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Life Cycle Analysis and Transportation Energy

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INTRODUCTION

As government actors and the private sector attempt to decarbonize the economy, the role of life cycle analysis (also known as life cycle assessment or LCA) has become increasingly important. Life cycle analysis is an evaluation of the environmental impacts of a product, process, or activity throughout its life cycle (i.e., the impacts associated with the extraction of raw materials used to produce the product as well as the impacts associated with the product's processing, transport, use, and disposal).[1] This article explores the use of life cycle analysis in the transportation sector to assess its influence in federal and state policy efforts to move toward a low-carbon energy future.

In the case of transportation fuels—whether petroleum, ethanol, or another source—life cycle emissions include the emissions associated with producing, transporting, consuming, and disposing of the fuel. For instance, for corn ethanol, which constitutes a large component of every gallon of gasoline sold today, the life cycle analysis includes a calculation of the carbon emissions associated with the land-use changes necessary to convert grassland or forest land to corn crop, the source of electricity used to convert corn to ethanol, the emissions associated with transporting the fuel to markets, and the tailpipe emissions themselves. As the United States Environmental Protection Agency (EPA) and state governments attempt to calculate life cycle emissions of ethanol and other fuels, they are rethinking long-held assumptions about the environmental

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1 *See infra* note 3 (defining life cycle analysis).

benefits of such fuels and whether longstanding government mandates to use such fuel are wise.

Policymakers and scientists also use life cycle analysis to consider the full impact of the vehicles beyond the implications of their fuel efficiency. As federal and state governments create incentives to promote a large-scale transition to electric vehicles (EVs), questions arise as to whether such vehicles always provide the answer to a low-carbon future. Once these experts apply life cycle analysis to vehicles, the source of electricity used to power EVs and the waste disposal issues associated with EV batteries will cause some to question the "no carbon" promise of such vehicles. Life cycle analysis also highlights the regional nature of electricity resources, showing EVs to be environmentally friendly in states that use little or no coal to generate electricity and less so in coal-heavy states.

Part I defines life cycle analysis and explains its use in evaluating the environmental impacts of all stages of a product, from production, to use, to disposal. Part II reviews the use of life cycle analysis in considering the carbon emissions associated with different types of biofuels, primarily ethanol—which now makes up 10% of nearly every gallon of gasoline sold in the United States as a result of federal mandates.[2] This evaluation shows that life cycle analysis for ethanol has undermined many of the basic premises federal policymakers relied upon to enact significant mandates and, for many years, major tax benefits, to promote the production and use of ethanol for transportation fuel. Part III discusses the increasing application of life cycle analysis to EVs, which compares the greenhouse gas (GHG) emissions associated with the production, use, and disposal of EVs with conventional automobiles, and evaluates the source of electricity used to power EVs in different parts of the country. Not surprisingly, the life cycle GHG emissions associated with an EV driven in California, where electricity is generated primarily by natural gas and renewable energy, are far lower than the GHG emissions associated with an EV driven in West Virginia, which relies almost exclusively on coal-fired electricity.

This article concludes by reflecting on the ways life cycle analysis can be used effectively to guide policymakers to incentivize the development of environmentally beneficial products and technologies. For instance, if today's life cycle analysis had been used to evaluate corn ethanol in the 1990s and

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[2] *See Almost All U.S. Gasoline Is Blended with 10% Ethanol*, U.S. ENERGY INFO. ADMIN. (May 4, 2016), http://www.eia.gov/todayinenergy/detail.php?id=26092 [https://perma.cc/36EG-TC3U]; *infra notes* 68–69 and accompanying text.

early 2000s, policymakers may have paused before creating the significant incentives and mandates that exist today and that are now very difficult to eliminate. At the same time, however, there are risks in relying too heavily on life cycle analysis when information gaps exist in comparing alternative fuels and vehicles with traditional fuels and vehicles. Such information gaps may result in creating disincentives for potentially beneficial new products and technologies that, with sufficient support, may be critical to meeting decarbonization goals in the transportation sector and the economy as a whole.

I. DEFINING LIFE CYCLE ANALYSIS

Life cycle analysis, also known as life cycle assessment, is a tool that scientists and policymakers use to assess the environmental impacts of a product, process, or activity throughout its life cycle—from the extraction of raw materials to its processing, transport, use, and disposal. In its early days, experts used life cycle analysis for product comparisons—for example, to compare the environmental impacts of disposable and reusable products. Today, its applications cover a broad span of subject areas: government policy, strategic planning, marketing, consumer education, process improvement, and product design.[3] Within this broad field, a variety of types and methods of life cycle analyses exist.[4] One type of life cycle analysis—attributional life cycle analysis—seeks to determine what portion of total human environmental impact can be traced to a particular product.[5] Another type of analysis—consequential life cycle analysis—asks how total human environmental impact changes as a result of producing and

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[3] *See Defining Life Cycle Assessment*, GLOB. DEV. RESEARCH CTR., http://www.gdrc.org/uem/lca/lca-define.html [https://perma.cc/P5SG-SAMW]; *see also* Jason Hill, *Life Cycle Analysis of Biofuels*, *in* 4 ENCYCLOPEDIA OF BIODIVERSITY 627 (2013); Robert G. Hunt & William E. Franklin, *LCA—How It Came About*, 1 INT'L J. LIFE CYCLE ASSESSMENT 4 (1996); NAT'L RISK MGMT. & RESEARCH LAB., EPA, LIFE CYCLE ASSESSMENT: PRINCIPLES AND PRACTICE 1 (2006) (Life Cycle Assessment is "the estimation of the cumulative environmental impacts resulting from all stages in the product life cycle . . . . a comprehensive view of the environmental aspects of the product . . . and a more accurate picture of the true environmental trade-offs in product and process selection."); *Life Cycle Assessment*, UNITED NATIONS ENV'T PROGRAMME, http://www.unep.org/resourceefficiency/Consumption/StandardsandLabels/MeasuringSustainability/LifeCycleAssessment/tabid/101348/Default.aspx; *Tool: Life Cycle Assessment (LCA)*, SD PLAN NET, http://www.sdplannet-ap.org/Pages/tool-lca.aspx [https://perma.cc/PF5C-LJ5E] ("Life Cycle Assessment (LCA) is a tool for the systematic evaluation of the environmental aspects of a product or service system through all stages of its life cycle.").

[4] *See* KEVIN R. CAFFREY & MARI S. CHINN, N.C. COOP. EXTENSION SERV., LIFE CYCLE ASSESSMENT (LCA): DESCRIPTION AND METHODOLOGY 3–4, https://content.ces.ncsu.edu/life-cycle-assessment-description-and-methodology [https://perma.cc/M9HX-PW55].

[5] Hill, *supra* note 3, at 627.

using that product.[6] Consequential life cycle analysis is of primary interest in this article, as it can address large-scale transportation policy decisions seeking to reduce total human environmental impact.[7]

The U.S. EPA is a major proponent of life cycle analysis,[8] encouraging its use both through direct partnership with other research entities[9] and independently.[10] In the policy sector, at both the federal and state levels, lawmakers and regulators increasingly use consequential life cycle analysis in the regulation of energy and biofuels with a particular emphasis on the use of energy and biofuels in transportation.[11]

In conducting a life cycle analysis, the analyst breaks the life of the studied product into various phases: the extraction phase, where raw materials are sourced and processed; the manufacturing phase, where the product is assembled; the use phase; and the disposal or recycling phase.[12] When applying a life cycle analysis to the environmental impacts of vehicles, the analysis is termed "cradle-to-grave,"[13] but for transportation fuels it is called "well-to-wheels."[14] The Argonne National Laboratory has developed a model fusing cradle-to-grave and well-to-wheels for the purposes of evaluating vehicles (both electric and standard) and transportation fuels called the Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation Model

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[6] *Id.*

[7] *See, e.g.*, Allison Weis et al., *Consequential Life Cycle Air Emissions Externalities for Plug-In Electric Vehicles in the PJM Interconnection*, 11 ENVTL. RES. LETTERS 1, 1–2 (2016) (discussing differences between attributional and consequential life cycle analyses).

[8] EPA has been at odds with the Federal Energy Regulatory Commission (FERC) over whether or not to require life cycle analysis in FERC's analysis of natural gas pipeline projects and natural gas import and export projects. *See* Jenny Mandel, *In Dispute over Climate Guidance, It's EPA vs. FERC*, NO FRACKED GAS IN MASS! (Feb. 4, 2016), http://www.nofrackedgasinmass.org/2016/02/04/in-dispute-over-climate-guidance-its-epa-vs-ferc/ [https://perma.cc/KY62-RKEB].

[9] *See, e.g.*, *Partnership to Conduct Life-Cycle Assessment for Lithium-Ion Batteries and Nanotechnology in Electric Vehicles*, EPA, http://www.epa.gov/saferchoice/partnership-conduct-life-cycle-assessment-lithium-ion-batteries-and-nanotechnology-0 [https://perma.cc/8JV2-JRBV].

[10] *See, e.g.*, *Research on Evaluating Risk Across the Life Cycle of Manufactured Chemicals, Materials, & Products*, EPA, http://www.epa.gov/chemical-research/analyzing-life-cycle-chemicals [https://perma.cc/KN3Z-AK42].

[11] Hill, *supra* note 3, at 629.

[12] *See, e.g.*, *Partnership to Conduct Life-Cycle Assessment for Lithium-Ion Batteries and Nanotechnology in Electric Vehicles*, *supra* note 9.

[13] *See* RACHAEL NEALER ET AL., UNION OF CONCERNED SCIENTISTS, CLEANER CARS FROM CRADLE TO GRAVE 1 (2015), http://www.ucsusa.org/sites/default/files/attach/2015/11/Cleaner-Cars-from-Cradle-to-Grave-full-report.pdf [https://perma.cc/S6RK-HW8T].

[14] *See* MICHAEL WANG, ARGONNE NAT'L LAB., WELL-TO-WHEELS ENERGY AND EMISSION IMPACTS OF VEHICLE/FUEL SYSTEMS (2003).

(GREET Model).[15] The GREET Model includes data on an enormous number of production pathways[16] and continuously adds and updates pathways as conditions change.[17]

The particulars of designing and conducting a life cycle analysis are technical, complex, and beyond the scope of this article.[18] Suffice to say that life cycle analysis is a laborious and data-intensive process; one in which examining the set parameters is of utmost importance to understanding a result. A life cycle analysis inquiry is theoretically infinite, as any choice could have a cascading series of results, all of which may or may not happen, and a truly exhaustive study would have to account for and quantify all of these outcomes.[19] Because of the difficulty (if not impossibility) of accounting for all possible outcomes, researchers must establish appropriate parameters at the initiation of a study and understand the limits of any results.[20] The next part explores the use of life cycle analysis in policies governing transportation fuels.

II. DEVELOPMENT OF U.S. POLICIES TO REDUCE U.S. DEPENDENCE ON GASOLINE AND TO PROMOTE THE USE OF LIFE CYCLE ANALYSIS IN THE TRANSPORTATION SECTOR

For over four decades, the United States has supported the development of alternative liquid fuels—primarily biofuels—as a substitute for gasoline in the transportation sector with the goals of achieving energy security, lowering transportation fuel prices, and reducing the harmful air emissions associated with the combustion of gasoline in vehicle engines.[21] The raw materials used to create biofuels are varied and include corn, grain, grasses, forest residues, crop residues, waste biomass, soy,

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[15] Michael Wang, Argonne Nat'l Lab., Overview of Life-Cycle Analysis with the GREET Model slide 2 (Dec. 7–8, 2011) (PowerPoint Presentation for the GREET Training Workshop).

[16] *Id.* at slides 10–15. Production pathways, in the GREET system, are the various methods by which a primary resource (e.g., natural gas) is transformed into a secondary product (e.g., liquefied natural gas, compressed natural gas, etc.). *Id.* at slide 10.

[17] *See Energy Systems*, ARGONNE NAT'L LAB., https://greet.es.anl.gov/index.php [https://perma.cc/VG7S-5JGY].

[18] For guidelines on constructing a life cycle analysis, see NAT'L RISK MGMT. & RESEARCH LAB., *supra* note 3. For an example of a completed life cycle analysis study, see Pierpaolo Giraldi et al., *A Comparative LCA of an Electric Vehicle and an Internal Combustion Engine Vehicle Using the Appropriate Power Mix: The Italian Case Study*, 20 INT'L J. LIFE CYCLE ASSESSMENT 1127 (2015).

[19] *See* Hill, *supra* note 3, at 627–28.

[20] *See id.* at 627.

[21] *See generally* Roland Geyer, *The Industrial Ecology of the Automobile*, *in* TAKING STOCK OF INDUSTRIAL ECOLOGY 331, 334–36 (Roland Clift & Angela Druckman eds., 2016).

sugarcane, soybean oil, vegetable oil, and recycled grease. Biofuels in the United States consist primarily of (1) ethanol, "an alcohol fuel made from the sugars found in grains like corn, sorghum, and barley," as well as in sugarcane, and is blended with gasoline for use in vehicle engines; and (2) biodiesel, "a fuel made from vegetable oils, fats, or greases" that can be blended with petroleum-based diesel for use in diesel engines.[22]

The U.S. government significantly increased its efforts to support biofuels in the mid-2000s by creating mandates for the blending of biofuels into gasoline and diesel fuel as well as implementing significant tax incentives (until 2012) for the production and use of biofuels in the transportation sector. This section discusses federal and state policies governing biofuels and transportation fuels generally, with an emphasis on the growing use of life cycle analysis in these policies.

The adoption of life cycle analysis for transportation fuels is extremely important because many of the assumptions that supported very favorable policies for biofuels are either no longer valid or were arguably incorrect from the start. First, this section focuses on the federal Renewable Fuel Standard (RFS), which, since 2007, uses a life cycle assessment to guide federal policies governing the amounts of different types of biofuels that must be blended into gasoline and diesel fuel throughout the United States. It then discusses the efforts of California and other states to use life cycle analysis to more directly lower the GHG emissions of all transportation fuels and the legal challenges to those efforts.

A. U.S. Ethanol Policy

For decades, and continuing into the early 2000s, policymakers and others expressed major concerns about the United States running out of domestic oil and gas, the nation's dependence on foreign oil, particularly from the Middle East, and the harmful air emissions associated with the combustion of gasoline in vehicle engines.[23] Ethanol, particularly corn ethanol, appeared to provide a solution to these problems. Corn was already grown in large quantities in midwestern and plains

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[22] *See Biofuels: Ethanol and Biodiesel Explained*, U.S. ENERGY INFO. ADMIN., https://www.eia.gov/energyexplained/index.cfm?page=biofuel_home [https://perma.cc/C45E-XK84].

[23] *See* Cole Gustafson, *History of Ethanol Production and Policy*, N.D. STATE UNIV., https://www.ag.ndsu.edu/energy/biofuels/energy-briefs/history-of-ethanol-production-and-policy [https://perma.cc/GA4Z-34WT]; Dan Somma et al., *Growing America's Fuel: An Analysis of Corn and Cellulosic Ethanol Feasibility in the United States*, 12 CLEAN TECHNOLOGIES & ENVTL. POL'Y 373 (2010).

states and farmers could easily grow more to supply both global food needs as well as support a new, renewable, domestic source of transportation fuels.[24] Moreover, ethanol, including corn ethanol, was seen as a more environmentally friendly fuel source than gasoline.[25] Corn, like other plants, absorbs CO_2 emissions as it grows; this offsets the emissions released when the ethanol burns.[26] Notably, ethanol releases less CO_2 than gasoline during combustion and acts as an oxygenate when mixed with gasoline; this further reduces vehicle tailpipe emissions as compared to vehicles running solely on gasoline.[27]

This narrow focus on the perceived benefits of lowered vehicle emissions from ethanol led Congress to create federal mandates for the blending of billions of gallons of ethanol (made almost exclusively from corn) into the U.S. gasoline supply beginning in 2005.[28] Congress combined this mandate with a forty-five-cent tax credit for fuel blenders for every gallon of ethanol they blended with gasoline.[29] This tax credit, known as the Volumetric Ethanol Excise Tax Credit, expired in 2012, but along with other subsidies, resulted in over $7 billion in tax credits to the ethanol production industry in 2011 and a much greater amount over the years the tax credits and subsidies remained in place.[30]

But environmental groups, the oil industry, and others began to question many of the assumptions favoring ethanol, particularly corn ethanol, soon after the enactment of these significant federal policies favoring its use. First, by the late

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[24] *See* Kris Bevill, *Building the "Minnesota Model"*, ETHANOL PRODUCER MAG. (Mar. 10, 2008), http://www.ethanolproducer.com/articles/3855/building-the-minnesota-model [https://perma.cc/9MUJ-NYJ4].

[25] Gustafson, *supra* note 23.

[26] *Ethanol Vehicle Emissions*, U.S. DEP'T OF ENERGY, http://www.afdc.energy.gov/vehicles/flexible_fuel_emissions.html [https://perma.cc/GE3G-AAHK].

[27] *See* U.S. DEP'T OF ENERGY, JUST THE BASICS: ETHANOL (2003), http://www1.eere.energy.gov/vehiclesandfuels/pdfs/basics/jtb_ethanol.pdf [https://perma.cc/3YAS-X8XD] (discussing reduced tailpipe emissions associated with ethanol as compared to those associated with gasoline and further discussing the fact that it is a renewable, domestically produced fuel that can reduce U.S. dependence on foreign oil and improve the economy).

[28] *See Renewable Fuel Standard Program*, EPA, https://www.epa.gov/renewable-fuel-standard-program [https://perma.cc/J7CJ-ANAA].

[29] *See* TAXPAYERS FOR COMMONSENSE, THE VOLUMETRIC ETHANOL EXCISE TAX CREDIT: HISTORY AND CURRENT POLICY (2011), http://www.taxpayer.net/images/uploads/downloads/2011_VEETC_Fact_Sheet_April_FINAL.pdf [https://perma.cc/DS7V-AE5Z].

[30] *See* RANDY SCHNEPF & BRENT D. YACOBUCCI, CONG. RESEARCH SERV., R40155, RENEWABLE FUEL STANDARD (RFS): OVERVIEW AND ISSUES 18 (2013); Alexandra B. Klass, *Tax Benefits, Property Rights, and Mandates: Considering the Future of Government Support for Renewable Energy*, 20 J. ENVTL. & SUSTAINABILITY L. 19, 33–35 (2013); MOLLY F. SHERLOCK & JEFFREY M. STUPAK, CONG. RESEARCH SERV., R41953, ENERGY TAX INCENTIVES: MEASURING VALUE ACROSS DIFFERENT TYPES OF ENERGY RESOURCES 1, 7, 12, 19–20 (2015).

2000s, the development of hydraulic fracturing and directional drilling technologies created a new abundance of U.S. domestic oil and gas production, which significantly reduced the energy security concerns associated with the dominant role petroleum has historically played in the transportation sector.[31] Moreover, the very large tax subsidies and mandates for ethanol had the direct consequence of subsidizing corn production, which was not without detrimental environmental and economic effects.[32] While many types of grains, grasses, and other plant materials can be used to produce ethanol, corn is the most popular feedstock for ethanol production in the United States as a result of its ready availability as well as the ease of converting it to a liquid fuel.[33] Because of the mandates on fuel blenders to use ethanol and the tax subsidies in place until 2012, farmers found it in their financial interests to devote a significant portion of their corn crops (approximately 40%) to fuel production, leading to concerns associated with higher corn prices for food and animal feed on a worldwide basis.[34] Farmers also increasingly converted grassland and forest lands to corn production, and these land-use changes reduced the number of carbon sinks and created new GHG emissions and other sources of air and water pollution associated with crop production (e.g., pesticides and fertilizers) not fully contemplated by policymakers at the time.[35]

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[31] In 2015, petroleum (gasoline, diesel, and jet fuel) made up 92% of U.S. transportation fuels, with natural gas providing only 3%, biofuels 5%, and other sources (including electricity, liquid petroleum gas, and other fuels) 3%. *Use of Energy in the United States Explained*, U.S. ENERGY INFO. ADMIN., http://www.eia.gov/EnergyExplained/?page=us_energy_transportation [https://perma.cc/PM6Y-H9L7].

[32] *See* Sarah Gonzalez, *ERS Reports 10 Percent Increase in Corn Acres During Ethanol Decade*, AGRI PULSE, http://www.agri-pulse.com/ERS_cropland_8192011.asp [https://perma.cc/SLF6-6Z7E]. There is further evidence that corn from existing cropland was increasingly devoted to ethanol production rather than production of food or livestock feed. James Conca, *It's Final—Corn Ethanol Is of No Use*, FORBES (Apr. 20, 2014), http://www.forbes.com/sites/jamesconca/2014/04/20/its-final-corn-ethanol-is-of-no-use/#6f0d62e72ca2 [https://perma.cc/NUL8-FTQ3].

[33] *Bioenergy Corn*, CROP WATCH, http://cropwatch.unl.edu/bioenergy/corn [https://perma.cc/PWY2-C5WS]; *see* SCHNEPF & YACOBUCCI, *supra* note 30, at 19; *see* CONG. BUDGET OFF., THE RENEWABLE FUEL STANDARD: ISSUES FOR 2014 AND BEYOND 1 (2014).

[34] LINCOLN L. DAVIES ET AL., ENERGY LAW AND POLICY 582–83 (2015); *see* U.S. ENERGY INFO. ADMIN., BIOFUELS ISSUES AND TRENDS 8 & tbl.2 (2012), https://www.eia.gov/biofuels/issuestrends/pdf/bit.pdf [https://perma.cc/3AZY-UNVB]; SCHNEPF & YACOBUCCI, *supra* note 30, at 18–20; Elisabeth Rosenthal, *As Biofuel Demand Grows, So Do Guatemala's Hunger Pangs*, N.Y. TIMES (Jan. 5, 2013), http://www.nytimes.com/2013/01/06/science/earth/in-fields-and-markets-guatemalans-feel-squeeze-of-biofuel-demand.html [https://perma.cc/994L-4A8L]; C. Ford Runge & Benjamin Senauer, *How Biofuels Could Starve the Poor*, 86 FOREIGN AFF. 41, 42–43 (2007).

[35] *See* SCHNEPF & YACOBUCCI, *supra* note 30, at 6 (discussing impact of indirect land-use changes on environmental effects of ethanol); NAT'L RESEARCH COUNCIL, RENEWABLE FUEL STANDARD: POTENTIAL ECONOMIC AND ENVIRONMENTAL EFFECTS OF U.S. BIOFUEL POLICY 188–95, 245–47 (2011) [hereinafter RENEWABLE FUEL STANDARD] (discussing air and water emissions associated with life cycle assessments of ethanol); *The*

Some scholars have even suggested that the mandated production of biofuels has lowered fuel prices and thus actually increased overall fuel consumption.[36]

Finally, the conversion of corn and other plant material to liquid fuel requires significant processing which, in turn, requires large amounts of electricity and thermal energy. In the midwestern and plains states, where the bulk of the nation's ethanol is produced, coal is the dominant fuel source used to produce electricity. Thus, the ethanol production process in those states generates significantly more GHG emissions and other air pollutants than ethanol produced in states that do not rely heavily on coal to generate electricity.[37] As these effects of ethanol production and use came to light, scientists, and later policymakers, attempted to incorporate life cycle analysis into the policies governing transportation fuels.[38] As described in the sections below, Congress required EPA to implement regulations to reduce the heavy reliance on corn in the production and use of biofuels in the United States, and to transition to "advanced biofuels" that emit less GHG emissions than traditional corn ethanol on a life cycle basis. As discussed below, EPA has struggled to implement these mandates because of the increasing power of the now-established biofuels industry, and the difficulty of developing the technologies necessary to produce cost-effective low-carbon biofuels on a large-scale commercial basis.

EPA Renewable Fuel Standard Mandate: Hearing Before the Subcomm. on Energy, Subcomm. on Oversight, Comm. on Sci., Space & Tech. (July 23, 2015) (statement of Jason Hill, Ph.D., Associate Professor of Bioproducts and Biosysytems Engineering, University of Minnesota), http://docs.house.gov/meetings/SY/SY20/20150723/103827/HHRG-114-SY20-Wstate-HillJ-20150723.pdf [https://perma.cc/SC4L-9RE9] (same).

[36] Jason Hill et al., *Climate Consequences of Low-Carbon Fuels: The United States Renewable Fuel Standard*, 97 ENERGY POL'Y 351, 351–53 (2016).

[37] *See* Jason Hill et al., *Climate Change and Health Costs of Air Emissions from Biofuels and Gasoline*, 106 PROC. NAT'L ACAD. SCIENCES U.S.A. 2077, 2078 (2009) ("[C]oal use at the biorefinery results in higher GHG emissions regardless of land-use change assumptions."), http://www.pnas.org/content/106/6/2077.full [https://perma.cc/LAW3-T6ZG]; *see also* Anduin Kirkbride McElroy, *Coal: A Fuel That Pays Its Way*, ETHANOL PRODUCER MAG. (June 1, 2006), http://www.ethanolproducer.com/articles/2072/coal-a-fuel-that-pays-its-way [https://perma.cc/TT7T-PMD7] (discussing use of coal as fuel for ethanol plants).

[38] Some scientists have rejected the use of life cycle analysis for ethanol and argued that land-use changes, among other factors, make it more environmentally damaging than petroleum. John M. DeCicco et al., *Carbon Balance Effects of U.S. Biofuel Production and Use*, 138 CLIMATIC CHANGE 667, 678 (2016). Other scientists have criticized this study for containing methodological flaws and a potential conflict of interest stemming from the American Petroleum Institute's funding of the work. John Upton, *Study Finds Biofuels Worse for Climate Than Gasoline*, CLIMATE CENT. (Aug. 25, 2016), http://www.climatecentral.org/news/study-biofuels-worse-for-climate-than-gasoline-20634 [https://perma.cc/AE69-HQXD].

B. *The Federal Renewable Fuel Standard and Adoption of Life Cycle Analysis*

In 2005, Congress enacted the first mandate for the use of biofuels in the transportation sector by creating the RFS in the Energy Policy Act of 2005.[39] The RFS, which the U.S. EPA administers under the Clean Air Act, mandated that a minimum of 4 billion gallons of renewable fuel be used in the nation's gasoline supply in 2006, and that this amount increase to 7.5 billion gallons by 2012.[40] Soon after, in 2007, Congress enacted the Energy Independence and Security Act (EISA), which increased those amounts significantly to require the use of 9 billion gallons of renewable fuel in 2008, increasing to 36 billion gallons in 2022, with a cap of 15 billion gallons from corn ethanol.[41]

EISA made other significant changes. EISA expanded the RFS to apply to most U.S. transportation fuels—not only gasoline but also diesel fuels used in automotive, non-road, locomotive, and marine engines.[42] EISA also required an increasing amount of the renewable fuel mandate to be met with "advanced" biofuels, which include biomass-based diesel fuel, cellulosic ethanol,[43] and other advanced biofuels produced from a variety of feedstocks other than corn starch. EISA sets different levels of required reductions of GHG emissions from these different types of fuels, each of which has a separate gallon mandate in the RFS that changes over time.[44] The following sections discuss how EPA implements the RFS and some of the current challenges facing the RFS.

1. Implementation of the RFS

To comply with the current version of the RFS, fuel producers and blenders must meet certain thresholds. To count toward the required amount of advanced biofuels and biomass-based diesel, the biofuel must have GHG reductions of 50% relative to the 2005 baseline average GHG emissions from the

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[39] Energy Policy Act of 2005, Pub. L. No. 109-58, 119 Stat. 594, 1067–68 (2005); CONG. BUDGET OFF., *supra* note 33, at 1–6 (overview of RFS).

[40] *See* SCHNEPF & YACOBUCCI, *supra* note 30, at 1.

[41] Energy Independence and Security Act of 2007, Pub. L. No. 110-140, 121 Stat. 1492, 1521–22 (2007); SCHNEPF & YACOBUCCI, *supra* note 30, at 1–5 & fig.1.

[42] SCHNEPF & YACOBUCCI, *supra* note 30, at 1–2.

[43] *See* KELSI BRACMORT, CONG. RESEARCH SERV., R41106, THE RENEWABLE FUELS STANDARD (RFS): CELLULOSIC BIOFUELS (2015) (discussing policies governing cellulosic ethanol, which are biofuels made from grasses, trees, or the inedible or waste parts of plants); *Ethanol Feedstocks*, U.S. DEP'T OF ENERGY, http://www.afdc.energy.gov/fuels/ethanol_feedstocks.html [https://perma.cc/8FUG-GDCT].

[44] SCHNEPF & YACOBBUCI, *supra* note 30, at 1–5 & tbl.1.

gasoline or diesel fuel it replaces.[45] Cellulosic ethanol must contain a 60% reduction from the baseline emissions to count toward that biofuel's mandated gallon amount.[46] These mandates create a guaranteed market for large amounts of biofuels, acting as an indirect subsidy for capital investments in biofuels plants and for the industry as a whole.[47]

Corn ethanol qualifies toward the total renewable fuel mandate if it reduces life cycle GHG emissions by at least 20% relative to the 2005 baseline average GHG emissions of the gasoline or diesel fuel that it replaces.[48] But if the corn or other ethanol plant commenced construction prior to December 2007 (the effective date of EISA) or was constructed prior to December 31, 2009, and is powered with natural gas or biomass, ethanol produced at those plants is "grandfathered" and counts toward the total renewable fuel amounts required by EISA regardless of GHG emissions.[49] Collectively, the grandfathered facilities have the capacity to produce all of the corn ethanol necessary to fulfill the total RFS mandate.[50] Thus, most of the corn ethanol produced today, which continues to make up the vast majority of U.S. biofuels, need not comply with the 20% GHG reduction requirement in the RFS.[51]

In order to determine which fuels qualify for reduced GHG emissions treatment to be included in the advanced biofuels or other biofuel category, Congress mandated in EISA that EPA use a life cycle analysis approach, requiring EPA to consider all significant emissions, both direct and indirect, from a wide array of fuels and feedstocks.[52] This mandate thus requires EPA to

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[45] *Id.* at 4.

[46] *Id.*

[47] *Id.* at 2.

[48] *Id.* at 4.

[49] Regulation of Fuels and Fuel Additives: Changes to the Renewable Fuel Standard Program, 75 Fed. Reg. 14670, 14670, 14785, 14787–91 (Mar. 26, 2010) (codified at 40 C.F.R. pt. 80).

[50] *See* Melissa Powers, *Lessons from US Biofuels Policy: The Renewable Fuel Standard's Rocky Ride*, *in* THE LAW AND POLICY OF BIOFUELS 151–56 (Yves Le Bouthillier et al. eds., 2016).

[51] *Id.* at 151; *see also* U.S. ENERGY INFO. ADMIN., *supra* note 34, at 6 ("[N]early all ethanol produced in the United States is derived from corn.").

[52] *See* 42 U.S.C. § 7545(o)(1)(H) (2012) ("[T]he aggregate quantity of greenhouse gas emissions (including direct emissions and significant indirect emissions such as significant emissions from land use changes) . . . related to the full fuel lifecycle, including all stages of fuel and feedstock production and distribution, from feedstock generation or extraction through distribution and delivery and use of finished fuel to the ultimate consumer . . . ."); Regulation of Fuels and Fuel Additives: Changes to Renewable Fuel Standard Program, 75 Fed. Reg. 14,670, 14,670 (Mar. 26, 2010) (codified at 40 C.F.R. pt. 80) ("This rulemaking [implementing EISA] marks the first time that greenhouse gas emission performance is being applied in a regulatory context for a nationwide program."). EPA has recently been found noncompliant with several provisions of EISA, including reporting requirements. *See* EPA, OFFICE OF INSPECTOR GEN., EPA HAS NOT

consider full carbon emissions from any fuel, taking into account GHG emissions associated with the combustion of the fuel, as well as the "upstream" emissions associated with the production and transportation of the fuel.[53]

A life cycle analysis for carbon emissions for fuels includes the emissions from the production or consumption of the fuel in vehicles, the emissions associated with transporting the fuel to the source of consumption by truck or train, the emissions associated with producing the fuel at the ethanol or other production plant, and the emissions associated with changing the land use to produce the feedstock.[54] In the case of ethanol, while all ethanol emits similar amounts of carbon dioxide at the moment of combustion, the life cycle carbon emissions associated with the use of ethanol with different production processes can vary significantly based on factors relating to the feedstock (e.g., corn, sugar, etc.), the energy used to convert the feedstock into ethanol (e.g., natural gas, wind, coal, etc.), how far the feedstock has to travel to be converted into ethanol, how far the ethanol has to travel to be used in vehicles, and the type of transportation (e.g., trucks, train, barges, etc.) used for those trips.[55] In calculating life cycle emissions for biofuels, EPA relies primarily on the GREET model, which incorporates massive amounts of data about the life cycle GHG characteristics of many different fuels.[56]

EPA has issued comprehensive rules to implement the RFS. It issued the first set—RFS1—in 2008 after the enactment of the initial 2005 RFS.[57] It enacted the second set—

MET CERTAIN STATUTORY REQUIREMENTS TO IDENTIFY ENVIRONMENTAL IMPACTS OF RENEWABLE FUEL STANDARD (2016).

[53] *See, e.g.*, Hill, *supra* note 3; SCHNEPF & YACOBUCCI, *supra* note 30, at 6–7; *Lifecycle Analysis of Greenhouse Gas Emissions Under the Renewable Fuel Standard*, EPA, http://www.epa.gov/renewable-fuel-standard-program/lifecycle-analysis-greenhouse-gas-emissions-under-renewable-fuel [https://perma.cc/G36Q-YLNH]; *see infra* notes 92–95 and accompanying text (discussing life cycle analysis in context of California's low-carbon fuels policy).

[54] *See Fuel Life Cycle Analysis*, LIFE CYCLE ASSOCS., http://www.lifecycleassociates.com/services/fuel-life-cycle-analysis/ [https://perma.cc/TJ2A-JJU3].

[55] *See* BRENT D. YACOBUCCI & KELSI BRACMORT, CONG. RESEARCH SERV., R40460, CALCULATIONS OF LIFECYCLE GREENHOUSE GAS EMISSIONS FOR THE RENEWABLE FUEL STANDARD (RFS) 7–8 (2010); *Lifecycle Analysis of GHG Emissions Under the Renewable Fuel Standard*, EPA, http://www.epa.gov/renewable-fuel-standard-program/lifecycle-analysis-greenhouse-gas-emissions-under-renewable-fuel [https://perma.cc/PE3B-FL4Y]; Michael Wang, Argonne Nat'l Lab., Overview of the GREET™ Life-Cycle Analysis Model (Oct. 15, 2015), https://greet.es.anl.gov/files/work15-lca-over-wang [https://perma.cc/7BKZ-F7HA] (PowerPoint Presentation Prepared for 2015 GREET Users Workshop); *GREET Model*, LIFECYCLE ASSOCS., http://www.lifecycleassociates.com/lca-tools/greet-model/ [https://perma.cc/DN7A-XVZ2].

[56] *See* Wang, *supra* note 55; *GREET Model*, *supra* note 55.

[57] *See* Regulation of Fuels and Fuel Additives, 40 C.F.R. pt. 80 (2013).

RFS2—in 2010 after Congress enacted EISA.[58] These rules (and subsequent amendments) "establish[] detailed compliance standards for fuel suppliers," create the different levels of required GHG emissions reductions for particular fuels based on GREET, and create a tracking and trading system for compliance credits based on renewable identification numbers (RINs).[59] EPA also has authority from Congress to temporarily waive portions of the biofuels mandate on its own authority or in response to a petition based on market and other circumstances.[60] For instance, EPA may reduce the total amount of biofuels required to be blended for a particular year if "there is inadequate domestic supply to meet the mandate, or if 'implementation of the requirement would severely harm the economy or environment of a State, a region, or the United States.'"[61]

Because there was no commercial production of cellulosic ethanol when EISA was enacted, EPA has separate waiver authority to lower the statutory total amounts of cellulosic ethanol when the projected volume for a given year is less than what the statute requires.[62] Although EISA requires that EPA set the required biofuel levels for each year by November of the prior year, EPA has often been unable to comply with that timeline, leading to market and investment uncertainties.[63]

2. Challenges Facing the RFS

Many members of Congress, the oil industry, vehicle manufacturers, the food and restaurant industry, and some

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58 Regulation of Fuels and Fuel Additives: Changes to Renewable Fuel Standard Program, 75 Fed. Reg. 14670, 14670 (Mar. 26, 2010) (EPA rule implementing EISA); SCHNEPF & YACOBUCCI, *supra* note 30, at 2.

59 SCHNEPF & YACOBUCCI, *supra* note 30, at 2. Fuel producers and blenders submit credits, or RINs, to EPA that equal the number of gallons of their annual obligation based on the obligated party's total gasoline and diesel sales multiplied by the annual renewable fuel percentage standard EPA sets for that year. KELSI BRACMORT, CONG. RESEARCH SERV., R43325, THE RENEWABLE FUEL STANDARD (RFS): IN BRIEF 2 (2015) [hereinafter BRACMORT, IN BRIEF]. RINs are valid for use in the year they are generated and the following year based on the number of credits generated or purchased from other parties through the EPA Moderated Transaction System (EMTS). *See id.* at 2–3.

60 SCHNEPF & YACOBUCCI, *supra* note 30, at 11.

61 BRENT D. YACOBUCCI, CONG. RESEARCH SERV., RS22870, WAIVER AUTHORITY UNDER THE RENEWABLE FUEL STANDARD (RFS) 3–4 (2014) (quoting 42 U.S.C. § 7545(o)(7)(A)(2)(i)–(ii) (2012)).

62 *See* 42 U.S.C. § 7545(o)(7)(D) (2012); KELSI BRACMORT, CONG. RESEARCH SERV., R44045, THE RENEWABLE FUEL STANDARD (RFS): WAIVER AUTHORITY AND MODIFICATION OF VOLUMES 5–6 (2016) [hereinafter BRACMORT, WAIVER AUTHORITY].

63 BRACMORT, WAIVER AUTHORITY, *supra* note 62, at 6–7 ("Waiver authority can impact RFS implementation and market confidence, as well as contribute to RFS uncertainty. . . . Many aspects of the RFS . . . could be viewed as unstable . . . partly because Administration decisions—including the use of RFS waiver authority—have not been made in a timely manner.").

environmental groups have called for the repeal or significant modification of the RFS.[64] These groups identify several problems with the RFS. First, the RFS is seen as a massive and unnecessary subsidy for the farming sector at a time when domestic oil is plentiful as a result of hydraulic fracturing and directional drilling technologies.[65] Second, the RFS is blamed for increasing food prices in the United States and around the world as so much corn is diverted from food production to fuel production.[66] Third, vehicle and engine manufacturers oppose the RFS because of concerns associated with the so-called "blend wall."[67] This term refers to what these industries contend is an increased risk of corrosion damage to older vehicle engines if the mix of ethanol in gasoline exceeds its current level of 10%.[68] EISA's growing volumetric requirement for renewable fuels means that, in future years, fuel blenders will need to far exceed the blend wall to meet the RFS because U.S. demand for transportation fuel has been flat or declining in recent years and is expected to remain that way[69] as a result of the increasing fuel efficiency of new motor vehicles.[70] Fourth, policy analysts state that the costs associated with producing the advanced biofuels and cellulosic ethanol in the amounts required by the RFS will increase fuel prices because, unlike corn ethanol, these biofuels are not cheap or easy to produce.[71] Last and most important for

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[64] *See* BRACMORT, IN BRIEF, *supra* note 59, at 1 (citing numerous Congressional hearings questioning the efficacy of the RFS and stating that "[m]embers of Congress have questioned whether it is time to amend or repeal the RFS, or [whether the best course is] to maintain the status quo").

[65] *Renewable Fuel Standard*, AM.'S ENERGY FORUM, http://www.americasenergyforum.com/topics/renewable-fuel-standard [https://perma.cc/B3B7-R97P] (stating that since the enactment of the RFS, the United States "became the world's leading producer of oil and natural gas").

[66] *Id.*; *see also* CONG. BUDGET OFF., *supra* note 33, at 2 (stating that food prices would not decline even if the RFS were repealed because "suppliers would probably find it cost-effective to use a roughly 10 percent blend of corn ethanol in gasoline in 2017 even in the absence of the RFS"); Conca, *supra* note 32.

[67] *Blend Wall*, RENEWABLE FUELS ASS'N, http://ethanolrfa.org/issues/blend-wall/ [https://perma.cc/4KCP-3GH5].

[68] BRACMORT, IN BRIEF, *supra* note 59, at 7; SCHNEPF & YACOBUCCI, *supra* note 30, at 28–31; Grocery Mfrs. Ass'n v. EPA, 693 F.3d 169, 172–73 (D.C. Cir. 2012) (discussing concerns by engine manufacturers regarding engine failures in older vehicles and equipment if ethanol content of gasoline exceeds 10%).

[69] *See EPA Mandates Renewable Fuel Levels Above 10 Percent Blend Wall*, INST. FOR ENERGY RESEARCH (May 24, 2016), http://instituteforenergyresearch.org/analysis/epa-mandates-renewable-fuel-levels-10-percent-blend-wall/ [https://perma.cc/GCL6-P4SP].

[70] Arup Mallik, *Fuel Economy Standards Drive Down Projected Gasoline Use; Diesel Use, Product Exports Rise*, U.S. ENERGY INFO. ADMIN. (June 26, 2014), http://www.eia.gov/todayinenergy/detail.php?id=16871 [https://perma.cc/2A2Q-HRX5].

[71] *See, e.g.*, CONG. BUDGET OFF., *supra* note 33, at 2–3 ("Meeting the [t]otal [v]olumes of [a]dvanced [b]iofuels [s]pecified in EISA [w]ould [h]ave [s]ignificant [e]ffects on [p]rices of [t]ransportation [f]uels.").

purposes of this article, the use of life cycle analysis in evaluating transportation fuels has caused many scientists and policy makers to conclude that ethanol, particularly corn ethanol, creates more GHG emissions and other air emissions per gallons than gasoline.[72] Of course, these criticisms are vehemently denied by the biofuels industry, corn states, and others, who maintain that corn ethanol, along with other forms of biofuels, should remain an integral part of the nation's transportation fuels and are environmentally superior to petroleum.[73] The heated debates over the benefits and harms of corn ethanol, as well as other advanced biofuels, will undoubtedly continue in both the science and policy realms.[74]

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[72] *See, e.g.*, *University of Mich. Researcher DeCicco Says RFS Not Delivering Environmental Benefits*, E&E TV (Nov. 4, 2015), http://www.eenews.net/tv/videos/2050/transcript [https://perma.cc/T798-8QML]; Nathanael Johnson, *The EPA Raises the Renewable Fuels Standard. Here's Why That Makes No Sense*, GRIST (Nov. 30, 2015), http://grist.org/climate-energy/the-epa-raises-the-renewable-fuels-standard-heres-why-that-makes-no-sense/ [https://perma.cc/8BFP-BM3F]; *see also* Herman Wang, *US EPA Auditor to Review Environmental Claims of Federal Biofuels Mandate*, S&P GLOB. PLATTS (Oct. 16, 2015), http://www.platts.com/latest-news/agriculture/washington/us-epa-auditor-to-review-environmental-claims-21310495 [https://perma.cc/F8WM-3DJD] (discussing decision by the EPA internal auditor to review the EPA's carbon intensity calculations for various biofuels); RENEWABLE FUEL STANDARD, *supra* note 35, at 197–206, 242, 245–47 (citing studies that GHG emissions and other emissions of air pollutants is greater from use of corn ethanol than from petroleum based fuels based on a life cycle analysis and that studies do not conclusively show that even cellulosic ethanol has environmental benefits over gasoline); *The EPA Renewable Fuel Standard Mandate: Hearing Before the Subcomm. on Energy, Subcomm. on Oversight, Comm. on Sci., Space, and Tech.* (July 23, 2015) (statement of Jason Hill, Ph.D., Associate Professor of Bioproducts and Biosysytems Engineering, University of Minnesota), http://docs.house.gov/meetings/SY/SY20/20150723/103827/HHRG-114-SY20-Wstate-HillJ-20150723.pdf [https://perma.cc/SC4L-9RE9]; Christopher W. Tessum et al., *Life Cycle Air Quality Impacts of Conventional and Alternative Light-Duty Transportation in the United States*, 111 PROC. NAT'L ACAD. SCI. U.S.A. 18490, 18490–95 (2014).

[73] *See, e.g.*, Tiffany Stecker, *Pelosi Called 'Robust' RFS Key to Curbing Climate Change*, GOVERNORS' BIOFUELS COAL. (Nov. 23, 2015), http://www.governorsbiofuelscoalition.org/?p=15416 [https://perma.cc/9ZNS-5RKG]; RENEWABLE FUELS ASS'N, RENEWABLE FUEL STANDARD: WHY IS THE PRESIDENT IGNORING AMERICA'S MOST SUCCESSFUL CLIMATE POLICY? 3–4 (2015). For sources responding to Tessum et al., *supra* note 72, see *Growth Energy Responds to Flawed University of Minnesota Study*, GROWTH ENERGY (Dec. 19, 2014), http://www.growthenergy.org/news-media/press-releases/growth-energy-responds-to-flawed-university-of-minnesota-study/ [https://perma.cc/B2CT-PHBW]; *U of M Report Contains Inaccurate and Misleading Information on Ethanol*, MINN. BIOFUELS ASS'N (Dec. 18, 2014), https://mnbiofuels.org/media-mba/blog/item/1034-u-of-m-report-contains-inaccuracies-and-misleading-information-on-ethanol [https://perma.cc/4ZLZ-GR5H]; RENEWABLE FUELS ASS'N, RESPONSE TO PNAS ARTICLE: "LIFE CYCLE AIR QUALITY IMPACTS OF CONVENTIONAL AND ALTERNATIVE LIGHT-DUTY TRANSPORTATION IN THE UNITED STATES" (2014), http://ethanolrfa.org/wp-content/uploads/2016/03/Response-to-UM-study.pdf [https://perma.cc/WYU2-Z7GP]; *see also* Timothy A. Slating & Jay P. Kesan, *The Renewable Fuel Standard 3.0?: Moving Forward with the Federal Biofuel Mandate*, 20 N.Y.U. ENVTL. L.J. 374 (2014) (discussing environmental benefits of biofuels).

[74] *See, e.g.*, *Should the U.S. End the Ethanol Mandate?*, WALL ST. J. (Nov. 15, 2015), http://www.wsj.com/articles/should-the-u-s-end-the-ethanol-mandate-1447643514 [https://perma.cc/4YUJ-EPL7]; Hill et al., *supra* note 36, at 351 (concluding that the "rebound effect," whereby increased production of biofuels increases fuel supplies and

In addition to calls for repeal or modification of the RFS, the oil industry and other RFS opponents have filed numerous petitions with EPA since the enactment of EISA requesting it to exercise its waiver authority to reduce the mandated amounts of biofuels for each year.[75] EPA has used its waiver authority to significantly reduce the required amount of cellulosic ethanol each year since 2010, based on the lack of sufficient commercial production of such fuel.[76] In 2015, for the first time, it used its waiver authority to also lower the total amount of renewable fuel mandated for 2014 (retroactively) as well as for 2015 and 2016, citing "blend wall" concerns and the biofuel industry's inability to produce sufficient volumes of advanced biofuels.[77] Oil companies and other interested parties have sued EPA numerous times for its refusal to exercise its waiver authority more frequently, with mixed results in the courts.[78]

Despite the increasing criticism of the RFS, the use of life cycle analysis in policymaking at the federal level has now been in place for nearly a decade.[79] By contrast, states are in the initial stages of attempting to incorporate life cycle analysis into their own policies governing transportation fuels and, in some cases, creating even stricter environmental standards in doing so. As explained in the next section, because life cycle analysis requires evaluation of the full life cycle of a fuel, it puts states in a position of giving preference to fuels produced in some states

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thereby decreases fuel prices, which in turn causes consumption of fuels to rise, means that the RFS may increase GHG emissions).

[75] *See Requests for Volume Requirement Waiver Under the Renewable Fuel Standard Program*, EPA, https://www.epa.gov/renewable-fuel-standard-program/requests-volume-requirement-waiver-under-renewable-fuel-standard [https://perma.cc/LG8U-7QBG].

[76] SCHNEPF & YACOBUCCI, *supra* note 30, at 11.

[77] *See* Renewable Fuel Standard Program: Standards for 2014, 2015, and 2016 and Biomass-Based Diesel Volume for 2017, 80 Fed. Reg. 77420, 77449 (Dec. 14, 2015) (to be codified at 40 C.F.R. pt. 80); *Renewable Fuel Standard Program, Final Renewable Fuel Standards for 2014, 2015 and 2016, and the Biomass-Based Diesel Volume for 2017*, EPA, www.epa.gov/renewable-fuel-standard-program/final-renewable-fuel-standards-2014-2015-and-2016-and-biomass-based#rule-summary [https://perma.cc/K6WU-HAWX]; Jim W. Rubin, *Fueling Controversy: EPA Seeks the Right Balance but Its Final RFS Volumes Are Likely to Be Challenged*, DORSEY & WHITNEY PUBLICATIONS (Jan. 8, 2016), https://www.dorsey.com/newsresources/publications/client-alerts/2016/01/epa-seeks-the-right-balance [https://perma.cc/F4P4-DREX].

[78] *See, e.g.*, Monroe Energy, LLC v. EPA, 750 F.3d 909 (D.C. Cir. 2014) (denying challenge for failure to reduce renewables quotas); Am. Petroleum Inst. v. EPA, 706 F.3d 474 (D.C. Cir. 2013) (same); Grocery Mfrs. Ass'n v. EPA, 693 F.3d 169 (D.C. Cir. 2012) (finding no standing for challenge to ethanol blend approval); Nat'l Petrochemical & Refiners Ass'n v. EPA, 630 F.3d 145 (D.C. Cir. 2010) (denying challenge to biodiesel requirements).

[79] *See* Debra Kahn, *Study Challenges Climate Benefits of U.S. Low-Carbon Fuels*, GOVERNORS' BIOFUELS COAL. (Feb. 18, 2015), http://www.governorsbiofuelscoalition.org/?p=12237 [https://perma.cc/PE9E-7VK] (discussing debates over different life cycle analysis models).

over others or the use of certain production processes over others. While the federal government may make these distinctions without major constitutional challenge, states can run afoul of the dormant Commerce Clause if their efforts are seen as discriminating against interstate commerce.

C. State Low-Carbon Fuel Regulations

Several states, particularly California, have gone beyond the RFS to rely more heavily on life cycle analysis in the transportation-fuels sector to limit GHG emissions of all fuels sold in the state. In 2006, the California Legislature enacted AB 32, the California Global Warming Solutions Act.[80] As part of AB 32, the Legislature made extensive findings about the connection between GHG emissions and global warming and, specifically, the threat global warming poses for California, including sea level rise, reduction in water quality and quantity, and harm to public health and the environment.[81] The Legislature set a target of reducing the state's GHG emissions to 1990 levels by 2020, with further reductions beyond 2020.[82] The Legislature directed the California Air Resources Board (CARB) to adopt rules and regulations "to achieve the maximum technologically feasible and cost-effective greenhouse gas emission reductions."[83]

1. CARB Regulations Implementing the LCFS

The California Legislature, the governor, and CARB recognized that in order to make any progress toward these targets, they would need to place a significant focus on reducing GHG emissions from the transportation sector.[84] Indeed, in a 2007 Executive Order, the governor noted that the transportation sector is the leading source of GHG emissions in California, contributing approximately 40% of the state's total GHG emissions in that year.[85]

For years, California had been a leader in requiring reductions in traditional air pollutants and GHG emissions from

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80 Assemb. B. 32, 2006 Leg., Reg. Sess. (Cal. 2006); *Assembly Bill 32 Overview*, CAL. AIR RES. BD., https://www.arb.ca.gov/cc/ab32/ab32.htm [https://perma.cc/95M8-TAR7].

81 Assemb. B. 32, 2006 Leg., Reg. Sess. (Cal. 2006).

82 *Id.*

83 *Id.* In 2016, Governor Brown signed Senate Bill 32 and Assembly Bill 197, which together established even stricter emissions limits for the state, requiring California to reduce its emissions by 40% below 1990 levels by 2030. *See* S.B. 32, 2015–2016 Leg., Reg. Sess. ch. 249 (Cal. 2016); Assemb. B. 197, 2015–2016 Leg., Reg. Sess. ch. 250 (Cal. 2016).

84 Cal. Exec. Order No. S-01-07 (Jan. 18, 2007).

85 *Id.*

vehicles sold in the state through, most recently, its low emission vehicle regulations and zero emission vehicle regulations.[86] But tailpipe emission standards cannot control the GHG emissions associated with the production of the fuel and transportation of the fuel used in those vehicles before it reaches the California market. Because those GHG emissions mix in the atmosphere, the fact that the emissions do not occur in California does not reduce the climate change impact on California. The next step for California was to achieve even greater emissions reductions in the transportation sector by reducing GHG emissions from the fuels themselves.[87]

Thus, in that same 2007 Executive Order, the governor directed CARB to adopt regulations that would reduce the average GHG emissions from the California fuel market by 10% by 2020.[88] In response, CARB created the Low Carbon Fuel Standard (LCFS), which established a baseline, average carbon intensity for all vehicular fuels consumed in California (using the average carbon intensity of the 2010 gasoline market). The LCFS required each supplier of vehicular transportation fuels in the state to reduce its average carbon intensity from that baseline by set amounts each year between 2011 and 2020 or acquire sufficient credits from other suppliers.[89] The LCFS allows suppliers to earn credits for exceeding the reduction required for that year and permits suppliers to use those credits to offset deficits or sell to other blenders, thus creating a market for trading, banking, and borrowing of credits.[90] CARB's intent was to create a market that would incentivize the development of low-carbon fuels for sale in the California market and allow the state to meet the requirements of AB 32.[91]

In its focus on transportation fuels, California, similar to the federal RFS, made life cycle analysis a central component in evaluating the GHG emissions of regulated biofuels. Like the federal RFS, the California LCFS adopted a life cycle analysis for carbon emissions for biofuels that included the emissions from: (1)

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[86] Rocky Mountain Farmers Union v. Corey, 730 F.3d 1070, 1078–79 (9th Cir. 2013); *The Advanced Clean Cars Program*, CAL. AIR RES. BD., https://www.arb.ca.gov/msprog/acc/acc.htm [https://perma.cc/24UZ-KAHJ] (describing California's Low-Emission Vehicle (LEV) regulations and Zero-Emission Vehicle (ZEV) regulations).

[87] *See Rocky Mountain Farmers Union*, 730 F.3d at 1079–81.

[88] Cal. Exec. Order No. S-01-07 (Jan. 18, 2007).

[89] *Rocky Mountain Farmers Union*, 730 F.3d at 1080; *see* CAL. CODE REGS. tit. 17, §§ 95480–82 (2009). In 2011, the carbon intensity cap was set 0.25% below the 2010 average with further reductions each year between 2011 and 2020. *Rocky Mountain Farmers Union*, 730 F.3d at 1082.

[90] *LCFS Credit Transfer Activity Reports*, CAL. AIR RES. BD. (May 17, 2016), https://www.arb.ca.gov/fuels/lcfs/credit/lrtcreditreports.htm [https://perma.cc/3ZXW-LSVV].

[91] *Rocky Mountain Farmers Union*, 730 F.3d at 1080.

the "conversion of [the] land to agricultural use"; (2) the growth and transportation of the feedstock (corn, sugar, other plant matter) with credit for the GHGs absorbed during photosynthesis; (3) the process used to convert the feedstock into liquid fuel and the efficiency of that process; (4) the source of electricity used to power the production plant (coal, natural gas, wind, nuclear, etc.); (5) the "fuel used for thermal energy"; and (6) the transportation distance of the fuel to the blender in California and the form of transportation (truck, train, ship, etc.).[92]

Thus, corn, which is grown primarily in the Midwest,[93] has only a short distance to travel to ethanol plants in the Midwest, which helps midwestern ethanol on that metric, as compared to Californian ethanol plants that must transport the midwestern corn a much longer distance before it can be made into ethanol. By contrast, the ethanol itself must travel a longer distance from ethanol plants in the Midwest to be used in vehicles in California, thus favoring Californian ethanol plants on that metric. Likewise, corn ethanol produced in California or sugarcane ethanol produced in Brazil generally relies on lower carbon electricity than ethanol produced in the Midwest. This is because California uses almost exclusively natural gas and renewable energy to power its electric grid, Brazil uses primarily hydropower, and the Midwest relies heavily on coal.[94] Consistent with EPA, California relies on a version of the GREET model (known as CA-GREET) that incorporates data on the life cycle emissions of various fuels as well as information about local conditions (such as California's environmental regulations and dominant electricity sources).[95]

California's LCFS differs from the RFS in that it addresses not just biofuels, but all transportation fuels, including gasoline, diesel, hydrogen, natural gas, and electricity, and requires producers to reduce the life cycle GHG emissions of all fuels over time. Also, with regard to biofuels, unlike the federal RFS, California's LCFS does not create fuel categories or minimum life cycle reductions, but instead considers the carbon emissions of each biofuel separately, and rewards all reductions in life cycle emissions.[96] In this way, the LCFS provides incentives for any biofuel producer to lower the carbon intensity of the fuel, regardless of the federal RFS category in which it might fit.

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[92] *Id.* at 1083.

[93] *Corn Facts*, SOYATECH, http://www.soyatech.com/corn_facts.htm [https://perma.cc/4WHC-ANW7].

[94] *Rocky Mountain Farmers Union*, 730 F.3d at 1083.

[95] *Id.* at 1081–82.

[96] *Id.* at 1089.

Because it would be difficult, if not impossible, for CARB to do an individualized analysis for every fuel type of every producer across the country (even a single ethanol plant can produce ethanols with varying carbon intensities over a single year based on different energy sources for thermal heat or different types of ethanol produced), CARB established aggregates, or averages, to develop a limited number of default life cycle "pathways" for several common transportation fuels, including natural gas, ethanol, hydrogen, and electricity.[97]

In its initial rules implementing the LCFS, CARB included a table (Table 6) with "carbon intensity" (CI)[98] values for eleven specific corn ethanol pathways (four for production in California and seven for production in the Midwest). Table 6 also included a Midwest average and a California average that took into account differences in transportation of the feedstock to ethanol production (longer for California and shorter for the Midwest, which is closer to the feedstock source), differences in the transportation of the ethanol itself (shorter for California and longer for the Midwest), source of electricity used in the production process, and plant efficiency.[99]

Importantly, ethanol producers need not use these averages. Instead, they can request individualized CI values for their specific fuel pathways and CARB has approved many of these pathways using procedures in the rules.[100] Thus, if an ethanol producer creates its ethanol using electricity obtained from a power plant fueled by natural gas or wind instead of coal, or using a more efficient processing plant, the CI for that particular ethanol from that particular producer will be lower than ethanol produced using one of the default pathways.[101] Beginning in 2011, several ethanol producers in the Midwest were able to obtain significantly lower CI values than the default values, primarily because they cogenerate heat and electricity or use a renewable source for thermal energy, either

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[97] *Id.* at 1082, 1093 ("CARB designed the default pathways to be appropriate for use by multiple ethanol producers, avoiding costly and unnecessary individualized determinations. Under this system, only those producers with a lower-than-average carbon intensity need apply for an individualized value.").

[98] A fuel's carbon intensity is the amount of life cycle GHG emissions caused by production and transportation of the fuel, per unit of energy of fuel delivered, expressed in grams of carbon dioxide equivalent per megajoule (gCO_2e/MJ). CAL. CODE REGS. tit. 17, § 95481(a)(20) (2015).

[99] *Rocky Mountain Farmers Union*, 730 F.3d at 1082, 1110 app. 1.

[100] *Id.* at 1082, 1084.

[101] *See id.* at 1082–83.

of which can significantly reduce GHG emissions.[102] In 2015, CARB readopted and refined the LCFS regulations to respond to lawsuits in state court challenging the process by which the rules were enacted, to relax the interim targets, to revise some of the indirect land-use change values, and to help the credit market run more smoothly.[103]

2. Legal Challenges to the LCFS

Despite the options California provided to allow producers to obtain lower CI values, in 2009, ethanol producers in the Midwest and oil companies nationwide sued California to invalidate the LCFS. They argued that the law was unconstitutional because it discriminated against interstate commerce, placed an undue burden on interstate commerce, and constituted "extraterritorial" regulation of interstate commerce.[104] In 2011, a U.S. district court in California agreed with those arguments and invalidated the LCFS, reasoning that it facially discriminated against out-of-state energy producers and illegally attempted to regulate activities (e.g., the production of ethanol and transportation of ethanol) outside the state.[105]

With regard to the ethanol provisions of the LCFS, the court focused primarily on the fact that California penalized midwestern ethanol based on emissions associated with transporting the ethanol from the Midwest (as compared to ethanol produced in California) and electricity-related emissions to produce the ethanol (based on use of coal in the Midwest and natural gas, nuclear, and hydropower in California).[106] According to the court, basing the CI pathways for various fuels on these

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[102] *Id.* at 1084. For a complete list of CARB-approved fuel pathways, see *LCFS Pathway Certified Carbon Intensities*, AIR RES. BD., http://www.arb.ca.gov/fuels/lcfs/fuelpathways/pathwaytable.htm [https://perma.cc/3WA7-52E].

[103] *See* CAL. CODE. REGS. tit. 17, §§ 95480–97 (2016); Julia Forgie, et al., Emmett Inst. on Climate Change & the Env't, Controlling Greenhouse Gas Emissions from Transport Fuels: The Performance and Prospects of California's Low-Carbon Fuel Standard (unpublished draft manuscript) (on file with author) (discussing CARB's adoption of revised regulations in 2015); CAL. AIR RES. BD., STAFF REPORT: INITIAL STATEMENT OF REASONS FOR PROPOSED RULEMAKING, PROPOSED RE-ADOPTION OF THE LOW CARBON FUEL STANDARD ES-1, I-5 (2014).

[104] The Commerce Clause of the U.S. Constitution grants Congress the power "[t]o regulate Commerce . . . among the several States." U.S. CONST. art. 1, § 8, cl. 3. The U.S. Supreme Court has also interpreted the Commerce Clause to include a negative, or "dormant" provision that bars states from engaging in economic protectionist behavior that discriminates against or burdens interstate commerce. *See, e.g.*, New Energy Co. v. Limbach, 486 U.S. 269, 273–74 (1988).

[105] Rocky Mountain Farmers Union v. Goldstene, 843 F. Supp. 2d 1071, 1089 (E.D. Cal. 2011).

[106] *Id.* at 1087–90.

location-related factors discriminated against interstate commerce and regulated extraterritorially.[107]

In 2013, however, the U.S. Court of Appeals for the Ninth Circuit reversed that decision and found that the LCFS did not facially discriminate against interstate commerce and did not regulate extraterritorially.[108] With regard to the ethanol provisions of the LCFS, the court focused on whether California assigned different CI values to ethanol from different locations based solely on state of origin or for reasons apart from state of origin.[109] The court concluded that California considered location only to the extent it impacted actual GHG emissions associated with a particular CI pathway.[110] The court emphasized that California could not promote lower carbon fuels and decrease GHG emissions in the transportation sector if it ignored GHG emissions associated with producing those fuels and with transporting those fuels.[111]

The court's decision contains significantly more detail on the LCFS and the constitutional arguments than is presented here.[112] For purposes of this article, however, the court's opinion is most important for the fact that it recognizes the importance of using life cycle analysis in setting policy to reduce the GHG emissions of transportation fuels. Indeed, without the use of life cycle analysis there would be no legitimate reason for California to treat midwestern corn ethanol (the dominant U.S. source of ethanol) any differently than California ethanol or sugarcane ethanol from Brazil (the dominant source of ethanol imports) because the tailpipe emissions associated with the combustion of each type of ethanol in vehicles is the same. It is only the land-use changes, the ethanol production processes, the varied electricity sources, and different emissions associated with transporting the ethanol to California that create different GHG emissions profiles for different types of ethanol.

The court found that CARB was justified in drawing distinctions between different types of ethanol based on these differences, even though some of them were based on geographic factors, such as distance traveled and regional electricity

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[107] *Id.* at 1090, 1092–93.

[108] Rocky Mountain Farmers Union v. Corey, 730 F.3d 1070, 1107 (9th Cir. 2013).

[109] *Id.* at 1089.

[110] *Id.*

[111] *Id.* at 1090.

[112] For a more detailed discussion of the constitutional arguments in the case, see Alexandra B. Klass & Elizabeth Henley, *Energy Policy, Extraterritoriality, and the Dormant Commerce Clause*, 5 SAN DIEGO J. CLIMATE & ENERGY L. 127 (2013–2014).

sources.[113] Thus, the court not only affirmed the use of life cycle analysis in California's efforts to reduce GHG emissions, but it also found that reliance on life cycle analysis justifies these distinctions in the face of dormant Commerce Clause challenges.[114] For instance, the court found that:

> Each factor in the default pathways is an average based on scientific data, not an ungrounded presumption that unfairly prejudices out-of-state ethanol, whether it is an average value for the use of coal in a boiler or for the shipment of raw corn from the Midwest to California. To the atmosphere, emissions related to an ethanol plant's source of electrical energy are no less important than those caused by a plant's source of thermal energy. If we ignore these real differences between ethanol pathways, we cannot understand whether the challenged regulation responds to genuine threats of harm or to the mere out-of-state status of an ethanol pathway.[115]

The court went on to state that "[i]f California is to successfully promote low-carbon-intensity fuels . . . it cannot ignore the real factors behind GHG emissions."[116] Thus, in upholding the law, the court relied heavily on the validity and importance of life cycle analysis both as a matter of science and of policymaking.

In other parts of the opinion, the court focused on the need for state policy experimentation in reducing GHG emissions associated with fuels and the critical importance of valid, scientific data in developing such policies. In response to claims that midwestern ethanol plants were penalized for relying on nearby, inexpensive coal plants for electricity, the court responded that ethanol producers in the Midwest "are not hostage to these regional electricity-generating portfolios," but instead can seek individualized CI pathways if they use waste heat or alternative energy sources to power the plant.[117] Ultimately, the court found that for any market-based policy solution to succeed, "the market must have full and accurate information about the real extent of GHG emissions" which, in turn, requires the use of life cycle analysis and a practical means

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[113] The court contrasted the geographic distinctions in this case from those the U.S. Supreme Court found to violate the dormant Commerce Clause in *Oregon Waste Systems, Inc. v. Department of Environmental Quality*, 511 U.S. 93 (1994). *See Rocky Mountain Farmers Union*, 730 F.3d at 1089. In *Oregon Waste Systems*, an Oregon statute imposed a $2.25 per ton surcharge on out-of-state waste but charged in-state waste only $0.85. *Or. Waste Sys.*, 511 U.S. at 96. The Court held that the fee difference facially discriminated against interstate commerce because there was no evidence out-of-state waste was more harmful or costly than in-state waste. *Id.* at 108.

[114] *Rocky Mountain Farmers Union*, 730 F.3d at 1090.

[115] *Id.* at 1089–90.

[116] *Id.* at 1090.

[117] *Id.* at 1091.

of compliance.[118] The court found that CARB's approach may not be perfect, but it did not facially discriminate against interstate commerce.[119] Although the court found that the LCFS did not facially discriminate against interstate commerce or regulate extraterritorially, it remanded the case to the district court to consider other constitutional challenges to the law, including whether the law discriminated in purpose or effect or posed an undue burden on interstate commerce.[120]

3. Impact of the LCFS and Next Steps in California

Since California's enactment of the LCFS, Governor Jerry Brown has issued an executive order to reduce petroleum use in the state by 50% by 2030; the LCFS will be a key component to reaching that goal.[121] Moreover, Oregon enacted its own low carbon fuel program in 2015. Adding to the focus on GHG emissions from the transportation sector, five northeastern states and Washington, D.C. announced in late 2015 that they will institute a new regional market-based cap-and-trade program to reduce GHG emissions from the transportation sector. The states plan to invest significant resources in new transportation policies to reduce traffic congestion and increase clean vehicle use, among other initiatives.[122]

The efforts of these states show an increasing use of life cycle analysis in transportation policy to encourage the use of lower carbon intensity fuels. But, as shown by the challenges to

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[118] *Id.* at 1106–07.

[119] *Id.* at 1094.

[120] *Id.* at 1078, 1107. Federal litigation over the LCFS as it applies to both ethanol and crude oil is ongoing as of the publication of this article. Moreover, a state court challenge to the LCFS was successful on state procedural grounds, which resulted in CARB re-enacting and revising the LCFS in 2015 in an effort to address that decision. *See* POET, LLC v. Cal. Air Res. Bd., 160 Cal. Rptr. 3d 69 (2013) (finding that CARB did not comply with the procedural requirements of the California Environmental Quality Act and California Administrative Procedure Act in enacting the LCFS but allowing CARB to continue to implement the rule with some modifications); *Low Carbon Fuel Standard*, CAL. AIR RES. BD., www.arb.ca.gov/fuels/lcfs/lcfs.htm [https://perma.cc/Q83E-T2AN]; News Release, Cal. Air Res. Bd., Air Resources Board Readopts Low Carbon Fuel Standard (Sept. 25, 2015), www.arb.ca.gov/newsrel/newsrelease.php?id=760 [https://perma.cc/P7GU-PSD9]; CAL. AIR RES. BD., UPDATED INFORMATIVE DIGEST REGULATION TO IMPLEMENT THE CALIFORNIA LOW CARBON FUEL STANDARD PROGRAM 2, www.arb.ca.gov/regact/2015/lcfs2015/uidlcfs.pdf [https://perma.cc/M86S-QKQZ]. The 2015 rules were also subject to legal challenge and any forthcoming decision may require further modifications to the LCFS.

[121] News Release, Cal. Air Res. Bd., *supra* note 120.

[122] The states involved are Connecticut, Delaware, New York, Rhode Island, and Vermont. Amanda Reilly, *5 States, D.C. Launch Market-Based Emissions Initiative*, GREENWIRE (Nov. 24, 2015), http://www.eenews.net/greenwire/stories/1060028533; *see* GEORGETOWN CLIMATE CTR., REDUCING GREENHOUSE GAS EMISSIONS FROM TRANSPORTATION: OPPORTUNITIES IN THE NORTHEAST AND MID-ATLANTIC 12–14 (2015).

California's LCFS, the dormant Commerce Clause places limits on what states can do in this area if their efforts discriminate against interstate commerce or other states without a legitimate, nondiscriminatory reason. However, at least according to the U.S. Court of Appeals for the Ninth Circuit, the use of life cycle analysis in policy efforts to reduce GHG emissions is a legitimate, nondiscriminatory means of distinguishing between different fuels and processes, even if it may have the effect of disfavoring fuels produced in states with higher carbon-intensity production processes.[123]

Thus, life cycle analysis is not only allowed, but constitutes a nondiscriminatory basis upon which states can preference certain fuels or processes in a way that recognizes regional differences in transportation emissions or electricity-related emissions. In this way, life cycle analysis can spur innovation for a wide range of inputs into transportation fuels through CARB's individualized CI determinations or similar processes in other states. To the extent a fuel producer uses wind or solar electricity in the ethanol production process, or can lower emissions associated with the transport of ethanol, it encourages other ethanol producers and the state itself to create new ways to reduce GHG emissions in the fuel production process and obtain market advantages associated with those lower emissions.

D. Summary: The Growing Importance of Life Cycle Analysis in Policymaking

The use of life cycle analysis has significantly impacted policymaking in the area of transportation fuels. Since Congress mandated its use in EISA in 2007, life cycle analysis has played a central role in efforts to reduce GHG emissions from transportation fuels, despite challenges biofuels producers have faced in developing the technology and markets required to meet those mandates. At the same time, increasing scientific refinement of life cycle analysis has called into question the environmental benefits of all forms of ethanol, leading to calls for repeal of, or significant amendment to, the RFS.

In incorporating life cycle analysis into the RFS, Congress recognized the environmental and economic drawbacks associated with corn ethanol and intended to spur innovation to create markets for advanced biofuels and cellulosic ethanol. But in many ways, lack of scientific data and changes in the technologies and

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[123] *See Rocky Mountain Farmers Union*, 730 F.3d at 1089–90.

markets surrounding transportation fuels in general has limited the promise of the RFS.

A growing body of research on the life cycle analysis of ethanol appears to show that the use of corn ethanol results in greater GHG emissions than petroleum on a per gallon basis.[124] This is in large part because the focus on life cycle GHG emissions prior to 2008 did not include the potential impacts of the rapid growth of the corn ethanol industry on the fuel's GHG profile.[125] The growth of the corn ethanol industry has resulted in major land-use changes, which have become a significant new source of GHG emissions associated with ethanol production and use in the United States.[126]

For its part, California's LCFS has focused less on mandating particular types of fuel (e.g., ethanol) and more on reducing the GHG emissions from all types of transportation fuels. This approach incentivizes a wide variety of innovative production processes for both ethanol and oil without worrying about fitting any fuels into particular categories with mandatory volume requirements.[127] Certainly, the dormant Commerce Clause and other federal constitutional and statutory provisions potentially limit the ability of California and other states to regulate activities beyond their borders. So far, though, at least one federal appellate court has upheld the use of life cycle analysis as a legitimate means to overcome these obstacles.[128]

More importantly, the Ninth Circuit has also recognized the role of life cycle analysis in spurring innovation. As the Ninth Circuit stated, ethanol producers in the Midwest are not "hostage" to regional electricity portfolios based on the historic ease of locating ethanol plants near "cheap and carbon-intensive sources of coal-fired electricity generation."[129] Instead, through the use of life cycle analysis and regulatory provisions

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[124] Matthew Cimitile, *Corn Ethanol Will Not Cut Greenhouse Gas Emissions*, SCI. AM. (Apr. 20, 2009), http://www.scientificamerican.com/article/ethanol-not-cut-emissions/ [https://perma.cc/8VR3-DP58].

[125] *See* SCHNEPF & YACOBUCCI, *supra* note 30, at 6 (discussing impact of indirect land-use changes on environmental effects of ethanol); RENEWABLE FUEL STANDARD, *supra* note 35, at 188–95, 245–47 ("GHG emissions from direct and indirect land-use and land-cover changes are the variables with the highest uncertainty and the greatest effect in many cases throughout the biofuel supply chain."); *see also* Kullapa Soratana et al., *The Role of Sustainability and Life Cycle Thinking in U.S. Biofuels Policies*, 75 ENERGY POL'Y 316 (2014) (discussing limited role of life cycle analysis in biofuels policy prior to 2007).

[126] *See* SCHNEPF & YACOBUCCI, *supra* note 30, at 6; RENEWABLE FUEL STANDARD, *supra* note 35, at 188–95, 245–47.

[127] *See* Soratana et al., *supra* note 125 (discussing benefits of California program with regard to implementation of life cycle analysis).

[128] *See* Rocky Mountain Farmers Union v. Corey, 730 F.3d 1070, 1093 (9th Cir. 2013).

[129] *Id.* at 1091–92.

for individualized CI determinations, innovative ethanol producers can benefit from obtaining electricity from wind farms (also readily available at low cost in many parts of the Midwest), or through the increasing number of natural gas plants or new waste to energy generating facilities.[130]

In sum, if sufficient scientific data is available for a robust life cycle analysis that governments can rely upon to encourage markets for low-carbon products and spur innovation, there is a greater chance of obtaining real reductions in the GHG emissions of the transportation sector. As shown by the federal RFS experience, however, creating mandates for particular fuels without the benefit of a full life cycle analysis in the initial policy design can promote industries and markets that may cause as much, or more, environmental harm than the fuels they replace.[131] The tax incentives and 2005 Energy Policy Act mandates for ethanol without regard to life cycle GHG emissions began a long-term reliance on corn ethanol. Although EISA attempted to graft a life cycle analysis onto the RFS, the entrenched infrastructure, incentives to convert grasslands and forestlands to corn crop, and the lower production cost of corn ethanol make it difficult to make this transition. It also tends to make it more difficult to create alternative policies that move toward more dramatic low-carbon alternatives to both fossil fuels and biofuels in the transportation sector.

III. LIFE CYCLES OF VEHICLES: EVS AND THE ELECTRIFICATION OF TRANSPORTATION

Many of the same concerns that led to the federal biofuels policies discussed in Part II (e.g., achieving energy security, ensuring sufficient domestic oil and gas reserves, reducing GHG emissions from the transportation sector) have also led to federal and state policies that promote the development and sale of alternative vehicles to reduce the use of gasoline in the transportation sector.[132] These alternative vehicles include hybrid electric vehicles (HEVs) such as the Toyota Prius, partial hybrid electric vehicles (PHEVs) such as the Chevy Volt, and all-electric

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[130] *Id.* at 1084 ("Most of the Midwest ethanol producers who have [obtained alternative fuel pathways] either co-generate heat and electricity or use a renewable source for thermal energy, either of which can dramatically reduce GHG emissions."); *LCFS Fuel Pathways*, CAL. AIR RES. BD., https://www.arb.ca.gov/fuels/lcfs/fuelpathways/fuelpathways.htm [https://perma.cc/EUB3-WXZJ] (last updated May 9, 2016) (providing procedures for obtaining alternative fuel pathways).

[131] *See supra* notes 64–74.

[132] *See* Geyer, *supra* note 21, at 331, 336.

vehicles such as the Tesla Model S and the Nissan Leaf.[133] All of these alternative vehicles boast a much higher rate of fuel efficiency than traditional internal combustion engine vehicles (ICEVs).[134] Nevertheless, fluctuating gasoline prices, consumer wariness of new technology, and the difficulty of creating the electric charging station infrastructure necessary for widespread use of EVs has made broad adoption of all of these technologies slower than many desire.[135] The U.S. Energy Information Administration (EIA) estimates that by 2040, all forms of alternative vehicles will make up approximately 13% of the nation's automotive stock.[136] But, as discussed below, some life cycle analysis studies call into question whether, at the present time, EVs are superior to ICEVs because, in many parts of the United States, electricity is generated primarily by coal-fired power plants, resulting in GHG emissions and adverse health effects that exceed those of ICEVs. Despite these studies, policymakers should look beyond these life cycle assessments and consider the benefits that EVs can provide as the nation moves away from coal-fired power toward more renewable electricity resources. As a result, policymakers should use life cycle analysis studies in policymaking to promote decarbonization of the grid and create policies that pair incentives for EVs with additional policies that encourage the reduction, and, ultimately, elimination, of coal from the electric grid across the country. In this way, life cycle analysis can be used to guide policymakers in creating incentives not for a particular fuel or vehicle, but instead for an entirely new transportation energy model.

A. *Federal and State Mandates and Incentives to Reduce GHG and Other Air Emissions from Vehicles and Promote the Use of EVs*

Congress, EPA, and many states have implemented mandates and programs to reduce CO_2 and other air emissions in the transportation sector through new vehicle efficiency

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[133] *Electric Vehicles*, CAA, http://electricvehicles.caa.ca/types-of-electric-vehicles/ [https://perma.cc/2RAD-D2AT]; *Cars*, PLUGINCARS, http://www.plugincars.com/cars [https://perma.cc/8NQ7-8D99].

[134] *Benefits and Considerations of Electricity as a Vehicle Fuel*, U.S. DEP'T OF ENERGY, http://www.afdc.energy.gov/fuels/electricity_benefits.html [https://perma.cc/DP5G-J7EG].

[135] The EIA estimates 3.09 million gasoline-electric hybrids were in use in 2015, and 100,000 all-electric vehicles. *Annual Energy Outlook 2015*, U.S. ENERGY INFO. ADMIN., http://www.eia.gov/beta/aeo/#/?id=49-AEO2015 (last visited Mar. 31, 2017).

[136] *Id.* The EIA includes as "alternative vehicle" for this prediction gasoline-electric hybrids and ethanol-fueled internal combustion engines, which together make up over 75% of the estimated total. *Id.*

standards that apply to all vehicles, including ICEVs, as well as specific mandates and tax incentives for EVs.[137] For instance, since 2010, EPA and the National Highway Traffic Safety Administration (NHTSA) have engaged in several joint rulemaking proceedings imposing significantly higher corporate average fuel economy (CAFE) standards[138] as well as limits on GHG emissions.

These standards impose an equivalent of 35.5 miles per gallon (mpg) for light duty model year 2016 vehicles and, after a landmark rulemaking in 2012, up to 54.5 mpg for light duty model year 2025 vehicles.[139] NHTSA and EPA have also enacted heightened CAFE standards and GHG emission standards for heavy-duty trucks.[140] Auto manufacturers that fail to meet the CAFE standards are subject to a civil penalty of $5.50 per each tenth of a mile per gallon under the target value multiplied by the total volume of vehicles manufactured for a model year for sale in the United States if the fleet fails to achieve the standard.[141]

Among the states, California has always been a national leader in setting stringent vehicle emissions standards and was the first to incentivize the production, marketing, and use of EVs, creating a Zero-Emission Vehicle (ZEV) program in 1990.[142] The program was designed to be technology-forcing and was initially successful,[143] but modifications to the program creating ZEV credits for cleaner conventional vehicles and low-emission vehicles diminished its success.[144] In recent years, however, CARB has substantially strengthened the program, with a

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[137] *See* GEORGETOWN CLIMATE CTR., *supra* note 122, at 2.

[138] CAFE standards set a required average fuel economy rating across an auto manufacturer's fleet, which has increased since the standards were created in 1975. *See Corporate Average Fuel Economy*, NHTSA, http://www.nhtsa.gov/fuel-economy [https://perma.cc/SM9D-86V8].

[139] *See Regulations for Greenhouse Gas Emissions from Passenger Cars and Trucks*, EPA, https://www.epa.gov/regulations-emissions-vehicles-and-engines/regulations-greenhouse-gas-emissions-passenger-cars-and [https://perma.cc/H6N5-A7WS]; *see also* EPA, EPA AND NHTSA SET STANDARDS TO REDUCE GREENHOUSE GASES AND IMPROVE FUEL ECONOMY FOR MODEL YEARS 2017–2025 CARS AND LIGHT TRUCKS, https://nepis.epa.gov/Exe/ZyPDF.cgi/P100EZ7C.PDF?Dockey=P100EZ7C.PDF [https://perma.cc/4FE4-NXZL] (describing standards).

[140] *See Regulations for Greenhouse Gas Emissions from Commercial Trucks & Buses*, EPA, https://www.epa.gov/regulations-emissions-vehicles-and-engines/regulations-greenhouse-gas-emissions-commercial-trucks [https://perma.cc/ZJF3-5P3G].

[141] *CAFE Overview—Frequently Asked Questions*, NHTSA, http://lobby.la.psu.edu/_107th/126_CAFE_Standards_2/Agency_Activities/NHTSA/NHTSA_Cafe_Overview_FAQ.htm [https://perma.cc/L5ZD-P876].

[142] Louise Wells Bedsworth & Margaret R. Taylor, *Learning from California's Zero-Emission Vehicle Program*, 3 CAL. ECON. POL'Y 1, 1 (2007), http://www.ppic.org/content/pubs/cep/EP_907LBEP.pdf [https://perma.cc/8EJ2-VCFK].

[143] *Id.* ("Patenting data . . . show an initial innovative push by industry in response to the ZEV program.").

[144] *Id.*

mandate that requires 22% of cars with a model year of 2025 or later to be ZEVs.[145]

California also worked with EPA and the NHTSA to harmonize their vehicle emissions standards, resulting in the 2012 joint rulemaking discussed above. As of 2015, approximately one third of the nation's new car sales occurred in a state governed by the ZEV rule.[146] Minnesota took a unique approach to incentivize EV use and passed a law requiring utilities to discount electricity used for charging EVs, and mandated an opportunity to use renewable energy resources for charging.[147]

Beyond the mandate in some states that car manufacturers and dealers offer EVs for sale, there are federal and state tax incentives to encourage the purchase of EVs. At the federal level, there is a federal tax credit of up to $7500 for the purchase of an EV or PHEV.[148] Many states have additional tax incentives ranging from $1000 to $6000 to encourage the purchase of EVs for private[149] and corporate[150] use, and some states have mandated that state agencies purchase EVs or other lower emission vehicles.[151] These subsidies increase demand for EVs by lowering their net costs, while state ZEV mandates create a market for EVs and force automakers to participate in it. This, of course, is similar to the biofuels mandate, but on a significantly smaller scale.

Because of the increasing subsidies and mandates for EVs, policymakers, the industry, and experts understandably wish to determine whether these policies will achieve their goals in a cost-effective manner.[152] With regard to reducing

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145 *See* CAL. CODE REGS. tit 13, § 1962.2 (2013).

146 John O'Dell, *Will California's Zero-Emissions Mandate Alter the Car Landscape?*, EDMUNDS, http://www.edmunds.com/fuel-economy/will-californias-zero-emissions-mandate-alter-the-car-landscape.html [https://perma.cc/WKK7-RTE4] (last updated May 27, 2015).

147 MINN. STAT. § 216B.1614 (2014); *see also* Matthew Prorok, *Plugged In: Understanding Drivers of Greenhouse Gas Emissions from Electric Vehicle Charging in Minnesota* (May 2015) (unpublished M.S. thesis, Humphrey School of Public Affairs, University of Minnesota) (on file with authors).

148 *Federal Tax Credits for All-Electric and Plug-In Hybrid Vehicles*, FUELECONOMY.GOV, https://www.fueleconomy.gov/feg/taxevb.shtml [https://perma.cc/386V-AZS8]; *see* LYNN J. CUNNINGHAM ET AL., CONG. RESEARCH SERV., R42566, ALTERNATIVE FUEL AND ADVANCED VEHICLE TECHNOLOGY INCENTIVES: A SUMMARY OF FEDERAL PROGRAMS (2013).

149 *See, e.g.*, COLO. REV. STAT. ANN. § 39-26-719 (West 2015).

150 *See, e.g.*, *Illinois Green Fleets Program*, ILL. GREEN FLEETS, http://www.illinoisgreenfleets.org/ [https://perma.cc/5MRE-4KZA].

151 *See, e.g.*, MINN. STAT. §§ 16C.137, 16C.138 (2016); *State Efforts Promote Hybrid and Electric Vehicles*, NAT'L CONFERENCE OF STATE LEGISLATURES (Dec. 3, 2015), http://www.ncsl.org/research/energy/state-electric-vehicle-incentives-state-chart.aspx [https://perma.cc/2D93-ADH6].

152 *See, e.g.*, Michael Birnbaum, *Electric Cars and the Coal That Runs Them*, WASH. POST (Nov. 23, 2015), https://www.washingtonpost.com/world/electric-cars-and-the-

dependence on foreign oil and increasing U.S. energy security, these efforts will ultimately lead to less U.S. dependence on gasoline,[153] although with low gasoline prices, there are real questions regarding the cost effectiveness of this shift.[154] A more complicated question is whether the use of EVs, at least at the present time, results in clear environmental benefits over ICEVs.[155]

EVs have no tailpipe emissions, so EVs will always be environmentally superior to ICEVs if those are the only emissions that are considered in the comparison.[156] But once the focus expands beyond tailpipe emissions to include the emissions associated with the production and transportation of the energy resources necessary to produce electricity to power EVs, the emissions associated with the generation of electricity, and the emissions associated with EV battery production and disposal, the benefits of EVs become more questionable.[157] Numerous experts have undertaken studies, some with a full life cycle analysis, to answer these questions.

B. Life Cycle Studies of EVs and ICEVs

Scientists have undertaken a variety of life cycle analysis studies comparing EVs with ICEVs. These studies, described in more detail below, fall into three broad categories based on their scope: (1) tailpipe-to-tailpipe comparisons; (2) "use phase" studies, some of which consider solely the emissions from power plants and vehicle tailpipes and others which also consider emissions associated with the extraction and transportation of oil,

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coal-that-runs-them/2015/11/23/74869240-734b-11e5-ba14-318f8e87a2fc_story.html [https://perma.cc/9Y4M-7VP4].

153 *See* Meg Handley, *Energy Sec. Chu: More Electric Vehicles, Less U.S. Dependence on Foreign Oil*, U.S. NEWS (Jan. 31, 2013), http://www.usnews.com/news/articles/2013/01/31/energy-sec-chu-more-electric-vehicles-less-us-dependence-on-foreign-oil [https://perma.cc/Y8PM-E9PN].

154 *See* Michael Lynch, *Cheap Gasoline Will Kill the Electric Car Again*, FORBES (Jan. 14, 2016), http://www.forbes.com/sites/michaellynch/2016/01/14/will-low-gasoline-prices-whipsaw-the-auto-industry-again/#33557a45e7e5.

155 *See, e.g.*, Rachael Nealer, *How Clean Are Electric Cars? A Life Cycle Assessment of Advanced Vehicle Technologies*, UNION OF CONCERNED SCIENTISTS (Sept. 18, 2014), http://blog.ucsusa.org/rachael-nealer/how-clean-are-electric-cars-a-life-cycle-assessment-of-advanced-vehicle-technologies-656 [https://perma.cc/9R3H-NF5B].

156 *Emissions from Hybrid and Plug-In Electric Vehicles*, U.S. DEP'T OF ENERGY, http://www.afdc.energy.gov/vehicles/electric_emissions.php [https://perma.cc/M93U-8379].

157 *See* Eric Jaffe, *4 Key Problems with Measuring EV Pollution vs. Gas Cars*, ATL. CITYLAB (July 10, 2015), http://www.citylab.com/weather/2015/07/4-key-problems-with-measuring-ev-pollution-vs-gas-cars/398093/ [https://perma.cc/RT95-6HJE]; Virginia McConnell & Joshua Linn, *Subsidies for EVs: Good Policy or Unnecessary Handout?*, RES. FOR THE FUTURE (July 25, 2013), http://www.rff.org/blog/2013/subsidies-evs-good-policy-or-unnecessary-handout [https://perma.cc/59PL-CLGK].

gas, and coal energy resources; and (3) broader life cycle analyses that also consider battery and vehicle production and disposal.

1. Tailpipe Studies

Tailpipe studies focus exclusively on the air emissions associated with driving the vehicle. In direct comparison to tailpipe emissions, EVs are always superior in terms of air pollution reduction to ICEVs, as EVs are virtually emission-free at the tailpipe level.[158] This compares to the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy's estimate of national average annual emissions of an ICEV of approximately 11,500 pounds of CO_2 equivalent GHG emissions.[159] Nevertheless, virtually no EV proponents rely solely on tailpipe emissions to support arguments in favor of EVs, recognizing that the air emissions and environmental impacts of electricity production must be included in any comparison of EVs and ICEVs.[160] Use phase studies more accurately compare the total impacts of EVs and ICEVs.

2. Use Phase Studies

A use phase analysis goes beyond tailpipe emissions and considers a broader suite of vehicle-related impacts. For EVs, this includes (1) the emissions associated with the extraction and transportation of coal, natural gas, nuclear, wind, hydropower, and solar energy resources used to produce electricity; and (2) the emissions associated with converting those energy resources into the electricity needed to charge the EV, such as the emissions from a coal-fired power plant or a natural gas-fired power plant.[161] For ICEVs, a use phase analysis considers the environmental impacts of producing oil and biofuels, transporting those fuels to refineries and blending facilities, refining and blending those fuels to turn them into

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158 *Emissions from Hybrid and Plug-In Electric Vehicles*, *supra* note 156.

159 Marc Lausier, *Are Electric Vehicles Really Zero-Emission: Yes or No?*, GREEN CAR REPORTS (Apr. 22, 2013), http://www.greencarreports.com/news/1083652_are-electric-vehicles-really-zero-emission-yes-or-no [https://perma.cc/3HWJ-K2UX]; *Emissions from Hybrid and Plug-In Electric Vehicles*, *supra* note 156 ("EVs and PHEVs running only on electricity have zero tailpipe emissions, but emissions may be produced by the source of electrical power, such as a power plant. In geographic areas that use relatively low-polluting energy sources for electricity generation, PHEVs and EVs typically have a well-to-wheel emissions advantage over similar conventional vehicles running on gasoline or diesel. In regions that depend heavily on conventional fossil fuels for electricity generation, PEVs may not demonstrate a well-to-wheel emissions benefit.").

160 *See Emissions from Hybrid and Plug-In Electric Vehicles*, *supra* note 156.

161 *Id.*

gasoline and other vehicle fuels, and the tailpipe emissions from the combustion of these fuels to drive the ICEV.[162]

Once these factors are considered as part of the environmental impact of each type of vehicle, the environmental benefits of EVs as compared to ICEVs are decidedly more mixed.[163] For instance, coal-fired electricity, which constitutes approximately one-third of electricity generation nationwide,[164] emits substantial amounts of criteria pollutants such as nitrogen oxides, sulfur dioxides, and particulate matter; toxic emissions such as mercury; as well as CO_2 and other GHG emissions that contribute to climate change.[165] Thus, a major question with regard to EVs is whether the decrease in tailpipe emissions compared to ICEVs can overcome the increase in electricity generation-related emissions and other use phase emissions.[166] Taking the average mix of generation sources for U.S. electricity, the U.S. Department of Energy found that average annual GHG emissions are lower for EVs, HEVs, and PHEVs.[167] However, the wide variety of energy resources used to produce electricity among the various states[168] means that focusing on national averages is not always useful.[169]

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162 TIAX LLC, FULL FUEL CYCLE ASSESSMENT: WELL-TO-WHEELS ENERGY INPUTS, EMISSIONS, AND WATER IMPACTS 5 (2007), http://www.energy.ca.gov/2007publications/CEC-600-2007-004/CEC-600-2007-004-F.PDF [https://perma.cc/KQP6-A5ZH].

163 *See, e.g.*, *Cleaner Than What?*, ECONOMIST (Dec. 20, 2014), http://www.economist.com/news/science-and-technology/21636715-why-electric-car-may-be-much-dirtier-petrol-one-cleaner-what [https://perma.cc/C3YX-LYUV].

164 *Frequently Asked Questions: What Is U.S. Electricity Generation by Energy Source*, U.S. ENERGY INFO. ADMIN., https://www.eia.gov/tools/faqs/faq.cfm?id=427&t=3 [https://perma.cc/QQ4T-QE6U] (last updated Apr. 1, 2016).

165 *Coal Power: Air Pollution*, UNION OF CONCERNED SCIENTISTS, http://www.ucsusa.org/clean_energy/coalvswind/c02c.html#.VrI_VfkrLIU [https://perma.cc/AX69-FYM4] ("A typical coal plant generates 3.5 million tons of CO2 per year."); *Learn About Carbon Pollution from Power Plants*, EPA, http://www.epa.gov/cleanpowerplan/learn-about-carbon-pollution-power-plants [https://perma.cc/WNE2-BTNS] ("Fossil fuel-fired power plants are the largest source of U.S. CO_2 emissions."). The precise mix of electricity generation varies substantially between states. *See* Alyson Hurt, *Coal, Gas, Nuclear, Hydro? How Your State Generates Power*, NPR (Sept. 10, 2015), http://www.npr.org/2015/09/10/319535020/coal-gas-nuclear-hydro-how-your-state-generates-power [https://perma.cc/2QF2-VNX3].

166 To better enable comparisons between ICEVs and EVs/HEVs, the U.S. Department of Energy has developed an online calculator that estimates greenhouse gas emissions based on car model, make, and zip code. *Beyond Tailpipe Emissions*, FUELECONOMY.GOV, https://www.fueleconomy.gov/feg/Find.do?action=bt2.

167 *Emissions from Hybrid and Plug-In Electric Vehicles*, *supra* note 156. This study exclusively examined greenhouse gas emissions (carbon dioxide, methane, and nitrous oxide). *See* ARGONNE NAT'L LAB., WELL-TO-WHEELS ENERGY USE AND GREENHOUSE GAS EMISSIONS ANALYSIS OF PLUG-IN HYBRID ELECTRIC VEHICLES 25 (2009), http://www.ipd.anl.gov/anlpubs/2009/03/63740.pdf [https://perma.cc/A7KN-T2GR] (evaluating the U.S. Department of Energy study).

168 Hurt, *supra* note 165.

169 The national average generation mix is more relevant in international comparisons. *See, e.g.*, LINDSAY WILSON, SHRINK THAT FOOTPRINT, SHADES OF GREEN: ELECTRIC CARS' CARBON EMISSIONS AROUND THE GLOBE (2013), http://shrinkthat

A 2015 study by economists Stephen P. Holland, Erin T. Mansur, Nicholas Z. Muller, and Andrew J. Yates sought to better understand how the geographical differences in electricity generation mix impacted the emissions of EVs across the country, and consequently whether existing federal and state subsidies for EVs were appropriate.[170] This study was not a full use phase analysis in that it did not consider emissions from the extraction and transportation of primary energy resources such as coal, oil, or natural gas used to power EVs and ICEVs. Instead, it compared power plant emissions used to power EVs with tailpipe emissions from ICEVs.[171] The researchers compared pollution rates from ICEVs and EVs for every county in the United States to determine and compare the environmental harm associated with each type of vehicle.[172]

To conduct this comparison, the researchers converted pollution statistics to dollar-cost impacts and charted damage amounts across the United States.[173] The researchers focused on five major pollutants: carbon dioxide, sulfur dioxide, mono-nitrogen oxides, particulate matter, and volatile organic compounds.[174] ICEV costs were fairly variable across states and counties, with particularly high damage calculations in dense, more polluted urban centers, such as Los Angeles, Atlanta, New York, and Chicago.[175] Damage in these environments is predominately due to non-GHG criteria pollutants, which cause localized harm.[176] Even in these areas, the marginal cost of pollution from driving an average ICEV one mile was under five cents.[177] By contrast, damage calculations for EVs varied widely, based on the primary energy sources used to generate electricity

footprint.com/wp-content/uploads/2013/02/Shades-of-Green-Full-Report.pdf [https://perma.cc/8XNA-K9FB].

170 Stephen P. Holland et al., *Environmental Benefits from Driving Electric Vehicles?* (Nat'l Bureau for Econ. Research, Working Paper No. 21291, 2015).

171 *See id.* at 1–2.

172 *Id.* at 12. For ICEVs, the authors calculated environmental damage based on fuel efficiency, pollutant dispersion, and health impacts. For EVs, they used a fuel efficiency equivalent to determine how much electricity the EV drew from the electric grid and the hourly emissions profiles for the target pollutants for power plants in each county. *Id.* at 11–12.

173 *Id.* at 15; Eric Jaffe, *Where Electric Vehicles Actually Cause More Pollution than Gas Cars*, ATL. CITYLAB (June 29, 2015), http://www.citylab.com/weather/2015/06/where-electric-vehicles-actually-cause-more-pollution-than-gas-cars/397136/?utm_source=SFFB [https://perma.cc/4WWE-J544]. This method also supported their conclusions on subsidies for EVs. *See infra* notes 183–186 and accompanying text.

174 Holland et al., *supra* note 170, at 11.

175 *Id.* at 32 fig.1; Jaffe, *supra* note 173 ("For the gas car, the worst damage . . . tends to occur in highly populated urban areas. That makes sense, because that's where tailpipe emissions can do the most immediate social harm.").

176 Holland et al., *supra* note 170, at 18, tbl.3.

177 *Id.* at 32 fig.1.

from state to state. In the coal-heavy Midwest, marginal damage estimates were nearly five cents per mile driven.[178] In the Southeast and Texas, which rely on a larger proportion of nuclear, hydropower, and wind resources to generate electricity, marginal damage estimates were less than three cents per mile.[179] The western states have the cleanest energy grids and thus had the lowest estimated marginal costs, at approximately one cent per mile.[180] Overall, this study suggests that electricity generation emissions cause marginal costs as high or higher than ICEV emissions in U.S. states east of the Rocky Mountains.[181] Only in the western states, and in high-density urban areas in the East, were EVs equal to or better than ICEVs, in terms of costs associated with emissions.[182]

Based on these data on the marginal costs of pollution from EVs and ICEVs, Holland et al. addressed the economic value of subsidizing EVs.[183] Where lifetime environmental impacts for EVs are less than ICEVs, they concluded that a subsidy is justified in the amount by which the EV incurs fewer costs. Vice versa, where lifetime impacts are higher, a tax was justified to recoup the additional environmental costs the EV produced. The study concluded that subsidies are justified across the western states, portions of Texas,[184] and Orlando, Atlanta, and New York.[185] In the remainder of the country, the authors concluded that EVs should be taxed, often quite heavily, at over $5000 per car in most of the Midwest.[186] By geographically breaking down where EVs are more environmentally friendly than ICEVs, Holland et al. challenged the blanket assurances that EVs are preferable everywhere.

Perhaps recognizing that county-specific taxes and incentives may not be feasible, Holland et al. examined what

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178 *Id.*

179 *Id.*

180 *Id.*

181 *Id.*

182 *Id.*

183 The researchers first determined the net environmental impact of EVs by subtracting the EV cost from the ICEV cost for each county. They then multiplied this per-mile net impact by a theoretical vehicle lifetime of 150,000 miles to determine the full-lifetime benefit or detriment of the EV compared to the ICEV. Holland et al., *supra* note 170, at 17–18. Note, however, that this calculus appears to presume that the EV studied will not leave the county during its lifetime.

184 Though not, interestingly, in the portions of Texas with a large proportion of wind-generated power. *Compare id.* at 32 fig.2, *with Texas State Energy Profile*, U.S. ENERGY INFO. ADMIN., http://www.eia.gov/state/?sid=TX [https://perma.cc/65JP-5PEY].

185 Holland et al., *supra* note 170, fig.2. In no case does the appropriate subsidy amount reach the current federal subsidy of $7500. *Id.* at 18.

186 *Id.* at 32 fig.2.

subsidies or taxes would be appropriate at the state level.[187] In doing so, the authors noted that while ICEV emissions are highly localized (i.e., because the emissions are from the car itself they occur where the car is), emissions attributable to EVs often occur several states away from where the vehicle actually is operating.[188] "Pollution exporting," as these authors termed it, may evolve into an environmental justice problem as wealthier states improve local air quality by driving EVs, while poorer states suffer the harmful environmental effects of continued reliance on coal-fired power generation in their communities.[189] Additionally, exporting pollution outside the state will affect the appropriate level of subsidy or tax, which (economically speaking) ought to be levied to account for EV externalities.[190] If state subsidy calculations do not properly account for out-of-state negative externalities, then advantaged states will price EVs too low (as they capture the benefits of increased EV use without incurring the harms).[191] For this reason, Holland et al. produced two maps recommending tax/subsidy amounts—one showing amounts that consider all damages incurred and another showing amounts that consider only damages incurred within the state.[192] While in the former case subsidies are only appropriate in the western states and Texas, in the latter case modest subsidies are appropriate across the majority of states, and modest taxes (under $1000 per vehicle) appropriate in about fourteen states.[193]

Notably, the study assumed that any retired coal-fired power plants in the United States would be replaced exclusively by natural gas facilities. As a result, it did not consider the impact of replacing coal-fired generation with wind, solar, or hydropower resources, even though much of the coal-fired power

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[187] *See id.* at 33 fig.3.

[188] Holland et al., *supra* note 170, at 3–4 ("[A]t the state level, 91% of local pollution damages from driving an electric vehicle are exported to states other than the state in which the vehicle is driven. In contrast, only 19% of local pollution damages from driving a gasoline vehicle are exported to other states.").

[189] *See* C.C. SONG, THE GREENLINING INST., ELECTRIC VEHICLES: WHO'S LEFT STRANDED? 9 (2011), http://greenlining.org/wp-content/uploads/2013/02/ElectricVehiclesReport.pdf [https://perma.cc/ZKU6-YLE6]; *see generally* RACHEL MASSEY, GLOB. DEV. & ENV'T INST., ENVIRONMENTAL JUSTICE: INCOME, RACE AND HEALTH (2004) (establishing the basic tenets of the environmental justice movement). A 2016 study by Holland et al. examined the environmental benefits of EVs by census tract and concluded that benefits tend to accrue in wealthier areas. Stephen P. Holland et al., *Distributional Effects of Air Pollution from Electric Vehicle Adoption* (Nat'l Bureau of Econ. Research, Working Paper No. 22862, 2016), http://www.nber.org/papers/w22862.pdf [https://perma.cc/2TD4-XVCD].

[190] Holland et al., *supra* note 170, at 4.

[191] *Id.* at 33 fig.3.

[192] *Id.*

[193] *Id.*

that has been retired in the past ten years has been replaced in part by renewable resources in many states.[194] As is discussed further below, the trend in electricity generation is toward less carbon-intensive sources, which substantially improves the environmental prospects for EVs across the country. A myopic focus on how EVs interact with the present electricity generation mix risks eliminating both the present benefits of EVs in those areas with greener grids, and the future benefits in other areas with greening grids. Moreover, use phase studies cannot provide a complete life cycle analysis of either EVs or ICEVs, so scientists have attempted to expand their focus to evaluate a broader suite of impacts, as discussed in the next section.

3. Broader Life Cycle Analyses: Localized Gasoline Impacts, Battery Impacts, and Charging Programs

Although use phase analyses evaluate a broader range of environmental impacts than tailpipe emissions, they cannot fully evaluate the relative environmental impacts of EVs and ICEVs. For example, on the component side, EV batteries are significantly different than ICEV batteries, requiring different material components and manufacturing processes, and potentially resulting in different disposal impacts.[195] To account for these aspects, plus others, researchers have performed life cycle analysis studies examining environmental consequences of EVs at the manufacturing and disposal phases as well as the use phase.[196] Several of these studies are discussed below, many of which find a more positive environmental impact associated with EVs than the Holland, et al. study.

A 2016 study by the Great Plains Institute (GPI)[197] challenged the conclusions drawn in the Holland et al. study, asserting that it neglected to account for the extraction and refining of gasoline fuels or analyze sufficiently local energy grid composition.[198] The GPI study focused specifically on

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194 *See* Hurt, *supra* note 165 (showing significant reductions in use of coal-fired electricity in many states over a ten-year period and an increase in the use of renewable energy).

195 Kwo Young et al., *Electric Vehicle Battery Technologies*, *in* ELECTRIC VEHICLE INTEGRATION INTO MODERN POWER NETWORKS (R. Garcia-Valle & J.A. Peças Lopes eds., 2013).

196 For an analysis of life cycle analysis as applied to EVs, with a focus on Minnesota, see Prorok, *supra* note 147.

197 *See* Dane McFarlane, *Electric Vehicles Provide Large GHG Reductions in Minnesota*, GREAT PLAINS INST. (Apr. 12, 2016), http://www.betterenergy.org/blog/electric-vehicles-provide-large-ghg-reduction-minnesota/ [https://perma.cc/N5NC-37SH].

198 Frank Jossi, *Minnesota Study Challenges 'Coal Car' Claims About Electric Vehicles*, MIDWEST ENERGY NEWS (Apr. 20, 2016), http://midwestenergynews.com/2016/04/

conditions in Minnesota, and found that several local factors meant that EVs are substantially superior to ICEVs in the state.[199] Chief among these is the fact that gasoline refined in Minnesota[200] has a higher carbon intensity than the national average due to its heavier reliance on oil derived from Alberta oil sands and North Dakota shale oil.[201] Furthermore, the Minnesota grid uses substantially more renewables than nearby states, which further lowers the carbon intensity of electricity in the state.[202] The study concludes that under Xcel Energy's current energy portfolio, EVs have lifetime emissions 61% below that of ICEVs.[203] The study also highlights that lifetime emissions drop to 95% below those of an ICEV[204] when EV owners enroll in all-renewable charging programs.[205] The study found that, in Minnesota at least, enrollment in such programs is relatively common, with 56% of surveyed EV owners participating.[206]

Likewise, Christopher W. Tessum, Jason D. Hill, and Julian D. Marshall conducted a 2014 study that included a full use phase assessment (including energy extraction, transportation, conversion to electricity (for EVs), and tailpipe emissions (for ICEVs)), as well as an assessment of battery-related impacts.[207] The study specifically focused on forecasting the human health impacts of air pollution from one of eleven types of vehicles (including EVs, HEVs, and ICEVs) if it accounted for 10% of U.S. miles driven in 2020.[208] Of the modes of vehicles studied, the highest negative health impacts (measured in increases in

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20/minnesota-study-challenges-coal-car-claims-about-electric-vehicles/ [https://perma.cc/6BK8-H6WP]; McFarlane, *supra* note 197.

199 McFarlane, *supra* note 197.

200 In-state refineries supply just over two-thirds of the state's gasoline demand, making this distinction particularly salient. *See* BOB ELEFF, RESEARCH DEP'T, MINN. HOUSE OF REPRESENTATIVES, MINNESOTA'S PETROLEUM INFRASTRUCTURE: PIPELINES, REFINERIES, TERMINALS (2013), http://www.house.leg.state.mn.us/hrd/pubs/petinfra.pdf [https://perma.cc/V3UZ-3D9Y].

201 McFarlane, *supra* note 197.

202 *Id.*

203 *Id.* Xcel Energy is Minnesota's dominant utility, providing electricity service in the state to over one million customers. *See, e.g.*, *Who We Are*, EXCEL ENERGY, https://www.xcelenergy.com/company/corporate_responsibility_report/who_we_are [https://perma.cc/DF6L-V6N2].

204 *Id.*

205 With a renewable charging program, the utility generates or purchases renewable electricity in the amount used to charge the EV or to supply all power to the customer. *See e.g.*, *Windsource Minnesota—Frequently Asked Questions*, XCEL ENERGY, https://www.xcelenergy.com/staticfiles/xe/Marketing/Files/Windsource-Minnesota-Res-FAQs.pdf [https://perma.cc/RS33-L5WK].

206 McFarlane, *supra* note 197. High rates of participation may have been influenced by a Minnesota statute requiring utilities to offer renewable-only options to EV owners. *See* Prorok, *supra* note 147, and accompanying text.

207 Tessum et al., *supra* note 72, at 18490.

208 *Id.*

annual mortality) were produced not by traditional gasoline cars, but by EVs powered exclusively by coal-burning power plants, followed by EVs powered by the U.S. average mix of electricity resources and corn ethanol-powered vehicles.[209] ICEVs, by contrast, produced the next lowest number of mortalities per year.[210] The cleanest of the studied vehicles was the EV powered by wind, solar, or hydroelectric sources.[211] Other than the extremely high magnitude of damage from coal-powered EVs, the other notable conclusion from this study was that, overall, biofuels were more damaging to human health than petroleum fuels.[212]

A study by James Archsmith, Alissa Kendall, and David Rapson adds an additional factor to the assessment of EVs by noting the effects of ambient climate on EV efficiency.[213] Both hot and cold temperatures substantially affect the range of an EV (due primarily to diversion of energy from propulsion to in-car climate controls),[214] which requires more frequent charging (and thus, more kilowatt-hours consumed per mile). In areas with coal-dependent electricity generation and relatively extreme climates (e.g., the Midwest), use of EVs can substantially increase GHG emissions.[215] The study concludes that, on average, most regions would see GHG reductions when comparing ICEVs to EVs, but states in the Midwest, South Central, and Mid-Atlantic regions might see increases.[216] In a detailed life cycle analysis study of EV charging in the PJM interconnection,[217]

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[209] *Id.* at 18492 & fig.2; *Cleaner Than What?*, *supra* note 163. According to the study, EVs powered exclusively by coal burning power plants would cause over 3000 deaths per year, EVs powered by the average mix of electricity resources would cause over 1500 deaths, vehicles powered by corn ethanol would result in over 1500 deaths, ICEVs would cause 878 deaths, and EVs powered by renewable energy would cause 231 deaths. Tessum et al., *supra* note 72, 18492 fig.2.

[210] Tessum et al., *supra* note 72, at 18492 & fig.2; *Cleaner Than What?*, *supra* note 163.

[211] Tessum et al., *supra* note 72, at 18492 & fig.2; *Cleaner Than What?*, *supra* note 163.

[212] Tessum et al., *supra* note 72, at 18492 & fig.2.

[213] JAMES ARCHSMITH ET AL., ENERGY INST. AT HAAS, FROM CRADLE TO JUNKYARD: ASSESSING THE LIFE CYCLE GREENHOUSE GAS BENEFITS OF ELECTRIC VEHICLES (2015), https://ei.haas.berkeley.edu/research/papers/WP263.pdf [https://perma.cc/65TE-4DU7]; *see also* Tugce Yuksel & Jeremy J. Michalek, *Effects of Regional Temperature on Electric Vehicle Efficiency, Range, and Emissions in the United States*, 49 ENVTL. SCI. & TECH. 3974 (2015) (finding that differences in average miles driven and temperature changes significantly impacted EV emissions).

[214] ARCHSMITH ET AL., *supra* note 213, at 16–17.

[215] *Id.* at 4, 50.

[216] *Id.* at 23, 49 fig.10.

[217] "PJM Interconnection is a regional transmission organization (RTO) that coordinates the movement of wholesale electricity in all or parts of Delaware, Illinois, Indiana, Kentucky, Maryland, Michigan, New Jersey, North Carolina, Ohio,

Allison Weis, Paulina Jaramillo, and Jeremy Michalek came to a similar conclusion.[218] Weis et al. found that the additional burden on the PJM grid produced by EV charging led to increased use of coal-fired electric plants, with higher-cost externalities, and that this would occur regardless of an increase in renewable wind resources.[219]

Other studies focus on the environmental impacts of the EV battery.[220] Overall, EV vehicle production represents about "2–15% of total life cycle environmental impact," and battery production is the largest factor.[221] Most EVs use a lithium-ion (Li-ion) battery to increase stored energy and range of the vehicle.[222] In 2013, EPA concluded a life cycle analysis of Li-ion batteries to "identify the materials or processes within a battery's life cycle that are likely to pose the greatest impacts to both public health and the environment, and to evaluate nanotechnology innovations in advanced Li-ion batteries for electric vehicles that may enhance battery performance."[223] This EPA study was one of the first to implement a full cradle-to-grave analysis of batteries based on data supplied by battery manufacturers and recyclers, and attempt to assess future developments in battery technology—specifically the use of carbon nanotubes.[224] The study found that upstream, material-sourcing impacts differed based on the chemical composition of the battery,[225] with rarer and more toxic metals increasing health-related and environmental costs. Batteries that used higher amounts of aluminum showed higher potential for ozone depletion simply because of the high amount of chlorofluorocarbon emissions required in the aluminum smelting process.[226] A large proportion of the aluminum could be recovered in the recycling process, however, which

Pennsylvania, Tennessee, Virginia, West Virginia and the District of Columbia." *Who We Are*, PJM, http://www.pjm.com/about-pjm/who-we-are.aspx [https://perma.cc/6NZ4-JED8].

[218] Allison Weis et al., *Consequential Life Cycle Air Emissions Externalities for Plug-In Electric Vehicles in the PJM Interconnection*, 11 ENVTL. RES. LETTERS 1 (2016).

[219] *Id.* at 11.

[220] *See* NEALER ET AL., *supra* note 13, at 16.

[221] Prorok, *supra* note 147, at 9–10.

[222] *See* Umair Irfan, *Cheap, Reliable, Lightweight Battery May Be Near, but Is Not Yet Here*, CLIMATEWIRE (Nov. 2, 2015), http://www.eenews.net/climatewire/2015/11/02/stories/1060027259 [https://perma.cc/WHH8-XJ3M] (reporting on continued research into developing cheaper, higher-capacity batteries for EVs and other uses).

[223] SHANIKA AMARAKOON ET AL., EPA, APPLICATION OF LIFE-CYCLE ASSESSMENT TO NANOSCALE TECHNOLOGY: LITHIUM-ION BATTERIES FOR ELECTRIC VEHICLES (2013), http://www.epa.gov/sites/production/files/2014-01/documents/lithium_batteries_lca.pdf [https://perma.cc/L2M9-YZAG].

[224] *Id.* at 4.

[225] *Id.* at 102 ("[T]he choice of active material for the cathode influences the results across most of the impact categories.").

[226] *Id.* at 98, 102.

somewhat mitigates the dangers of its production.[227] Other methods of production brought varied impacts across the production phase of analysis.

With regard to battery disposal, the relative novelty of EVs in any substantial number has so far impeded life cycle analysis of battery disposal. EV Li-ion batteries cannot be disposed of in the same away as ICEV lead-acid batteries, and thus are worthy of separate consideration. An EPA study of Li-ion batteries concluded that their recycling potential was high, with only 3% of the original battery materials (measured by weight) going to landfill.[228] The study cites the presence of valuable metals, including cobalt, lithium, and nickel, in the batteries as rendering recycling cost effective.[229] The study notes two potential near-term developments that may improve disposal-phase impacts: the development of direct-recycling processes (where used batteries are broken down and their components used to create new batteries), and refurbishment processes (where used batteries are drained, replenished, and returned to use in EVs or altered for other uses, including home computers).[230] As of yet, these processes are not fully viable, but both the EPA study and a 2015 study by Rachael Nealer, David Reichmuth, and Don Anair concluded that the use of these alternative processes would likely offset energy consumption at the manufacturing phase.[231] The Nealer study found relatively low impacts from battery production,[232] though still higher than ICEV batteries, but noted that changes in the chemical makeup of the battery could, for a midsize EV, increase related emissions up to 43% or decrease it up to 18%.[233] Because of this emission-reduction potential, one of the

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[227] *Id.* at 102.

[228] *Id.* at 56–57 & figs.2–9.

[229] *Id.* at 56. *But see* CHARLES R. STANDRIDGE & LINDSAY CORNEAL, MINETA NAT'L TRANSIT RESEARCH CONSORTIUM, REMANUFACTURING, REPURPOSING, AND RECYCLING OF POST-VEHICLE-APPLICATION LITHIUM-ION BATTERIES 1, 16, 17 tbl.3 (2014), http://transweb.sjsu.edu/PDFs/research/1137-post-vehicle-Li-Ion-recycling.pdf [https://perma.cc/7ZXF-QF8D]. *See* John Voelcker, *Electric-Car Batteries: What Happens to Them After Coming Out of the Car?*, GREEN CAR REPORTS (Aug. 12, 2014), http://www.greencarreports.com/news/1093810_electric-car-batteries-what-happens-to-them-after-coming-out-of-the-car [https://perma.cc/3YG9-NQWV] (challenging the economic viability of battery recycling by concluding only 20% of the battery cost is recoverable).

[230] AMARAKOON ET AL., *supra* note 223, at 58.

[231] *Id.* at 56–60; NEALER ET AL., *supra* note 13, at 41; *see also* Thomas P. Hendrickson et al., *Life-Cycle Implications and Supply Chain Logistics of Electric Vehicle Battery Recycling in California*, 10 ENVTL. RES. LETTERS 1 (2015) (examining impacts of siting and methods of EV battery recycling).

[232] NEALER ET AL., *supra* note 13, at 38. The Archsmith study noted the same fact, deriving it from the GREET model pathways. ARCHSMITH ET AL., *supra* note 213, at 16.

[233] NEALER ET AL., *supra* note 13, at 39.

recommendations of the study is for further research and development of battery technology.[234]

C. *Policy Implications for EV Life Cycle Analyses*

The life cycle analysis studies discussed above reveal that despite the complete lack of tailpipe emissions associated with EVs, the use of coal in the electric grid can significantly compromise the environmental benefits of EVs as compared with ICEVs.[235] This calls into question the federal and state programs that incentivize the purchase and use of EVs.[236]

In the Netherlands, for example, officials worried when experts suggested that because of the immense amount of energy required to charge an electric vehicle (as much energy as a refrigerator requires in a month per charge), a proliferation of EVs could actually increase GHG emissions.[237] The Holland et al. study discussed above similarly questioned the economic justifiability of EV subsidies across large swathes of the United States.[238] It may very well be the case that today's EVs are not superior to ICEVs in certain parts of the country. But, that does not mean that EV incentives should be abandoned. First, there are areas of the country where EVs already produce lower emissions than ICEVs—where the grid is relatively clean—and incentives should certainly continue to operate in those regions.[239] Second, the electric grid in the United States and across the world is in a state of transition, with an increasing focus on green technologies and renewable fuels.[240] In 2015, coal accounted for only 34% of U.S. electricity generation—its lowest share since EIA recordkeeping began—as compared with 50% of total U.S. electricity generation as recently as 2005.[241]

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[234] *Id.* at 25–26.

[235] *See generally* ELEC. POWER RESEARCH INST., ENVIRONMENTAL ASSESSMENT OF A FULL ELECTRIC TRANSPORTATION PORTFOLIO—VOLUME 1: BACKGROUND, METHODOLOGY, AND BEST PRACTICES (2015), http://www.eenews.net/assets/2015/09/18/document_cw_01.pdf [https://perma.cc/BRL4-V6LM] (analyzing potential impacts of a widespread shift toward electricity in the transportation sector).

[236] *See, e.g.*, Michael Birnbaum, *Electric Car Craze Fueled by Coal Burning*, ENERGYWIRE (Nov. 25, 2015), http://www.eenews.net/energywire/2015/11/25/stories/1060028559 [https://perma.cc/JC4B-KNNJ].

[237] *Id.*

[238] *See supra* notes 183–193 and accompanying text.

[239] Birnbaum, *supra* note 236 ("In upstate New York, though, the hydropower generation means a [gasoline] car would have to get better than 112 mpg to beat out electric.").

[240] *See Energy in Brief: How Is the Fuel Mix for U.S. Electricity Generation Changing?*, U.S. ENERGY INFO. ADMIN., https://www.eia.gov/energy_in_brief/article/fuel_mix_for_elect_generation.cfm [https://perma.cc/4TR8-PKDE] (last updated Feb. 19, 2016).

[241] Suzanne Goldenberg, *US Electricity Industry's Use of Coal Fell to Historic Low in 2015 as Plants Closed*, GUARDIAN (Feb. 4, 2016), https://www.theguardian.com/

These ongoing, substantial changes to the grid prompted the Union of Concerned Scientists to note that "[t]wo-thirds of all Americans now live in areas where driving an EV produces fewer climate emissions than almost all comparable gasoline and gasoline hybrid cars—a fact attributable to more efficient EVs and an increasingly clean electricity grid."[242] As the grid improves, EVs will become increasingly able to reach their potential.[243] While the environmental benefits of EVs may not be significant in all parts of the country, the electric grid is evolving to resemble those areas where EVs are manifestly beneficial.[244] Though it may take decades for the most coal-dependent grids to embrace renewables, the benefits of EVs on grids powered by natural gas, hydropower, and renewable energy are already a reality. Decreasing or eliminating EV incentives for failure to provide immediate benefit would be shortsighted and ultimately harmful. Life cycle analysis tends to describe the world as it is, and it is a mistake to eliminate EV incentives in reliance on studies that show no environmental improvement over ICEVs. The greening of the electricity grid is still a relatively recent phenomenon and has significant potential for GHG reduction that would be left partially unrealized by continued reliance on gasoline-powered vehicles.

CONCLUSION

This article evaluates the ways that life cycle analysis can be used to guide policymakers as they attempt to reduce GHG emissions and promote energy security in the transportation sector by placing mandates on fuel producers and vehicle manufacturers and creating incentives for consumers to purchase

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environment/2016/feb/04/us-electricity-industrys-use-of-coal-fell-to-historic-low-in-2015-as-plants-closed [https://perma.cc/22XK-AEJN]; *see Peak Coal: US Coal-Fired Power Is Steadily Declining*, ECONOMIST (Aug. 11, 2015), http://www.eiu.com/industry/article/1703426954/peak-coal-us-coal-fired-power-is-steadily-declining/2015-08-11 [https://perma.cc/D63Y-WZ6U]; *see also* Hurt, *supra* note 165; Seth Feaster, *IEEFA Data Bite: Wind on the Rise, Coal on the Wane*, INST. FOR ENERGY ECON. & FIN. ANALYSIS (May 12, 2016), http://ieefa.org/ieefa-data-bite-wind-rise-coal-wane/ [https://perma.cc/XUZ2-WEDA].

[242] *Cleaner Cars from Cradle to Grave*, UNION OF CONCERNED SCIENTISTS (2015), http://www.ucsusa.org/clean-vehicles/electric-vehicles/life-cycle-ev-emissions#.VyKbaTArLIV [https://perma.cc/6QCE-89P8].

[243] As a practical corollary to this argument, widespread EV use will require a corresponding increase in EV-specific infrastructure, namely, charging stations. Continued incentives to purchase EVs will also incentivize continued development of charging stations, which will in turn support increased EV use. *See, e.g.*, Anne C. Mulkern, *PG&E May Build Nation's Largest Deployment of EV Charging Spots*, CLIMATEWIRE (Aug. 26, 2016), http://www.eenews.net/stories/1060042082 [https://perma.cc/YJ8M-BBRS].

[244] EVs themselves are sometimes drivers of grid adaptation. *See* Camille von Kaenel, *How to Make a Clean Car Even Cleaner*, CLIMATEWIRE (Aug. 4, 2016), http://www.eenews.net/climatewire/2016/08/04/stories/1060041166 [https://perma.cc/59NF-GC6K].

innovative vehicles. The story of the RFS and federal policies promoting biofuels is a cautionary tale. Creating a guaranteed market for biofuels through the RFS encouraged the agriculture and biofuels industries to devote significant resources to the production of corn ethanol.

Although EISA attempted to incorporate life cycle analysis to mandate a transition in favor of advanced biofuels and cellulosic ethanol, economic and technological challenges in the advanced biofuels industry coupled with the flexibility built into the law to waive those requirements has resulted in continued reliance on corn ethanol to meet the mandates. Moreover, these mandates appear even more questionable in an era of readily available, inexpensive, domestic petroleum resources brought about by hydraulic fracturing technologies. The story of biofuels and the RFS illustrates the importance of incorporating life cycle analysis early in the development of regulatory policies. It also shows the importance of creating regulatory structures that adapt to changing conditions and technologies, as the California LCFS has attempted to do from the outset.

As for EVs, policies governing them are at a much earlier stage, and allow the opportunity to incorporate life cycle analysis in the federal and state regulatory process at the outset. This creates a foundation for a debate over whether, in light of the GHG emissions associated with electricity production, to incentivize or mandate EVs at all, particularly in states that continue to rely heavily on coal-fired electricity.

These debates and discussions are extremely important in evaluating the benefits and limitations of EVs today and in the future. But the limited environmental benefits that may exist for EVs in certain regions of the country should not serve to dampen enthusiasm for the push toward electrification of the transportation sector. Instead, policymakers should turn to life cycle analysis to ensure that decarbonization of the grid accelerates and create policies that pair incentives for EVs with additional policies that encourage significant reductions in coal-fired electricity across the country. In this way, life cycle analysis can be used to guide policymakers in creating incentives, not just for a particular fuel or vehicle, but for a new transportation energy model entirely.