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Estimating Greenhouse Gas Emissions from Proposed Changes to the Renewable Fuel Standard through 2022

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Introduction

The US Environmental Protection Agency (EPA) has proposed a significant change to the US Renewable Fuel Standard (RFS) for 2014 and beyond, which will have an impact on greenhouse gas (GHG) emissions. We have used GREET1.2013 data and the US Energy Information Administration (EIA) projections to estimate the change in GHG emissions, measured in carbon dioxide equivalents (CO_2e), between the statutory RFS volumes and the newly proposed RFS methodology through 2022. Cumulatively, the lowering of required biofuel volumes will result in nearly 1 billion metric tons of additional emissions when compared to the statutory RFS numbers. Following is a discussion of the goals and evolution of the RFS, how it works, the metrics and process we used to model GHG emissions based on the EPA's proposed changes to the RFS, our calculations of the estimated emissions impact of the proposed RFS changes, and the implications of those results.

As the basis for modeling GHG emissions we used data from the latest version of the fuel lifecycle model developed at the Argonne National Laboratory, GREET—The Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation Model. The GREET model is used to evaluate various vehicle and fuel combinations on a full fuel-cycle/vehicle-cycle basis. The GREET model comprises more than 100 fuel pathways (including petroleum, natural gas, biofuels, hydrogen, and electricity produced from various energy feedstock sources), stimulates three vehicle classes (passenger cars, Light Duty Truck 1 and 2), and includes more than 80 vehicle/fuel systems that cover multiple different vehicle technologies. Our use of this data allows us to aggregate average emissions from various fuel choices and compare differing levels of biofuel and petroleum blendstock use over time.

The RFS was first established in 2005 to mandate the use of renewable transportation fuels. It is part of the Clean Air Act and is administered by the EPA. The program was expanded in 2007 to ensure that the federally mandated use of renewable fuels achieved measureable reductions in GHG emissions as they displaced petroleum fuels. Broadly, the goals of the program are to reduce both GHG emissions from the US transportation sector and the nation's reliance on imported oil by displacing petroleum fuels. The RFS statute establishes annually increasing requirements for renewable fuels to be produced and used in the US—rising to 36 billion gallons in 2022.

The EPA finalized the administrative rules to enforce the expanded RFS in March 2010. Through 2013 the EPA issued annual rules that consistently increased, year-over-year, the mandated amount of biofuel to be used in the US. In November 2013, however, the EPA proposed a rule that would reduce biofuel use in 2014 compared to 2013. The agency further indicated that it would follow a newly proposed use-constrained methodology for setting the annual mandates in future rulemakings, through 2022. The proposal is subject to public comment and review prior to a final rulemaking.

Because the US is projected to consume more transportation fuel in 2014 than in 2013, the requirement for fewer gallons of renewable fuel will increase use of petroleum fuels. The EPA did not include an analysis of the impact on GHG emissions in its proposed rule for 2014. However, given the statute's stated goals, such an analysis is necessary. We have modeled the changes in GHG emissions, measured in carbon dioxide equivalents, associated with the EPA's proposed methodology for 2013 through 2022 using GREET1.2013 data and the US EIA projections for transportation fuel use.

We present the results of this modeling to illustrate to the industrial biotechnology community how proposed changes to the RFS would affect US GHG emissions in the future. This estimate is intended to inform the EPA of one of the potential impacts of its proposed rule, allowing for appropriate changes

EDITOR'S NOTE:

Some of the information and conclusions included in this article were presented in the report ''Estimating GHG Emissions from Proposed Changes to the Renewable Fuel Standard through 2022,'' submitted to the Environmental Protection Agency as Appendix LXIV of Comment submitted by Brent Erickson, Executive Vice President, Industrial and Environmental Section, Biotechnology Industry Organization (BIO), www.regulations.gov/contentStreamer?objectId=0900006481530edd&disposition=attachment&contentType=pdf

before the final rulemaking. The EPA could perform a similar analysis, using its own modeling of GHG impacts of various fuel choices.

How the RFS Works

The statute establishes a set of nested Renewable Volume Obligations (RVOs) for use of cellulosic biofuels, biomass-based diesel (BBD), and unspecified advanced and conventional renewable fuels.[1] *Figure 1* depicts the nested structure of the RVOs. Both the BBD RVO and the cellulosic RVO are subcategories of the advanced RVO. As such, biomass-based diesel and cellulosic fuels can be used to meet the entire advanced and total RVOs. But any qualifying advanced biofuel (transportation, jet, or heating fuel) can be used to meet the advanced RVO once the specific BBD and cellulosic RVOs are met. Likewise, any advanced biofuel can be used to meet the total RVO, but the portion not set aside for advanced can be met with conventional biofuels (defined as renewable fuels, such as ethanol from corn).

To meet the cellulosic RVO, a biofuel must reduce GHG emissions on a lifecycle basis by at least 60% compared to the 2007 baseline for petroleum gasoline, and be derived from a qualifying biomass feedstock. Likewise, biomass-based diesel and all other advanced biofuels must reduce GHG emissions by 50% and be derived from a qualifying source of biomass. Conventional fuels must reduce GHG emissions by 20% compared to the same baseline. The nested RVOs are designed to achieve measurable reductions—not merely to slow growth—in GHG emissions associated with transportation, jet, and heating fuels, with greater reductions achieved each year.

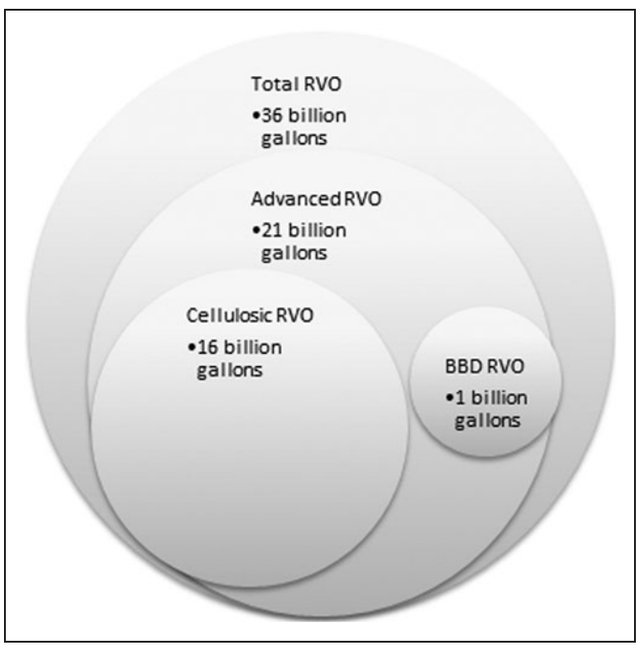


Fig. 1. Nested structure of 2022 statutory Renewable Volumes Obligations (RVOs).

The statutory RVOs are displayed in *Table 1*. Of the total obligation, at least 1 billion gallons must be biomass-based diesel and an annually increasing volume must be qualifying gallons of cellulosic biofuel. Though the statutory volumes of cellulosic biofuel grow to 16 billion gallons in 2022, the EPA is required to reset the annual RVO to the projected available quantity. When the EPA waives the statutory cellulosic RVO to the projected available volume, it may reduce the overall and advanced RVOs by up to the same amount. Each year since 2010, the EPA has waived nearly all of the cellulosic RVO because to date cellulosic fuels have been commercially available only in very limited quantities.

But the EPA has maintained the statutory overall advanced and total RVOs. The EPA has set the annual RVOs at the maximum achievable levels of production of renewable fuels, taking into account the availability of compliance credits from prior years. Biomass-based diesel and other advanced biofuels have been produced, imported, and sold in sufficient quantities to meet the advanced RVO. Corn ethanol — which has proven to be a very cost-effective additive to fuel—has met the remaining portion of the total RVO.

Modeling Emissions from EPA's Proposed Changes to the RFS

The EPA's proposed 2014 Standards for the RFS Program would set aside the statutory RVOs and establish a new methodology for determining the annual requirements for renewable fuel use.[2] Under this proposed new methodology, the EPA would first determine the amount of ethanol that could be used with gasoline in E10 and E85 blends. EPA would next project the amount of non-ethanol cellulosic, BBD and other advanced biofuels that could be produced and used within the US. As a third step, the agency would establish the cellulosic, BBD and undifferentiated advanced RVOs at or below the projected volumes available, to ensure that the ethanol content does not exceed the volume determined in the first step.

To begin to estimate the emissions impact of this change to the methodology for establishing RVOs, we first developed an estimate of the methodology's impact on fuel use. We utilized the volumes for 2014 published in the EPA's proposed rule, but then developed new estimates of the annual RVOs for 2015–2022 based on the EPA's proposed change to methodology. The EPA's new methodology limits ethanol use to 10% of the gasoline supply plus limited E85 blending and retailing infrastructure. The proposed methodology also limits non-ethanol biofuels and higher blends of ethanol to their established share of the market. We also developed an estimate of fuel use under the statutory volumes of the RFS.

To approximate market shares, we used the EIA projections of fuel use and the market penetration of various fuel sources for 2013–2022 from the 2014 Annual Energy Outlook, early release.[3] The EIA's projections are based on assumptions of current policy carried forward and market growth of existing technologies. We assume that use of ethanol and biodiesel directly displace consumption of gasoline blendstock and biodiesel.

Use of transportation fuels is expected to increase in 2014 compared to 2013.[4] Even though gasoline use will decline,

Table 1. Statutory Renewable Volumes Obligations (RVOs) under the Renewable Fuel Standard

YEAR	CELLULOSIC RVO	BIOBASED DIESEL RVO	TOTAL ADVANCED RVO	UNSPECIFIED ADVANCED (TOTAL – CELLULOSIC + BIOBASED DIESEL)	TOTAL RENEWABLE RVO	CONVENTIONAL BIOFUEL MAXIMUM (TOTAL – ADVANCED)
2009	0	0.50	0.60	0.10	11.10	10.50
2010	0.10	0.65	0.95	0.20	12.95	12.00
2011	0.25	0.80	1.35	0.30	13.95	12.60
2012	0.50	1.00	2.00	0.50	15.20	13.20
2013	1.00	1.00	2.75	0.75	16.55	13.80
2014	1.75	1.00	3.75	1.00	18.15	14.40
2015	3.00	1.00	5.50	1.50	20.50	15.00
2016	4.25	1.00	7.25	2.00	22.25	15.00
2017	5.50	1.00	9.00	2.50	24.00	15.00
2018	7.00	1.00	11.00	3.00	26.00	15.00
2019	8.50	1.00	13.00	3.50	28.00	15.00
2020	10.50	1.00	15.00	3.50	30.00	15.00
2021	13.50	1.00	18.00	3.50	33.00	15.00
2022	16.00	1.00	21.00	4.00	36.00	15.00

diesel use is expected to increase in 2014. Through 2022, the EIA projects overall transportation fuel consumption to decline. Gasoline consumption is expected to decline by nearly 10%, from 132.8 billion gallons in 2014 to 121.1 billion gallons in 2022. Diesel fuel consumption is expected to increase, from 55.2 billion gallons in 2014 to 61.5 billion gallons in 2022. The decline in gasoline use will more than offset the increase in diesel use in 2022, resulting in an overall decrease in transportation fuel use. These estimates are presented in *Figure 2*.

The EIA also projects E85 use to grow 20-fold from its current level of 153.3 million gallons to nearly 3.1 billion gallons per year by 2022. Production and use of biodiesel remains unchanged from 2014 to 2022. Given its cost-competitiveness, we would expect corn ethanol to be the first choice of renewable fuel used in E10 gasoline and E85 blends, filling the undifferentiated overall RVO to the maximum extent, just as it has in past years. However, we used the EIA estimates of imported ethanol as an estimate of advanced biofuel.

To estimate emissions through 2022, we assume a continuation of the EPA's newly proposed methodology of limiting RVOs to the estimated market use of various biofuel categories. We also assume no additional cellulosic biofuel growth beyond the 100 million gallons of capacity currently in production or under construction, due to the uncertainty for investors created by the change in the rules.

Under the model, in 2022, the EPA could be expected to establish the total amount of ethanol to be used in the market at 15.2 billion gallons—equivalent to 10% of estimated gasoline use of 121.1 billion gallons plus market growth of E85, equivalent to 3.1 billion gallons. The EIA projects that 1.1 billion gallons of ethanol will be imported, so emissions are estimated as though these gallons make up the undifferentiated portion of the advanced RVO. The overall advanced RVO is therefore estimated to be 2.6 billion gallons and the total RVO is estimated at 16.7 billion gallons. The EIA also projects that 61.5 billion gallons of petroleum diesel will be used. The EPA would be expected to establish the BBD RVO at 1.4 billion gallons, based on steady market demand from 2014 to 2022, directly displacing an equivalent volume of petroleum diesel.

We modeled the resulting emissions for 2014 through 2022 under both the statutory RFS volumes and the modeled RFS volumes, using the GREET1.2013 model developed by Dr. Michael Wang and others at Argonne National Labs. Wang estimates that because the United States now imports more oil from Canada and Venezuela than it did in 2007, and more of Canada's oil exports come from oil sands, the GHG intensity of petroleum fuels has increased. Comparatively, the GHG intensity of biofuels is decreasing.[5] Updated estimates from 2012 of the GHG intensity of petroleum and biofuels, measured in CO_2e, were incorporated in the latest GREET model.

The GREET1.2013 model estimate of GHG emissions for petroleum fuels is 94 grams CO_2e per megajoule (gCo_2e/MJ) on average for gasoline blendstock and 96 gCo_2e/MJ for diesel. EIA projects that US imports of petroleum from Canada will increase through 2022, even while overall petroleum import levels decline. However, the GHG intensity of petroleum in 2022 is not captured or estimated in GREET1.2013.

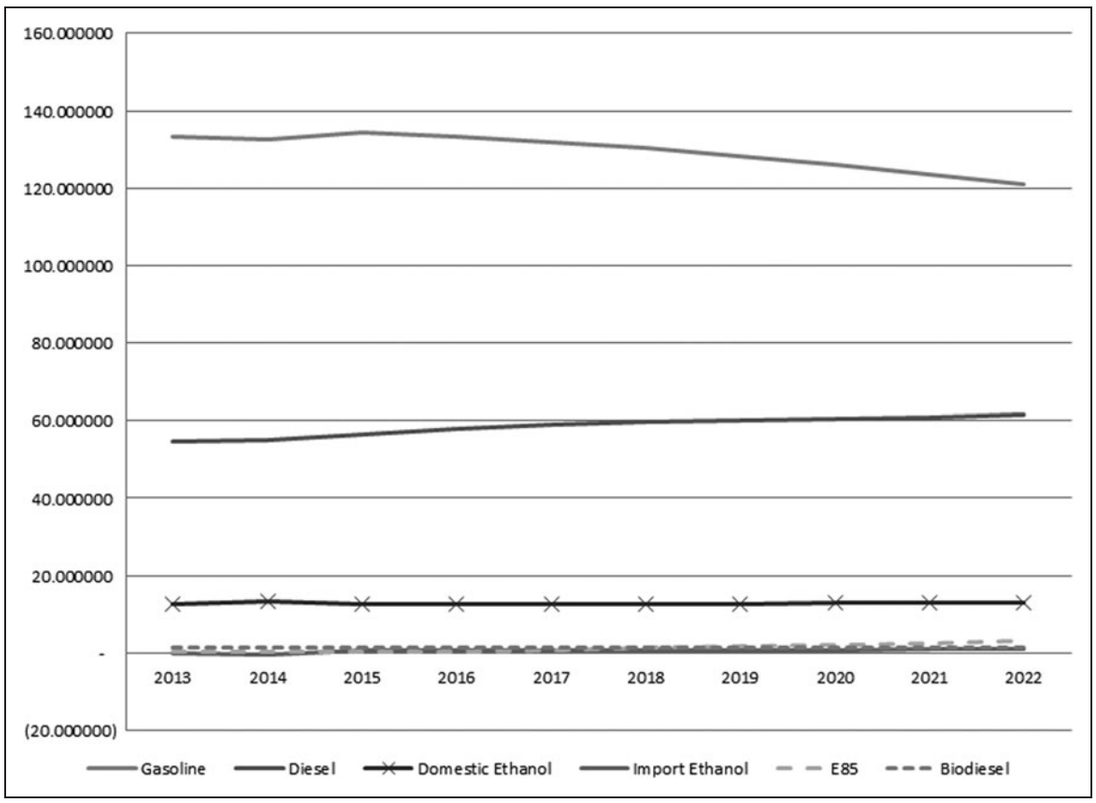


Fig. 2. Liquid fuel consumption, 2013–2022.

The GREET value for corn ethanol of 65 gCO_2e/MJ, which includes a measurement of land use change, is used to estimate emissions for the conventional biofuel RVO. A soybean biodiesel value of 23 gCO_2e/MJ is used to estimate emissions from the BBD RVO; and a Brazilian sugarcane value of 35 gCO_2e/MJ is used to estimate emissions from the advanced biofuel RVO. The GREET value for corn stover ethanol of 13 gCO_2e/MJ, with land use change, is used to estimate emissions from the cellulosic biofuel RVO. The volume of displacement of gasoline by ethanol and diesel by biodiesel is adjusted by the difference in

Table 2. Estimated Changes in Greenhouse Gas Emissions (GHG) from 2013 to 2014

	GHG EMISSIONS (THOUSAND METRIC TONS CO_2e)			CHANGES IN GHG EMISSIONS FROM 2013	
	2013	2014	2014	2014	2014
EMISSIONS SOURCE		PROPOSED RENEWABLE VOLUMES OBLIGATIONS (RVOs)	STATUTORY RVOs	PROPOSED RVO	STATUTORY RVO
Gasoline blendstock	1,394,363	1,387,719	1,342,689	−6,643	−51,674
Diesel	685,039	704,068	707,718	19,029	22,678
Conventional (corn ethanol)	72,003	67,829	75,134	−4,174	3,131
Biobased diesel (soy biodiesel)	3,757	3,757	2,935	0	−822
Advanced (Brazilian sugarcane ethanol)	2,238	681	2,826	−1,557	588
Cellulosic (corn stover ethanol)	7	18	1,897	12	1,891
Total	2,157,407	2,164,073	2,133,199	6,666	−24,208

Table 3. Estimated Changes in Greenhouse Gas Emissions from 2013 to 2014 Under Varying RVO Assumptions

EMISSIONS SOURCE (THOUSAND METRIC TONS CO_2e)	PROPOSED RENEWABLE VOLUMES OBLIGATIONS (RVOs)	STATUTORY RVOs	PROPOSED RVOs FOR BIOBASED DIESEL AND CELLULOSIC, STATUTORY TOTAL ADVANCED	PROPOSED RVOs FOR BBD AND CELLULOSIC, EQUIVALENT REDUCTION OF ADVANCED
Gasoline Blendstock	−6,643	−51,674	−48,434	−31,623
Diesel	19,029	22,678	19,029	19,029
Conventional (Corn ethanol)	−4,174	3,131	3,131	3,131
Biobased diesel (soy biodiesel)	0	−822	0	0
Advanced (Brazilian sugarcane ethanol)	−1,557	588	4,695	588
Cellulosic (corn stover ethanol)	12	1,891	12	12
Total	6,666	−24,208	−21,568	−8,864

heating values. To enable comparison, all values are converted to a gasoline gallon equivalent of gCO_2e.

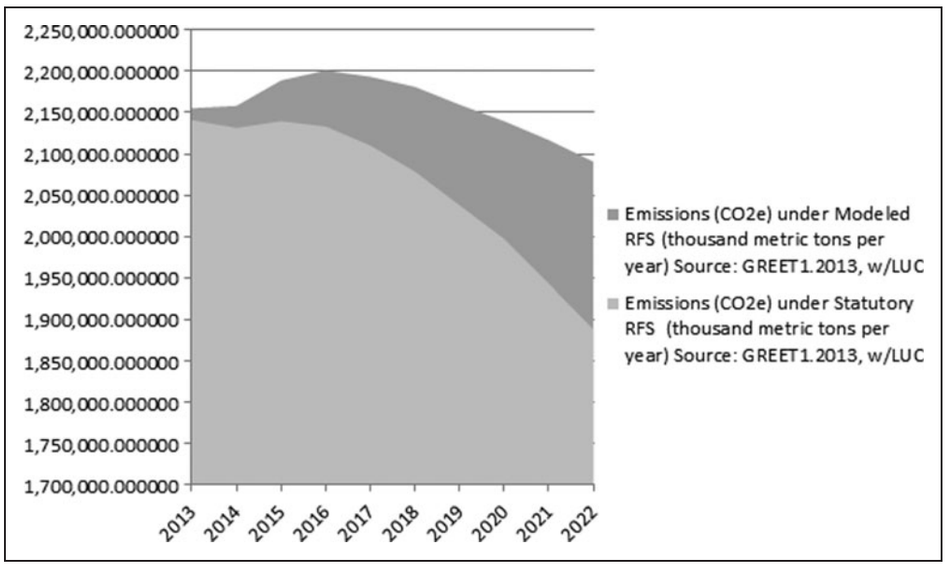
Our Estimates of the Emissions Impact

If the proposed rule is finalized without changes, the use of biofuels will decline in 2014, compared both to 2013 and to the volumes specified in the statute. The use of additional petroleum in 2014, compared to 2013, will automatically increase GHG emissions. The EPA's proposed RVOs for 2014 result in an estimated increase of 6.66 million metric tons of CO_2e from 2013 to 2014. If the EPA were to maintain the RFS at the statutory volumes in 2014, the US would achieve an estimated reduction of emissions of 24.2 million metric tons CO_2e. The results of the modeling of GREET1.2013 values are displayed in *Table 2*. T2

The statutory volume of 1 billion gallons of BBD is less than the proposed volume for 2014 of 1.28 billion gallons, which results in additional use of petroleum diesel under the statute when compared to the proposal. Additionally, the EPA proposes to lower the cellulosic biofuel RVO to the projected available volume of 17 million gallons, as required. If these values are substituted for the statutory volumes, allowing the overall advanced RVO to remain at the statutory level as the EPA has done in prior years, the achieved reduction in GHG emissions would be 21.6 million metric tons CO_2e. If the EPA were to reduce the advanced and overall RVOs by the same amount as they reduce the cellulosic RVO, which they may do under their statutory authority, GHG emissions would be reduced by 8.9 million metric tons CO_2e compared to 2013. These results are presented in *Table 3*. The EPA's proposed change in methodology results in a net increase of 28.2 million metric tons CO_2e in 2014 T3

Table 4. Estimated GHG Emissions in 2022 under Varying Renewable Volumes Obligations (RVOs) Assumptions

EMISSIONS SOURCE (THOUSAND METRIC TONS CO_2e)	MODELED RVOs	STATUTORY RVOs	STATUTORY RVOs, WITH CELLULOSIC WAIVER AND STATUTORY TOTAL ADVANCED	STATUTORY RVOs WITH CELLULOSIC WAIVER AND EQUIVALENT REDUCTION OF ADVANCED
Gasoline Blendstock	1,224,097	1,070,680	1,008,133	1,192,095
Diesel	783,572	706,675	775,062	775,062
Conventional (Corn ethanol)	73,569	78,264	78,264	78,264
Biobased diesel (soy biodiesel)	4,050	5,870	5,870	5,870
Advanced (Brazilian sugarcane ethanol)	3,109	8,479	53,417	8,479
Cellulosic (corn stover ethanol)	108	17,344	108	108
Total	2,088,506	1,887,313	1,920,855	2,059,879
Difference from 2013	−68,901	−270,094	−236,552	−97,529



AU1 **Fig. 3.** CO_2e emissions under statutory Renewable Fuel Standards (RFS) and modeled RFS biofuel levels.

relative to previously established methodology. This is equivalent to the emissions of 5.9 million additional vehicles.

If fuel use declines along the lines of the EIA projections through 2022, GHG emissions would fall from 2014 levels in 2022. However, with ongoing changes in the sources of US petroleum supply, the decline in emissions is not guaranteed. Use of more petroleum from Canada and from enhanced oil recovery technologies in the United States could increase emissions from each gallon of petroleum.

Under our assumptions for the modeled use of fuel in 2022, and using 2012 estimates of GHG intensity from GREET that include land use change, emissions would be expected to fall by 68.9 million metric tons of CO_2e when compared to 2013. However, by not maintaining the statutory advanced and total RVOs, the EPA is foregoing additional emission reductions of more than 168 million metric tons CO_2e relative to previously established methodology. This is equivalent to the emissions of more than 35 million additional vehicles. Results are presented in *Table 4*.

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Cumulative foregone emissions reductions over the period 2014–2022 approach 1 billion metric tons CO_2e. Additionally, due to a projected increase in gasoline consumption in 2015 and 2016 (compared to 2013), the change in methodology increases the use of petroleum fuels and associated emissions of greenhouse gases. Overall petroleum use does not fall below 2013 levels until 2019, increasing the emissions of greenhouse gases measured in CO_2e, as shown in *Figure 2*.

Conclusions

The EPA's proposal to change the methodology of setting the RVOs for the Renewable Fuel Standard will have an immediate impact on GHG emissions in 2014, since it will lower biofuel use as transportation fuel use increases. The EPA did not include an estimate of the greenhouse gas impact when it issued the proposal, but may be required to do so for the final rule. Emissions can be modeled using the EPA's own estimates of the GHG intensity of various fuel options, but it is indisputable that an increase would occur. Only by maintaining the prior methodology for setting the RVOs, based on the availability of renewable fuel, can the EPA ensure a reduction in greenhouse gas emissions in 2014 compared to 2013.

The EPA should carefully consider the impact on CO_2 emissions in the transportation sector in assessing its proposed change in methodology. As fuel use declines through 2022, associated GHG emissions will naturally decline as long as the emissions intensity of various fuel choices remains stable. However, if the EPA's proposed new methodology is applied in 2022, when statutory levels of biofuel use would reach 36 billion gallons, the country will forego additional emission reductions of more than 168 million metric tons CO_2e relative to previously established methodology. This is equivalent to the emissions of more than 35 million additional vehicles. Cumulative foregone emissions reductions over the period 2014–2022 approach 1 billion metric tons CO_2e.

The social costs of these additional emissions should be weighed carefully in any cost-benefit analysis of EPA's proposed change in methodology. According to the Interagency Working Group on Social Cost of Carbon, that cost is approximately $37 per ton. The 6.66 million ton increase in CO_2e emissions next year that would directly result from EPA's proposed reduction of biofuel use would come at a cost of $246 million to the US. Foregoing the additional savings of 21.57 million metric tons of emissions in 2014 by not following past practice and maintaining the advanced and total pools at the maximum achievable volume would cost the US an additional $798 million in lost opportunity. In contrast, recent analyses suggest little, if any, of the cost of RFS compliance is borne by consumers.[6] Even were the full cost of compliance passed on to consumers, biofuels would be a bargain for the US, since even at Renewable Identification Numbers (RIN) prices of $1 per gallon, RIN costs remain substantially below the social cost of carbon saved per gallon of gasoline.

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