantic States could raise the share under a LCFS program to almost 30%[1]. If such a significant volume of fuel were fall under a policy that is analogous to the California's LCFS, then fuel blenders in those states, too, would scour their sources to get the right mix to meet their targets.

In order to determine the impacts of a broader state-level initiative we apply the same assumptions used in the California to the increased level of fuel consumption of that state plus the 11 Northeast and Mid-Atlantic states. For these scenarios we assume the same LCFS standards, E85 limits and implementation as California. Further, we assume the fuels have a similar CI value and cost spread.

It is instructive to first consider a scenario analogous to that of the primary California scenario. Figure 7 shows that, as with California, in 2012 conventional ethanol is no longer able to supply an adequate CI to meet the LCFS. At this point Brazilian ethanol begins to increase in volume. After 2015 cellulosic ethanol becomes necessary to meet the LCFS but the volume needed quickly rises past total national supply at the waived level shown in Figure 1. Accordingly, under this cellulosic constraint the widely adopted LCFS would be unobtainable after 2016. The black line denotes the point at which the cellulosic assumption is relaxed, allowing the LCFS to continue to be met. Under this relaxed constraint up to 3.8 billion gallons of cellulosic ethanol would be utilized in 2020 –approximately 35% of the total RFS mandate. Brazilian ethanol, on the other hand, would stay stable from its 2015 level of approximately 4.2 billion gallons.

Figure 7. Primary scenario of multi-state LCFS fuel consumption (gal)

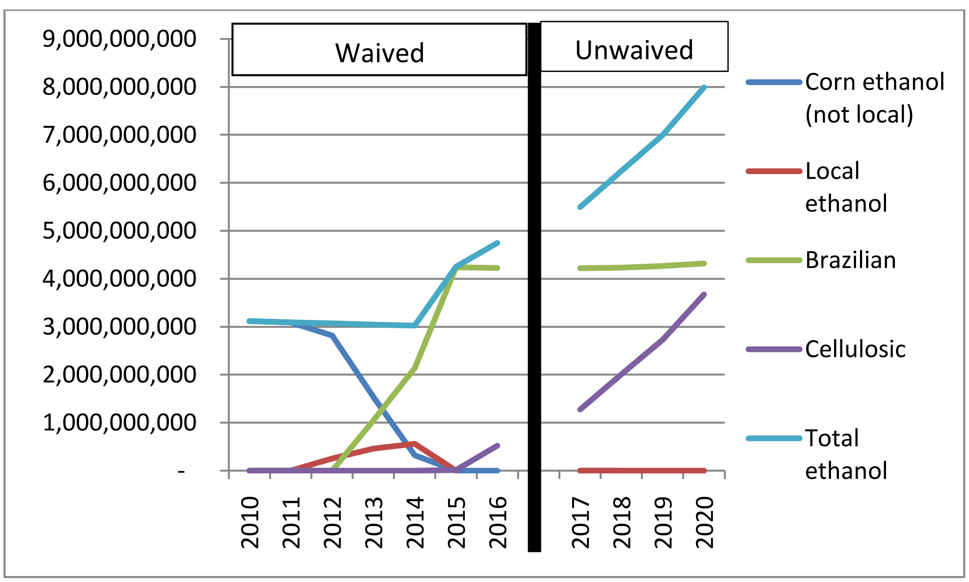
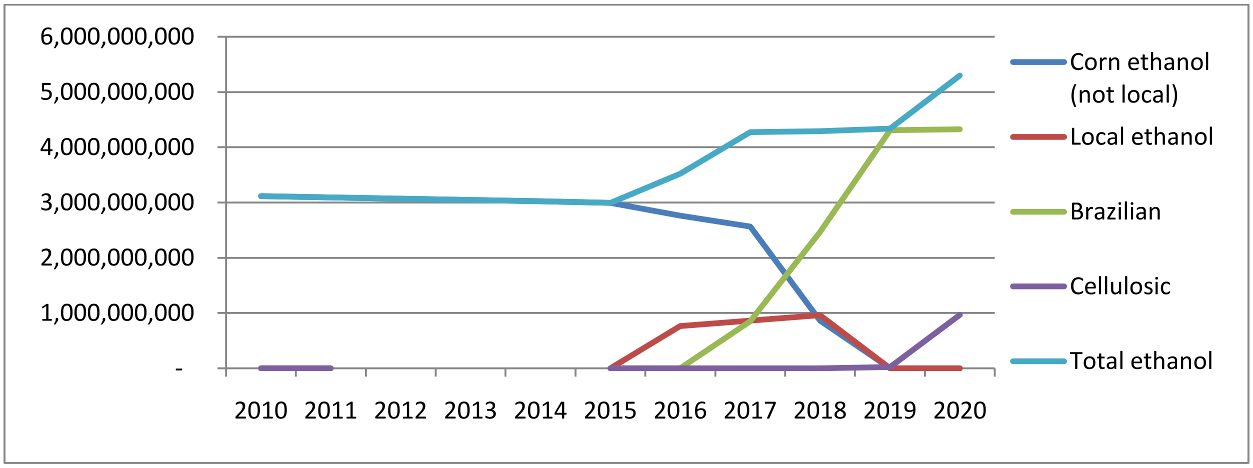


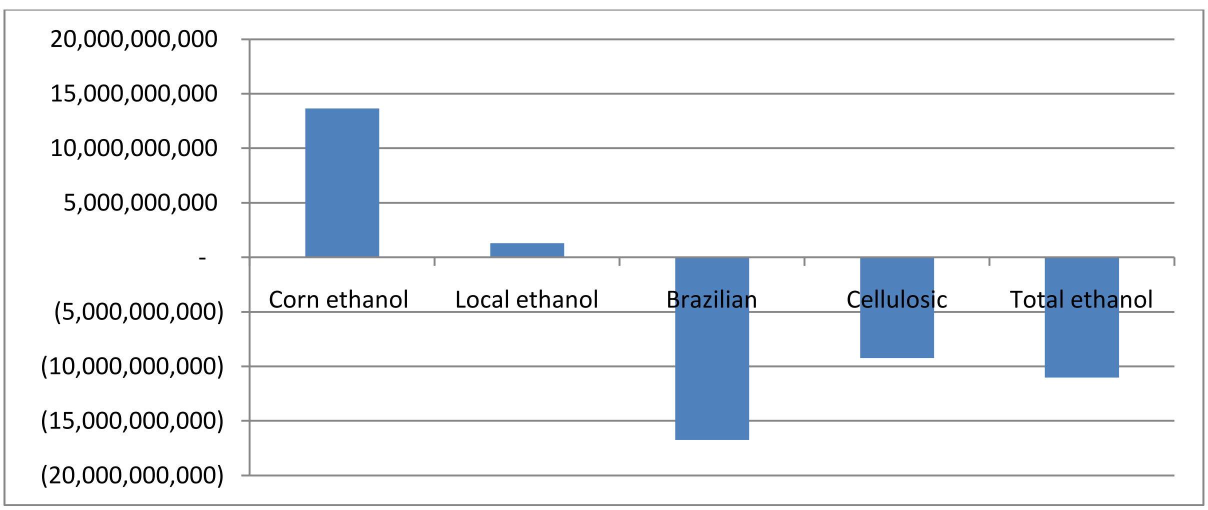
Figure 8 shows that without ILUC in the calculation of CI of ethanol the multistate group is able to meet the LCFS with comparative ease. Conventional corn-based ethanol can be used exclusively through 2015 and the addition of locally produced ethanol is adequate to meet the 2016 standard. In 2016 Brazilian ethanol begins to displace rapidly corn-based ethanol. By 2019 corn-based ethanol is completely phased out from these states and instead Brazilian and cellulosic ethanol are employed.

Figure 8. No ILUC CA & Northeast/Mid-Atlantic LCFS Fuel Consumption Scenario (gal)



Comparing the scenarios with ILUC and without, we see a considerable shift in the use of ethanol (Figure 9). Over the 10-year period ethanol demand is lowered by more than 10 billion gallons. More dramatic is the shift in the ethanol feedstocks used. Corn ethanol is used for longer periods resulting in almost 14 billion more gallons being used in total. Imported Brazilian and Cellulosic ethanol both decrease, by 17 and 10 billion gallons respectively, over the 10-year period.

Figure 9. Total 10 year change in CA & Northeast/Mid-Atlantic case associated with removing ILUC from primary scenario (gal)



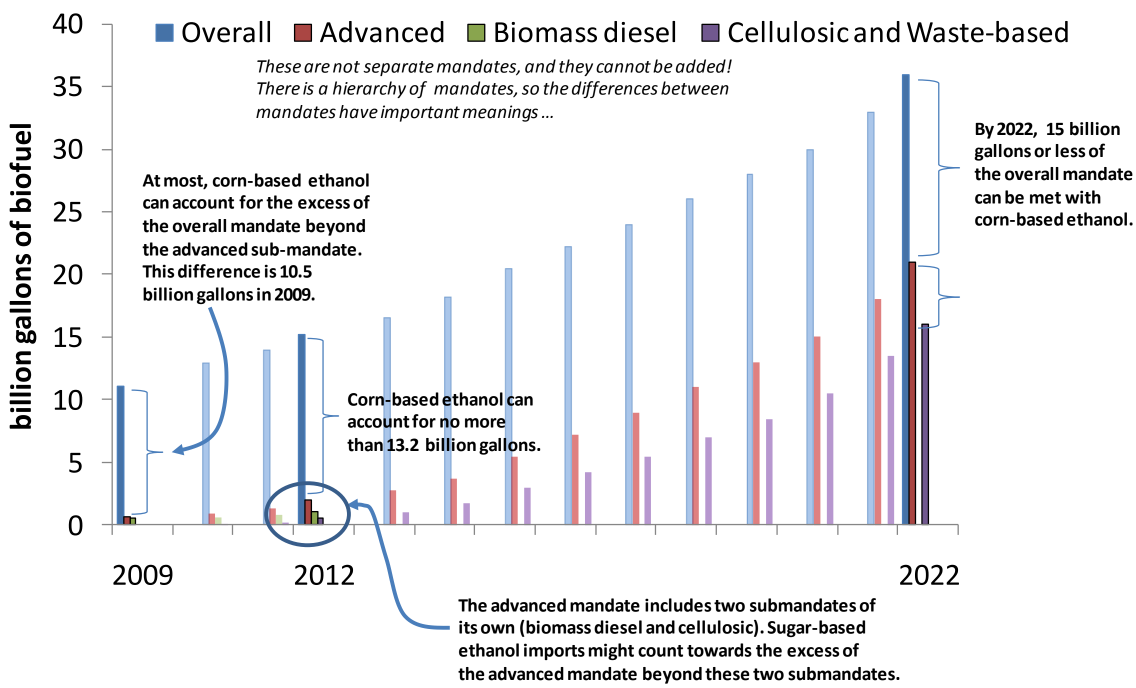
If these state level policies are evaluated in isolation of national markets the shifts in biofuel consumption would seem to represent major additional costs. The increasing use of ethanol, especially ethanol from lower CI sources, would likely raise fuel costs for the end user, presumably raising the cost of travel to a point of lower total fuel usage. However, these state policies do not operate in a vacuum and must be placed in the larger national context –a context where RFS policy is expected to be implemented. Next we consider how state and national policy interact, to better understand how impacts might be realized.

National biofuel use mandates

The national mandates are summarized here. These biofuel use mandates are relevant because they may already require levels of biofuel use sufficiently high that the LCFS is met in passing as the fuel blenders work to meet the broader national requirements.

There are four hierarchical mandates of the RFS (Figure 10). The criteria for each category relate to the eligible feedstocks and the GHG emission reductions relative to petroleum-based fuel. The overall mandate is the broadest one in scope (meaning the lowest threshold of GHG reduction) and it rises to 36 billion gallons by 2022. The advanced mandate is a subset of the overall mandate that has a higher GHG reduction threshold and expressly disallows one feedstock, namely ethanol made from corn starch. We assume that ethanol from sugar cane will count as an advanced biofuel, although final rules are not issued so we cannot be certain at this point. As a sub-mandate of the overall mandate, any biofuel that qualifies as an advanced biofuel automatically also counts against the overall mandate, but the reverse is not true in that a biofuel that meets the criteria of the overall does not automatically meet the advanced biofuel mandate criteria. The advanced biofuel mandate rises to 21 billion gallons by 2022. The difference between the overall and advanced biofuel mandates, which is the maximum volume that could be met by non-advanced biofuels, peaks at 15 billion gallons in 2015. The fact that the most common US biofuel today, ethanol from corn starch, counts against the overall mandate but not the advanced mandate has certain implications. If more advanced mandate is used than is strictly required, then less corn-based ethanol need be used in order to meet the mandate.

Figure 10. Overview of RFS (national mandates) as established by the EISA of 2007



Source: copied from Thompson, Meyer, and Westhoff, "Renewable Identification Numbers Are the Tracking Instrument and Bellwether of US Biofuel Mandates," Eurochoices 2009.

The GHG reduction associated with corn-based ethanol for purposes of RFS compliance was not certain at the time that the EISA was drafted, but Congress included a "grandfather" provision that allowed capacity that existed or was under construction at the time the EISA was signed to count towards the overall mandate. Depending on the rules to implement the EISA, the maximum volume of corn-based ethanol that could count towards the mandate is no more than 15 billion gallons but could be lower.

The advanced mandate has two sub-mandates of its own. The cellulosic and agriculture-waste based ("cellulosic") mandate has a higher GHG reduction threshold as well as certain feedstock requirements. While work is underway to identify the potential to supply cellulosic biofuels, such as from dedicated feedstocks like switchgrass or crop residues like stover, there is uncertainty about the feasibility of the cellulosic mandate which rises to 16 billion gallons by 2022. Congress recognized this uncertainty: EISA provisions to waive the mandate are most clearly expressed in the case of the cellulosic mandate and include specific instructions that would imply an upper bound on the premium paid for cellulosic biofuels in the event that the mandate is waived. We assume this sub-mandate is waived (Figure 1).

The biomass-based diesel ("biodiesel") mandate rises to 1 billion gallons in 2012, after which its level is uncertain but is assumed here to be constant. We also assume that one unit of biodiesel counts as 1.5 units of ethanol when tallying up different biofuels. This implies a lower amount of "other advanced" biofuels that meet the general advanced biofuel criteria, but do not qualify for either biodiesel or cellulosic mandates. If the conversion rate from biodiesel to ethanol were 1-to-1 instead of 1-to-1.5, then other advanced biofuels such as sugar-cane ethanol could fill a greater share of the advanced mandate and there could be more ethanol imports to meet the national mandate than we show in our analysis.

National ethanol and agricultural market effects of LCFS

The national market effects depend on (1) the interaction of the LCFS of California that other states might choose to adopt similar measures and the national mandates of the RFS and (2) the impact of any additional requirements caused by the LCFS on biofuel markets and, through them, on agricultural commodity markets.

The RFS mandates do not correspond exactly to the LCFS GHG reduction estimates of the CARB. Where the RFS sets minimum use levels for specific biofuels, CARB allows the market to decide the optimal mix of fuels. Further, fuels and associated carbon intensities do not match exactly. Here, we assume that RFS cellulosic biofuels include all applicable fuels under the LCFS (e.g. cellulosic and advanced renewable). Sugar-cane ethanol from Brazil identified in the LCFS corresponds to "other advanced" in the RFS. Almost all ethanol made from grains (not crop residues) in the US, and certainly all ethanol from corn, is assumed to count as non-advanced biofuels in the RFS regardless of the CARB calculations.

Compliance with the RFA is accomplished using a tracking system based on Renewable Identification Numbers (RINs) that are associated with biofuels used in the US. RINs are generated by the biofuel producer or importer and tracked throughout the fuel supply. Ultimately, it is the blenders' responsibility to ensure that adequate RINs are supplied to the fuel market to meet the RFS. These RINs are tradable creating a market for RINs separate (but tied) to the fuel market.

The RFS mandates are national and the RINs can be traded among states. Traders in one region (e.g. California) might use more than their share of the national mandate and then sell extra RINs to traders in another region who use less than their mandated volumes. If a state's LCFS requires that more of a particular biofuel be used than they are required to use under the RFS, then they would likely sell the extra RINs. The demand for the RINS would presumably come from blenders in other states who found buying those RINs a cheaper way to meet their own mandates than buying the actual biofuels.

Does RFS span LCFS?

If the LCFS does not imply any greater use of imported or cellulosic biofuels than the RFS, then there may be very little effect on the national market. The first step is to consider whether or not the RFS spans the LCFS based on the correspondences noted above.

Table 6. Implications of scenarios for CY 2018 national biofuel requirements relative to baseline.

Description	**Cellulosic ethanol**		**Imported ethanol**	
	(volumes in billions of gallons)			
Baseline				
Baseline levels of national cellulosic and imported (	1.00		2.59	
Scenarios of LCFS adoption	*Level in LCFS states in scenario*	*Difference from national use in baseline*	*Level in LCFS states in scenario*	*Difference from national use in baseline*
LCFS in California, base cellulosic ethanol	0.81	no increase	1.72	no increase
LCFS in California, base cellulosic ethanol, force CA to use all cellulosic available	1.00	0.00	0.81	no increase
LCFS in California, base cellulosic ethanol, alternative vehicles	0.63	no increase	1.70	no increase
LCFS widely adopted, greater cellulosic ethanol, very fast alternative vehicle expansion	0.60	no increase	4.09	1.50
LCFS in California, base cellulosic ethanol, exclude indirect land effects	0.00	no increase	1.00	no increase
LCFS widely adopted, base cellulosic ethanol, exclude indirect land effects	0.00	no increase	2.47	no increase
LCFS in California, greater cellulosic ethanol	0.81	no increase	1.72	no increase
LCFS widely adopted, greater cellulosic ethanol	2.01	1.01	4.23	1.65

The calculations of California fuel use that are consistent with the LCFS suggest that the RFS likely spans the LCFS (Table 6). Even given a lower assumption about cellulosic biofuel use, as might occur if the cellulosic RFS mandate is waived, the volumes necessary to comply with the LCFS in California may well be met. This sets aside distributional questions implied if the bulk of national cellulosic consumption takes place in a particular state, and in particular the transaction and transportation costs, but suggests nevertheless that there would be few direct effects on national markets or on agricultural commodity markets in this case.

The calculated implications for ethanol use of more widespread LCFS adoption shown above are not always spanned by the RFS. We explore the implications of three cases for national markets. First, the widely adopted LCFS is met in part by rapid expansion in the use of alternative vehicles, as well as sugar-based imports and much of the available cellulosic biofuels. Second, the LCFS is met by expanded cellulosic ethanol use, albeit without considering the source of the additional cellulosic biofuels in terms of their effects on agricultural commodity markets. And, third, we explore the case that indirect land use change (ILUC) is excluded from the CARB calculations (which are otherwise unchanged). This last case does not imply any change in 2018, but does cause some modest changes in other years.

Method

National market analysis is based on a modified version of a standard economic model of the US agricultural and biofuel markets. This model is developed and maintained at the Food and Agricultural Policy Research Institute at the University of Missouri (FAPRI-MU). It represents the behavioral and technical relationships of national markets for ethanol, biodiesel, main field crops, and key livestock products. The representation includes important biofuel and agricultural policies that are expected to affect markets at least under certain conditions, such as biofuel mandates, tax credits, and tariffs as well as key agricultural policies. The model supports analysis that looks ahead over a ten-year period, ending in 2018 (or 2018/19 marketing year for many crops).

The model is revised here in order to impose these scenarios. The key mechanism is to set cellulosic ethanol volumes and ethanol trade, particularly imports, to the level required to meet the levels required by the scenario. In cases where the state-level requirements do not imply greater use nation-wide, we assume the effects are distributional more than on prices, ignoring the potential that transportation and transaction costs would play an important part in determining national average prices. In cases where the state-level requirements do imply a greater use of cellulosic or sugar-based ethanol than national mandates imply, then we impose these higher levels and simulate the model to see how national biofuel and agricultural commodity markets react. The changes in ethanol imports costs in these scenarios are assumed to be passed on to motor fuel consumers.

The results of each scenario are compared to a baseline case.[10] Results are expressed as the changes (in quantities, prices) from the baseline caused by the policy. The baseline is roughly similar to the January 2009 FAPRI baseline.[11] A few facts about the baseline used for this analysis are useful to establish the context of policy analysis. For example, the cellulosic mandate is assumed to be waived so a lower amount is used (Figure 1). Whereas the mandate rises to seven billion gallons by 2018, the waived level assumed here is one billion gallons in that year.

The petroleum price is another important assumption. If the petroleum price is very high, then consumers might, over time, opt to buy additional biofuels, to the point that the national or state mandates are not binding at all. If the petroleum price is very low, then cheap gasoline might limit consumers' willingness to use substitute biofuels and policies may determine use. This oversimplifies the consumer problem – both in reality and as represented in the model. Biofuels are chosen for a variety of reasons, including: as an additive if required to change fuel properties and ethanol might be mixed in automatically, if a state mandate requires ethanol, when it is a cheaper fuel source, or because consumers buy biofuels with a view to achieve other purposes (such as car performance, energy

[10] We do not iterate between models to ensure that they are completely consistent. We do not take final national model results for fuel prices and uses back to state models.

[11] Apart from the changes listed below, another difference is endogenous RIN rollover. We expect fuel blenders to use a likely rollover provision allowing up to 20% of one year's mandate to be met by RINs carried over from the previous year as a sort of RIN stock-holding mechanism.

security, farmer support, or suchlike). We assume that the petroleum price (West Texas intermediate) peaks at over $90 per barrel in 2013 and then slides back to $85 for the remainder of the projection period to 2018. Partly as a consequence of these petroleum prices, the RFS mandates are found to be mostly binding from 2012 on as the flat petroleum price does not encourage biofuel consumption to keep pace with the rising volumes required, so the EISA provisions require that more biofuels are used in the US than would otherwise occur.

If Grandfathering Excludes 2 Billion Gallons of Corn-Based Ethanol

Depending on how the grandfathering provision of the EISA will be applied, corn-based ethanol might not be eligible to count against all 15 billion gallons of the overall mandate beyond the advanced mandate. Using the method defined here, we note the implications if the effective limit to count corn-based ethanol towards the RFS is reduced by 2 billion gallons and, instead, imported sugar-based ethanol is used. The scale of the reduction is somewhat arbitrary.

In either case, the amount that can be met using corn-based ethanol peaks in marketing year 2015. Given our assumptions, the mandate is binding at that time, so if 2 billion gallons less of corn-based ethanol can be used to meet the RFS then blenders choose to buy imported ethanol instead. The lower demand for domestically produced corn-based ethanol leads to less corn demand. The farm price of corn is about 4% lower, and trade-offs in crop area and use lead to lower farm prices of soybeans, wheat, and other crops.

A relevant point to this discussion is that it would be easier to meet the requirements of the state-level LCFS if more imported sugar-based ethanol were already in use because of the national RFS. In the case that less corn-based ethanol were eligible and imported sugar-based ethanol were used in its place for the national mandates, then it is less likely that the LCFS would affect the national fuel mix. Again, this would depend on the exact emission calculations applied as well as on the wider context, such as the petroleum price.

National market results

If the LCFS is adopted widely – as represented by California and the New England and Mid Atlantic states here – then the volumes of sugar-cane and cellulosic ethanol are likely to exceed the nationally mandated volumes. The scenarios below show how those additional requirements would affect national biofuel and commodity markets. These scenarios are:

- Scenario A: LCFS adopted widely, baseline cellulosic ethanol use but assume less motor fuel is used as non-traditional vehicle (e.g. electric) use rises quickly.
- Scenario B: LCFS adopted widely, cellulosic ethanol use increased relative to baseline.
- Scenario C: LCFS adopted widely, indirect land use change is excluded from CARB calculations.

The results for ethanol markets follow directly from the additional requirements above those of the RFS that could be required if the LCFS is adopted by many states (Table 7). The first scenario shows the implication of forcing more ethanol imports to meet a more widely adopted LCFS without assuming any expansion in cellulosic biofuel availability, but with a very fast rate of increase in non-traditional vehicle use. In that case, the higher volumes of imported sugar-cane ethanol to meet the broadly adopted LCFS requirements are a key result of the policy.

In Scenario A, ethanol imports increase by nearly two-thirds over the six-year period in order to meet the multi-state LCFS, based on calculations shown above. In this case, the LCFS forces more imports of sugar-based ethanol than would be required to meet the binding advanced mandate of the RFS. Because they do not have to worry about meeting the mandate, nobody is willing to bid the price of "other advanced" biofuels higher than the price of corn-based ethanol – at least, not outside of states that adopt the LCFS for whom there is no reason to trade imported sugar-based ethanol when they can presumably instead buy RINs for less. (The question of distributional effects is discussed more below.)

The additional imported ethanol in the domestic market largely displaces corn-based ethanol. This nearly one-for-one trade-off follows from the binding overall biofuel use RFS mandate. As the overall mandate can be met by either of these two fuels, more imports implies less domestically-made corn-based ethanol is required.

This result would be different if the overall mandate were not binding. If the petroleum price was high enough that the mandate was not binding, for example, then consumers would opt to buy more than the mandated volumes anyways. In that case, first of all, the level of imported biofuels already might be sufficient to meet the LCFS requirements. Second, if the LCFS did require greater imports, then total ethanol might increase if consumers opt to buy more biofuels so the trade-off with corn-based ethanol might not be so pronounced if the overall mandate were not binding.

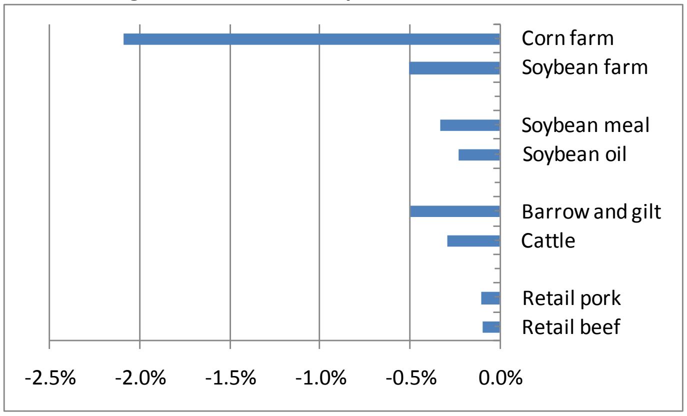
Table 7. Changes from no-LCFS baseline if widespread LCFS adoption, 2013/14 to 2018/19 averages.

	Baseline level	More non-traditional vehicles		With greater cellulosic ethanol		No ILUC in emission calculations	
Ethanol market		(absolute and percent changes from the baseline due to LCFS)					
Domestic production, million gallons	15,687	-936	-6.0%	-1,365	-8.7%	-148	-0.9%
From corn	14,714	-895	-6.1%	-1,719	-11.7%	-139	-0.9%
Other feedstocks	319	-41	-12.8%	-57	-17.8%	-9	-2.7%
Cellulosic	653	0	0.0%	411	62.9%	0	0.0%
Imports, million gallons	1,524	977	64.1%	1,796	117.8%	196	12.9%
Domestic use, million gallons	17,004	53	0.3%	434	2.6%	55	0.3%
Prices and returns, dollars per gallon							
Conventional	2.09	-0.11	-5.3%	-0.18	-8.4%	-0.02	-0.8%
Other advanced	2.25	-0.27	-12.2%	-0.34	-15.1%	-0.10	-4.3%
Dry mill net returns	0.37	-0.08	-22.6%	-0.12	-33.6%	-0.01	-2.9%
Crop markets							
Area planted, million acres							
Corn	90.05	-1.10	-1.2%	-2.18	-2.4%	-0.11	-0.1%
Soybeans	77.10	0.54	0.7%	1.07	1.4%	0.06	0.1%
Wheat	58.32	0.14	0.2%	0.27	0.5%	0.02	0.0%
Farm prices, dollars per bushel							
Corn	4.09	-0.09	-2.1%	-0.16	-3.9%	-0.02	-0.4%
Soybeans	9.89	-0.05	-0.5%	-0.10	-1.0%	-0.01	-0.1%
Wheat	5.83	-0.05	-0.9%	-0.10	-1.6%	-0.01	-0.1%
Net market returns, dollars per acre							
Corn	369.63	-14.68	-4.0%	-27.18	-7.4%	-2.86	-0.8%
Soybeans	302.91	-2.07	-0.7%	-3.94	-1.3%	-0.26	-0.1%
Wheat	133.88	-2.34	-1.7%	-4.42	-3.3%	-0.33	-0.2%

The lower use of corn-based ethanol has impacts on agricultural commodity markets. Lower demand for corn leads to a 2% lower corn price. More corn goes to other uses, such as for feed or export. Land planted to corn falls by more than 1% as it is shifted towards competing uses, with half of the reduction in corn area going to soybeans. With higher supplies of other crops, their prices tend to fall, but by less than 1%. The lower corn price also has implications for the demands of other crops. For example, a lower corn price encourages feed use. Animal feeds also include oilseed meals, so more soybean meal is purchased for this purpose. The net effect of greater soybean supplies and higher feed demand is a reduction in the soybean and soybean meal prices.

Lower feed costs allow an expansion of livestock production, eventually leading to lower prices. Consumer prices are lower, but the percent changes in consumer prices are smaller than the percent changes in farm prices (Figure 11). As the initial incidence falls on corn markets, the corn farm price change is unsurprisingly largest (in relative terms). The effects tend to get smaller as they are transmitted to soybean and soybean product markets, livestock markets, and finally to retail meat prices.

Figure 11. Changes in farm and retail prices in Scenario A, 2013-2018 averages.



Scenario B assumes that more cellulosic ethanol is available. We do not consider any additional costs of pushing beyond levels that were assumed to be a practical limit before, nor the possibility that resources such as land allocated to additional feedstocks are drawn from the agricultural commodities studied here. We do assume that this greater volume of cellulosic ethanol is incorporated as part of the RFS: the cellulosic biofuel mandate is still assumed to be waived, but it is reduced to the new (higher) level of cellulosic use assumed instead of the base (lower) level.[12] This implies greater ethanol consumption as the mandated volume expands. Even with greater cellulosic ethanol, the calculations above still suggest a large increase in imported ethanol.

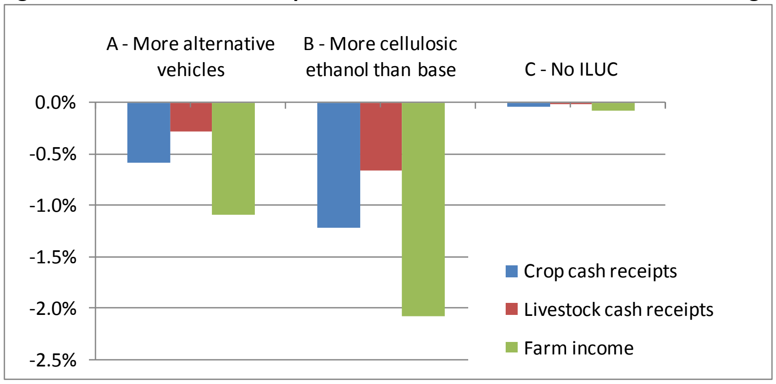
Widespread LCFS adoption of Scenario B leads to more cellulosic and imported ethanol. As noted above, the cellulosic biofuel expansion leads to a higher mandate, which explains most of the increase in domestic use. Imported sugar-based ethanol displaces domestically produced corn-based ethanol, as in the previous case. But the magnitudes are greater: imports more than double and corn-based ethanol use is 12% lower. The eventual effect on the farm corn price is a 4% reduction, and soybean and wheat farm prices are 1-2% lower due to the consequent area and demand shifts.

There is a need for additional imported ethanol in Scenario C, but the magnitudes are more modest than in the previous case. Omitting indirect land use effects from the CARB calculations implies a much

[12] The terms “higher” and “lower” are relative ones, of course. Both levels of this scenario are less than the seven billion gallons cellulosic RFS in 2018, and both exceed the less than 25 million gallons of cellulosic biofuel production capacity that EPA identified as potentially on-line by 2010 in draft regulations released in May 2009.

lower need for imported sugar-based ethanol to meet the multi-state LCFS. And, moreover, much of this need is met anyway by the baseline level of imports.

Figure 12. National cash receipts and farm income effects, 2013-2018 average



The relative effects of these three cases on crop and livestock cash receipts follow from the price effects shown above (Figure 12). The falling crop prices lower crop receipts, clearly, and also feed costs to livestock producers. As livestock production increases due to the lower costs, livestock prices are bid lower to move more pounds of meats and milk, leading livestock cash receipts to fall. A better measure of the implications for farms is their income, the gap between revenues and costs. The net effects on average farm income over the six years is a 1% reduction in Scenario A (more alternative vehicles), a 2% reduction in Scenario B (more cellulosic and imported ethanol), and a much smaller reduction in Scenario C (no ILUC in CARB calculations) reflecting the much smaller changes in national biofuel markets of that case.

Key questions about national effects

The present analysis is based on the view that Brazilian supplies of sugar-based ethanol will rise rapidly if the US importers start to bid the price higher. The view that Brazilian export supplies to the US are elastic, responding strongly even to modest price changes, at such quantities is difficult to test because US ethanol imports have not reached one billion gallons to date. This responsiveness would be supported by the expectation that Brazil could increase their supplies of sugar-based ethanol substantially (if not necessarily quickly) as prices rise. It would also be supported if Brazilian consumers are sensitive to the price of ethanol and if price changes are transmitted to them. For example, if the US import price is bid higher and this is transmitted to Brazilian consumers, then their reductions in ethanol use as local ethanol prices rise relative to petroleum prices would free up more of Brazil's supplies for export to the US.

We do not address certain complicating effects relating to greater ethanol use. We focus on national market averages and do not differentiate among consumers. Our analysis does not allow us to assess whether or not ethanol-blended fuels are priced lower in states that adopt the LCFS in order to increase consumption as compared to the prices in states that do not adopt the LCFS. For example, the price of E85 might be low in states where fuel blenders are obligated to trade much greater volumes of ethanol so that consumers will choose to buy more of this fuel. We also do not consider the implications that greater ethanol use could have on energy prices, including the price of gasoline.

The distributional effects of the LCFS are not addressed here, but the results suggest a certain shift in the costs to meet a binding RFS towards states that adopt LCFS and away from others. In the absence of the LCFS, national biofuel use mandates would be met where it is cheapest to do so and fuel blenders would then trade RINs so each would meet their own mandate and whatever costs are generated would be shared out. Thus, if mostly concentrated use in one region proved the cheapest way to meet the national mandate, then blenders there would buy up biofuels and sell RINs to blenders in other states. The LCFS could affect this outcome in a way that raises costs even if no more biofuels are required in total. For example, reconsidering the scenario that assumes that California adopts an LCFS and relies on cellulosic biofuels, the implication is that California would draw in most of the cellulosic biofuel produced in the US, even if those gallons might otherwise have been used at lower cost closer to where they were produced. These distributional effects should not be overstated given that ethanol blends are already the predominant fuel in California although it produces almost none of the ethanol it uses. However, one might expect that buying only a certain type of ethanol that meets particular benchmarks set by CARB is likely to cost more than buying the cheapest ethanol on offer to meet local requirements.

The LCFS could also have distributional effects by shifting costs of RFS compliance. Even if the LCFS does not require more sugar-based imports or cellulosic biofuels than the RFS, it could lead to a concentration of their use within the state that adopts the LCFS even though this may not be the least cost way to meet the national mandates. If so, then the blenders in those states would have to incur at least the initial costs of meeting a binding mandate. If other states could have met the RFS more cheaply, by procuring imported ethanol or cellulosic biofuels at lower cost, then the net effect would be higher costs in total, as well as a shift in their initial distribution. Taking again the scenario that California adopts the LCFS and uses most or even all US cellulosic biofuel, regardless of the costs of moving it from wherever it was produced, the costs of RFS compliance would be larger and fall first on fuel blenders in California before being passed on through RIN trade and to consumers.

In an extreme case, if the LCFS is met by importing more sugar based ethanol than is required by the advanced biofuel mandate, then the consumption in states that adopt the LCFS meet the advanced mandate in passing (excluding the parts covered by sub-mandates). The RINs generated by their imports of sugar-based ethanol are more than enough to meet the advanced mandate. In this case, RINs in excess of the RFS could be traded to non-LCFS-compliant states, but at a price presumably only enough to cover the transaction costs of transmitting the RINs. This change suggests a substantial swing in costs and who pays them. The baseline without LCFS would have the costs of the advanced mandate spread throughout the nation because of the shared responsibility to meet the RFS. An LCFS that requires more imports than the RFS would all but eliminate the costs of meeting the national advanced fuel mandate (excluding sub-mandates), and the costs of imported ethanol to comply with the LCFS in those states that adopt it would presumably be greater than the national advanced mandate costs would have been without the LCFS.

In addition, there could be costs incurred to prove that a biofuel's contribution towards meeting the LCFS if these steps differ from those of RFS compliance. In our analysis of national markets, we assume that blenders pass costs associated with a binding RFS to motor fuel consumers, and we expect that blenders would also pass on LCFS costs in some way.