Greenhouse gas emission benefits of E15 in California

By Philip Sheehy, ICF

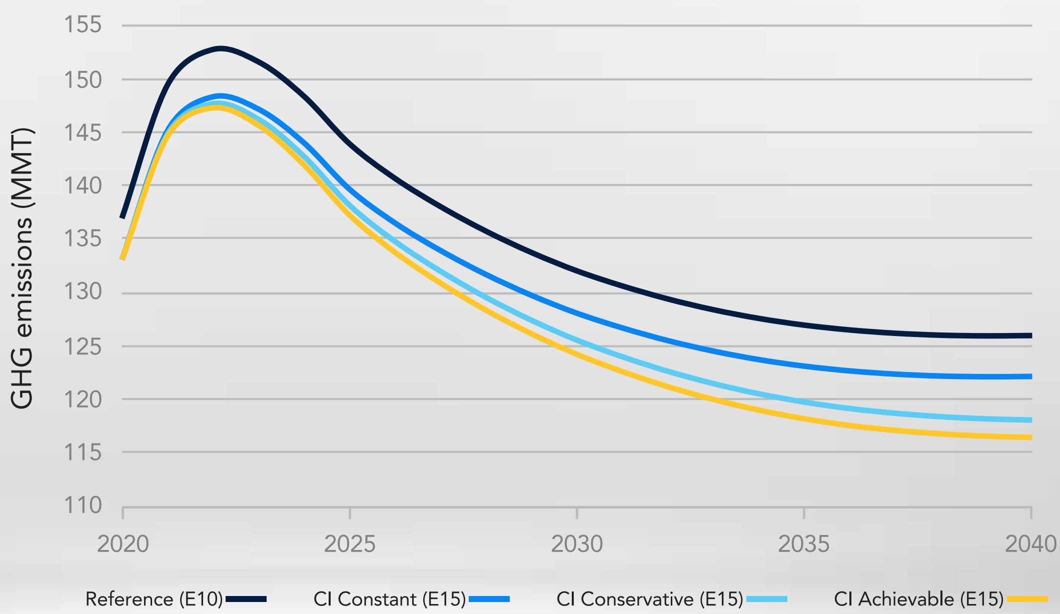
Executive summary

Increasing the amount of ethanol blended into gasoline from 10% to 15% (known as E15), coupled with the potential for decreasing carbon intensity of ethanol, has the potential to reduce greenhouse gas (GHG) emissions significantly. More specifically, ICF estimates that the combination of transitioning to E15 blends, reducing the carbon content of ethanol attributable to improved process efficiencies at biorefineries, implementing agronomic practices at farms, and switching some feedstock could yield between 4.0 to 7.5 MMT of GHG emissions annually. By 2040, 85 to 159 MMT of GHG emissions could be reduced with a transition to E15 and lower carbon ethanol. ICF calculated the GHG emissions using a lifecycle accounting methodology consistent with California's Low Carbon Fuel Standard (LCFS) program. The emissions factors in the LCFS program are reported in units of grams of carbon dioxide equivalents per megajoule of fuel consumed, or gCO2eq/MJ.

ICF developed three trajectories for the carbon intensity (CI) of ethanol out to 2040, assuming no change in the carbon content of ethanol (CI Constant), a decrease of 3.2% annually in the carbon intensity of ethanol in a conservative case (CI Conservative), and a decrease of 5.4% annually in the carbon intensity of ethanol in an achievable case (CI Achievable). The assumptions in the CI Conservative case are linked to historical efficiency gains, some feedstock switching, and that a GHG accounting system was implemented whereby the benefits of implementing agronomic practices are rewarded with a lower CI. The assumptions in the CI Achievable case are similarly linked to historical efficiency gains, some feedstock switching, and more aggressive reductions than in the CI Conservative case linked to the implementation of agronomic practices. Using these assumptions, the CI of ethanol decreases by about a half and two thirds, respectively, by 2040.

The figure below shows the GHG emissions in a reference case whereby the market stays at E10 and the CI of ethanol is unchanged. It also shows the GHG emissions from the three scenarios considered in the analysis including E15 and varying levels of reduced CI of ethanol.

Figure 1. GHG emissions of E10 and E15 in California



On average, E15 and a lower CI of ethanol have the potential to reduce GHG emissions compared to E10 by 3-6% between now and 2040, depending on the rate at which the CI of ethanol decreases over time. The average light-duty vehicle in California consumes about 500 gallons of gasoline per year, emitting about 5.7 tons of GHG emissions. In other words, the transition to E15 coupled with the projected decline in the CI of ethanol would be equivalent to reducing the number of cars on the road by an average of 700,000 cars in the CI Constant case, 1.1 million cars in the CI Conservative case, and 1.3 million cars in the CI Achievable case.

A transition to E15 coupled with lower carbon ethanol would have two benefits to California's LCFS program: firstly, it would increase the number of credits generated by ethanol substantially. Secondly, it would decrease the number of deficits generated by gasoline blendstock (the petroleum component) because there is less fossil fuel blended into each gallon of reformulated gasoline. For the sake of reference, the LCFS program currently generates about 15 million credits per year. ICF estimates that the transition to E15 and lower carbon ethanol would yield about 1.0 to 1.8 million additional credits by 2025 and 1.0 to 2.7 million credits by 2030.

Introduction

As part of a requirement to reduce harmful air pollutants, California requires the sale of reformulated gasoline, which is a blend of California Reformulated Blendstock for Oxygenate Blending (CARBOB) and ethanol. Most of the reformulated gasoline in the state contains 10% ethanol by volume. In June 2011, the U.S. Environmental Protection Agency (EPA) approved the use of a 15% ethanol blend by volume (E15) in vehicles with model year (MY) 2001 or later. However, California has not approved the use of E15 as part of its reformulated gasoline standards, in part because the California Air Resources Board (CARB) has communicated that it would take several years to complete the vehicle testing and rule development necessary to introduce a new transportation fuel into California's market. Some market observers contend that California is in the early stages of considering E15.[1]

This report considers the greenhouse gas (GHG) emissions benefits of California transitioning to E15 blends, coupled with reductions in the carbon content of ethanol attributable to improved process efficiencies at biorefineries and from the implementation of agronomic practices at corn farms. The GHG emissions are calculated using a lifecycle accounting methodology consistent with California's Low Carbon Fuel Standard (LCFS) program. The emissions factors in the LCFS program are reported in units of grams of carbon dioxide equivalents per megajoule of fuel consumed, or gCO2eq/MJ.

Overview of methodology

ICF conducted the analysis in this report with a timeframe of 2040. The analysis was conducted over a series of steps: 1) forecast gasoline fuel consumption, 2) characterize the share of the California light-duty vehicle fleet that could fuel using E15 using EMFAC2017 (the model that calculates emissions inventories for motor vehicles operating on roads in California), and 3) develop potential carbon intensity (CI) reductions for ethanol.

Projected gasoline fuel consumption

Reporting from the LCFS program indicates that California has consumed on average 15.3 billion gallons of gasoline (as E10) since 2015 as shown in the table below in units of billion gallons (B gals); consumption has been decreasing since peaking in 2017 as vehicles have become more efficient.

Table 1. Reported gasoline consumption in the LCFS program, 2015-2019[2]

Fuel	2015	2016	2017	2018	2019
Gasoline (B gals)	14.9	15.6	15.6	15.3	15.3

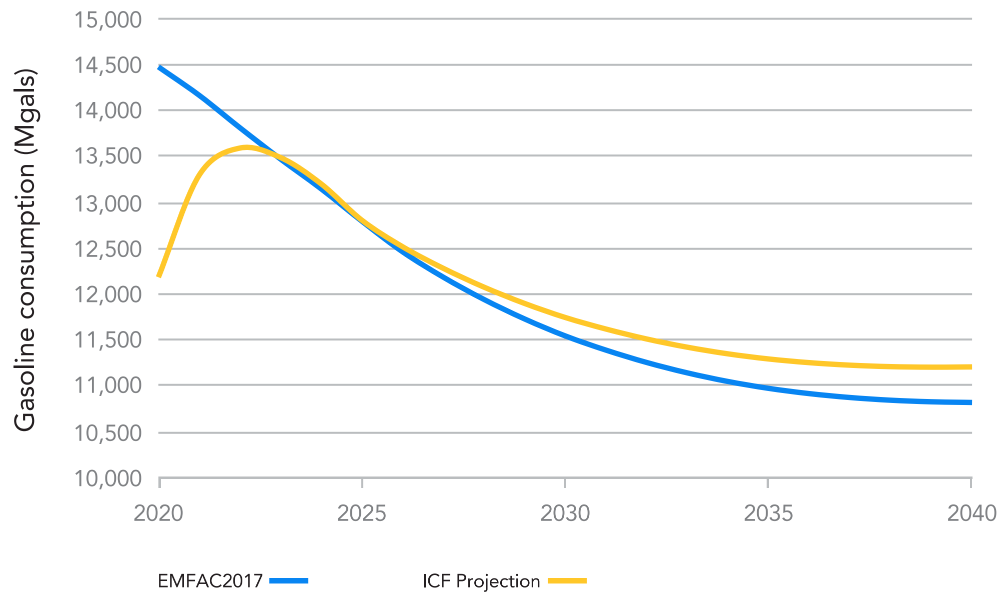
The EMFAC2017 model includes a fleet turnover component, broken down by parameters including (but not limited to) calendar year, vehicle model year, vehicle class, fuel type (e.g., gasoline, diesel, natural gas, or electricity), emissions (e.g., NOx and PM), and fuel consumption. Although we can extract fuel consumption from the EMFAC2017 model, ICF opted not to because of the recent substantial decreases in gasoline linked to the COVID-19 pandemic and associated stay-at-home orders. Even as stay-at-home orders have subsided, there is still a significant portion of the population that is working from home, thereby decreasing gasoline demand. ICF developed the projected gasoline fuel consumption as shown in

[1] *For instance, see "Some states looking to end prohibition of E15" from Ethanol Producer, November 8, 2019. Available online at http://ethanolproducer.com/articles/16695/some-states-looking-to-end-prohibition-of-e15*

[2] *The volumes shown in the table are based on the fuel volumes reported by CARB on a quarterly basis and include all gasoline reported as part of the LCFS program, which would include gasoline consumption in more than just light-duty vehicles. However, ICF estimates that more than 96% of the gasoline reported in the LCFS program is consumed by light-duty vehicles.*

the figure below, most notably with a 20% reduction in gasoline for 2020 compared to 2019 levels.[3] For the sake of reference, the figure includes the gasoline consumption by light-duty vehicles in the EMFAC2017 model.[4]

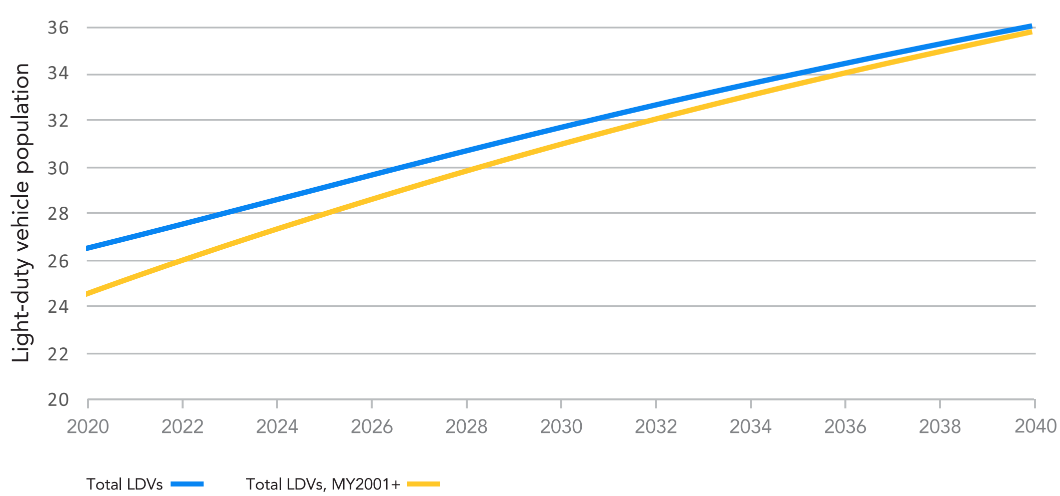
Figure 2. Projected gasoline consumption in California, 2020-2040



E15 eligible fleet

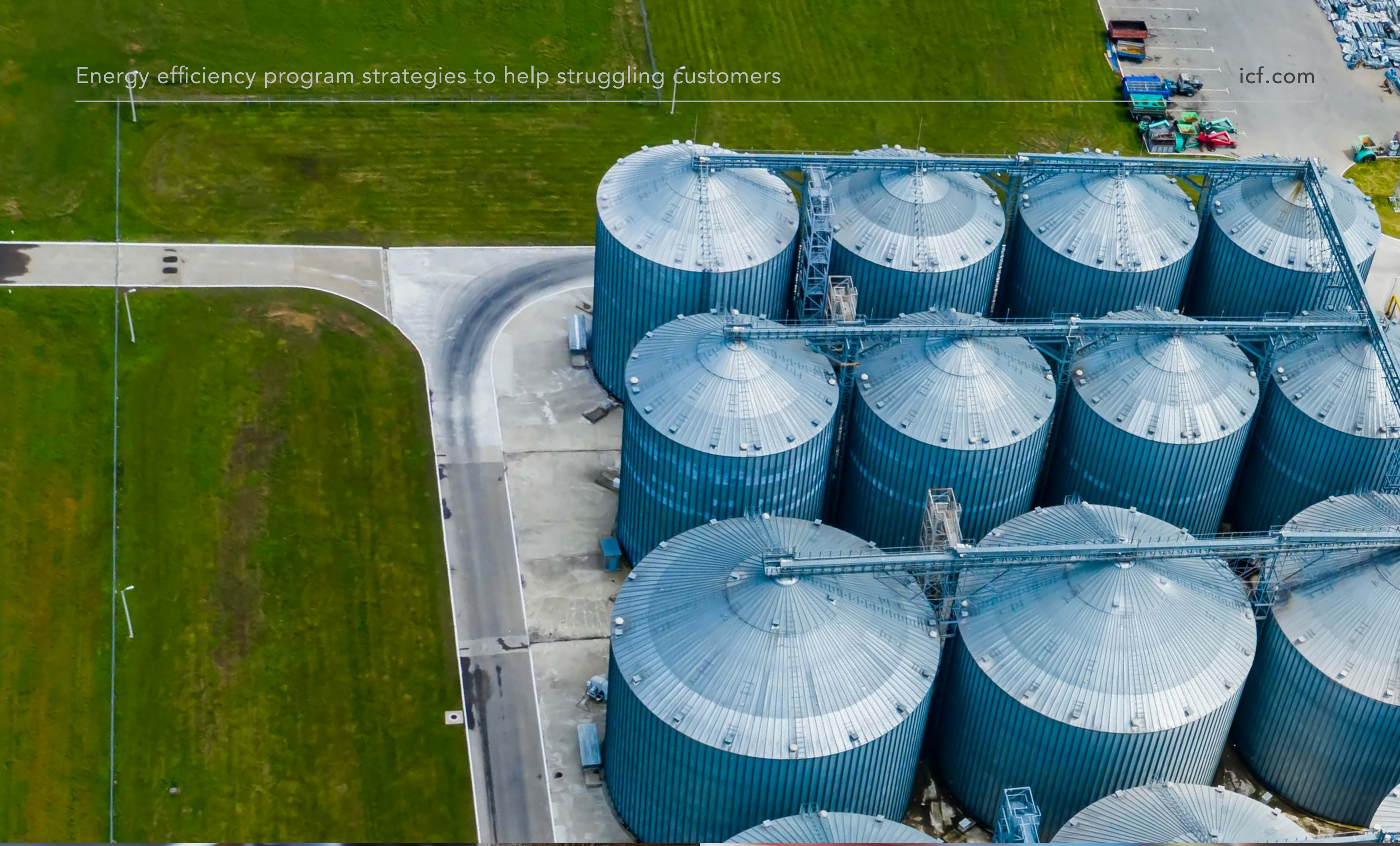
As noted previously, the EPA issued a waiver for vehicles with MY2001 or later. ICF characterized the share of light-duty vehicles that are MY2001 or later using EMFAC2017. The figure below shows the total number of light-duty vehicles expected in California's fleet through 2040 (in blue) and the corresponding number of light-duty vehicles that are MY2001 or later.

Figure 3. California's light-duty vehicle fleet population, 2020-2045



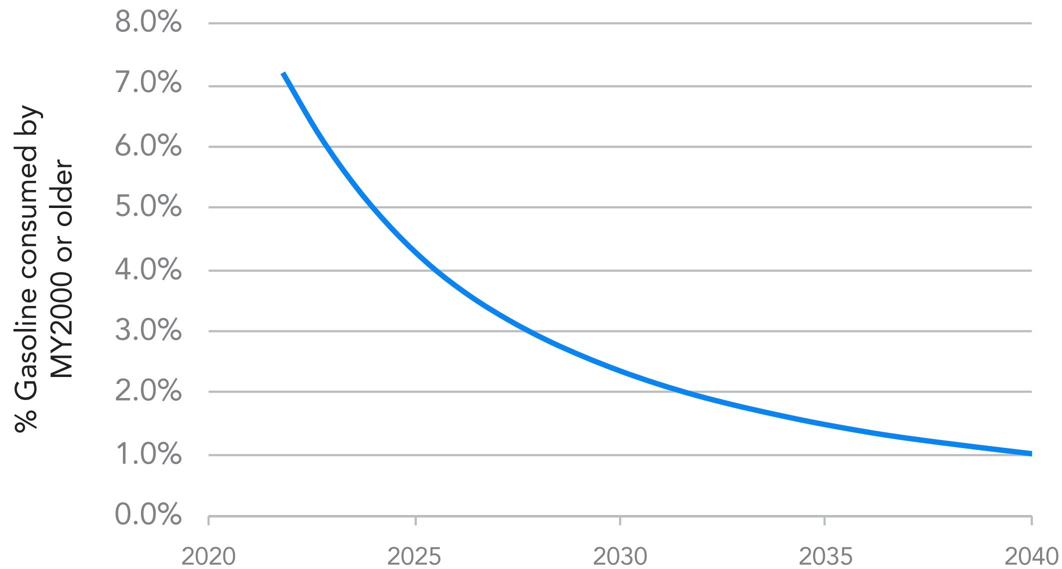
[3] *California Energy Commission, Energy Insights, July 2020, available online at https://www.energy.ca.gov/sites/default/files/2020-07/Energy%20Insights_FINAL%2007-17-2020.pdf.*

[4] *Note that ICF's projection is higher than EMFAC2017 projection because of different assumptions regarding the light-duty vehicle mix. ICF assumes that there is a greater share of light-duty trucks than is assumed in the EMFAC model.*



As shown in the figure below, the share of fuel consumed by vehicles MY2000 or older decreases substantially over time as a function of fleet turnover. By 2034, for instance, less than 1% of gasoline consumption is expected to be attributable to vehicles with MY2000 or older.

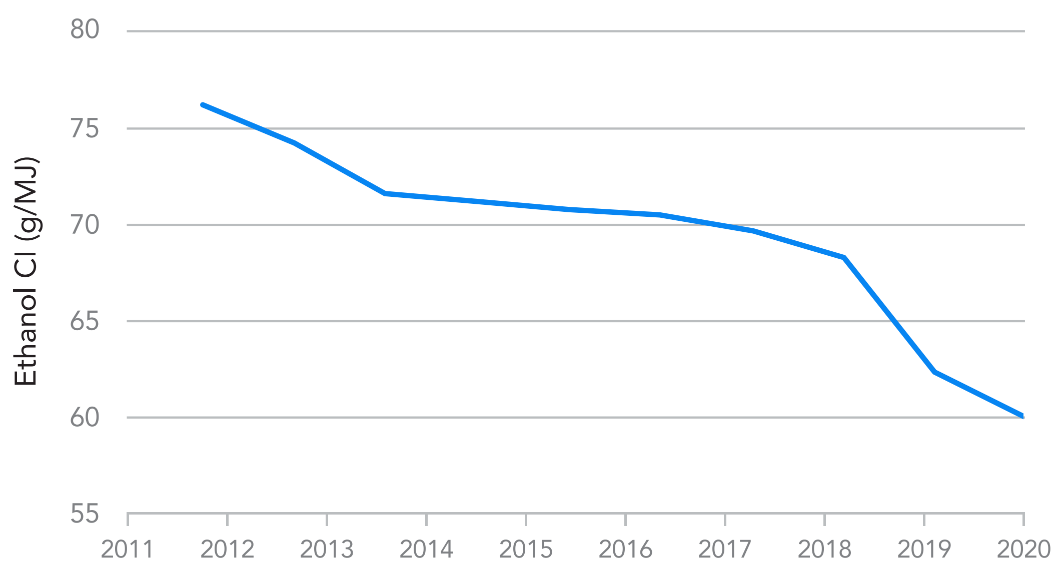
Figure 4. Percent of gasoline consumed by MY2000 or older in California



Carbon intensity of ethanol

Data reported via California's LCFS program shows that since 2011, the CI of ethanol delivered to California has decreased by a compounded annual rate of 2.7% (see figure below). Note that the values presented in the figure have been adjusted for the different emissions factor that has been added to the CI for ethanol associated with so-called land use change (LUC). In 2016, the LUC emission factor was reduced from 30 g/MJ to 19.8 g/MJ.

Figure 5. Ethanol carbon intensity delivered to CA, 2011-2020



ICF developed three trajectories for the CI of ethanol out to 2040, as summarized here:

- CI Constant: In this case, the CI of ethanol was held constant at 2019 levels of 62.1 g/MJ.
- CI Conservative: In this case, ICF assumed that the CI of ethanol continues to decrease annually at a rate of 2.7% attributable to efficiency gains, some feedstock switching, and that a GHG accounting system was implemented whereby the benefits of implementing agronomic practices are rewarded with a lower CI. In this case, ICF assumed that a maximum 21.6% CI reduction could be achieved via the implementation of agronomic practices. Combined, these changes yield a compound annual decrease of 3.2% over the course of the analysis. In the CI Conservative case, the 2040 CI of ethanol is assumed to be 32.2 g/MJ or 68% less than CARBOB.
- CI Achievable: In this case, ICF assumed that the CI of ethanol decreased annually at a rate of 3.8% attributable to efficiency gains, some feedstock switching, and that a GHG accounting system was implemented whereby the benefits of implementing agronomic practices are rewarded with a lower CI. In this case, ICF assumed that a maximum 30.5% CI reduction could be achieved via the implementation of agronomic practices. Combined, these changes yield a compound annual decrease of 5.4% over the course of the analysis. In the CI Achievable case, the 2040 CI of ethanol is assumed to be 20.3 g/MJ or 80% less than CARBOB.

ICF assumed CI reductions consistent with an analysis that ICF performed for the U.S. Department of Agriculture (USDA) referred to as a high efficiency-high conservation projection of the CI profile of ethanol. That scenario includes CI reductions from the following:

- Domestic farm inputs and fertilizer N2O: **yield increases** and conservation **technologies and practices**.
- Domestic LUC: **reduced tillage** decreases soil disturbance during field operations and leaves a large proportion of plant residues on the field.
- Fuel production: **process fuel switching** to biomass and **increased corn to ethanol yield**.

More specifically, ICF incorporated the farm-level adoption of three conservation practice standards (CPS) in the production of corn used to produce ethanol that USDA's Natural Resources Conservation Service have recognized as having GHG benefits. These are:

- CPS 345—Residue and Tillage Management, Reduced Till
- CPS 590—Nutrient Management: Improved Nitrogen Fertilizer Management
- CPS 340—Cover Crops

ICF bundled the considerations for CI reductions by a) process efficiencies, b) agronomic practices, and c) feedstock switching and other considerations. For process efficiencies, we assumed that a 1.2%-1.7% per year decrease in CI of ethanol attributable to process efficiencies during ethanol fuel production. For the implementation of agronomic practices, ICF assumed that a maximum CI reduction of 21.6% and 30.5% from the baseline ethanol CI could be achieved in the CI Conservative and CI Achievable scenarios, respectively. Lastly, with regard to feedstock switching and other considerations that can help to reduce the CI of ethanol, we assumed that additional 1.5-2.1% per year decrease in CI of ethanol.

ICF also had to make assumptions about the share of corn crop that would be able to implement these practices. In the CI Conservative case, ICF assumed that about 50% of crops would be credited for the implementation of these agronomic practices by 2040; whereas in the CI Achievable case, ICF assumed that about 95% of crops would be credited for the implementation of these agronomic practices by 2040.

The table below shows the 5-year increments of CI values used in each of the three scenarios.

Table 2. Carbon intensity values assumed for ethanol, 2020 to 2040 in units of g/MJ

Scenario	2020	2025	2030	2035	2040
CI Constant	62.1	62.1	62.1	62.1	62.1
CI Conservative	62.1	52.4	44.4	37.6	32.2
CI Achievable	62.1	46.5	35.1	26.3	20.3

Calculating GHG emissions

The GHG emissions of each scenario are calculated using the following steps:

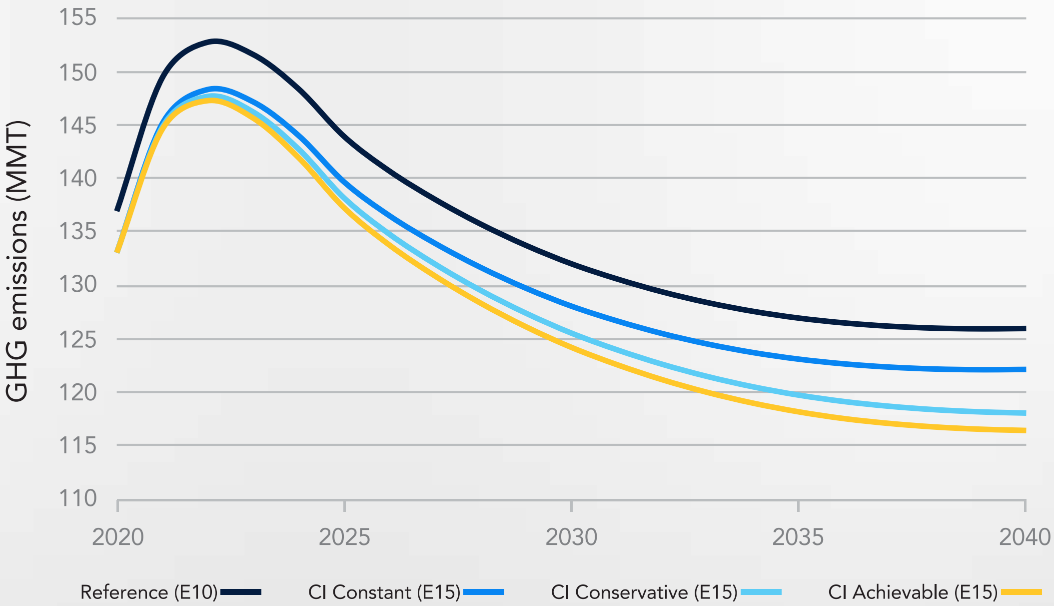
- Determine the volume of CARBOB and ethanol at a 15% blend rate based on the forecasted gasoline demand.[5]
- Determine the share of gasoline (as E15) that can be consumed by MY2001 or newer light-duty vehicles.
- Calculate the GHG emissions by multiplying the volume of fuel (in gallons) by the corresponding energy density (in MJ per gallon) and carbon intensity (g/MJ).

[5] *Even though E15 has a slightly lower energy density than E10, ICF did not adjust the volumes as it is inconclusive if there is a fuel economy penalty associated with the use of E15 compared to E10 in part because higher ethanol content corresponds with an in increase in octane and related performance characteristics.*

Key findings

The figure below shows the GHG emissions in a reference case whereby the market stays at E10 and the CI of ethanol is unchanged. It also shows the GHG emissions from the three scenarios including E15 and varying levels of reduced CI of ethanol.

Figure 6. GHG Emissions of E10 and E15 in California



On average, E15 and a lower CI of ethanol have the potential to reduce GHG emissions compared to E10 by 3-6% between now and 2040, depending on the rate at which the CI of ethanol decreases over time. Annually, this amounts to 4.0 to 7.5 MMT of GHG emissions. Over the 20-year timeframe considered in this analysis, ICF estimates between 85 to 159 MMT of GHG emissions will be avoided with a transition to E15 coupled with the projected decline in the CI of ethanol.

The average light-duty vehicle in California consumes about 500 gallons of gasoline per year, emitting about 5.7 tons of GHG emissions. In other words, the transition to E15 couple with lower CI ethanol would be equivalent to reducing the number of cars on the road by an average 700,000 cars in the CI Constant case, 1.1 million cars in the CI Conservative case, and 1.3 million cars in the CI Achievable case.

In the context of the LCFS program, a transition to E15 coupled with lower carbon ethanol would have two benefits: Firstly, it would substantially increase the number of credits generated by ethanol and secondly, it would decrease the number of deficits generated by CARBOB because there is less fossil fuel blended into each gallon of reformulated gasoline. For the sake of reference, the LCFS program currently generates about 15 million credits per year. By 2025, ICF estimates that the transition to E15 in the CI Conservative case would yield a net impact of 1.5 million additional credits (1 million fewer deficits and 0.5 million additional credits) and 1.8 million additional credits in the CI Achievable case (1 million fewer deficits and 0.8 million additional credits).

By 2030, as the LCFS program requires a CI reduction of 20% for transportation fuels, ICF anticipates that gasoline and diesel consumption will generate about 27-30 million deficits annually. By 2030, ICF calculates that an additional 2.2 and 2.7 million credits would be generated through the transition to E15 and the lower CI of ethanol. In other words, E15 coupled with a decrease CI of ethanol could help generate about 7%-10% of the credits that will be needed to achieve LCFS program compliance in 2030.

About the author

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Philip is committed to identifying cost-effective solutions to meet the challenge of decarbonization, with over 15 years of experience navigating the technical, economic, and regulatory challenges associated with decarbonizing transportation fuels.

Philip provides advisory services to public and private entities engaged in low carbon fuel deployment, including program feasibility and design, market analysis and forecasting, and project due diligence.

Philip plays a critical role in various aspects of transportation decarbonization. He has helped analyze and design transportation electrification initiatives for governments and utilities. For instance, he worked closely with the San Diego Association of Governments to create the Regional Electric Vehicle Charging Program, a novel regional effort to support transportation electrification. Philip has also led multiple studies on renewable natural gas (RNG) potential as a low carbon fuel for use in the transportation sector and other sectors. He was the lead author and researcher for a nationwide analysis of RNG for the American Gas Foundation and has followed that work up with various engagements with utilities and investors. Philip also provides market insights and analysis to investors, developers, and other market actors concerned with low carbon fuel deployment. He focuses on California's Low Carbon Fuel Standard Program and the federal Renewable Fuel Standard Program. Philip has extensive work experience and recognized expertise in low carbon fuel standards, having led regulatory assessments in California, Oregon, Washington, Colorado, and the Midwestern States.

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