BRIEFING

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Policy recommendations for a national low-carbon fuel standard

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There has been growing interest in introducing a national low carbon fuel standard (LCFS) in the United States as a replacement for the current Renewable Fuel Standard (RFS). The RFS, a program that mandates increasing volumes of various types of biofuels over time, is not well defined by law after 2022 and has become politically divisive. A national-level low-carbon fuel standard, similar to existing policies implemented in California and Oregon, would be technology-neutral, wherein fuels would generate credits or deficits based on their greenhouse gas (GHG) intensity.

Depending on how it is designed, the transition from the existing RFS to a national-level LCFS could pose new risks or exacerbate existing issues in U.S. fuels policy. Notably, it may simply accelerate demand for existing, food-based biofuels and fail to deliver its intended GHG savings. This briefing paper discusses several of the motivations behind implementing a national LCFS, evaluates key risks associated with LCFS policy design, and lastly, provides a set of recommendations to mitigate those risks and maximize the effectiveness of the policy. We recommend a complementary set of proposals that would cap the contributions of the riskiest feedstocks, such as food-based biofuels, to a national LCFS and provide targeted support for more sustainable, second-generation biofuels.

BACKGROUND

The federal RFS, introduced into law in 2005 and updated in 2007, has largely fallen short of its intended GHG emissions reductions. The RFS was originally designed to transition the U.S. biofuel market from first-generation corn ethanol to second-

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generation cellulosic biofuels produced from non-food biomass. The continued use of food-based biofuels in climate policy has been further called into question by science linking them to emissions from deforestation and other indirect land-use change (ILUC); the impact of these land-use change emissions may be large but is also highly uncertain.[1] In contrast, cellulosic biofuels can be made from corn stover, grasses, wood, municipal solid waste, and other widely available waste materials, using more advanced technologies than corn ethanol and other first-generation biofuels prevalent today. Cellulosic biofuels can be produced more sustainably and deliver much deeper GHG reductions compared to petroleum or first-generation food-based biofuels.

However, despite the intention of the RFS to drive a massive increase in cellulosic biofuel volumes, over the course of its implementation, the policy has fallen far short of this goal. The RFS cellulosic biofuel mandates, statutorily set at its outset to reach 16 billion gallons in 2022, have been drastically revised downward each year by the U.S. Environmental Protection Agency (EPA), reaching only 400 million ethanol-equivalent gallons in 2019, largely from landfill gas.[2] Instead of cellulosic biofuels with high GHG savings, in practice the RFS primarily incentivizes the use of corn ethanol and soybean biodiesel, whose production has increased to approximately 14 billion gallons and 1.7 billion ethanol-equivalent gallons, respectively.[3] Citing these trends, a recent analysis by the Government Accountability Office suggests that the RFS has promoted limited, if any net GHG reductions.[4] The bulk of fuels blended only meet the RFS's least stringent eligibility category, which requires only a 20% GHG reduction compared to fossil fuels. Additionally, the definition of "renewable" fuels in the RFS only includes biomass-based energy sources, excluding low-carbon alternatives such as most renewable electricity which could be used in electric and fuel cell vehicles.

In response to criticism over the efficacy of the RFS, LCFS proponents argue that the policy may achieve deeper GHG reductions than the RFS and provide a larger incentive to decarbonize the transport fuel sector. The House Select Committee on the Climate Crisis, as part of a sweeping set of recommendations, recommends that Congress transition the existing RFS to an LCFS, arguing that it would further reduce GHG emissions from the road sector and promote electric vehicles.[5] Similarly, the National LCFS Project convened by University of California, Davis and other stakeholders provides a series of recommendations for implementing a federal LCFS, arguing that it would support a broader set of alternative fuels (e.g., electric vehicles, hydrogen fuel cells) and provide an incentive to innovate within existing biofuel pathways.[6] Some in the biofuel industry have praised the design of the LCFS because it could drive

1 Tyler J. Lark, Nathan P. Hendricks, Aaron Smith, Nicholas Pates, Seth A. Spawn-Lee, Matthew Bougie, Eric G. Booth, Christopher J. Kucharik, and Holly K. Gibbs, "Environmental Outcomes of the US Renewable Fuel Standard," *Proceedings of the National Academy of Sciences* 119, no. 9 (March 1, 2022). https://doi.org/10.1073/pnas.2101084119.; Richard J. Plevin, Jayson Beckman, Alla A. Golub, Julie Witcover, and Michael O'Hare, "Carbon Accounting and Economic Model Uncertainty of Emissions from Biofuels-Induced Land Use Change," *Environmental Science & Technology* 49, no. 5 (March 3, 2015): 2656–64. https://doi.org/10.1021/es505481d.

2 U.S. Environmental Protection Agency, "RINs Generated Transactions," (updated March 10, 2021), https://www.epa.gov/fuels-registration-reporting-and-compliance-help/rins-generated-transactions.

3 U.S. EPA, "RINs Generated Transactions."

4 Government Accountability Office, "Renewable Fuel Standard: Information on Likely Program Effects on Gasoline Prices and Greenhouse Gas Emissions," (2019), https://www.gao.gov/assets/gao-19-47.pdf.

5 House Select Committee on the Climate Crisis, "Solving the Climate Crisis: The Congressional Action Plan for a Clean Energy Economy and a Healthy, Resilient, and Just America, Majority Staff Report," (2020.), https://climatecrisis.house.gov/sites/climatecrisis.house.gov/files/Climate%20Crisis%20Action%20Plan.pdf.

6 Sonia Yeh, Daniel Sperling, Michael Griffin, Madhu Khanna, Paul Leiby, Siwa Msangi, James Rhodes, and Jonathan Rubin, "National Low Carbon Fuel Standard: Policy Design Recommendations," *SSRN Electronic Journal*, (2012), https://doi.org/10.2139/ssrn.2105897.

additional investment towards farmers and biofuel producers to reduce emissions along their supply chains.[7]

Unlike the volumetric mandates of the RFS, which mandate the production of a specific quantity of fuels, an LCFS is a performance standard that mandates a certain greenhouse gas (GHG) reduction in the average fuel mix over time. This provides more flexibility to meet the policy targets cost-effectively. An LCFS has a declining GHG target for the average carbon intensity (CI) of the transport fuel mix; fuels with life-cycle emissions above the target each year generate deficits, while fuels below the target generate credits. A life-cycle assessment (LCA) is used to estimate that fuel's well-to-wheel (WtW) GHG emissions using a standardized, harmonized approach to compare different types of fuels on a consistent basis (i.e., CO_2-equivalents per MJ of delivered energy). The policy can therefore be entirely technology neutral and incentivize fuels proportionally to their delivered GHG reductions.

Figure 1 below illustrates the structure of an LCFS in practice, with the dotted line reflecting the mandated GHG intensity of the mix of fuels consumed in the road sector through 2035, which declines over time. Higher-emitting fuels in the red area generate deficits that must be offset through the purchase of credits, which are generated by the lower-emitting fuels in the green area. The further a fuel is from the GHG intensity target, the greater quantity of deficits or credits it generates. Credit generators such as alternative fuel producers can sell credits to deficit generators, which are typically fossil fuel suppliers. The value of a credit is dictated by the market, though different jurisdictions have implemented cost control mechanisms to cap the maximum cost of credits or provide flexibility when credits are scarce; for example, California's LCFS limits credit costs to an inflation-adjusted $200 per tonne of CO_2-equivalents.[8]

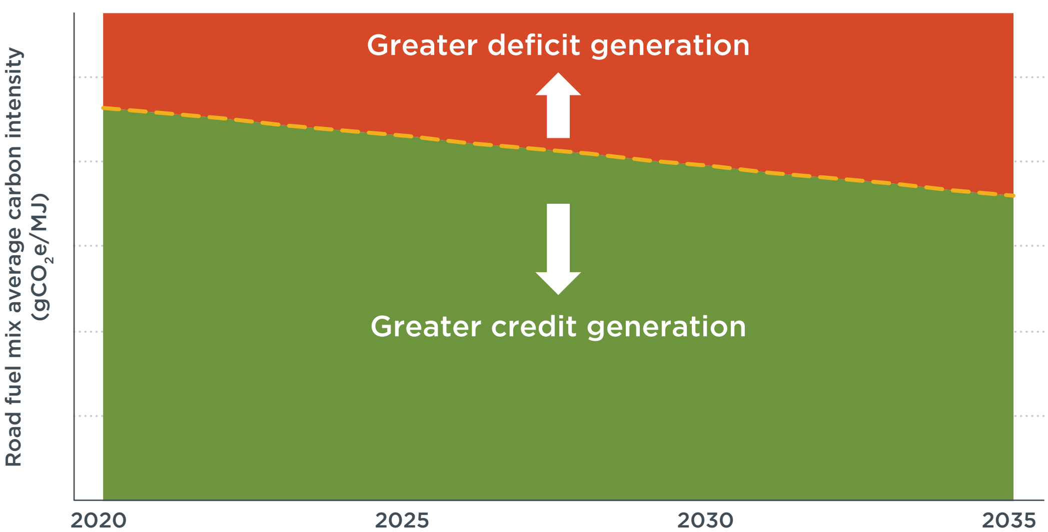

Figure 1. Illustration of a Hypothetical LCFS, from 2020 through 2035

Proponents of an LCFS highlight several advantages of the LCFS approach compared to the existing RFS. First, as a performance standard, it rewards alternative fuels

7 "RFA Welcomes Inclusion of Low Carbon Fuel Standard in Select Committee Recommendations," *Fuels Market News*, June 30, 2020, https://fuelsmarketnews.com/rfa-welcomes-inclusion-of-low-carbon-fuel-standard-in-select-committee-recommendations/

8 California Low Carbon Fuel Standard Regulation, CCR 17 § (2020).

according to their GHG reductions; for example, at a credit price of $200/tonne of CO_2-equivalents, corn ethanol blended in California that provides a life-cycle GHG reduction of 25% relative to fossil gasoline generates $0.34 per gasoline-equivalent gallon, whereas ethanol with a 50% reduction generates $0.93 per gallon.[9] Second, it allows producers to differentiate themselves even within a given fuel production pathway based on their performance, providing, for example, an incentive for efficiency improvements. Pathways that offer steeper GHG reductions beyond first-generation biofuels, such as cellulosic ethanol and biogas, can generate even greater credit values, which could theoretically help to offset their added cost of production compared to existing commercialized biofuels. Lastly, the technology-neutral design of the LCFS can allow all alternative fuels to generate credits solely on their GHG reductions, avoiding the potential of picking winners and losers among technologies and allowing the LCFS to promote a wider range of non-biomass technologies than the RFS, such as solar and wind power used in electric vehicles.

Though there are some credible advantages to an LCFS design compared to volumetric biofuel mandates, there are also some risks associated with LCFS policies. Existing issues observed in state-level LCFS's may be exacerbated when scaled up to a national level. Chiefly, there is a risk that implementing an LCFS may fail to solve the issues associated with the RFS, particularly the ongoing increase in food-based biofuel production and corresponding failure to promote significant volumes of second-generation and ultralow-carbon alternative fuels. Depending on how it is designed, a National LCFS may 1) further increase the demand for unsustainable food-based biofuels, 2) promote reliance on wase oil feedstocks with a high fraud potential and, 3) fail to provide a sufficient incentive to deploy second-generation alternative fuels. Over the next section, we assess these three areas of risk and evaluate policy design options to mitigate those risks and thereby improve the effectiveness of an LCFS.

OPTIONS FOR LCFS POLICY DESIGN

REDUCING RELIANCE ON FOOD-BASED BIOFUELS

Depending on how they are designed, LCFS programs may offer a large incentive to maintain or increase the production of food-based biofuels. Reliance on these fuels, as well as the integrity of their emissions reductions, has been called into question by research on the linkages between biofuel demand and land conversion and deforestation.[10] Around 40% of corn and 30% of soybean oil produced in the United States is currently used in biofuel production, respectively, diverting these commodities from the food and feed markets.[11] In doing so, food-based biofuels dramatically increase the overall demand for crops, leading to agricultural expansion within the United States and elsewhere around the world. Cropland expansion contributes to deforestation and the destruction of other natural lands globally,

9 Calculated based on the California LCFS 2022 CI standard for gasoline. California Air Resources Board (CARB), "LCFS Credit Price Calculator," http://ww3.arb.ca.gov/fuels/lcfs/dashboard/creditvaluecalculator.xlsx.

10 Geert Woltjer, Vassilis Daioglou, Berien Elbersen, Goizeder Barberena Ibañez, Edward Smeets, David Sánchez González, and Javier Gil Barnó "Analysis of the latest available scientific research and evidence on indirect land use change (ILUC) greenhouse gas emissions associated with production biofuels bioliquids," (Directorate-General for Energy, 2017), https://ec.europa.eu/energy/studies_main/final_studiesanalysis-latest-available-scientific-research-and-evidence-indirect-land_en

11 Alternative Fuels Data Center: Maps and Data. "U.S. Corn Production and Portion Used for Fuel Ethanol," 2022. https://afdc.energy.gov/data/.; Energy Information Administration (EIA). "Soybean Oil Comprises a Larger Share of Domestic Biodiesel Production," 2019. https://www.eia.gov/todayinenergy/detail.php?id=39372.

releasing large amounts of carbon from biomass and soils. These linkages are known as indirect land-use change (ILUC). The process of quantifying ILUC emissions for use in LCFS policies is a highly contested topic because ILUC emissions are estimated using complex global economic models and are highly uncertain. However, the science generally agrees that ILUC emissions for food-based biofuels are high enough to undermine a significant portion of their emissions savings, and for oilseeds such as palm and soy may be high enough to offset their benefits entirely.[12] Though California's LCFS generally assesses higher GHG intensity scores for food-based biofuels than second-generation biofuels, in part by including their estimated indirect land-use change (ILUC) emissions, most food-based biofuels can still generate credits in the program.[13] Other LCFS-like policies, such as British Columbia's LCFS, exclude ILUC emissions accounting entirely, putting food-based biofuels on an even footing with second-generation or waste-based biofuels.[14]

Despite having higher emissions intensities, food-based biofuels may continue to find a market even under an LCFS because some of these commercialized biofuel pathways, such as corn ethanol and soy renewable diesel, are significantly cheaper and less risky to investors than second-generation pathways; for example, corn ethanol production costs over the last 5 years averaged approximately $1.95 per gasoline-equivalent gallon (GGE) using existing technologies that can scale up quickly.[15] In contrast, while we expect cellulosic ethanol costs to come down eventually, in the near-term it may cost between $4.00 and $6.00 per GGE to produce, and construction and scale-up timelines are uncertain.[16]

Due to their relatively high emissions, it takes greater quantities of food-based biofuels to generate the same GHG reductions as a smaller quantity of lower-carbon, second-generation fuel. California utilizes large quantities of food-based biofuels with diminishing returns. The quantity of food-based biofuels and non-food biofuels consumed in the state over the lifetime of the California LCFS is illustrated in Figure 2 below; food-based biofuel consumption has stabilized at approximately 1.1 billion GGE. Within the gasoline pool, liquid fuel compliance is generated largely through corn ethanol up to the ethanol blend wall of approximately 10%.[17] Though ethanol supplied approximately 42% of California's alternative fuel mix (on a GGE basis) in 2020, it only generated approximately 25% of the LCFS credits, with both shares decreasing steadily year-over-year. We note that though food-based biofuels dominate the gasoline pool, diesel pool compliance in California has been dominated by the use of waste fats, oils, and greases, which we discuss in the subsequent section.

12 Stephanie Searle, *How rapeseed and soy biodiesel drive oil palm expansion*, (Washington, DC: ICCT, 2017), https://theicct.org/wp-content/uploads/2021/06/Oil-palm-expansion_ICCT-Briefing_27072017_vF.pdf

13 Notably, only palm oil has a sufficiently high indirect land-use change score to put palm oil-derived fuels above the carbon intensity baseline; California Air Resources Board (CARB), "Detailed Analysis for Indirect Land Use Change," 2015, https://ww2.arb.ca.gov/sites/default/files/classic/fuels/lcfs/iluc_assessment/iluc_analysis.pdf.

14 Greenhouse Gas Reduction (Renewable and Low Carbon Fuel Requirements) Act: Renewable and Low Carbon Fuel Requirements Regulation, Pub. L. No. O.C. 907/2008, B.C. Reg. 394/2008 https://www.bclaws.gov.bc.ca/civix/document/id/complete/statreg/394_2008.

15 CARD Research: "Biorenewables Policy—Historical Ethanol Operating Margins," (accessed January 8, 2022), https://www.card.iastate.edu/research/biorenewables/tools/hist_eth_gm.aspx.

16 Adam Brown, Lars Waldheim, Ingvar Landalv, Jack Saddler, Mahmood Ebadian, James Mcmillan, Antonio Bonomi, and Bruno Klein, "Advanced Biofuels – Potential for Cost Reduction," IEA Bioenergy, 2020), https://www.ieabioenergy.com/wp-content/uploads/2020/02/T41_CostReductionBiofuels-11_02_19-final.pdf

17 California Air Resources Board (CARB), "LCFS Data Dashboard," (2020), https://ww3.arb.ca.gov/fuels/lcfs/dashboard/dashboard.htm

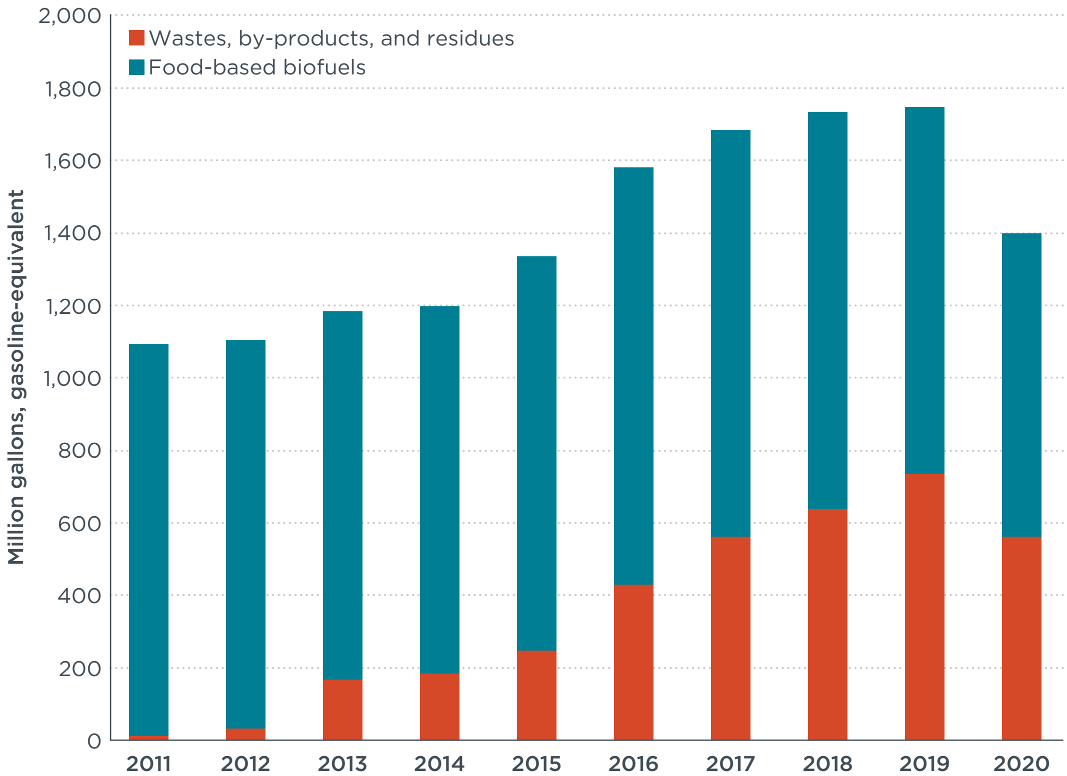

Figure 2. Comparison of food-based vs. other biofuel volumes consumed in California, 2011-2020

Due to blending constraints on ethanol, one of the primary methods used to generate LCFS credits in California and other LCFS jurisdictions has been the increasing reliance over the last five years on drop-in renewable diesel produced by hydrotreating vegetable or waste oils.[18] While there are limits to how much ethanol and biodiesel can be blended into gasoline and diesel fuel, respectively, renewable diesel can be blended into diesel with essentially no limit. The bulk of growth in the non-food biofuel consumption in California in the last five years, illustrated by the blue bar in Figure 2, has been through the increased consumption of waste oil derived hydrotreated renewable diesel. However, cheaper and more available soybean oil may soon outpace the contribution of more desirable, lower-carbon waste oils. One modeling analysis of the California LCFS finds that in the absence of rapid electrification, LCFS targets will necessitate a substantial increase in drop-in renewable diesel production, with soybean oil becoming the primary source of diesel as the diesel blend rate exceeds 50% by 2030.[19] These projections align with the large expansion in renewable diesel capacity geared towards the California market, with another 5 billion gallons of capacity either under construction or planned to reach the market by 2024. This substantial increase in capacity will likely greatly outpace the availability of waste oils and necessitate an increase in soy oil consumption in California.[20]

18 California Air Resources Board (CARB), "LCFS Data Dashboard."

19 James Bushnell, Daniel Mazzone, Aaron Smith, and Julie Witcover, "Uncertainty, Innovation, and Infrastructure Credits: Outlook for the Low Carbon Fuel Standard Through 2030," (UC Institute of Transportation Studies, 2020), https://doi.org/10.7922/G2XD0ZXH.

20 Chris Malins and Cato Sandford, *Animal, vegetable or mineral (oil)? Exploring the potential impacts of new renewable diesel capacity on oil and fat markets in the United States*, (Washington DC: ICCT, 2022). https://theicct.org/publication/impact-renewable-diesel-us-jan22/

At the national-scale, increased demand for oilseeds to meet renewable diesel demand would have even larger impacts. An economic modeling analysis developed by Pavlenko et al. (2022) finds that a national LCFS policy may significantly increase the demand for food-based biofuels.[21] Assuming similar life-cycle emission factors for biofuels as in the California LCFS, and a targeted reduction of the road sector fuel GHG intensity of 20% below 2020 levels by 2035, the authors estimated that food-based biofuel consumption would increase by 67% nationwide (approximately 8 billion GGE), primarily driven by the increase in drop-in renewable diesel produced from soy. This would greatly exceed existing domestic soy oil production, necessitating a mix of land conversion, increased imports of virgin vegetable oils, and diversion of soybean oil from other existing uses.[22]

There are several options to mitigate the sustainability risks posed by food-based biofuels; policymakers may choose to cap their contribution or exclude them entirely. Recognizing that there is inherent uncertainty with estimating the ILUC emissions associated with biofuels, an LCFS may be paired with a GHG reduction threshold for eligibility. This approach is similar to the categorization of biofuels within the RFS; here, biofuels would need to provide a minimum GHG reduction relative to fossil fuels in order to be eligible for an LCFS. The higher the threshold, the greater certainty that the fuel is generating emissions reductions relative to conventional fossil fuels. Several fuels policies utilize this approach; for example, the European Union requires alternative fuels to generate between 50% and 65% GHG reductions relative to fossil fuel to qualify for the Renewable Energy Directive (RED II).[23] In contrast, the International Civil Aviation Organization's Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) uses only a 10% eligibility threshold for alternative aviation fuels to qualify to generate GHG reductions.[24] The proposed "Sustainable Aviation Fuel Act" in the U.S. House utilizes a 50% GHG reduction threshold to determine fuel eligibility for an aviation-sector LCFS.[25] A 50% GHG reduction threshold on a fuel's combined direct and indirect emissions, when applied to the pathways eligible in the California LCFS, would exclude all food-based biofuels from eligibility, absent further process improvements such as carbon capture and sequestration at biorefineries.

Policymakers may also directly limit the contribution of food-based biofuels to policy targets through an explicit cap or ban. For example, in the European Commission's "Fit for 55" proposal to revise the Renewable Energy Directive (RED II), the policy would transition to a GHG intensity standard, but will maintain an energy-based cap on the contribution of food and feed-based biofuels at a maximum of 7% of transport

21 Nikita Pavlenko, Stephanie Searle, and Adam Christensen, *Opportunities and risks for a national low-carbon fuel standard*, (Washington, DC: ICCT, 2022)

22 Malins and Sandford, "Animal, vegetable or mineral (oil)? Exploring the potential impacts of new renewable diesel capacity on oil and fat markets in the United States."

23 Directive 2009/30/EC of the European Parliament and of the Council of 23 April 2009 amending Directive 98/70/EC as regards the specification of petrol, diesel and gas-oil and introducing a mechanism to monitor and reduce greenhouse gas emissions and amending Council Directive 1999/32/EC as regards the specification of fuel used by inland waterway vessels and repealing Directive 93/12/EEC (Text with EEA relevance, Pub. L. No. Directive 2009/30/EC, OJ L 140, 5.6.2009 88 (2009).

24 International Civil Aviation Organization (ICAO), "CORSIA Eligible Fuels – Life Cycle Assessment Methodology [CORSIA Supporting Document]," (2019), https://www.icao.int/environmental-protection/CORSIA/Documents/CORSIA%20Supporting%20Document_CORSIA%20Eligible%20Fuels_LCA%20Methodology.pdf

25 "Brownley Introduces 'Sustainable Aviation Fuel Act' to Reduce Carbon Emissions," (2021, February 3). Office of Congresswoman Julia Brownley. https://juliabrownley.house.gov/brownley-introduces-sustainable-aviation-fuel-act-to-reduce-carbon-emissions/

energy.[26] Furthermore, the EU will phase out “High-ILUC risk” palm oil’s contribution towards the RED II entirely by 2030.[27] A cap on food-based biofuels in a national LCFS could be based on either the quantity of energy or the quantity of credits supplied by these fuels. An energy-based cap may, for example, cap the contribution of food-based biofuels at the level in a baseline year. In the U.S., the contribution of food-based biofuels could be capped based on their consumption in the year of LCFS implementation to facilitate a smoother transition from the RFS. A National LCFS capping food-based biofuels at 2020 consumption levels would limit their energy contribution at 12 billion GGE, though there would be flexibility in which feedstocks and pathways contribute to that target.[28] This method would require a separate method to track LCFS compliance, necessitating bookkeeping and enforcement of fuel volumes in addition to credit generation. In contrast, a simpler approach could be to cap the contribution of credits from food-based biofuels at their initial level during the implementation of the LCFS program; Though a cap on credits is simpler to implement, it would dilute one of the benefits of LCFS design by reducing the incentive for food-based biofuel producers to reduce their own production emissions; in contrast, an energy-based cap would preserve the incentive for those producers to improve their production and support innovation within the food-based biofuel cap. Either of these approaches could be implemented by introducing a parallel LCFS credit market for credits from food-based biofuels, with the quantity of credits fixed, or more flexible and adjusted based on the cap on fuel volumes from the category.

Either of these options, a 50% GHG reduction threshold or a cap on food-based biofuels, would be an effective measure to direct policy support from a national LCFS towards cellulosic biofuels and other second-generation pathways compatible with the long-term deep decarbonization necessary for the U.S. transport sector.

MAINTAINING THE USE OF WASTE OILS AT SUSTAINABLE LEVELS

A key outcome of the California LCFS has been the rapid expansion of the production of drop-in renewable diesel made from waste oils. Waste oils have quickly grown to become the largest source of LCFS credits over the last 5 years. These fuels are one of the most cost-effective compliance pathways in the program because they offer low GHG emissions and can be produced relatively cheaply using existing first-generation biofuel conversion processes, such as those used to convert soy and canola oil. Existing petroleum refineries can even be retrofitted to process lipids (including both waste oils and virgin vegetable oils) at high capacities.

Though the use of waste oils in California’s LCFS has largely been viewed as a success story for supplying low-carbon fuels, these fuels pose long-term issues for sustainability and scalability at the national level. Domestic supplies of waste oils are highly constrained and their supply will increase slowly, if at all; a recent analysis estimates that by 2030, the domestic availability of waste FOGs will only reach approximately 700 million GGE, compared to the 4.5 billion GGE of additional

26 Proposal for a Directive of the European Parliament of the Council amending Directive (EU) 2018/2001 of the European Parliament and of the Council, Regulation (EU) 2018/1999 of the European Parliament and of the Council and Directive 98/70/EC of the European Parliament and of the Council as regards the promotion of energy from renewable sources, and repealing Council Directive (EU) 2015/652. 2021/0218 (COD).

27 Commission Delegated Regulation of (EU) 2019/807 13 March 2019 supplementing Directive (EU) 2018/2001 of the European Parliament and of the Council as regards the determination of high indirect land-use change-risk feedstock for which a significant expansion of the production area into land with high carbon stock is observed and the certification of low indirect land-use change-risk biofuels, bioliquids and biomass fuels

28 U.S. Environmental Protection Agency (EPA), Public Data for the Renewable Fuel Standard [Data and Tools], https://www.epa.gov/fuels-registration-reporting-and-compliance-help/public-data-renewable-fuel-standard

renewable diesel capacity that has been announced will be built by 2024.[29] Much of this domestic availability is already being utilized to supply California's state-level LCFS, which used approximately 500 million GGE of waste FOGs to produce renewable diesel in 2019, as shown in the growth of the yellow bars in Figure 3 below. Steep competition for limited waste FOGs has led some obligated parties in California to suggest that domestic supplies are nearly fully utilized.[30]

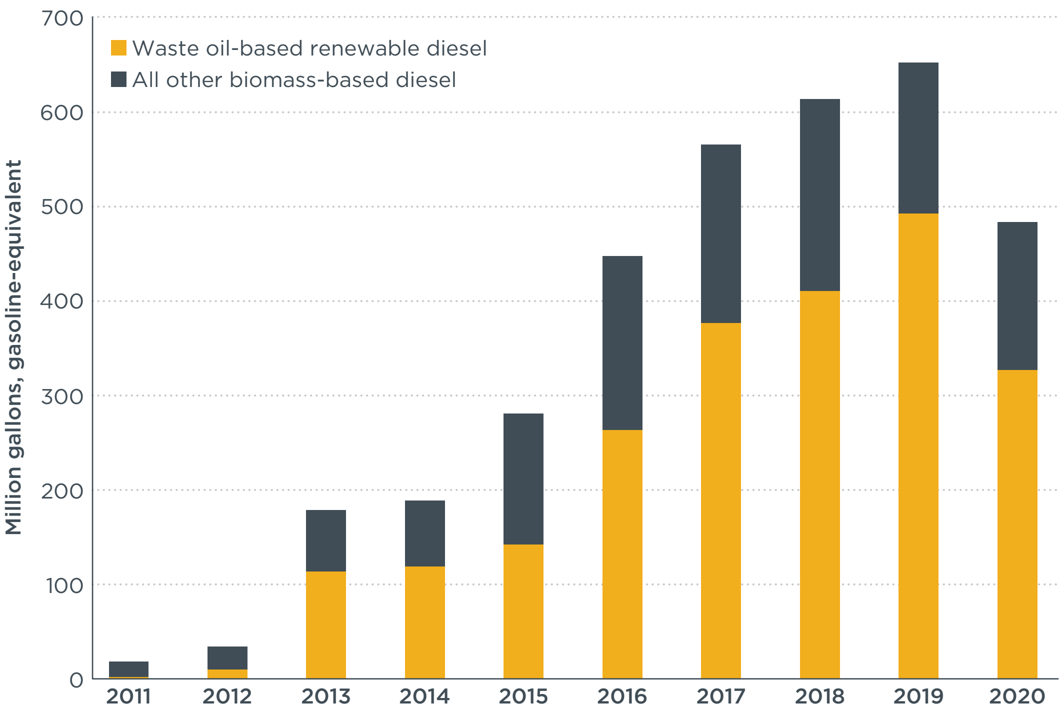

Figure 3. Consumption of renewable diesel made from waste fats, oils, and greases vs. all other biomass-based diesel in California, 2011-2020

An important risk associated with the implementation of a National LCFS is whether it would promote the use of waste oils at higher levels and exceed the sustainable availability of these feedstocks. As seen in California and the EU, the high policy value of waste FOGs has incentivized imports from abroad—approximately 60% of U.S. biofuel imports consist of waste oil-derived renewable diesel imported from Singapore.[31] Scaling up the LCFS from California to meet nationwide demand for waste oils may increase the pressure to import waste oils from abroad even further, particularly as domestic availability reaches its limits. A recent estimate of used cooking supply in major Asian markets suggests approximately 8 million tonnes of theoretical potential collection (relative to 2020 consumption), with an increasing share dedicated to those countries' domestic use.[32] Competition for foreign waste oils is

29 Yuanrong Zhou, Chelsea Baldino, and Stephanie Searle, *Potential biomass-based diesel production in the United States by 2032*, (Washington, DC: ICCT, 2020), https://theicct.org/publications/potential-biomass-based-diesel-production-united-states-2032

30 Laura Sanicola, "Used cooking oil, a renewable fuels feedstock, nearly 'tapped out' in U.S. -Valero," *Reuters*, April 22, 2021, https://www.reuters.com/business/energy/used-cooking-oil-renewable-fuels-feedstock-nearly-tapped-out-us-valero-2021-04-22/

31 "U.S. imports of biomass-based diesel increased 12% in 2020—Today in Energy," U.S. Energy Information Administration (EIA), May 4, 2021, https://www.eia.gov/todayinenergy/detail.php?id=47816

32 Tenny Kristiana, Chelsea Baldino, and Stephanie Searle. S. *An Estimate of current collection and potential collection of used cooking oil from major Asian exporting countries*, (Washington, DC: ICCT, in press)

expected to increase substantially as other jurisdictions implement their own biofuel policies and scale back their exports.[33]

As strong demand for waste oils collides with global supply constraints, the threat of fraud increases. Renewable diesel produced from waste oils is impossible to distinguish from renewable diesel produced from unsustainable sources such as virgin palm oil, so ensuring the integrity of waste oils would require extensive monitoring and verification.[34] Because waste oils tend to be collected from many different sources such as restaurants, verifying every claimed waste oil source may never be possible. The high policy value of waste oils in the EU has generated several documented cases of fraud, wherein virgin vegetable oil was claimed to be used cooking oil.[35] An economic modeling analysis of a national-level LCFS estimates that in all scenarios without an explicit cap, the demand for waste oils would increase substantially, vastly exceeding likely global availability and greatly increasing the risk of fraud.[36] The authors also find that a combined food and waste oil cap would still result in increased waste oil imports at high levels in excess of 1 billion GGE; therefore, they recommend a separate, explicit cap on waste oils.

Limiting the risks of waste oils in a national LCFS may require changes to the current technology-neutral LCFS approach used in jurisdictions such as California and Oregon. To mitigate against the risk of feedstock diversion and fraudulent imports, policymakers may opt to cap the contribution of waste oils towards overall LCFS compliance, either on an energy basis or volume basis. This would balance the benefits of crediting existing waste oil pathways with low GHG emissions while also protecting against the risks posed by further expansion and imports. This approach is again precedented in the EU RED II, where the contribution of waste oils and inedible animal fats is limited to 1.7% of transport energy.[37] As with the cap on food-based biofuels discussed above, an energy-based cap provides greater flexibility within the waste oil pool to achieve further GHG reductions through process efficiency, though it would require tracking and enforcing the energy contribution of waste oils separately from the program's GHG target. In contrast, capping the contribution of waste oils' total credit generation could be simpler to implement but would reduce the incentive to further improve the efficiency of existing waste oil conversion. As with food-based biofuels, either of these approaches could implemented by introducing a parallel credit market for waste oil biofuels, operating with either a fixed volume of credits or a more flexible approach based on the capped volume of fuels supplied.

33 GreenEA, "Horizon 2030: Which investments will see the light in the biofuel industry?" (2021), https://www.greenea.com/wp-content/uploads/2021/01/Greenea-Horizon-2030-Which-investments-will-see-the-light-in-the-biofuel-industry-1.pdf

34 Anouk van Grinsven, Emiel van den Toorn, Reinier van der Veen, and Bettina Kampman, *Used Cooking Oil (UCO) as biofuel feedstock in the EU*. (CE Delft, 2020), https://www.transportenvironment.org/sites/te/files/publications/CE_Delft__200247_UCO_as_biofuel_feedstock_in_EU_FINAL%20-%20v5_0.pdf

35 Court of Rotterdam. (2020). Kort geding, opheffing conservatoir beslag op inhoud 39 containers biobrandstof tegen zekerheidsstelling. ECLI: NL: RBROT: 2020: 11063. https://uitspraken.rechtspraak.nl/inziendocument?id=ECLI:NL:RBROT:2020:11063; European Anti-Fraud Office. (2019). The OLAF Report. https://ec.europa.eu/anti-fraud/system/files/2021-09/olaf_report_2019_en.pdf

36 Pavlenko, Searle, and Christensen, " Opportunities and risks for a national low-carbon fuel standard."

37 Directive 2009/30/EC of the European Parliament and of the Council of 23 April 2009 amending Directive 98/70/EC as regards the specification of petrol, diesel and gas-oil and introducing a mechanism to monitor and reduce greenhouse gas emissions and amending Council Directive 1999/32/EC as regards the specification of fuel used by inland waterway vessels and repealing Directive 93/12/EEC (Text with EEA relevance, Pub. L. No. Directive 2009/30/EC, OJ L 140, 5.6.2009 88 (2009).

PROMOTING SECOND-GENERATION BIOFUELS

An important drawback to LCFS policy design is that its market-based credit trading system and flexible, technology-neutral compliance both weaken the incentive to invest in riskier, second-generation fuel technologies. Credit values in an LCFS can fluctuate significantly over the course of its lifetime based on not only the difficulty of achieving it, but also outside factors such as political uncertainty. Though second-generation biofuels, such as those using cellulosic feedstocks such as agricultural residues, have much lower life-cycle GHG emissions than food-based biofuels, these fuels may be more expensive and technically challenging to produce. Investors may view these more capital-intensive projects with skepticism, as the timeline and market value of their credit generation is uncertain and the finished fuel may not have a guaranteed market.[38] The summary paper from UC Davis's National LCFS project notes that the market failures in the transportation fuels sector are strong and varied, including R&D underinvestment, weak long-term price signals, and uncertain markets for new technologies; an LCFS is unlikely to address all of these problems at once. Therefore, complementary policies are necessary to maximize the benefits of an LCFS and bring second-generation fuels into the market.

Though second-generation biofuels can theoretically generate high credit value under the California LCFS, relatively low volumes have thus far entered the market; this is particularly striking given that LCFS credits may be combined with RFS credits for compliance at the federal level, increasing the effective value of these fuels. For example, cellulosic ethanol may generate approximately $1.50 per GGE from the LCFS credits alone. In conjunction with the value of RFS compliance and other tax credits at the federal level, this is on par with the policy support for waste FOG renewable diesel and greatly exceeds the policy value of food-based biofuels as illustrated in Figure 4 below. The total theoretical policy value for cellulosic ethanol, estimated at around $4.50 per GGE on top of the value of the fuel itself, compares favorably to techno-economic assessments that estimate the production cost of cellulosic ethanol at approximately $4.00 to $6.00 per GGE.[39] Despite this high theoretical value, however, other market barriers such as policy uncertainty and low risk tolerance by investors steer compliance towards cheaper, existing biofuel pathways. Cellulosic ethanol therefore only provided approximately 6.5 million GGE's of liquid fuels nationwide in 2019, compared to nearly 500 million GGE of waste FOG renewable diesel in California alone.[40]

38 Nikita Pavlenko, Stephanie Searle, and Brett Nelson, *A comparison of contracts for difference versus traditional financing schemes to support ultralow-carbon fuel production in California*, (Washington, DC: ICCT, 2017), https://theicct.org/publication/a-comparison-of-contracts-for-difference-versus-traditional-financing-schemes-to-support-ultralow-carbon-fuel-production-in-california/

39 Brown, Waldheim, Landalv, Saddler, Ebadian, Mcmillan, Bonomi, and Klein, *Advanced Biofuels – Potential for Cost Reduction*.

40 U.S. Environmental Protection Agency (EPA), Public Data for the Renewable Fuel Standard [Data and Tools], https://www.epa.gov/fuels-registration-reporting-and-compliance-help/public-data-renewable-fuel-standard

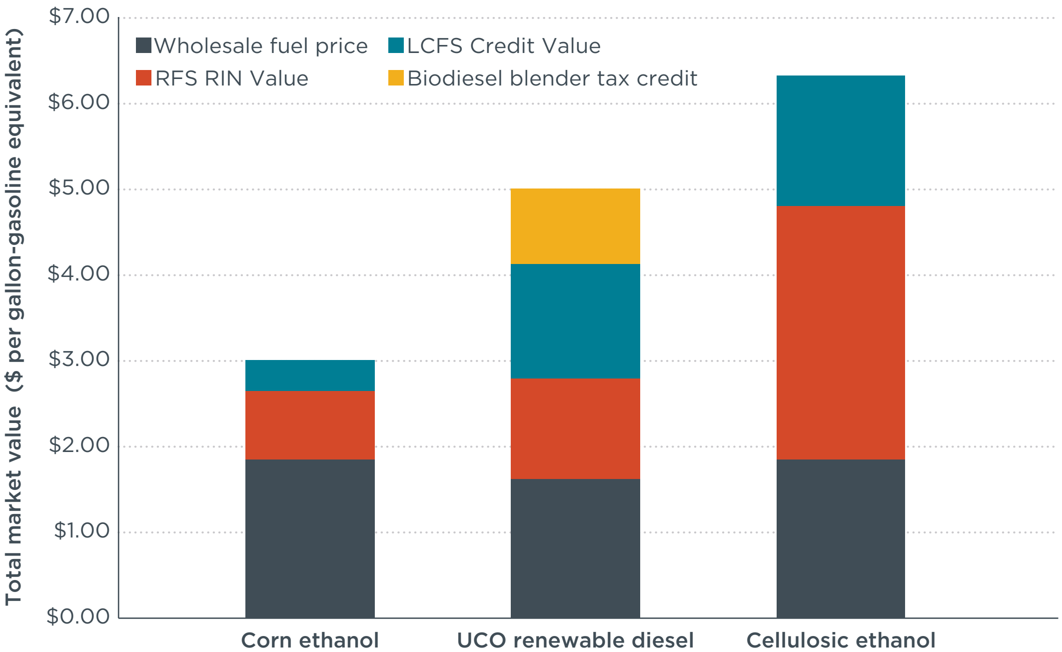

Figure 4. Comparison of market value for cellulosic ethanol to UCO-based renewable diesel and corn ethanol. Assumes an LCFS credit value of $200/tonne and life-cycle GHG reductions of 25%, 75%, and 75% for corn ethanol, UCO renewable diesel, and cellulosic ethanol, respectively. Assumes a $1/gallon biodiesel blender's tax credit. RIN values are based on a five-year average of RIN trading data collected by EPA, Wholesale fuel prices are based on the 2017-2021 spot price average for reformulated gasoline and ultralow-sulfur diesel sold in Los Angeles, collected by EIA.

The analysis presented in Pavlenko et al. (2022) suggests that if a national LCFS were implemented based on existing, state-level LCFS programs, it would follow largely the same trajectory as those policies and incentivize a greater quantity of food-based biofuels and drop-in renewable diesel made from waste FOGs. However, the authors estimate that in scenarios with caps on the contribution of waste FOGs and food-based biofuels, greater quantities of second-generation biofuels are supplied; in a scenario with separate caps on waste FOGs and food-based biofuels, the share of second-generation biofuels rose to provide nearly 40% of the liquid alternative fuels supplied.[41] This suggests that by capping the contribution of the cheaper but riskier pathways, there is a reduced risk of first-generation pathways crowding out investment and greater market certainty for second-generation biofuels.

Targeted support for second-generation biofuels within a national LCFS may be another option to directly address the perception of risk associated with these pathways. A staff review of the California LCFS in 2011 notes that, if the development of ultralow-carbon fuels does not reach sufficient volumes under the current structure of the program, "special provisions in the regulation may aid in their development".[42] This may take the form of a sub-target within the policy, which is essentially the opposite of the caps for the riskier biofuel pathways discussed above. In this case, either an energy-based or credit target for the contribution of a subset of feedstocks or pathways would be mandated within the broader GHG reduction target of the

41 *Opportunities and risks for a national low-carbon fuel standard*

42 R. Corey, M. Buffington, and L. Hatton, "Low Carbon Fuel Standard 2011 Program Review Report") California Air Resources Board, 2011).

LCFS. For example, within the proposed GHG intensity standard for transport fuels in the RED II, the European Commission has proposed that 2.2% of transport energy supply come from a limited set of non-food, non-feed cellulosic feedstocks by 2030.[43] Developing this sub-target should be done with care, taking into account both the sustainable availability of domestic feedstocks for second-generation biofuels and the time necessary to construct facilities and scale up the industry. The combination of a stable, long-term target with intermediate sub-targets would provide greater market certainty for second-generation biofuel producers and reduce investment risk.

The uncertainty of future credit values in an LCFS may be another difficult barrier to the deployment of second-generation biofuels, whose facility lifetimes can span 10 or even 15 years. Complementary policies that reduce this uncertainty and directly mitigate risk could help to leverage the value of an LCFS and promote more challenging technologies. A "contracts for difference" program, in which selected fuel producers enter into a contract with the auctioning body or government for a fixed quantity of fuel produced over a set period of time, ideally at least 10 years to reduce policy uncertainty that locks in an agreed-upon price floor (i.e., the strike price). This price floor can be established through a competitive reverse auction wherein second-generation fuel producers compete to see which ones can offer the lowest price. Over the lifetime of the contract, the governing body would only pay the producer whenever the market price drops below the price floor, taking into account all outside incentives such as tax credits and LCFS credits. This can be an extremely cost-effective mode of policy support, as it leverages the value of existing policies and only pays out when necessary for delivered fuel.[44]

POLICY RECOMMENDATIONS

To justify the complex transition and regulatory overhaul from the existing RFS to a national LCFS, the new policy should deliver deeper GHG reductions than the status quo and drive the use of second-generation and ultralow-carbon fuels. There are benefits to implementing specific GHG reduction targets and incentivizing alternative fuels proportionally to their GHG savings; however, the technology-neutral structure of an LCFS also risks increasing the demand for unsustainable, food-based biofuels and waste FOGs that can be produced more cheaply than second-generation biofuels; these problems would be exacerbated if a national level LCFS is based strictly on existing state-level policies. The integrity and effectiveness of a national LCFS could be improved by drawing upon the experience at the state level and implementing the following design changes at the federal level:

» **Cap the contribution of food-based biofuels at 2020 consumption levels.** Though most food-based biofuels have higher life-cycle emissions than second-generation biofuels, the structure of an LCFS would largely incentivize the blending of cheaper, existing commercialized fuel pathways at higher volumes rather than support the blending of more expensive lower-carbon, second-generation biofuels at lower volumes. An energy-based cap on the contribution of food-based biofuels towards the overall GHG target of an LCFS set at 2020 consumption levels of approximately

43 Proposal for a Directive of the European Parliament of the Council amending Directive (EU) 2018/2001 of the European Parliament and of the Council, Regulation (EU) 2018/1999 of the European Parliament and of the Council and Directive 98/70/EC of the European Parliament and of the Council as regards the promotion of energy from renewable sources, and repealing Council Directive (EU) 2015/652. 2021/0218 (COD).

44 Pavlenko, Searle, and Nelson, *A comparison of contracts for difference versus traditional financing schemes to support ultralow-carbon fuel production in California*.

12 million GGE would maintain the incentive to reduce emissions from existing biofuel production and generate more credits. At the same time, it would reduce the risk associated with further food-based biofuel demand and reduce the risk of crowding out second-generation biofuel producers.

» **Implement a GHG intensity reduction threshold compared to fossil fuels of 50% for eligibility.** Estimates of ILUC emissions associated with food-based biofuels continue to remain a significant area of uncertainty. The GHG reductions of a biofuel pathway with a GHG intensity close to that of petroleum will have uncertain climate benefits. To mitigate against this risk, we recommend an eligibility requirement of a 50% GHG reduction threshold based on the sum of a fuel's direct and indirect emissions to qualify for an LCFS. This would exclude some more marginal pathways from eligibility and provide greater certainty that fuels generating credits are providing genuine GHG reductions.

» **Introduce a separate, energy-based cap on the contribution of waste oil-derived biofuels based on their domestic availability.** In the absence of an explicit cap on waste oils, an LCFS risks increasing consumption of these feedstocks far beyond their domestic availability and would likely drive a massive increase in the import of waste FOGs to meet policy targets. Depending on the policy target, an LCFS could increase demand beyond even the availability of waste oils in foreign markets and greatly raise the risk of waste oil fraud. Fraudulent palm oil imports with high deforestation risk could both undermine the integrity of the program and generate significant indirect emissions to reduce its GHG savings. A separate, energy-based cap on the contribution of waste oils, based on domestic waste oil availability, would credit existing producers using low-carbon feedstocks while also limiting additional demand that could further stress feedstock availability or promote fraud.

» **Introduce complementary incentives for second-generation biofuels.** In the RFS and existing state-level LCFS's, the production of first-generation biofuels greatly outpaces the growth of the second-generation biofuel industry, even with high credit prices. This suggests that the technology-neutral structure of an LCFS does not necessarily support the transition to emerging technologies, largely because these fuels are perceived as riskier for investors compared to cheaper fuels produced using existing technologies. To combat this perception of risk, an energy-based sub-target or complementary incentives such as contracts for difference could help to provide a long-term signal for demand for second-generation biofuels and reduce policy uncertainty compared to a pure performance standard. This would help to get these more challenging pathways into the fuel mix, particularly in the early years of the program where they are at a cost disadvantage.