THE EMPLOYMENT IMPACTS OF A LOW-CARBON FUEL STANDARD FOR MINNESOTA

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EXECUTIVE SUMMARY

In this study we estimate the employment impacts of a low-carbon fuel standard (LCFS) in the state of Minnesota. We develop three scenarios by which the demand for transportation fuels in the state could change by 2021, and further to 2035. Under each scenario, we estimate the number of jobs that could be created in construction and manufacturing (CM) as the transportation fuel infrastructure expands, as well as the number of jobs that could be created in harvesting, transportation, and production (HTP) as the supply of alternative fuels expands. We find that a LCFS would significantly increase the demand for alternative fuels such as corn-based ethanol, cellulosic ethanol, and bio-diesel, as well as increasing the demand for electric vehicle charging stations and alternative fuel blending pumps. Over the next ten years, enactment of a LCFS could result in the creation of over 7,500 jobs building alternative energy capacity and infrastructure.[1] In addition, over 1,200 jobs could be created in harvesting, transporting, and processing transportation fuels. When we extend the analysis to 2035, we find that a LCFS could create over 32,500 job-years in manufacturing, installing, and building renewable energy infrastructure and capacity, and an additional 12,000 jobs could be created in the ongoing production of this level of alternative transportation energy. Finally, in addition to the substantial net employment benefits, employment in the state's oil refining sector decreases slightly under a LCFS, but losses are more than offset by the significant employment gains in ethanol.

INTRODUCTION

The state of Minnesota has established policies to reduce its greenhouse gas emissions by increasing its energy efficiency and use of renewable energy sources. Enacted in 2007, the Next Generation Energy Act established a goal to reduce per capita use of fossil fuels 15 percent by 2015, require that 25 percent of all energy used in the state come from renewable resources by 2025, and increase energy

[1] Throughout this report, what we refer to as a 'job' is one full-time position for one year, also known as a 'job-year.' The concept of 'job-year' is explained in more detail below.

efficiency savings goals.[2] Further, the Act sets a goal of reducing greenhouse gases (GHG) to 30 percent below 2005 levels by 2025 across all sectors. According to the Minnesota Pollution Control Agency, statewide GHG emissions totaled 154.1 million tons CO_2-equivalent (CO_2e) in 2005.[3] The state must therefore reduce GHG emissions by 46.2 million tons CO_2e annually, to emit no more than 107.9 million tons CO_2e per year by 2025.

In this study, we focus on strategies to reduce greenhouse gas emissions by reducing the carbon intensity [see text box at right] of transportation fuels in the state. The transportation sector accounts for over one-quarter of all greenhouse gas emissions,[4] thus it is vital to reduce transportation emissions in order to meet statewide goals. There are a number of strategies that the state could pursue to meet these reductions, including the use of more renewable transportation fuels and electric vehicles. A LCFS would bring about reductions in carbon emissions intensity while allowing flexibility in determining how best to meet these reductions.

This study focuses on the employment impacts of a LCFS in the state of Minnesota. We evaluate three possible scenarios in which the transportation fuel mix differs:

- we assume no change to the distribution of transportation fuel consumption;
- we assume that the fuel mix will change in response to a national Renewable Fuel Standard (RFS2);
- we outline a more aggressive change in the fuel mix in response to instituting a statewide LCFS.

For each of these three scenarios, we estimate the employment that would result from building the capacity to produce these alternative fuel mixes as well as the ongoing employment that would be created from producing these transportation fuels in-state. We find that in all scenarios, employment increases in response to increased consumption of transportation fuels. Employment increases the least in the baseline scenario, in which fuel shares remain the same as today, and employment increases the most in the LCFS scenario, in which production of renewable fuels increases dramatically in response to a low-carbon fuel standard.

Carbon intensity measures the use of carbon in relation to a given economic or energy output. For example, carbon intensity can refer to the amount of carbon used per dollar of GDP, per vehicle mile traveled, or per gallon of fuel. In the transportation sector, it is useful to measure carbon intensity per vehicle mile traveled or per megajoule of energy used. Reducing carbon intensity implies that we can achieve the same outcome, such as driving a certain number of miles, while using less carbon.

BACKGROUND: LOW-CARBON FUEL STANDARDS AND RENEWABLE FUEL STANDARDS

One method to reduce the carbon intensity of transportation fuels is to implement a LCFS. These standards have been implemented in other states such as California and Oregon, and in other parts of the world such as British Columbia and the European Union. The goal of a LCFS is to reduce the carbon intensity of transportation fuels by a certain amount before a certain date. California's LCFS was created by Executive Order of the California Governor in 2007 and was established as a regulation in January 2010. This LCFS calls for a 10 percent reduction in the carbon intensity of California's transportation fuels by 2020. The California LCFS applies to any transportation fuel that is sold, supplied, or offered for sale in California. The types of transportation fuels to which the LCFS applies include gasoline, diesel, compressed or liquefied natural gas, biogas, electricity, hydrogen, fuel blends containing more

[2] Laws of Minnesota for 2007, CHAPTER 136–S.F.No. 145, https://www.revisor.mn.gov/data/revisor/slaws/2007/0/136.pdf.

[3] www.pca.state.mn.us/index.php/topics/climate-change/climate-change -in-minnesota/greenhouse-gas-emissions-in-minnesota.html.

[4] www.eia.doe.gov/oiaf/1605/ggrpt/index.html#economy.

than 10 percent ethanol, biodiesel (blended or B100), denatured fuel ethanol (E100), and any other liquid or non-liquid fuel.

Existing low-carbon fuel standards set an example for states such as Minnesota to follow in order to meet reductions in fossil fuel use. In addition, the U.S. Environmental Protection Agency recently revised the Renewable Fuel Standards (RFS) program which is required under the Energy Independence and Security Act of 2007 (EISA). This new set of standards, known as RFS2, specifies criteria for renewable fuels and the feedstocks used to produce them, and also sets volumetric requirements for the production of biofuels.[5] The fuels and pathways modeled which meet or exceed the respective required minimum greenhouse gas (GHG) reduction standards include:

- corn-based ethanol using efficient technologies;
- soy based biodiesel;
- biodiesel made from waste grease, oils, and fats;
- sugarcane based ethanol; and
- fuels derived from cellulosic materials (including wood, grasses, agricultural waste, and non-edible parts of plants).

The RFS2 sets specific greenhouse gas reduction thresholds. The lifecycle GHG emissions of a qualifying renewable fuel must be less than the lifecycle GHG emissions of the 2005 baseline average gasoline or diesel fuel that it replaces. Four different levels of reductions are required for the four different renewable fuel standards:

- renewable fuel: 20 percent
- advanced biofuel: 50 percent
- biomass-based diesel: 50 percent
- cellulosic biofuel: 60 percent

According to the national renewable fuel standard, the volumetric requirements for renewable fuels are as follows: Total renewable fuels must reach 36 billion gallons by 2022, with 16 billion of these from cellulosic biofuel. The standard for 2010 is 12.95 billion gallons of renewable fuels, or 8.25 percent of a refiner's or importer's gasoline and diesel volume.

By reducing the carbon intensity of its transportation fuels and increasing its production of renewable fuels, Minnesota can not only remain a leader in the production and consumption of low-carbon fuels within the U.S., but can also increase employment within the state.

Below we develop three scenarios in which renewable fuels play an increasingly large role to meet the forecast demand for transportation fuels in the state, and we estimate the employment impacts attributable to each scenario. We base the overall level of transportation fuel consumption on forecasts in the Energy Information Administration's *Annual Energy Outlook 2011*, and then alter the mix of fuels used to meet projected consumption levels in 2021 and 2035. In the first scenario (baseline scenario), the shares of gasoline, diesel, and alternative fuels remain the same as today's shares. In the second scenario (RFS2 scenario), the shares change according to assumptions in the AEO2011, which include a national Renewable Fuel Standard (RFS2). In the third scenario (LCFS scenario), the shares change more aggressively in favor of renewable fuels and transportation electricity in response to implementation of a LCFS. The details of each scenario as well as the methodology used to develop them are explained below. Further, we estimate the construction and manufacturing jobs that would result from building new transportation energy capacity, as well as the ongoing jobs in harvesting, transportation, and production, that would be created from expanding the supply of renewable fuels.

STRATEGIES TO REDUCE THE CARBON INTENSITY OF TRANSPORTATION FUELS IN MINNESOTA

Strategies within the ethanol industry

Corn-based ethanol is the primary renewable transportation fuel sold in the U.S. It is blended with gasoline and sold as 'E-10'– a blend which contains up to 10 percent ethanol and 90 percent gasoline.

[5] "Feedstock" is raw material that can be used for energy production, either as energy for heating and powering industrial processes, or as raw materials from which liquid transportation fuels such as ethanol can be produced.

Nationally, the ethanol industry produces more than 10 billion gallons of fuel ethanol annually, representing 7 percent of the gasoline supply, and 70 percent of all gasoline sold contains some ethanol.[6] As of 2010, Minnesota had 21 ethanol plants with a combined capacity of 1.1 billion gallons annually.[7] Minnesota is thus a leading state in ethanol production.

Various studies have shown that corn-based ethanol has a lower carbon intensity than petroleum-based gasoline. While estimates vary depending on the precise location of the plant, the feedstock, and type of process energy used, lifecycle analysis has shown that corn-grain ethanol produced with the latest technologies has a carbon intensity that is nearly equal to or significantly below that of gasoline.[8] Increasing the use of ethanol can be a prominent strategy to reduce the carbon intensity of transportation fuels, depending on the feedstock used. And changes within the ethanol industry itself can further reduce this fuel's carbon intensity. Within the industry, we evaluate four strategies to reduce the carbon intensity of transportation fuels: 1) using renewable energy in place of fossil fuels for the processing of ethanol; 2) increasing the use of flex-fuel vehicles which use a higher proportion of ethanol to gasoline; 3) increasing the blend wall for low-level ethanol blends; and 4) increasing production of cellulosic ethanol. Below we discuss each of these strategies.

USING RENEWABLE ENERGY IN PLACE OF FOSSIL FUELS FOR THE PROCESSING OF ETHANOL

The production of ethanol is an energy-intensive process. According to the Department of Energy, as of 2006, 96 percent of all ethanol plants in the U.S. used natural gas as their primary source of process energy. Not including the cost of the feedstock, fuel costs (mainly natural gas) account for about one-third of operating expenses in an ethanol plant.[9]

While ethanol is a renewable fuel, its current mode of production relies heavily on the use of fossil fuels for process heat and electricity. In order to reduce the lifecycle carbon intensity of ethanol, plants can shift to renewable energy sources to meet their process energy needs.

A study by Kaliyan, Morey, and Tiffany published in 2011 analyzes the greenhouse gas emissions reductions that could be achieved by replacing fossil fuels in ethanol plants with biomass such as corn stover and ethanol co-products.[10] The authors find that conventional ethanol production (using natural gas for process heat) reduces GHGs by 38.9 percent compared to gasoline, over the lifecycle and without accounting for indirect land use change. If the natural gas is replaced by corn stover for process heat, the emissions reductions rise to 57.7 percent of gasoline emissions, and if corn stover is used for both process heat and electricity, reductions rise to 79.1 percent of gasoline.

Replacing fossil fuels with renewable sources for ethanol production will yield employment gains within the state of Minnesota. As existing ethanol plants are retrofitted to use biomass for process heat, both short term and ongoing jobs will be created. In the short term, it will create jobs in manufacturing and installing the new equipment used to generate renewable process heat and electricity. Over the life of the plant, it will also create and maintain jobs in agriculture and transportation as biomass is grown, harvested, and transported to facilities within the state.

INCREASING THE USE OF FLEX-FUEL VEHICLES

Flex fuel vehicles (FFVs) are designed and built to run on fuel blends which contain up to 85 percent ethanol and 15 percent gasoline, termed 'E-85.' These vehicles can also operate on lower-level blends or simply on conventional gasoline. While the manufac-

6 Mark D. Stowers, "The U.S. Ethanol Industry," *Regional Economic Development*, Federal Reserve Bank of St. Louis, Vol. 5, No. 1, 2009.

7 Minnesota Department of Agriculture, "Minnesota Ethanol Industry", 2010.

8 For a range of estimates based on various feedstocks, see National Academy of Sciences (2009) *Liquid Transportation Fuels from Coal and Biomass*, Washington D.C., National Academies Press.

9 U.S. Department of Energy, Office of EERE, *Biomass Energy Data Book, Edition 2.*

10 N. Kaliyan, R.V. Morey, and DG Tiffany, March 2011, "Reducing Lifecycle Greenhouse Gas Emissions of Corn Ethanol by Integrating Biomass to Produce Heat and Power at Ethanol Plants," Biomass and Bioenergy, Vol 35, Issue 3, pp 1103-1113.

ture of FFVs has risen dramatically in recent years, the owners of these vehicles still rely primarily on E-10 as their fuel source, rather than E-85. As of 2010, about 8 percent of vehicles sold or leased were flex-fuel vehicles.[11] However, only about 5 percent of these were used as FFVs.[12] The use of higher level blends by FFV owners has been limited for two reasons: (1) limited availability of E85 pumps at fueling stations; and (2) lack of knowledge by FFV owners.

Increasing the use of E85 in FFVs is one strategy to lower the carbon content of transportation fuels in Minnesota. In order to increase the use of FFVs, consumer awareness must be raised and more blending pumps must be installed.[13] Minnesota already leads the country in its number and share of fuel stations which have E85 pumps. As of 2010, there are E85 pumps in 354 fueling stations, which accounted for over 17 percent of all E85 pumps nationwide.[14] However, Minnesota has a total of 3,080 fuel stations, thus more blending pumps must be installed statewide to increase the availability and use of E85.

The cost of adding E85 fueling to existing gasoline stations varies greatly. The major variables include whether the station owner needs to install multiple new multiproduct dispensers or just to convert one dispenser. New tank installation costs could include concrete and excavation work, which themselves could vary widely. Other variables include whether owners can sell previously used tanks in the second-hand market, whether the project will include a new canopy, how large the tank is, and in which region the station is located. Given these factors, the cost of a new tank installation can range from $50,000 to $200,000 with a mean cost of $71,735 and a median of $59,153. The costs of converting/ retrofitting an existing tank/dispenser are much lower, with a mean of $21,031 and a median of $11,237.[15] Of Minnesota's 3,080 total fuel stations, only 354 currently host E85 pumps. Retrofitting or installing new blending pumps at 1,000 additional stations would mean that flex fuel vehicles would be able to refuel with E85 at almost half of all fueling stations in Minnesota.

INCREASING THE BLEND WALL FOR LOW-LEVEL ETHANOL BLENDS

Until recently, 10 percent ethanol was the maximum approved blend rate as determined by the U.S. Environmental Protection Agency. While other states allow E-10 to include any amount of ethanol equal to or less than 10 percent, Minnesota mandates that the full 10 percent be included in E-10 blends. In October 2010, the EPA announced that blends up to E15 were safe for vehicles produced since 2007. Further testing is needed to see if vehicles older than 2007 can use E15 without any adverse effects. In the short term, it is therefore unlikely that blends beyond E10 will be offered for sale. However, if blends such as E12 or E15 are proven safe for a wider range of vehicles, then we may see greater use of these low-level blends. As described below, we assume that low level blends remain at E10 in the baseline and RFS2 scenarios. In the LCFS scenario, we assume that the blend wall will increase to E20 by 2035.

INCREASING PRODUCTION OF CELLULOSIC ETHANOL

Minnesota currently does not have any commercially operable cellulosic ethanol plants. This fuel has been produced commercially in very small volumes in other states. Several commercial cellulosic ethanol production plants are under construction nationwide, and intensive research and development is rapidly advancing the state of cellulosic ethanol technology.[16]

Cellulosic ethanol offers a promising route to achieving dramatic reductions in the carbon content of transportation fuels. While each gallon of gasoline produces 25 pounds of CO_2-equivalent GHG emissions, cellulosic ethanol produces on average fewer

[11] DOE, Alternative Fuels and Advanced Vehicles Data Center, www.afdc.erergy.gov/afdc/data /vehicles.html.

[12] Table 1061 from Census Bureau Statistical Abstract 2010.

[13] Blending pumps allow users to select from a range of ethanol/gasoline blends, including low-level blends such as E10 and high-level blends such as E85.

[14]Energy Information Administration, http://tonto.eia.doe.gov/state/state_energy_profiles.cfm?sid=MN

[15] NREL, "Cost of Adding E85 Fueling Capability to Existing Gasoline Stations: NREL Survey and Literature Search."

[16] DOE, Alternative Fuels & Advanced Vehicles Data Center.

than 4 pounds.[17] Replacing corn-based ethanol with cellulosic ethanol could help Minnesota reduce the carbon intensity of its transportation sector and also contribute to the national renewable fuel standard (RFS2) which mandates the production of 16 billion gallons of cellulosic ethanol by 2022. However, this industry is not yet commercially viable in Minnesota. In other states, cellulosic biorefineries are coming online, either as new plants or as integrated parts of corn ethanol plants.

Project LIBERTY, an integrated corn cellulose biorefinery, will transform a corn ethanol plant in Iowa owned by the POET company to an integrated plant which will produce 25 million gallons of cellulosic ethanol (corn-based) in addition to 100 million gallons of corn ethanol. The project will cost upwards of $200 million, will reduce the use of fossil fuels by 100 percent, and will create 30 new jobs at the facility. It is expected to be operational in late 2013.[18]

AEBiofuels opened an integrated facility in Montana in 2008 which processes both starch (corn) and cellulosic feedstocks. In this integrated facility, energy and labor costs are virtually unchanged, feedstock costs are lower for cellulosic feedstock, and tax incentives are higher, resulting in a rise in profit per gallon. Up to 35 percent cellulosic feedstock can be integrated into the ethanol production process.[19]

These integrated biorefineries offer an example that Minnesota could follow to increase the refining of cellulosic feedstock and integrate it into its dominant corn ethanol industry. Cellulosic ethanol would displace starch-based ethanol in blended gasoline.

Biodiesel

Biodiesel is a renewable alternative to petroleum diesel and is produced from both new and used vegetable and animal fat sources. It is sold in the U.S. at varying levels, but generally is sold as B2 (a blend of up to 2 percent biodiesel and 98 percent diesel), B5 (a blend of up to 5 percent biodiesel and 95 percent diesel), B20 (a blend of up to 20 percent biodiesel and 80 percent conventional diesel) or B100 (up to 100 percent biodiesel). Biodiesel is considered a 'drop-in' fuel and therefore can be used in any engine which uses conventional diesel and is compatible with current diesel infrastructure. One current drawback to using B100 is that, like diesel, in extremely low temperatures (below 0°F) it becomes too viscous. There are countermeasures available, but this viscosity issue must be considered. However, at most times of the year, both B20 and B100 can be used in any diesel engine with no change in performance.

The production and use of biodiesel remains relatively limited in the U.S., based in part on the expiration of the biodiesel tax credit in 2009, which led to the idling or reduced production of biodiesel in many plants. Biodiesel is, however, a promising renewable fuel with overall greenhouse gas emissions significantly below those of gasoline. Conventional diesel emissions are 15 percent below gasoline, while B20 emissions are 27 percent below, and B100 emissions are 76 percent below gasoline and 72 percent below conventional diesel.[20] Minnesota has continued to be a strong supporter of biodiesel. The state passed one of the first biodiesel blending mandates in the country in 2002, requiring 2 percent blending of biodiesel in all diesel fuels sold in Minnesota. In 2008, Minnesota significantly increased this mandate, requiring the amount of biodiesel blended into diesel fuel sold in the state to increase incrementally to a B20 blend by 2015.[21] While consumption levels are still relatively low in Minnesota, biodiesel use could expand rapidly if blending pumps were installed at fueling stations throughout the state.

The infrastructure and employment effects of expanding the use biodiesel would be similar to those

[17] Mark D. Stowers, "The U.S. Ethanol Industry," *Regional Economic Development*, Federal Reserve Bank of St. Louis, Vol. 5, No. 1, 2009.

[18] See www.projectliberty.com..

[19] AEBiofuels, "Looking Beyond Conventional Oil: Cellulosic Ethanol," December 2008.

[20] Author's calculations based on the standard assumptions contained in the GREET model (Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation) maintained by the Argonne National Laboratory.

[21] www.mda.state.mn.us/renewable/biodiesel/aboutbiodiesel.aspx.

for high level blends of corn ethanol: new tanks and dispensing equipment would need to be installed at fueling stations, which would create short-term jobs in construction and manufacturing. In the longer term, biodiesel would create more jobs within the state of Minnesota than petroleum-based diesel, on par with the employment differences between corn ethanol and conventional gasoline. This is mainly due to the fact that petroleum-based diesel and gasoline are refined from imported crude oil while the feedstocks for biodiesel and ethanol can be grown and harvested within the state, creating jobs in agriculture, warehousing, transportation, and related industries.

As of June 2012, three biodiesel refineries have been established in Minnesota. Their total combined capacity is about 63 million gallons per year.[22] Most of the biodiesel capacity in Minnesota is based on soybean oil. The biorefineries also use recycled and rendered grease and oils as feedstocks. Yellow grease is currently the cheapest feedstock for biodiesel, but these refineries could also process corn oil, soybean oil, and various other vegetable and animal fat sources.

Electric vehicles

Electric vehicles offer another promising long term approach to reducing the carbon intensity of transportation and achieving significant emissions reductions. EVs are considered zero-emissions vehicles, since they do not produce any tailpipe emissions. They are nonetheless responsible for some emissions since they need to be plugged in and recharged. If they are connected to the grid, which is predominantly powered by fossil fuels, EVs will have lower emissions than gasoline-powered cars, but will still produce some carbon emissions. If powered by renewable sources such as wind, solar, or geothermal energy, EVs can indeed become zero-emissions vehicles and can contribute to large decreases in the carbon intensity of transportation.

Until very recently, electric vehicles have seen limited production and adoption in the U.S. In 2008, only 2,802 electric vehicles were sold or leased nationwide. An additional 312,386 hybrid electric vehicles, (HEVs) led by the Toyota Prius, were sold or leased in 2008. Combined, EVs and HEVs made up only about 2 percent of all vehicle sales. As with FFVs, the increased use of EVs will require behavioral change and infrastructure improvements, and therefore EVs represent medium-term and longer-term solutions to reducing the carbon content of transportation in Minnesota.

Increased use of EVs will require increased production of these vehicles. As of October 2010, there are no manufacturers of mass-produced electric vehicles within the state of Minnesota. Thus the state is unlikely to benefit from the increased manufacture of EVs in the short term. In the medium term, jobs will be created in infrastructure development as EV charging stations are installed in homes and public areas. EV charging stations cost between $1,000 and $10,000, with home charging stations being less expensive and public curbside charging stations being more expensive.[23] The average installed cost for a home charging station ranges from $1,500 to $2,500.[24] The cost of public charging stations has a larger range, depending on the location of the installation. According to the Alternative Fuels and Advanced Vehicles Data Center of the Department of Energy, public charging infrastructure should consist of charging locations where vehicle owners are highly concentrated, such as shopping centers, city parking lots and garages, airports, hotels, government offices, and other businesses. Widespread public charging infrastructure will help facilitate the penetration of all-electric vehicles and plug-in hybrid electric vehicles and help address consumer 'range anxiety' for vehicles with limited range. The manufacture of charging stations as well as the installation of these stations can both lead to job creation, as electric vehicles become a more prominent transportation alternative.

[22] Ibid.

[23] http://earth911.com/news/2010/07/20/nyc%E2%80%99s-first-ev-charging-station-now-open/.

[24] www.afdc.energy.gov/afdc/vehicles/electric_charging_home.html.

METHODOLOGY

Fuel mix scenarios

The three scenarios developed in this report were derived by using forecasts of transportation energy consumption and then altering the mix of fuels and electricity used to meet the forecast consumption levels. The total fuel use levels for 2021 and 2035 were taken from the 'Reference Case for Light-Duty Vehicle Energy Consumption' in the Energy Information Administration's *Annual Energy Outlook 2011.* In 2010, Minnesota's share of transportation energy was 2.1 percent of the national total, and we kept this share the same in 2021 and 2035. Applying this percentage to the AEO2011 forecasts yielded a total level of fuel use for the state of Minnesota for these years. This level of fuel consumption can be met through various combinations of gasoline, diesel, electricity, and alternative fuels. We altered these combinations to create the following scenarios.

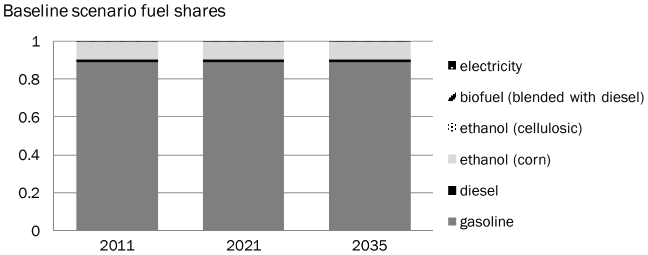
BASELINE SCENARIO: SHARES OF FUEL USE REMAIN CONSTANT OVER TIME

- The total level of energy use for transportation in Minnesota is about 339 trillion BTU in 2011, rising to 342.4 trillion BTU in 2021 and 371.4 trillion BTU in 2035. This is 2.1 percent of the national total fuel use forecasts for light-duty vehicles in the AEO2011.
- In 2011, motor gasoline accounts for approximately 89 percent of transportation fuel consumption, corn ethanol accounts for 10 percent and diesel accounts for the remaining 1 percent. These percentages remain constant from 2011 to 2035.
- Sales of biodiesel, cellulosic ethanol, and transportation electricity are less than one percent over the period.
- Blended gasoline is E10 (90 percent gasoline and 10 percent corn-based ethanol) since Minnesota has a mandate to blend a minimum of 10 percent ethanol into blended gasoline.
- Biodiesel is B2 (2 percent biofuel and 98 percent diesel) in 2011. In 2021 and 2035 biodiesel is B10.

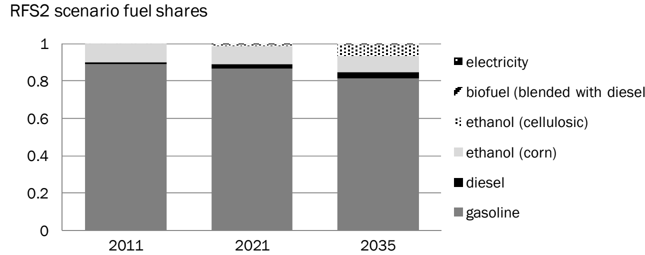
RFS2 SCENARIO: SHARES OF FUEL USE CHANGE AS IN THE AEO2011 REFERENCE CASE

- The total level of energy use for transportation in Minnesota is about 339 trillion BTU in 2011, rising to 342.4 trillion BTU in 2021 and 371.4 trillion BTU in 2035. This is 2.1 percent of the national total fuel use forecasts for light-duty vehicles in the AEO2011.
- In the RFS2 scenario, we alter the shares of transportation fuels according to assumptions in

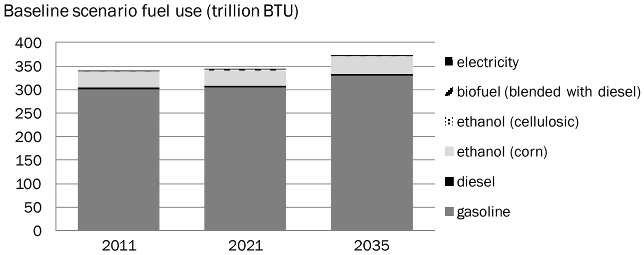
Baseline scenario fuel shares



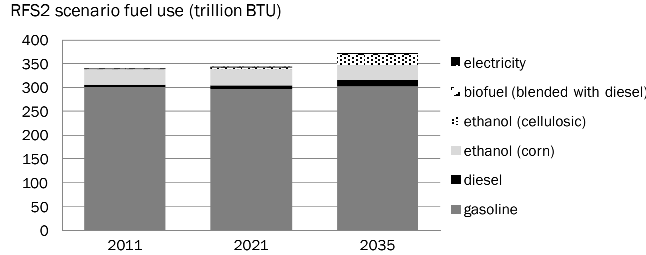
RFS2 scenario fuel shares



Baseline scenario fuel use (trillion BTU)



RFS2 scenario fuel use (trillion BTU)

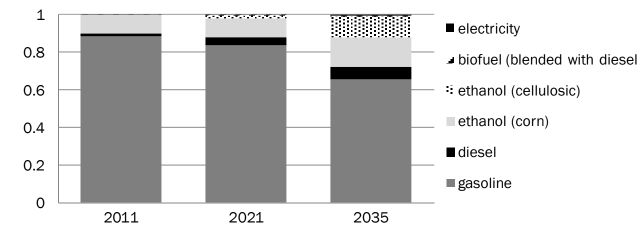


- the AEO2011 Reference Case for Light-Duty Vehicle Use, which include implementation of RFS2, an updated national renewable fuel standard.
- In 2011, motor gasoline accounts for approximately 89 percent of transportation fuel consumption, corn ethanol accounts for 10 percent and diesel accounts for the remaining 1 percent.
- In 2021, the share of gasoline consumption falls slightly, to 87 percent, and falls further to 81 percent by 2035.
- The share of diesel fuel increases from 1 percent in 2011 to 2 percent in 2021 and 3 percent in 2035.
- The share of ethanol grows from 10 percent in 2011 to 11 percent in 2021 and 13 percent in 2035, with corn ethanol growing in the first period and falling in the second period as cellulosic ethanol accounts for a larger share. Cellulosic ethanol accounts for zero percent of ethanol in 2011, 10 percent in 2021, and 40 percent in 2035.
- Blended gasoline is E10 throughout the period.
- Biodiesel is B2 in 2011 and B10 in 2021 and 2035.

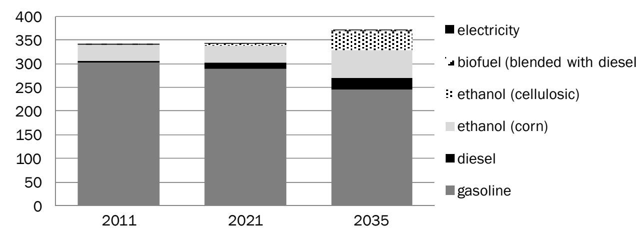
LCFS SCENARIO: SHARES OF FUEL USE CHANGE IN RESPONSE TO A LOW-CARBON FUEL STANDARD

- The total level of energy use for transportation in Minnesota is about 339 trillion BTU in 2011, rising to 342.4 trillion BTU in 2021 and 371.4 trillion BTU in 2035. This is 2.1 percent of the national total fuel use forecasts for light-duty vehicles in the AEO2011.
- In the LCFS scenario, shares of fuel change in response to a low-carbon fuel standard, which increases the shares of ethanol, biodiesel, and electricity, and decreases the share of gasoline. To simulate the effects of the LCFS, we double the growth of ethanol, biodiesel, and electric vehicles as compared to the RFS2 scenario.

LCFS scenario fuel shares



LCFS scenario fuel use (trillion BTU)



- The share of gasoline falls from 89 percent in 2011 to 84 percent in 2021 and 66 percent in 2035.
- Diesel grows from a 1 percent share to 4 percent in 2021 and 7 percent in 2035.
- Both corn-based ethanol and cellulosic ethanol grow over the period, accounting for a combined total of 10 percent of fuel consumption in 2011, 11 percent in 2021, and 25 percent in 2035. Cellulosic ethanol accounts for zero percent of ethanol consumption in 2011, 10 percent in 2021 and 40 percent in 2035.
- Blended gasoline is E10 in 2011 and 2021 and E20 in 2035.
- Biodiesel is B2 in 2011 and B10 in 2021 and 2035.

Estimating employment

For this report we use an input-output (I-O) model to analyze the statewide employment effects of various methods to meet a LCFS in Minnesota. An I-O model is useful for analyzing the direct, indirect, and induced levels of job creation that result from an increase in demand for any sector or combination of sectors in the economy. For this analysis, we use IMPLAN's version 3.0 software along with Minnesota state data from 2008 for the direct and indirect employment effects, and we model the induced effects separately. Each of these is discussed below.

DIRECT EFFECTS

The direct employment effects are the jobs that are created from an increase in demand for the products or services of a given industry. Using the example of the ethanol industry, the direct jobs that are created from an increase in demand for ethanol include jobs in grain farming, truck transportation, and biorefining. An I-O model estimates the number of jobs resulting from a given level of spending. Thus we can compare the direct jobs created through, for example, $1 million in increased ethanol demand versus $1 million in increased gasoline demand.

INDIRECT EFFECTS

Indirect employment represents the jobs that are created throughout the supply chain of the industry we are analyzing. Using the example of ethanol once again, the indirect jobs are created in industries such as support services for agriculture and wholesale trade – industries which supply goods or services to the ethanol industry. It is important to note here that the indirect effects of any program are lower at the state level than they would be at the national level. The ethanol industry in Minnesota will, for example, source many of its goods and services from within Minnesota, but will also source some of its goods from out of state. By using the Minnesota-specific data set from IMPLAN, these leakages out of state are captured in our analysis and in the estimates we present below. The indirect employment effects could be raised if more of the supply chain were located within the state. But for the sake of this report, we rely on the current supply chain structure of Minnesota industries.

INDUCED EFFECTS

The third tier of employment creation results from the induced effect. When workers in the direct (e.g., ethanol) and indirect (e.g., warehousing) industries spend their earnings, they create demand for goods and services in other sectors of the economy, such as retail and healthcare. The initial increase in demand for ethanol thus results not only in newly employed workers in the ethanol industry, but also in new employment in indirect and induced industries. Induced employment, we have shown elsewhere, is equivalent to approximately forty percent of the total of direct and indirect employment at the national level.[25] However, at the state level, induced effects are lower, since a household within a U.S. state will buy goods imported not only from outside the U.S. but also from outside the state. Therefore the induced effect in Minnesota will tend to be lower than the induced effect at the national level. In order to adjust for this interstate trade, we compare the supply/demand ratio of all commodities within the U.S. to the supply/demand ratio of all commodities with Minnesota, using IMPLAN data in both cases. The ratio in Minnesota is 70 percent of the U.S. ratio. Using this information to scale our induced effect downward, we estimate that induced jobs in Minnesota are approximately 30 percent of the combined direct and indirect jobs.

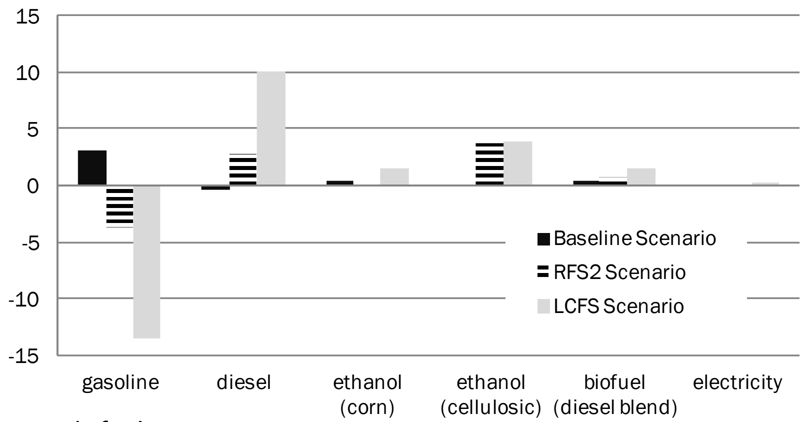
RESULTS

Changes in fuel consumption

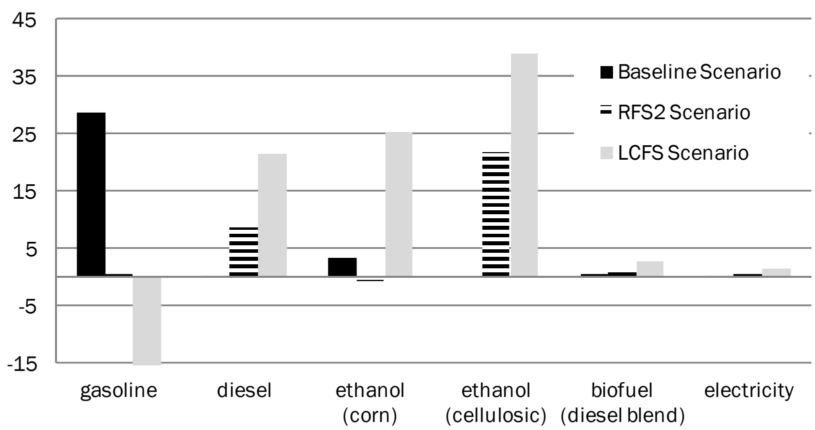
The charts on page 11 show changes in the levels of consumption of various transportation fuels in response to the scenarios outlined above. We evaluate these changes for the period 2012 to 2021, which reflects the ten-year period during which the first phase of a LCFS could be implemented. We further extend the analysis to 2035, the final year of fuel consumption forecasts contained in the AEO2011. From 2012 to 2021, consumption of motor gasoline increases under the baseline scenario but decreases slightly under the RFS2 scenario and further declines under the LCFS scenario. Diesel fuel consumption decreases slightly in the baseline scenario as biofuel makes up a larger share of biodiesel - the blend increases from B2 to B10, so although biodiesel as a whole increases, the level of diesel fuel decreases in the baseline scenario. Diesel consumption increases in both the RFS2 and LCFS scenarios as biodiesel consumption grows. Corn-based ethanol increases in the baseline and LCFS scenarios, but decreases

[25] See the discussion on pp 32-33 of "Green Prosperity" by Pollin, Wicks-Lim, and Garrett-Peltier available at www.peri.umass.edu.

Changes in fuel use
from 2012 to 2021 (trillion BTU)



Changes in fuel use
from 2012 to 2035 (trillion BTU)



slightly in the RFS2 scenario as overall ethanol consumption increases but cellulosic ethanol displaces some corn ethanol. Combined corn-based and cellulosic ethanol grows in all three scenarios. Electricity also grows in all three scenarios but its level remains almost negligible by 2021.

By 2035, gasoline consumption increases significantly in the baseline scenario, as the share of total fuel consumption remains the same but the level increases. Gasoline consumption is nearly flat over the period in the RFS2 scenario, as renewable fuels meet increased demand for transportation fuels. In the LCFS scenario, gasoline is displaced by renewable fuels. Diesel fuel and biodiesel grow in all three scenarios, as do electricity and ethanol. As cellulosic ethanol makes up a larger share of ethanol production, there is a slight decline in corn ethanol production in the RFS2 scenario. Corn ethanol production grows in both the baseline and LCFS scenarios. Cellulosic ethanol production is non-existent in the baseline scenario but grows significantly by 2035 in both the RFS2 and LCFS scenarios.

Employment impacts

We estimate two categories of employment that could result from each of our three scenarios. The first we refer to as construction-manufacturing (CM) jobs. These are the jobs that will be created in building new capacity and infrastructure to meet increased demands for transportation fuels. CM jobs will be directly created as new facilities are built, existing facilities are retrofit, and new pumps and charging stations are installed. Additionally, jobs will be created in manufacturing the equipment and machinery which will be installed in these new plants. For any one project, such as building a new ethanol plant, CM jobs will have a limited duration; however, building the infrastructure required to meet increased demands for transportation fuels will require the work of a generation. Construction and manufacturing workers will be needed for multiple projects, and therefore while each project has a limited duration, CM jobs are in no way short-term.

The second category of employment that we estimate is what we call HTP employment. These are jobs in harvesting, transporting, and producing the transportation fuels. While CM jobs will be created in building the transportation fuel infrastructure, HTP jobs will continue from year to year as long as the demand for fuel is level or growing.

For both CM jobs and HTP jobs, the level of employment creation varies across the three scenarios, with employment increasing as the state moves more aggressively toward alternative transportation energy. While refining both gasoline and ethanol is currently done within the state of Minnesota, the feedstock used to produce these fuels varies widely in its employment creation within the state. Gasoline and diesel are refined from imported oil, therefore creating no employment in feedstock production. The ethanol and biodiesel industries, on the other hand, create jobs in-state in agriculture, transportation, and warehousing. Since Minnesota is currently a net exporter of renewable fuels, we assume in this analysis that all increased consumption of renewable fuels is met by in-state production of those fuels. Thus in each scenario, alternative fuels make up an increasingly large share of transportation energy, and harvesting-transportation-production employment grows concomitantly.

CONSTRUCTION AND MANUFACTURING EMPLOYMENT CREATION

A number of jobs will be created in construction and manufacturing in order to increase the capacity of renewable fuel production and to build up the infrastructure to enable vehicles to use higher blends of ethanol and biodiesel as well as electricity. For each of the three scenarios, we forecast the needed level of capacity change (as shown in the figures on page 11 and tables 1 and 2) and then estimate the associated costs and employment of building this capacity. In table 1 (page 13), we show the jobs that could be created over the next ten years, from 2012 to 2021. In table 2, (page 14) we show the jobs that could be created if we extend the forecast to 2035. All of these estimates are in 'job-years,' meaning that if a project lasts multiple years (such as construction of a new ethanol plant), the total number of job-years would be divided by the number of years of the project to yield the number of people employed full-time for the life of the project. As an example, if a new plant took three years to build and required 300 job-years, then 100 people would be employed full-time for the three year period.

The baseline scenario entails a modest increase in ethanol consumption by 2021, which can be met by increasing the capacity of existing biorefineries but will also necessitate installation of blender pumps for distribution of E85. Based on the forecast capacity needs, we estimate that no new biorefineries will be built. Only three blender pumps are forecast to be installed in this scenario, creating only one additional job-year.

In the RFS2 scenario, no new additional corn ethanol plants are built, but there is one new cellulosic plant by 2021, and two existing corn ethanol plants are retrofit to use biomass for process energy. In addition, 2,726 blender pumps for ethanol are installed in this scenario so that all of Minnesota's 3,080 refueling stations have one blending pump; 36 biodiesel blending pumps as well as 1,350 EV charging stations are installed. The manufacturing jobs to produce these technologies as well as the construction jobs to install them total about 3,500 job-years when we include direct, indirect, and induced effects. Over half of those are the direct jobs in construction and manufacturing.[26]

The LCFS scenario entails a greater expansion of renewable fuels production capacity. In this scenario, one new corn ethanol plants is built and seven existing plants are retrofit; one new cellulosic plants is built; 2,726 ethanol blender pumps are installed; 118 biodiesel pumps are installed and 2700 EV charging stations are installed. Over 3,800 direct job-years are created in construction and manufacturing, and over 7,500 job-years are created when we include the indirect and induced effects.

In table 2, we estimate the CM jobs created in these three scenarios during the period 2012 through 2035.

[26] As described above, these estimates were derived using Minnesota-specific industry data. While construction jobs will necessarily be created in the local economy, manufacturing jobs could be created within or outside of the state. For these short-term employment estimates we assume that manufactured goods will be produced in-state as well as imported from out-of-state, according to the current shares of production and imports in these industries.

TABLE 1: CONSTRUCTION AND MANUFACTURING (CM) JOBS-YEARS CREATED BETWEEN 2012 AND 2021

2021		New corn ethanol plants	New cellulosic plants	Retrofitting ethanol plants	Installing blender pumps for E85	Installing blender pumps for B10/B20	New biodiesel plants	Charging stations for EVs	Total CM jobs across all strategies
Baseline scenario	Additional capacity needed (trillion BTU)	0.342	0	0	-	-	0.355	-	
	Units needed	0	0	0	3	0	0	0	
	Total cost ($million)	-	-	-	0.18	-	-	-	
	Direct job-years	-	-	-	1	-	-	-	1
	Indirect job-years	-	-	-	0	-	-	-	0
	Induced job-years	-	-	-	0	-	-	-	0
	Total jobs	-	-	-	**1**	-	-	-	**1**
RFS2 Scenario	Additional capacity needed (trillion BTU)	0	3.69	-	-	-	0.709	-	
	Units needed	0	1	2	2726	36	0	1350	
	Total cost ($million)	-	171.77	118.5	163.56	2.16	-	3.38	
	Direct job-years	-	687	474	572	8	-	16	1,757
	Indirect job-years	-	326	225	393	5	-	8	957
	Induced job-years	-	304	210	290	4	-	7	815
	Total jobs	-	**1,317**	**909**	**1,255**	**17**	-	**31**	**3,529**
LCFS Scenario	Additional capacity needed (trillion BTU)	1.591	3.896	-	-	-	1.506	-	
	Units needed	1	1	7	2726	118	1	2700	
	Total cost ($million)	171.77	171.77	414.87	163.56	7.08	52	6.75	
	Direct job-years	687	687	1,659	572	25	208	32	3,870
	Indirect job-years	326	326	788	393	17	99	16	1,965
	Induced job-years	304	304	734	290	13	92	14	1,751
	Total jobs	**1,317**	**1,317**	**3,182**	**1,255**	**54**	**399**	**61**	**7,585**

In the baseline scenario, ethanol consumption continues to expand, with one new corn-ethanol plant and 33 ethanol blender pumps installed. Biodiesel also increases slightly, with four new biodiesel blending pumps installed. In total this scenario leads to over 1,300 new job-years between 2012 and 2035 if we include the direct, indirect, and induced effects from building the new plants and manufacturing and installing pumps.

The RFS2 scenario has greater ethanol production, though all new plants are cellulosic. Six cellulosic plants are built and 30 percent of current ethanol plants are retrofit to use biomass for process heat. In addition, 2,726 ethanol blender pumps are installed (so that all Minnesota refueling stations have one), 102 biodiesel blender pumps are installed, and 2,900 EV charging stations are installed. Over 6,000 direct job-years are created in construction and manufacturing, and close to 13,000 job-years are created if we include the indirect and induced effects.

Employment increases more dramatically under the LCFS scenario, which sees a significant increase in

TABLE 2: CONSTRUCTION AND MANUFACTURING (CM) JOB-YEARS CREATED BETWEEN 2012 AND 2035

2035		New corn ethanol plants	New cellulosic plants	Retrofitting ethanol plants	Installing blender pumps for E85	Installing blender pumps for B10/B20	New biodiesel plants	Charging stations for EVs	Total CM jobs across all strategies
Baseline scenario	Additional capacity needed (trillion BTU)	3.206	0	-	-	-	0.392	-	
	Units needed	1	0	0	33	4	0	0	
	Total cost ($million)	171.77	-	-	1.98	0.24	-	-	
	Direct job-years	687	-	-	7	1	-	-	695
	Indirect job-years	326	-	-	5	1	-	-	332
	Induced job-years	304	-	-	4	0	-	-	308
	Total jobs	**1,317**	-	-	**15**	**2**	-	-	**1,334**
RFS2 Scenario	Additional capacity needed (trillion BTU)	0	21.82	-	-	-	1.346	-	
	Units needed	0	6	7	2726	102	1	2900	
	Total cost ($million)	-	1,030.60	414.87	163.56	6.12	52	7.25	
	Direct job-years	-	4,122	1,659	572	21	208	34	6,616
	Indirect job-years	-	1,958	788	393	15	99	17	3,270
	Induced job-years	-	1,824	734	290	11	92	15	2,966
	Total jobs	-	**7,905**	**3,182**	**1,255**	**47**	**399**	**66**	**12,854**
LCFS Scenario	Additional capacity needed (trillion BTU)	25.16	39.09	-	-	-	2.779	-	
	Units needed	6	10	21	2726	249	1	5700	
	Total cost ($million)	1,030.60	1,717.67	1,244.61	163.56	14.94	52	14.25	
	Direct job-years	4,122	6,871	4,978	572	52	208	67	16,870
	Indirect job-years	1,958	3,264	2,365	393	36	99	33	8,148
	Induced job-years	1,824	3,040	2,203	290	26	92	30	7,505
	Total jobs	**7,905**	**13,175**	**9,546**	**1,255**	**115**	**399**	**130**	**32,525**

ethanol production from both corn and cellulosic feedstocks. In this scenario, six new corn-based ethanol plants are built, ten cellulosic plants are built, and all current ethanol plants are retrofit. In addition, 2,726 ethanol blender pumps, 249 biodiesel blender pumps, and 5,700 charging stations are installed. Close to 17,000 direct job-years are created and approximately 32,500 direct, indirect, and induced job-years are created under this scenario.

HARVESTING-TRANSPORTATION-PRODUCTION EMPLOYMENT EFFECTS

In addition to the CM jobs created by building new transportation energy capacity, a number of HTP jobs will be created to meet the new demands for transportation energy. HTP employment will grow in all three scenarios, with stronger growth in the RFS2 and LCFS scenarios. As production shifts more toward renewable fuels using feedstocks grown in-state, employment in agriculture, warehousing, and transportation increase. In the baseline scenario, the oil refining industry sees a small amount of employment growth and corn-based ethanol sees more growth. In the RFS2 scenario, oil refining stays relatively level by 2021 with some growth by 2035; corn ethanol production falls but cellulosic production increases, with overall employment gains in the ethanol industry. In the LCFS scenario, there are job losses in oil refining, but these losses are more than offset by employment creation in ethanol. In all three scenarios, employment in biodiesel rises.

Tables 3 and 4 show the direct, indirect, and induced jobs that could be created in each of our three scenarios. Table 3 focuses on the period from 2012 to 2021 and Table 4 on the period from 2012 to 2035.

TABLE 3: CHANGE IN HARVESTING-TRANSPORTATION-PRODUCTION (HTP) JOBS FROM 2012 TO 2021

		Oil refining : gas	Oil refining: diesel	Oil refining: total	Ethanol: corn	Ethanol: cellulosic	Biodiesel	Net change in jobs
Baseline scenario	Direct jobs	5	-1	4	45	0	33	82
	Indirect jobs	25	-3	22	14	0	17	53
	Induced jobs	9	-1	8	18	0	15	41
	Total jobs	**39**	**-4**	**35**	**77**	**0**	**64**	**176**
RFS2 scenario	Direct jobs	-6	5	-1	-35	380	65	410
	Indirect jobs	-30	25	-5	-11	118	33	135
	Induced jobs	-11	9	-2	-14	149	30	164
	Total jobs	**-47**	**39**	**-8**	**-59**	**647**	**128**	**708**
LCFS scenario	Direct jobs	-22	17	-5	211	401	138	746
	Indirect jobs	-110	87	-24	65	124	71	237
	Induced jobs	-40	31	-9	83	158	63	295
	Total jobs	**-172**	**135**	**-37**	**359**	**683**	**272**	**1,277**

TABLE 4: CHANGE IN HARVESTING-TRANSPORTATION-PRODUCTION (HTP) JOBS FROM 2012 TO 2035

		Oil refining : gas	Oil refining: diesel	Oil refining: total	Ethanol: corn	Ethanol: cellulosic	Biodiesel	Net change in jobs
Baseline scenario	Direct jobs	47	0	47	425	0	36	508
	Indirect jobs	234	0	234	131	0	18	384
	Induced jobs	84	0	84	167	0	16	268
	Total jobs	**365**	**0**	**365**	**723**	**0**	**71**	**1,159**
RFS2 scenario	Direct jobs	1	15	16	-99	2,248	123	2,289
	Indirect jobs	5	74	79	-31	695	63	807
	Induced jobs	2	27	29	-39	883	56	929
	Total jobs	**8**	**116**	**124**	**-168**	**3,826**	**243**	**4,025**
LCFS scenario	Direct jobs	-93	37	-56	3,336	4,028	255	7,562
	Indirect jobs	-464	185	-279	1,031	1,245	131	2,128
	Induced jobs	-167	67	-100	1,310	1,582	116	2,908
	Total jobs	**-724**	**289**	**-435**	**5,677**	**6,855**	**502**	**12,598**

In each table, we see the various levels of job creation and loss in oil refining, ethanol production (both corn-based and cellulosic) and biodiesel production. As mentioned above, we assume here that all increased consumption of transportation fuels will be met by in-state production. If gasoline, diesel, or alternative fuels are produced out of state and imported into Minnesota, then job creation will of course be lower in Minnesota.

In table 3 we see that by 2021, oil refinery jobs, as well as the indirect and induced jobs connected to them, increase in the baseline scenario but decrease in the RFS2 and LCFS scenarios as more of Minnesota's transportation energy needs are met by alternative sources. A LCFS entails larger decreases in oil refinery employment, with up to 37 jobs lost over the period as oil refining shrinks. Meanwhile, ethanol production increases in all three scenarios, with a greater expansion in the LCFS scenario. Corn ethanol production shrinks in the RFS2 scenario as cellulosic ethanol substitutes for some corn-based ethanol. In the LCFS scenario, both corn and cellulosic ethanol expand. Over the 10 year period, the net change in jobs is positive in all three scenarios, with 176 jobs created in the baseline scenario (including direct, indirect, and induced), about 700 jobs in the RFS2 scenario, and over 1,200 jobs in the LCFS scenario. These are ongoing jobs in harvesting feedstock, warehousing and transporting the feedstock, and processing the fuel. The number of HTP jobs reported here will be maintained as long as fuel production continues.

Table 4 extends the analysis to 2035. This table includes the jobs created over the next ten years (captured in table 3) as well as the additional jobs needed by 2035 in order to meet increased production of transportation fuels. In table 4 we see that oil refining jobs, as well as the indirect and induced jobs created in relation to refining, increase by 365 under the baseline scenario. Oil refinery and related employment increases by 124 total jobs in the RFS2 scenario and falls by over 400 direct, indirect, and induced jobs in the LCFS scenario. These job losses are more than offset by job gains in the ethanol industry. Once again, corn ethanol employment increases in the baseline scenario, decreases in the RFS2 scenario as corn is displaced by cellulosic ethanol, and increases substantially in the LCFS scenario. Cellulosic ethanol remains at zero employment in the baseline scenario but increases dramatically in both the RFS2 and LCFS scenarios. Biodiesel employment grows in all three scenarios.

These results suggest that a shift to alternative transportation fuels such as ethanol and biodiesel will yield employment gains in the state over the next ten years and beyond. A more moderate approach to shifting transportation energy, such as that forecast by the AEO2011 and estimated here in the RFS2 scenario, yields small employment losses in oil refining but large gains in alternative fuels production. A more aggressive approach, achievable with a LCFS, would entail larger losses in the oil refining sector but even greater gains in ethanol and biodiesel production. These results not only suggest that a LCFS will yield economic benefits to the state of Minnesota, but also imply that oil refineries have an opportunity to offset any job losses by adding ethanol refining to their operations. By 2021, over 1,200 net ongoing jobs could be created in the state of Minnesota, and by 2035 that number could rise above 12,000. These jobs would be created in harvesting, transporting, and processing alternative fuels.

CONCLUSION

Minnesota is a national leader in alternative fuel production and consumption. With the enactment of a low-carbon fuel standard, the state could also be a leader in carbon emissions reductions. With a LCFS modeled after one such as California's, Minnesota could reduce the carbon intensity of its transportation fuels by 10 percent in 10 years. To do so would require increased production of alternative fuels such as ethanol (both corn-based and cellulosic) and biodiesel; changes within the ethanol industry, such as using biomass for process energy; and behavioral changes and infrastructure improvements that would enable consumers to use higher blends of ethanol and biodiesel as well as electric vehicles.

Over the ten year period that a LCFS would be implemented, new infrastructure and additional alternative energy capacity would need to be built in Minnesota. This would include retrofitting ethanol plants to use biomass for process energy, building new corn and cellulosic ethanol plants, and installing blender pumps and EV charging stations throughout the state. These construction and installation projects would create jobs manufacturing equipment, machinery, and building materials, as well as in the construction industry. In addition to the construction and manufacturing jobs that would be created in expanding the transportation fuel infrastructure, there would be ongoing employment creation in harvesting, transporting, and producing fuels. As Minnesota shifts from producing gasoline from imported crude oil to producing ethanol and biodiesel from feedstock produced in-state, employment would expand.

In this report we examined the job creation potential of a low-carbon fuel standard. To give context to our employment estimates, we developed three alternative scenarios for meeting transportation energy needs by 2021 and 2035. In all three scenarios we based our forecasts on transportation consumption forecasts by the Energy Information Administration in their *Annual Energy Outlook 2011.* In the baseline scenario, we assumed that those consumption levels are met by using the same shares of gasoline and alternative fuels as in 2011. In the RFS2 scenario, we assumed that the shares will change according to assumptions in the AEO2011, which includes enactment of the National Renewable Fuel Standard. In the low-carbon fuel standard scenario, we simulated the effects of a statewide LCFS which would lead to greater reductions in the use of motor gasoline and increased consumption of ethanol, biodiesel, and transportation electricity.

In all three scenarios, employment in Minnesota would increase. The employment expansion would be larger in the LCFS scenario than in the baseline or RFS2 scenarios, since expansion of alternative fuels entails more in-state labor than oil refining. Under the LCFS scenario we found that by 2021 over 7,500 jobs could be created in building alternative energy capacity and infrastructure. In addition, over 1,200 ongoing jobs could be created in harvesting, transporting, and processing transportation fuels. When we extended the analysis to 2035, we found that a LCFS could create over 32,500 jobs in manufacturing, installing, and building renewable energy infrastructure and capacity, and an additional 12,000 jobs could be created in the ongoing production of this level of alternative transportation energy.

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A note on the data

The analysis in this paper is based partly on the transportation and energy forecasts in the U.S. Energy Information Agency's *Annual Energy Outlook 2011*. Since the time that the analysis was performed, the EIA has released the *Annual Energy Outlook 2012*. Here we discuss some differences between the two sets of forecasts that could affect the results presented in this study.

The AEO2011 forecasted an increase in energy use by light-duty vehicles of nearly ten percent between 2009 and 2035. Within this, gasoline consumption was expected to remain relatively flat (with a slight decrease of about 1%), while electricity and ethanol use for transportation were both expected to increase significantly. In the AEO2012, however, the forecast for total energy consumption was revised downward. Whereas the AEO2011 predicted 17.66 quad BTU of light-duty transportation energy use by 2035 (an increase of 9% over 2009), the AEO2012 predicted a decrease of nearly 3%, to 15.46 quad BTU. As total energy use declines, so does gasoline consumption. The updated estimates in the AEO 2012 predict a 12% decrease in gasoline consumption. Ethanol and transportation electricity consumption are predicted to be at about the same level as forecast in the AEO2011.

Reproducing the analysis in this paper with the newer AEO2012 forecasts would be certain to change the results. The Baseline and RFS2 scenarios would both change in response to the more recent forecasts, with gasoline consumption falling in both cases. The employment estimates in the oil refining sector would thus be altered. However, since ethanol and transportation electricity estimates (which are key areas of focus for this study) remain relatively unchanged in the updated AEO, there is likely to be little change in the resulting employment impacts. Finally, since the LCFS scenario is only partly based on the AEO2011 forecasts, the results of this scenario might or might not change in response to the updated forecasts.

About the author

Heidi Garrett-Peltier is an Assistant Research Professor at the Political Economy Research Institute, and holds a Ph.D. in Economics from the University of Massachusetts, Amherst. Her research focuses on the employment impacts of public and private investments, particularly in the realm of clean-energy programs. Heidi has written and contributed to a number of reports on the clean energy economy. She has also written about the employment effects of defense spending with co-author Robert Pollin, consulted with the U.S. Department of Energy on federal energy programs and is an active member of the Center for Popular Economics. Dr. Garrett-Peltier's recent publications can be found on the PERI website.

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