Moving Michigan Beyond Oil

Fueling Our Transportation While Growing Jobs and Reducing Global Warming Pollution

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Executive Summary

Increasing dependence on petroleum-based transportation fuels is negatively impacting Michigan's economy and environment. Michiganders send over $14 billion per year to other countries and states to import petroleum. On the environmental front, petroleum is increasing ecological degradation from global warming, air pollution, water pollution, habitat destruction and related issues. Moreover, petroleum-based products with even higher environmental impacts—such as tar sands—are increasing their market share in Michigan and throughout our region.

Fortunately, Michigan's political leaders have begun to position our state as a leader in the manufacturing and development of alternative transportation fuels–such as advanced batteries and cellulosic ethanol. These rapidly developing, low-impact transportation options have the potential to help mitigate the economic and environmental problems caused by petroleum use and allow Michigan to emerge as a leader in the jobs-rich new energy economy. However, there is new evidence that the production of some biofuels and other alternative fuels could actually increase global warming pollution and other environmental impacts, rather than decrease them. Thus, public policy must prioritize the use of fuels that deliver the greatest benefit for Michigan and its environment.

The best policy vehicle to ensure benefits to Michigan's transportation sector is a low-carbon fuel standard (LCFS), which sets declining targets for lifecycle greenhouse gas emissions for all transportation fuels. A well-designed LCFS stimulates demand for the production and use of locally grown biofuels and encourages the development of energy-saving technologies (such as advanced batteries for electric vehicles) that can reduce carbon dioxide emissions. An LCFS also ensures that the fuels that replace gasoline will be the least-cost alternatives, thus growing jobs and new economic opportunities while also reducing emissions.

Moving Michigan Beyond Oil finds that:

1) Global warming pollution caused by Michigan's dependence on oil will cause ecological damages and exacerbate economic instability.

- Emissions from transportation create widespread air and water pollution, and accounted for 28 percent of Michigan's global warming emissions in 2005. On-road gasoline and diesel vehicles were responsible for approximately 92 percent of Michigan's transportation-sector emissions.

- Global warming pollution is predicted to increase average temperatures in Michigan approximately 5-10°F. While precipitation is predicted to increase by 20-40 percent, much of that increase will come in the form of extreme weather events, leaving Michigan with an overall drier climate that results in lower lake levels, increased vulnerability to invasive species, and increased pressure to overuse and divert Great Lakes water.[1]

- The environmental consequences of global warming will translate to economic costs:[2]

    - Lower water levels along the Great Lakes-St. Lawrence shipping route could cause Michigan losses of $2.6 billion and 13,000 jobs from dredging and reduced imports and exports;

    - Flooding could lead to $506 million in economic damages and job losses for nearly 9,700 Michigan workers;

    - Erosion could cause economic losses in the range of $11.5 billion to $20.7 billion to the agricultural sector, and heat stress could harm Michigan's dairy industry; and

    - Our snowmobiling, hunting, and angling industries face significant economic losses and job cuts.

2) Our current petroleum-heavy transportation fuel mix is a significant drain on our troubled economy.

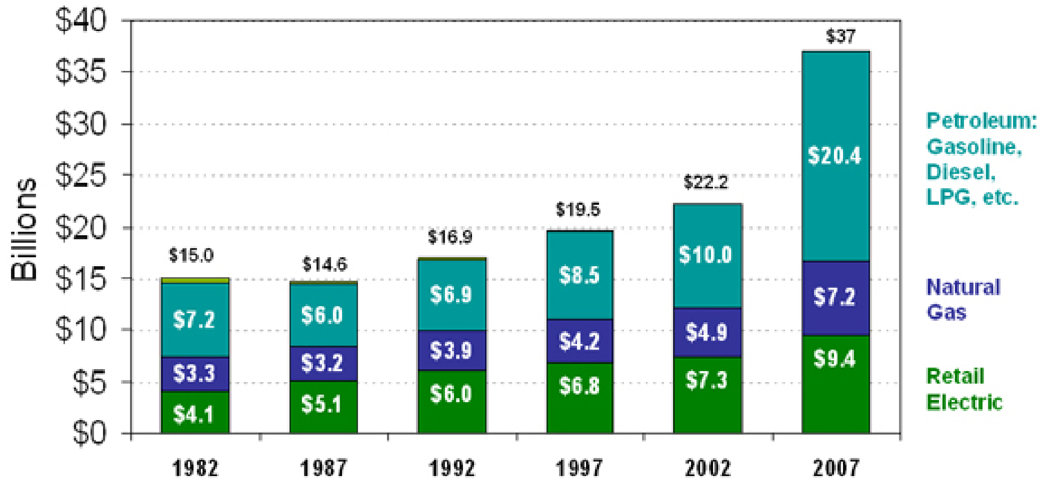
As illustrated in Figure ES-1, transportation fuels account for a majority of Michigan's energy expenditures. In addition, approximately 70 cents of every dollar Michigan spends on energy leaves the state to pay for the petroleum, natural gas, coal, and nuclear fuels we import. This is an enormous drain on Michigan's economy, and a prime opportunity for helping lead the state's economic revival.

- *Clean transportation technologies can generate many local jobs.* Based on a comprehensive direct survey of private sector employers, the Michigan Department of Energy, Labor & Economic Growth found that the "Clean Transportation and Fuels" sector comprises 41 percent of all Michigan green jobs, close to 40,000 jobs.[3] These are direct jobs in the research, development, and production of new technologies for energy storage and alternative fuels, as well as improved fuel efficiency and emissions reduction engineering.[4]

- *Clean Transportation and Fuels is a growing sector of the economy.* Despite a 3.6 percent reduction in overall job growth in Michigan, investment in clean energy sectors yielded job growth of 10.7 percent.[5]

- *Further investment could lead to even more robust growth.* Re-directing even a portion of the approximately $14 billion currently leaving Michigan's

Figure ES-1: Michigan Total Energy Expenditures



Source: Michigan Public Service Commission, Michigan Energy Overview, September 2008

economy to this thriving sector will deliver economic benefits and ripple effects within economy.

3) Non-petroleum transportation fuels vary greatly in their environmental impact.

Moving Michigan Beyond Oil evaluates fuels—including ethanol and biodiesel, but also advanced ethanol, electricity, natural gas, hydrogen, and coal-to-liquids—based on their life-cycle impacts on global warming emissions (from production to use), air and water pollution, deforestation and land use, food crop displacement, oil replacement, and cost.

Table ES-1 summarizes the pros and cons of seven alternatives to petroleum. (See page 4.):

4) Michigan needs a comprehensive strategy to reduce global warming pollution from transportation and benefit economically from clean fuels. Low-carbon transportation fuels policy can play an important role in that strategy for Michigan and the Midwest.

With innovative policies like those detailed below, Michigan can be a model for the region and for the nation in developing and implementing a low-carbon transportation strategy that emphasizes both ecological protection and job creation. Key principles that should guide a low-carbon transportation policy should include:

A) Combine the most promising approaches to maximize environmental benefits.
While working to make vehicles more fuel efficient, we should reduce gasoline and diesel consumption by increasing the use of electricity (in the short-term, through plug-in hybrids) *and* replacing a significant share of the liquid fuel that remains with lower-carbon options. Such a comprehensive approach can slash global warming pollution from vehicles by as much as 74 percent compared to conventional gasoline vehicles.

B) Develop fuels with long-term potential.
Michigan's policy choices should emphasize the development of infrastructure to support promising long-term fuel options over those with only short-term potential. In some cases, that may mean developing policies that encourage the use of fuels, like electricity, with limited short-term benefits but greater long-term potential.

Table ES-1. Pros and Cons of Petroleum Alternatives

Corn-based Ethanol	• Greater life-cycle global warming emissions than gasoline, when produced at the high volumes forecast for coming years • Production increases demand for cropland worldwide • Significant environmental impacts from increased farming • Modern facilities have the potential for improving carbon footprint by using more efficient processes
Cellulosic Ethanol	• Significant emission reductions with less environmental impact, especially if made from agricultural and forest residues, crops grown on abandoned or marginal cropland, or waste • Still in the very early stages of development • Michigan became a key player in commercial-scale development when Mascoma Corporation – a biofuels technology research company – announced plans to build a 40 million gallon/year facility in the Upper Peninsula
Biodiesel	• Produces less air and global warming pollution than conventional diesel • 98 percent less global warming pollution than conventional diesel when made from waste oil • Supplies of low-carbon biodiesel are extremely limited • Algae-based biodiesel could have great potential, but is in early stages of development
Electricity	• Can be used to power plug-in hybrids and all-electric vehicles • Michigan-based General Motors is a leader in the race to the first mass marketable electric vehicle with the Chevy Volt • Electric motors almost always produce less global warming pollution than internal combustion engines because they are far more efficient—even when the electricity is generated from coal • Michigan has great wind potential according to the American Wind Energy Association, which ranked us 2nd among all states for potential (but 25th for current capacity); This could be a clean, inexpensive source to generate electricity for fuel
Natural gas	• Can reduce air pollution and global warming pollution compared with gasoline vehicles • Fueling infrastructure is expensive and domestic supplies are finite • ***Biogas***: Anaerobic digesters produce methane that can be used in vehicles equipped to run on natural gas, or for electricity production or heating, from organic materials such as wood waste • City of Flint, Kettering University and Swedish Biogas Intl. announced partnership to produce biogas at the city's wastewater treatment plant
Hydrogen	• Can reduce air pollution and global warming pollution compared with gasoline vehicles • Environmental impacts depend greatly on how it is produced, and hydrogen-powered vehicles are still a long way from being available to American consumers
Coal-to-liquids	• Would vastly increase global warming pollution from transportation and exacerbate environmental impacts from coal production • Even with underground carbon sequestration, coal-to-liquids fuels do not provide an improvement, with respect to global warming pollution, compared to today's petroleum-based fuels • Great Lakes Energy Research Project, in Alma, Michigan is a multi-billion-dollar potential project that includes gasification of coal to make a liquid fuel as part of its production plans

C) Set strict environmental standards; mitigate environmental and social impacts.

We will be more likely to reduce the environmental impacts of transportation fuels if we set stringent environmental standards for those fuels. The first step should be to establish a low-carbon fuel standard that encourages the development of fuels with lower life-cycle global warming emissions. Standards should also be developed and implemented to mitigate the impacts of alternative fuels on the quality of our air, water and natural ecosystems.

5) A Low Carbon Fuel Standard (LCFS) should be the centerpiece of Michigan's alternative transportation fuels policy.

Michigan does not have time to lose in addressing the challenges posed by global warming pollution, nor can it afford to send an increasing proportion of its limited resources out-of-state. We also cannot rely on other states or the federal government to take action for us, or to account for our unique needs and promote our strengths. A Low Carbon Fuel Standard (LCFS) and other complementary policies would help Michigan become a leader in addressing these joint environmental and economic concerns.

An LCFS allows fuel providers flexibility in deciding how to reduce the global warming emissions from the fuel mix they sell, and encourages investment in the least-cost and most popular fuels that ensure decreased greenhouse gas emissions. By setting a 10 percent reduction goal for global warming emissions from transportation fuels by 2020, Michigan would rely on market-driven approach that encourages low-carbon transportation fuels without picking winners and losers. As complements to this policy, Michigan needs to encourage construction of additional infrastructure for delivering low-carbon fuels, support research and development of the fuels themselves, and develop and expand state programs to encourage landowners to grow feedstocks sustainably, in ways that target improvements in soil and water quality, wildlife habitat, soil erosion and carbon sequestration.

Legislative and state government leaders in Michigan have already taken a number of steps to advance next-generation biofuels and electric batteries, yet far more needs to be done to create the market *demand* for these fuels and to ensure that Michigan leads the nation in developing the low-carbon, sustainable fuels for the 21st century. This report finds that an LCFS is Michigan's best option for growing its economy while also reducing oil dependence and lowering greenhouse gas pollution from transportation fuels. It is also the best strategy for ensuring that Michigan's unique resources and needs are taken into account in any future federal or regional standard that may be established.

Introduction: Michigan's Critical Role in Breaking Oil Dependency

Michiganders—like all Americans—are increasingly desperate to break their addiction to petroleum. Our reliance on imported oil leaves us vulnerable to economic and political instability abroad, and sends billions of dollars out of state that could be invested locally. The gasoline consumed in America's cars and trucks produces more global warming pollution each year than the entire economies of all but a handful of other nations. The most recent science tells us that we must slash global warming pollution immediately and dramatically if we hope to avoid the worst consequences of global warming.

These urgent imperatives of economic turmoil, energy security, and global warming are driving a search for alternative transportation fuels, specifically those that are clean, homegrown and sustainable. Thus, this is the time for Michigan to shift our thinking to innovate, invent, and invest in manufacturing and infrastructure that supports low-carbon transportation fuels.

Michigan has little time to lose in addressing these challenges. We cannot afford false starts. We also cannot rely on other states or the federal government to respond to our unique needs and promote our strengths. Michigan and the Midwest have an abundance of natural resources and a manufacturing infrastructure that make us uniquely poised for success in developing biomass-based alternatives to traditional fuels and transitioning to plug-in hybrids and all-electric vehicles.

As the race for alternative fuels accelerates, public policies should both encourage continued progress in developing new fuel alternatives as well as steer the development of new fuels toward options with the greatest potential to reduce global warming

pollution and avoid severe environmental impacts. Current policies leave a critical gap in this regard.

By taking a creative approach that combines the best technologies, encourages the use of clean fuels, and sets rigorous environmental standards for alternative fuels from the very beginning, Michigan can improve its energy security, while cutting global warming pollution, protecting our environment, and establishing a strong national foundation for low-carbon transportation fuels policy. Michigan's economy stands to benefit substantially from these policy strategies as well, particularly if we show leadership for the rest of the country.

Purdue University/Alex Turco

Miscanthus, the perennial grass pictured [above] with corn, grows well in the Midwest, requires less water and fertilizer than corn, and produces more ethanol.

Problem: The Need for Locally-Produced, Low-Carbon Fuels

Consumption of oil for transportation has long caused its share of environmental, economic and social problems. And now, with the serious consequences of global warming becoming more widely understood, the auto industry in crisis and our economy in turmoil, the need to reduce oil consumption while boosting prospects for domestic, low-carbon fuels is even more urgent. A low-carbon fuel strategy is a critical step to address these interrelated problems.

Global Warming Pollution

Global warming threatens massive changes across the globe in the coming decades. Many of those changes have already begun to take place.

The first major signs of global warming are appearing throughout the world. Over the last century, global average temperatures have increased by 1.3°F.[6] Scientists believe that temperatures from 1950 to 2000 were likely the highest in the last 1,300 years.[7] Over the course of the 20th century, average sea level increased by approximately 6.7 inches worldwide.[8]

Snow cover in the Northern Hemisphere has declined over the last several decades, dropping by 5 percent during the 1980s.[9] Glaciers are retreating around the globe and the annual extent of Arctic sea ice has declined by 2.7 percent per decade since 1978.[10]

Worldwide, spring events—such as leaf unfolding, egg laying and bird migration—are occurring earlier in the year. In addition, numerous species of plants and animals appear to be moving toward the poles in response to rising temperatures.[11]

Impact of Global Warming on Michigan and the Great Lakes

The Great Lakes region has already observed a number of changes that can be attributed to global warming: rising temperatures (especially in winter), shorter duration of ice cover, and increased incidence of extreme precipitation events (rain and snowfall).[12] Researchers are already reporting evidence that water levels in the Great Lakes, which were recently at near record low levels, may decline further over the long-term due to global warming.[13]

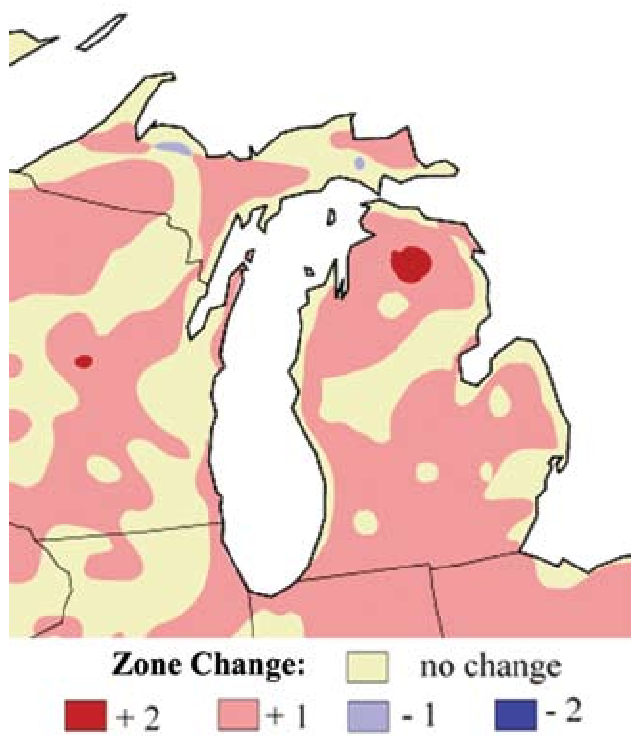
The predicted effects of global warming pollution include an increase in Michigan's average temperature from 5.4-10.8°F over the next century, as well as an increase in precipitation during the winter and drier summers.[14] Michigan will face an overall drier climate with increased extreme weather events, which will result in lower lake levels, increased vulnerability to invasive species, and increased pressure to overuse and divert Great Lakes water. Lake levels could drop during the next century by approximately 1 foot on Lake Superior, 3 feet on Lake Michigan and Huron, 2.7 feet on Lake Erie, and 1.7 feet on Lake Ontario.[15] Agricultural zones have already shifted approximately 100 miles north in certain parts of the Midwest (see Figure 2-1).

High temperatures also decrease the viability of pollen, which is temperature sensitive, increasing the likelihood of crop failure. Moreover, a phenomenon already evidenced is expected to increase as temperature rises: the northern migration of weeds and increased prevalence of invasive species. Michigan is home to an incredible diversity of native wildlife species, including 303 birds, 67 mammals, 27 reptiles, 137 fish and 23 amphibians.[16] Even small increases in temperature are likely to alter the makeup of entire ecosystems, forcing wildlife to shift their ranges or adapt.

The impacts of these health risks and environmental changes on our economy will be broad, affecting industries like healthcare, agriculture and shipping, as well as recreation and tourism. Extreme weather—heavy rainstorms and hotter days—is also expected to increase in frequency. Less precipitation in the summer, combined with lower groundwater levels, makes it more difficult for streams and wetlands to recharge. Lower water levels along the Great Lakes-St. Lawrence shipping route could cause Michigan losses of $2.6 billion and 13,000 jobs from dredging and reduced imports and exports.[17] Climate change will also threaten jobs in our snowmobiling, hunting, and angling industries—and lead to $506 million in economic damages and job losses for nearly 9,700 Michigan workers due to flooding alone.[18]

Drought will not only have a devastating impact on wildlife habitat and decrease the ability of natural systems to mitigate pollution, but it will also burden Michigan's agricultural and recreation industries—including everything from the cherry industry to recreational fishing and skiing. Stress due to heat and extreme weather events affects wildlife, feedstock animals, and crops in much the same way that these things affect humans: immune

Figure 2-1. Climate Change Reflected by Plant Hardiness Zone Changes between 1990 and 2006.[19]



systems worsen (making disease outbreaks more likely and disastrous), and appetites and physiology (e.g., milk production frequency and capacity) change. Meanwhile, erosion will cause economic losses in the range of $11.5 billion to $20.7 billion to the agricultural sector, and heat stress will encumber Michigan's dairy industry.[20]

Michigan residents are likely to experience significant changes to their regions and their quality of life. Higher summertime temperatures pose a significant health risk, especially to fragile populations such as children and the elderly.[21] Moreover, increased sewer overflows from storm events lead to beach closings and increased exposure to toxic sediments, which pose serious public health risks.

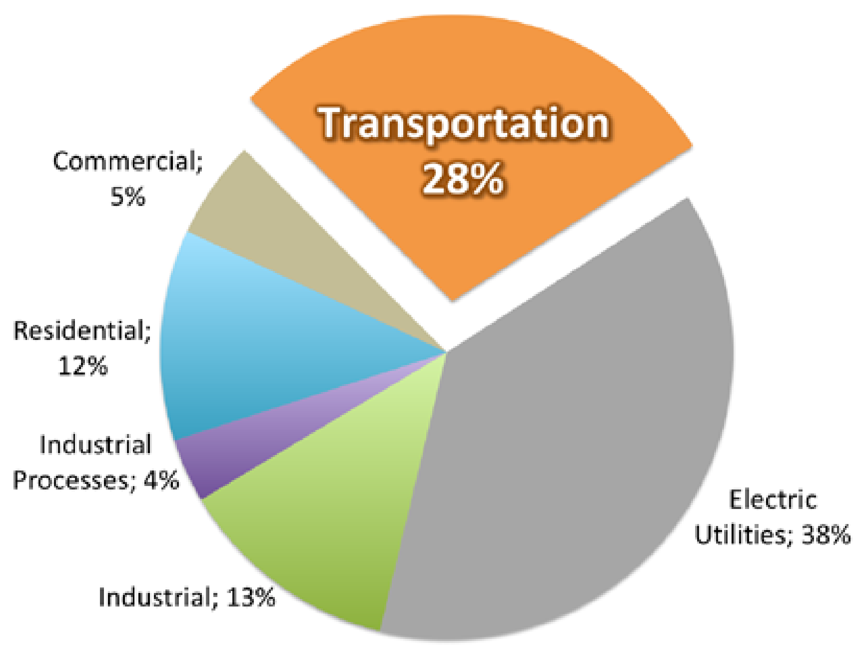
Should emissions of global warming pollutants continue to increase, Michigan and the rest of the world will experience dramatic warming over the next century and beyond, with major impacts on the environment, the economy and on human health.

Emissions from the Transportation Sector

The transportation sector (including personal travel in cars, light trucks and SUVs; freight shipping by truck and train; and airplane travel) is responsible for 33 percent of carbon dioxide emissions in the United States.[22] Only electricity generation, much of which relies on carbon-intensive coal, results in greater global warming emissions.

In 2006, the United States alone was responsible for approximately 20 percent of the world's energy-related emissions of carbon dioxide, the leading global warming pollutant.[23] Our transportation system produced more carbon dioxide than *the entire economy* of any nation in the world, other than China.[24] Emissions from U.S.

Figure 2-2: Michigan 2005 Greenhouse Gas Emissions by Sector[26]



transportation gasoline use (the vast majority of which fuels cars and light trucks) were greater than those from any nation's economy except for China, Russia and Japan.

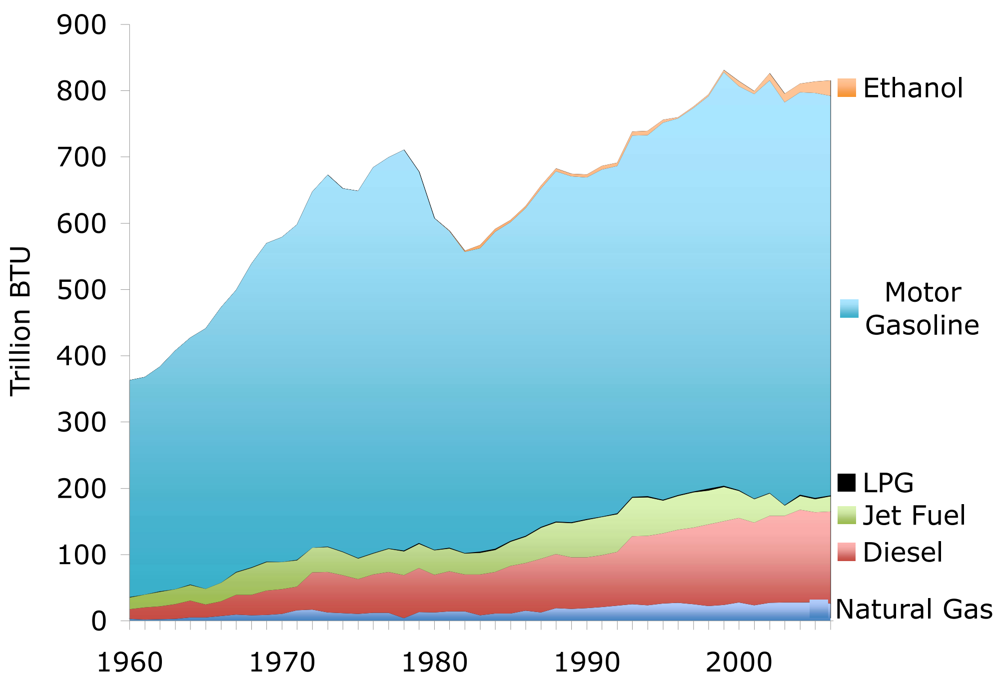
Emissions from transportation accounted for 28 percent of Michigan's global warming emissions in 2005. Onroad gasoline and diesel vehicles were responsible for approximately 92 percent of Michigan's transportation-sector emissions.[25]

The magnitude of emissions from the transportation sector means that any plan to achieve meaningful reductions in global warming pollution must include transportation. An approach that eliminated all emissions from the electric sector, for example, without touching transportation-sector pollution would still leave total emissions in the U.S. higher than those from any country other than China. Curbing emissions from the transportation sector will require a multi-faceted approach, including improving the efficiency of vehicles, reducing how much Americans drive by offering transportation alternatives, and lowering the carbon content of fuels.

Economic Impacts of Petroleum Dependence

As illustrated in Figures 2-3 and 2-4, most of Michiganders' energy expenditures are on transportation fuels, of which the vast majority are for motor gasoline, with smaller fractions for alternative fuels like ethanol and natural gas. Moreover, transportation fuels account for more than half of Michigan's energy expenditures. In 2007, Michigan spent an estimated $20.4 billion on petroleum products and $37 billion in total energy expenditures. Michigan imports 97 percent of its petroleum, meaning that approximately 70 cents of every

Figure 2-3: Transportation Energy Use in Michigan, 1960-2006[31]



dollar Michigan spends on energy leaves the state to pay for the petroleum, natural gas, and coal we import.[27]

Investing in technologies to reduce emissions—such as electric vehicle batteries powered by wind and solar electricity—can generate more local jobs than imported petroleum fuels. Based on a comprehensive direct survey of private sector employers, the Michigan Department of Energy, Labor & Economic Growth found that the "Clean Transportation and Fuels" sector comprises 41 percent of all Michigan green jobs, close to 40,000 jobs.[28] These are jobs in the research, development, and production of new technologies for energy storage and alternative fuels, as well as improved fuel efficiency and emissions reduction engineering.[29]

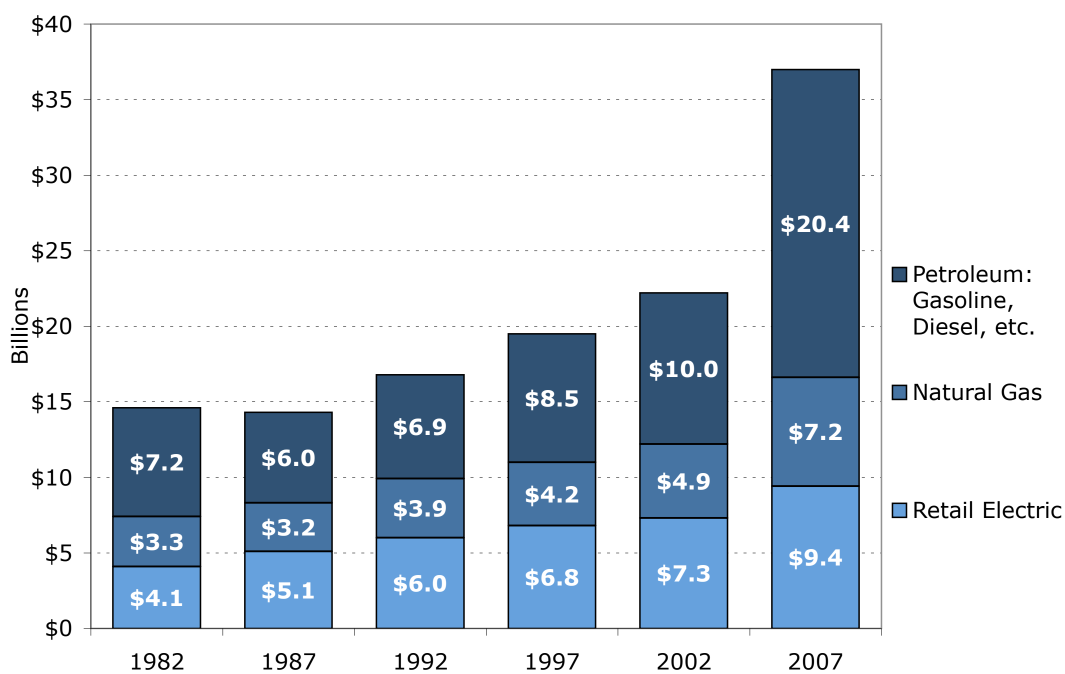
Moreover, despite a 3.6 percent reduction in overall job growth in Michigan, investment in clean energy sectors yielded job growth of 10.7 percent.[30] Re-directing even a portion of the approximately $14 billion currently leaving Michigan's economy to this thriving sector will deliver economic benefits and ripple effects within our economy.

Energy Insecurity

The environmental impacts and economic costs of oil production and use are more than enough reason for the United States to take steps to reduce our consumption. But our dependence on foreign oil—and rising prices for that oil—present another set of compelling reasons to end our reliance on petroleum.

America is highly dependent on oil—particularly for transportation. The United

Figure 2-4: Michigan's Total Energy Expenditures, 1982-2007[32]



States uses more petroleum for transportation than for any other purpose. In 2005, the transportation sector consumed 5.1 billion barrels of gasoline, diesel and other liquid fuels, or 67 percent of total oil consumption in the U.S.[33] Americans spent $466 billion on transportation fuels in 2005, of which more than three-quarters was for imported fuel.[34]

Demand for petroleum has grown in recent years, both in the U.S. and in industrializing nations. The United States consumed 20.7 million barrels per day of petroleum products during 2007, making us the world's largest petroleum consumer.[35] The equipment needed to drill, mine and refine oil is expensive, and producers have been unwilling to invest in new infrastructure in the face of energy markets made volatile by political unrest or storms that disrupt production. Nor can additional production capacity be brought on line quickly in response to consistently higher energy prices.

However, a larger problem underlies the lack of petroleum, and that is limited natural deposits of high-quality oil in accessible locations. "Proved reserves" of oil, a figure that oil-producing countries and corporations have been known to overstate, are estimated at 1.2 trillion barrels.[36] That is only slightly more petroleum than the world has consumed since oil production began in the mid-1800s.[37] At the current rate of worldwide annual petroleum consumption—approximately 30.5 billion barrels of oil—all proved reserves would be consumed in the next 38 years.[38] Nearly 75 percent of these reserves are concentrated in just seven nations: Saudi Arabia, Iran, Iraq, Russia, Venezuela, Kuwait, and United Arab Emirates.

Growing demand coupled with limited supply that is increasingly concentrated in unstable parts of the world means that prices will continue to rise in coming years and that oil-producing countries will have opportunities to manipulate the price and availability of petroleum. Moreover, oil prices are notoriously volatile and could become even more so in the years to come, exacerbating the economic damage of our heavy reliance on petroleum.

Other Pollution from Petroleum Use

The production, refining, and use of petroleum damages ecosystems, and causes air and water pollution.

Air Pollution

Oil refineries emit cancer-causing chemicals that present a threat to workers and nearby residents. The chemicals include benzene, formaldehyde, and polycyclic aromatic hydrocarbons (PAHs). Benzene and formaldehyde are known to cause cancer in humans, while PAHs are suspected carcinogens. Total emissions of benzene in the United States are high enough to cause 10.5 more cases of cancer per million people each year than would otherwise occur.[39] The petroleum industry was responsible for more than 50 percent of the nation's total "fugitive" emissions of benzene in 2005, for example.[40] The combustion of gasoline and diesel in vehicles releases many of the same chemicals as come from refineries.

The use of petroleum products creates particulate matter pollution and contributes to smog. Particulate matter can penetrate deep into the body, carrying chemicals that cause cancer, irritate lung tissues, and change how the heart functions.[41] Exposure to particulate matter also is suspected to depress immune function, increasing susceptibility to other disease.[42] As a result, particulates cause and aggravate a host of health problems, including lung cancer and cardiovascular disease. Smog, or ground-level ozone, can irritate sensitive lung tissue, impair lung development in children, and increase the risk of developing asthma.

Of Michigan's total population of 10,003,422 people, 9.5 percent of children and 9.5 percent of adults already suffer from asthma.[43] And, more than 200,000 Michigan residents suffer from chronic bronchitis and more than 100,000 suffer from emphysema.

Water Pollution

Oil spills from drilling rigs, refineries, tankers, pipelines and storage tanks can result from carelessness, accidents and rough weather. Spilling even a small amount of oil can contaminate large volumes of drinking water, surface waters or the ocean.

The 1989 Exxon Valdez spill in Alaska was the largest oil spill in U.S. history, but many smaller spills occur each year, causing damage to wildlife and ecosystems. In 2005, hurricanes caused 43 oil spills in the Gulf of Mexico.[44] In 2007, a cargo ship collided with the Golden Gate Bridge in San Francisco and released 58,000 gallons of oil.[45]

Discharge from the BP Whiting facility in Indiana has been found to contain small amounts of 23 different toxic pollutants, including chromium, strontium, benzeprine, mercury, ammonia, and total suspended solids. A controversial BP project designed to increase this plant's capacity to refine heavy Canadian oil from the current level – 30 percent – to 90 percent and to increase fuel output by 1.7 million gallons per day would dump 54 percent more ammonia and 35 percent more suspended solids containing metals and other minerals into Lake Michigan.

Reducing gasoline and diesel use will mean less oil-producing infrastructure and fewer opportunities for releasing oil into the environment.

Options for Reducing Transportation-Sector Pollution and Petroleum Use

Reducing global warming pollution in the United States will require cutting pollution from all sectors of the economy, including transportation. To prevent the most dangerous impacts of global warming, we need to cut emissions by at least 15 to 20 percent by 2020 and by 80 percent by 2050. Such reductions are not possible without a broad approach that includes more efficient use of energy and cleaner fuel—ranging from wind and solar power to liquid fuels with a lower carbon content. Reducing emissions from just one or two sectors of the economy, such as electricity generation and industrial energy use, will not be sufficient to reduce pollution to levels sustainable over the long term. Changes in the transportation sector are essential to any pollution-reduction plan.

Global warming pollution from transportation and oil consumption can be reduced through three complementary approaches.

- The first element is to improve vehicle efficiency. New federal fuel economy standards announced by the Obama administration now require a minimum target of a 40 percent increase in new vehicle fuel economy by 2016. The new requirements are expected to save 1.8 billion barrels of oil and eliminate 900 million metric tons of greenhouse gases – the equivalent to taking 177 million cars and trucks off the roads.

- The second element is to reduce

vehicle travel. Driving in personal vehicles can be reduced by encouraging transit, walking, or bicycling, by using carpools, and by finding ways to avoid trips altogether. Compact development—where shops, houses and services are within walking distance of each other—facilitates the use of alternative transportation and is crucial to reducing driving in the long term. Vehicle travel can also be cut by reducing how far freight must be shipped by truck or by using alternatives such as rail, which consumes less fuel per ton of freight shipped and thereby produces lower overall emissions.

- The third element is to transition to the use of transportation fuels that contribute less to global warming.

To achieve the most dramatic results in reducing oil consumption, we must combine all three of these approaches. For example, a car that is 25 percent more efficient, is driven 25 percent fewer miles, and replaces 25 percent of its fuel with lower carbon alternatives will consume 58 percent less oil. To obtain the same reduction from transportation sector emissions without any reduction in the carbon intensity of fuel would require a 35 percent reduction in driving and a 35 percent improvement in vehicle efficiency—both of which are possible, but more difficult to achieve.

Thus, though reducing the carbon intensity of fuels is not straightforward, it is an essential step to cutting emissions from the transportation sector. And, Michigan must play a leadership role in setting the policies that will reduce carbon intensity while providing the maximum economic growth potential for the auto industry and related sectors.

This report specifically focuses on the role that low-carbon fuels can play in reducing the global warming impact of Michigan's transportation system and our consumption of oil. In the following sections, we will briefly discuss the global warming and other environmental impacts of several alternative fuels and then discuss policy options for encouraging increased production and distribution of the best low-carbon fuels.

Assessment: Evaluating Alternative Transportation Fuels

Every fuel that can replace gasoline or diesel has different economic, global warming, environmental and social impacts. A complete environmental and global warming understanding of the impacts of each fuel is possible only through a life-cycle analysis, an evaluation of the effect of a fuel from the time a crop is planted for a biofuel or fossil fuel is drilled to generate electricity, all the way through to its final use in a vehicle. The best fuels are those that have the lowest life-cycle global warming emissions and create the fewest negative environmental and social side effects. This section will provide some basic outlines of this environmental analysis for each fuel, the details of which are located in the Appendix.

Factors used to evaluate carbon intensity of non-petroleum transportation fuels

For the many reasons enumerated in previous section, we know our dependence petroleum is bad for Michigan and the United States as a whole. Alternative transportation fuels like ethanol and biodiesel also have some drawbacks. This section enumerates the impacts that should be assessed to minimize the negative impacts of Michigan's new fuels, including ethanol and biodiesel, but also advanced ethanol, electricity, natural gas, hydrogen, and coal-to-liquids.

1. Global Warming Impact

A multitude of factors determine life-cycle global warming emissions from fuel; for example, how the feedstock is produced, transported for refining, refined, transported to market, and consumed all influence emissions. The interplay of these factors, especially with worldwide agricultural land use, means that high-volume production of biomass-based energy feedstocks could result in a fuel with life-cycle emissions that are approximately twice that of gasoline.[48]

Farming and management practices affect the amount of global warming pollution that results from a feedstock. Energy-intensive approaches and crops that require more fertilizer increase fossil fuel use and thus global warming pollution. Poor farming methods can result in the release of nitrous oxide and carbon dioxide from soil, both of which contribute to global warming. Modern farming practices rely heavily on fossil fuels. Natural gas is used to make synthetic fertilizers, petroleum is an essential component of pesticide manufacturing, and diesel fuel powers the equipment needed for planting, spraying and harvesting crops.

Feedstocks grown according to sustainability criteria have a smaller global warming footprint. Farmers who decrease their usage of chemical fertilizers, practice conservation tillage, use buffer zones for waterways, and follow other organic farming principles help to remove approximately 7,000 pounds of carbon dioxide from the air and store it in an acre of farmland.[49] Not only do such practices serve to sequester carbon, but they also build soil stability while mitigating erosion and water pollution.

Feedstocks must be transported from the field or natural source to a refinery or distillery. Emissions are lowest when the refinery is located close to where the feedstock or resource is produced. In addition, transportation emissions usually are lower when the feedstock is moved by train or pipeline rather than by truck. Moving freight by train rather than truck requires only one-third the amount of fuel and thus produces far less global warming pollution.[50]

Refineries can be powered by coal, natural gas or even biomass. The choice of fuel to generate heat plays a large role in determining the global warming impact. To produce the same amount of heat, coal produces 89 percent more global warming pollution than natural gas.[51] Currently, most refineries use natural gas as their principal energy source. A switch to coal-powered production would result in ethanol with higher emissions than gasoline, even before the effects of indirect land use change are considered.[52] Another factor affecting the carbon intensity of ethanol and biodiesel refining is how co-products are used. Refining creates co-products that can be used for animal feed and wastes that can be used as fuel.

For the end use of a fuel, some means of powering vehicles—electric motors, in particular—are far more efficient than others. Also, some of the fuels discussed have higher fuel-carbon intensity relative to gasoline because current engines are not optimized to burn such fuels, thus there is a loss in miles-per-gallon through consumption of these alternative or bio-based fuels.

Renewable Transportation Fuel Use in Michigan

Michigan currently has five operating ethanol plants with a combined capacity of 837 million gallons per year and others are under construction. By 2012, maximum Michigan ethanol production capacity is estimated to be 990 million gallons, which is expected to displace 13.6 percent of our gasoline consumption. Most of the ethanol sold in Michigan is blended with gasoline to create a 90 percent gasoline-10 percent ethanol mix. In 2006, we used 1.3 million gallons of E-85, which is a blend containing 85 percent ethanol. Four biodiesel production plants are in operation, producing between 25 and 35 million gallons per year.

Source: See footnote 47.

Life-Cycle Analysis of Global Warming Emissions

Typically, when we think of air pollution from transportation, we think of emissions from a car's tailpipe. However, this does not account for the full extent of the global warming pollution from transportation. Drilling for oil, refining it into gasoline and transporting it to consumers all create pollution in addition to the emissions released directly from a vehicle's tailpipe. These emissions that occur before fuel is used in a vehicle are called "upstream" emissions.

With most light-duty vehicles in the U.S. currently operating on gasoline—and thus having roughly uniform upstream emissions—there has been little need for life-cycle analysis of pollution from various fuels. However, as alternative fuels enter the market—and as some of those fuels have greater "upstream" emissions than emissions at the tailpipe—life-cycle analysis becomes an important tool for evaluating the global warming impact of different fuels.

A comprehensive life-cycle evaluation includes global warming emissions from the following steps:

- **Production and extraction**. For biofuels, this includes global warming pollution released when soil is disturbed by tilling, emissions from farm equipment and pollution from fertilizers. It also includes the benefit of carbon absorption by biomass. For fossil fuels, this includes emissions related to extracting crude oil, coal or natural gas from the ground.
- **Transportation to the refinery**. Both the distance and the method of transport affect emissions.
- **Refining or conversion**. For biofuels, this includes the conversion of crop material into biofuels, including emissions from burning coal, natural gas or biomass to dry the feedstock and process it. For petroleum, this includes emissions from refineries and related operations. For electricity, this step would include the combustion of fossil fuels to produce electricity.
- **Transportation of the fuel to market**. Both the distance to market and the method of transport affect emissions.

(Continued on next page)

The global warming impact of each fuel is the result of the interaction of all the elements of its life cycle. However, the global warming pollution from some of those elements may change depending on the total volume of the fuel that is produced and how it alters global markets for food and other agricultural products. Production of any biomass-based fuels in volumes large enough to meet U.S. demand has the potential to profoundly affect global markets. For this reason, the source of feedstock for biofuels is integral. Waste-derived fuels do not require

Life-Cycle Analysis of Global Warming Emissions *(Continued from previous page)*

- **Consumption of the fuel in the vehicle**. Carbon released by the burning of biofuels is counted here. This step also includes adjusting for how much of the energy in the fuel is translated to propulsion. Electric motors, for example, are five times more efficient than gasoline engines.[46]

- **Indirect impacts**. Secondary impacts are the broader changes that occur when a new form of transportation fuel is used. For example, biofuels create secondary impacts in land use when one farmer replaces a wheat field with corn for ethanol, and a second farmer responds by turning pasture into a tilled field to grow wheat. These effects are complex and can occur around the world. Other indirect impacts include increased emissions from fertilizer production and reduced emissions from replacing animal feed with byproducts from ethanol production. Fossil fuels have indirect impacts as well. Increasing natural gas use in vehicles might result in increased demand and higher prices, which could encourage switching from natural gas to coal to generate electricity.

A comprehensive life-cycle analysis allows for consideration of other environmental impacts from fuels, such as whether growing a biofuel encourages deforestation or other negative land use practices, whether processing a biofuel strains water supplies, and if the fuel, when processed or burned, adds to air pollution. A final consideration for crop-based fuels in particular is how demand for these fuels might compete with food uses of some crops.

Life-cycle analysis of the global warming pollution for transportation fuels includes a large degree of uncertainty. A comprehensive calculation includes all the factors discussed above, each of which is contingent upon multiple assumptions and complex interactions. The researcher also needs to decide what secondary and tertiary impacts should be included in the analysis. The result is that every estimate of the life-cycle emissions of different fuels includes a degree of uncertainty—sometimes very large. Nonetheless, the estimates that researchers have produced for different fuels are valuable for guiding public policy toward fuels with lower emissions, and as life-cycle analysis matures, we will have access to better and more refined estimates of the impacts of various fuels on the climate.

the conversion of existing land for their production, which significantly decreases their life cycle global warming impact because additional land, water, fertilizer and other resources are not required for their cultivation.

2. Air Pollution

Air pollution during the refining process and during vehicle use could increase or decrease with the use of non-petroleum based fuels. However, this depends largely on pollution control regulations.

Unfortunately, current standards are not very strong, leading to increased air pollution near refineries. Also, tailpipe emissions of some air toxins have been shown to decrease with biofuels, while others increase. It is unclear whether the mix will produce a net public health benefit or not. Better pollution controls in vehicles and refueling infrastructure can address some of these emissions.

3. Water Pollution

Increased agricultural production or greater use of fertilizers to boost production on existing land may increase runoff and leaching of nitrogen and phosphorus into surface and ground water. These contaminants can cause eutrophication, harm aquatic life, and taint drinking water supplies.[53]

Refining can also lead to water pollution. Depending on how refineries treat wastewater before releasing it, discharge water may contain levels of organic material that can harm waterways.

4. Deforestation and Land Use Impacts

Cutting down a forest or plowing up grassland increases emissions in several ways. Those trees, grasses and other plants contain carbon that is released into the atmosphere as they decay or are burned as the land is cleared. Moreover, they no longer are available to absorb and store carbon.

Planting crops to produce biofuels, especially on a wide scale, will spread the problems of modern agriculture and lead to the loss of forests and natural areas. Even collecting crop and forestry wastes can be problematic.

Cultivating land to grow energy crops creates the same environmental problems as other forms of industrialized agriculture, including pesticide runoff, soil erosion, nutrient enrichment of waterways, and use of genetically engineered organisms. These problems are more severe with corn than with switchgrass and other energy crops, which require less fertilizer and pesticide.

Converting currently unfarmed areas to production of an energy crop can cause additional environmental problems. First, the change in land use and loss of ecosystems that absorb carbon can increase global warming pollution so much that it negates any benefit from producing alternative fuels.[54] Second, a strong push for more energy crops can lead to the destruction of valuable and sensitive natural areas. Diverse habitats may be replaced by monoculture. Biodiversity can be maintained by requirements for preserves, or limits on what land can be farmed.

Collecting agricultural and forestry wastes for waste-derived fuel or other co-products can reduce the need for new farmland for biofuels production. However, over-aggressive harvesting can result in the loss of soil nutrients, less moisture retention and greater erosion in the case of crop wastes, and could harm forest health in the case of forestry wastes.[55]

Secondary land use changes—such as how the increased use of corn for fuel reduces exports of agricultural products including soybeans, wheat, and rice, thus prompting farmers elsewhere to clear more land for cultivation of food crops—are a major factor in life-cycle emissions from bio-based feedstock production, especially as demand grows.

As U.S. farmers dedicate more of their cropland to energy crop production, food exports decline. Farmers in other countries respond to declining imports and rising prices by producing more food crops. Some energy crops may be produced on existing cropland, but those displaced food crops still need to be produced. Ultimately, new land is cleared for cultivation.

5. Competition with Food

A final concern about growing plants to make fuel is that it displaces the cultivation of food crops. In the short term, the too-fast development of crops for energy can raise the price of food, both here and abroad. The U.S. currently provides 65 percent of international corn exports.[56] Countries that rely upon corn imports from the United States to feed their populations are finding it more difficult and expensive to do so. However, the entire blame cannot fall on energy crops as many other factors contribute to this phenomenon, including population growth, increased meat consumption, and drought.[57]

6. Oil Replacement

The ability of fuels to replace petroleum depends on their energy content, energy inputs needed to produce each fuel, current methods of production, and feasibility of large scale production.

7. Cost

In comparing the price of non-petroleum or alternative fuels to gasoline, the energy-equivalency ratio is key because ethanol, for example, contains less energy than gasoline on a gallon-per-gallon basis. Subsidies are another important factor for consideration—these can apply to producers, blenders, suppliers, or consumers. Finally, infrastructure costs—from pipelines and other transportation infrastructure to construction of dedicated fueling stations to production of vehicles capable of using the fuel—are an important factor in evaluating feasibility of non-petroleum fuels.

Fuels Assessed

The following chart provides a summary of the alternative fuels assessed in preparation for this report. Detailed information about each fuel based on the assessment factors is available in Appendix 1.

Table 3-1: Summary of Alternative Fuel Assessment

Fuel	Pros	Cons	Bottom Line
Corn Ethanol	• Domestically produced • Reduces petroleum consumption • Refining produces co-products such as distillers grains (used as animal feed) and lignin (can be burned for heat to power the refinery or provide electricity to the grid) • Lower tailpipe emissions of benzene and formaldehyde than gasoline	• Competes with food production: Worldwide land use change potentially caused by decreased supply of corn for food results in increased emissions from direct and indirect causes • Lower energy content per gallon than gasoline • Increased evaporative emissions, plus higher emissions of acetaldehyde—especially problematic at low percentage blends • To achieve a high yield, corn crops require significant fertilizer and water inputs	While ethanol can reduce the demand for oil imports, it is not clear that ethanol necessarily has lower global warming emissions than gasoline.
Biodiesel	• Domestically produced • Reduces petroleum consumption • Reduces air pollution: lower tailpipe emissions of VOC, carbon monoxide, particulate matter, and sulfur dioxide emissions	• Potential to use waste oil; however, not enough supply • Biodiesel crops yield less energy per acre farmed than ethanol crops and thus have a larger land use impact • Increased production of oil crops conflicts with other land uses • If derived from oil crops (soybeans, canola), requires increased inputs of fertilizers and water • Limited petroleum replacement ability	Though it reduces global warming emissions relative to gasoline, biodiesel has limited large-scale potential to meet Michigan consumption demands.

Table 3-1 (cont'd.): Summary of Alternative Fuel Assessment

Fuel	Pros	Cons	Bottom Line
Advanced Cellulosic Ethanol	• Domestically produced • Reduces petroleum consumption • Feedstocks such as waste and residue have little to no indirect land use impacts, and fewer global warming emissions than corn ethanol • Restores abandoned/ marginal cropland with plantings that increase carbon content of soil (compared to previous use) • Opportunity for Michigan: significant wood/ cellulosic feedstocks • Lower tailpipe emissions of benzene and formaldehyde than gasoline	• Not yet available at commercial scale • Lower energy content per gallon than gasoline • Increased evaporative emissions from fuel, plus higher emissions of acetaldehyde—especially problematic at low percentage blends	Once commercially viable, cellulosic ethanol provides a number of global warming emissions benefits and economic opportunities for Michigan.

Table 3-1 (cont'd.): Summary of Alternative Fuel Assessment

Fuel	Pros	Cons	Bottom Line
Natural Gas	• Reduces petroleum consumption • Compressed natural gas vehicles produce as much as 26 percent less global warming pollution over their lifecycle than gasoline powered-vehicles[58] • Natural gas vehicles release 56 percent less nitrogen oxide, 41 percent less carbon monoxide, and 84 percent less sulfur dioxide, but 68 percent more particulate matter[59] • Natural gas vehicles could use biogas produced from farms, landfills and sewage treatment plants, enabling them to be powered by renewable fuel	• Drilling for natural gas creates sediment and toxic pollution, as well as large quantities of saline water that can degrade the quality of waterways or groundwater resources if improperly managed[60] • Natural gas drilling offshore disturbs marine wildlife. Onshore, drilling infrastructure and pipelines create industrial sites within otherwise natural areas and fragment habitat • Pipelines for transporting natural gas extend hundreds or thousands of miles, cutting through ecosystems and fragmenting habitats • Current refueling infrastructure is insufficient	Natural gas has potential in certain areas; however, its production and large-scale distribution release significant global warming pollution, and the long-term supplies are limited.
Biogas	• Potential for negative greenhouse gas emissions based on the type of feedstock used		Biogas is a promising fueling option for natural gas powered vehicles because of its potential for not only zero, but negative GHG emissions.

Table 3-1 (cont'd.): Summary of Alternative Fuel Assessment

Fuel	Pros	Cons	Bottom Line
Electricity	• Domestically produced • Reduces petroleum consumption • Electric motors are inherently more efficient than internal combustion engines, thus electric-powered vehicles produce lower global warming emissions than conventional gasoline-powered cars and trucks • Charging electric vehicles with power from zero-emission renewable energy sources would result in vehicles with extremely low emissions • Michigan ranks 2nd in the nation with respect to on- and off-shore wind energy capacity • Michigan ranks 4th in the nation with respect to potential for manufacturing wind energy components	• Re-charging infrastructure required • Widespread use of electric vehicles could lead to increased air pollution if power plants are expanded or constructed • Some forms of electricity generation pollute or otherwise degrade resources	Electricity has strong and long-term promise, if properly pursued.

Table 3-1 (cont'd.): Summary of Alternative Fuel Assessment

Fuel	Pros	Cons	Bottom Line
Hydrogen	• Domestically produced • Reduces petroleum consumption	• Not yet commercially feasible • Electrolysis requires large amounts of electricity, which results in increased emissions • Greater hydrogen demand could cause natural gas consumption to increase, potentially requiring greater imports of natural gas • Expensive to create, use, generate and distribute	Hydrogen must be "done right" to limit its global warming emissions. Further research is needed.
Coal to Liquid Fuel	• Domestically produced • Reduces petroleum consumption	• Creates high amounts of global warming pollution, air pollution, water pollution, and irreversible land use impacts • Mining destroys habitat and pollutes land so that future uses are limited, scrapes away entire hillsides to expose the coal beneath, increasing air pollution, water pollution, and erosion • With carbon sequestration, still produces life-cycle emissions 4 to 8 percent greater than those of gasoline[61]	Coal-to-liquids has significant, harmful global warming pollution and should not be pursued as a transportation fuel solution.

New Petroleum-Based Fuels Have High Emissions

Oil shale and tar sands have drawn the interest of energy companies for decades as possible new sources of oil. As oil prices rise and as the U.S. seeks to increase its domestic production of oil and decrease reliance on oil from the Middle East, oil shale and tar sands have again entered the conversation. In fact, production from tar sands in Alberta, Canada, has taken off. However, these fuels have very high life-cycle global warming emissions, producing them creates extensive environmental damage, and they have little potential to displace much imported oil.

By 2013, an additional 1.4 million barrels per day of Canadian crude oil will be piped to Midwest markets—more than doubling today's imports. This increase will require a great deal of infrastructure, including at least 36 new or upgraded pipelines and 12 new or upgraded refineries. In Michigan, the Marathon Oil Refinery in Detroit is expanding its capacity to refine an additional 15,000 barrels per day.[62] In Whiting, Indiana, the BP Refinery on Lake Michigan is undergoing an increase in capacity of 205,000 barrels per day.[63]

Oil Shale

Oil shale refers to sedimentary rock with a solid petroleum substance trapped between the layers. If the rock is heated, the oil becomes a liquid and is released, at which point it can be processed as a synthetic crude oil.

Transportation fuels produced from oil shale have significantly higher global warming pollution emissions than conventional gasoline or diesel.[64] Oil shale releases its oil when it is heated to 700 to 900 degrees Fahrenheit. Producing that much heat requires a tremendous amount of energy: under one method of production, all the electricity from a medium-sized power plant would be required to produce fuel that would replace just 1 percent of daily U.S. gasoline consumption.[65] A coal or natural gas power plant of this size would release millions of pounds of carbon dioxide. Thus, total life-cycle emissions of oil shale are extremely high.

Processing oil shale causes other environmental damage. Producing a single barrel of oil from shale requires as much as 5 barrels of water, a severe problem given that oil shale deposits in the U.S. are concentrated in the arid Mountain West.[66] Whether oil shale is processed on site or is mined and processed off-site, the low energy density of oil shale means that large areas have to be disturbed. To extract just one barrel of fuel, 1.2 to 1.5 tons of oil shale must be crushed and processed, which increases the volume of rock by as much as 25 percent.[67]

Oil shale has limited potential to displace conventional oil. Though oil shale deposits in the U.S. contain several times more oil than exists in Saudi Arabia, mining it would entail tremendous environmental destruction from increased

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New Petroleum-Based Fuels Have High Emissions *(Continued from previous page)*

global warming pollution, use of all available water in the region, and destruction of thousands of acres of habitat.

Tar Sands

Tar sands consist of clay, sand, water and extremely viscous oil. With strip mining and extensive processing at high heat, the oil can be separated from tar sands for fuel.

As with oil shale, tar sands must be heated to turn the oil that they contain into a liquid, a process that results in high global warming emissions. Canada's tar sands industry estimates that producing a barrel of oil from tar sands consumes the same amount of natural gas that could heat a home for one to four days.[68] Overall, increasing production of oil from tar sands is the biggest factor driving up Canada's emissions of global warming pollution.[69]

Extracting oil from tar sands tears up land and consumes high volumes of water. Deposits of tar sands near the surface are accessed with vast surface mines. Two tons of sand produce just one barrel of oil, so any large-scale production requires moving huge amounts of soil.[70] Mining and processing tar sands can consume nearly six gallons of water for every gallon of oil produced.[71] As with oil shale, tar sands in the U.S. are concentrated in areas with limited water resources. Tar sand mining in Canada has caused widespread environmental damage.[72]

U.S. reserves of tar sands are equal to 12 to 19 billion barrels of oil.[73] Recovering even a small percentage of this will raise global warming pollution and destroy natural resources near the mining site.

Solution: Low Carbon Fuel Standard

No single alternative fuel will be the solution to our energy and global warming challenges. Indeed, the use of alternative transportation fuels must be just one piece of a larger strategy to reduce the contribution of the transportation system to global warming—a strategy that also includes reducing the number of miles driven in vehicles and improving vehicle energy efficiency.

Alternative transportation fuels, however, can play an important role in addressing these challenges, if we develop a smart strategy to maximize their benefits and minimize potential negative impacts. Such a strategy should have three key components.

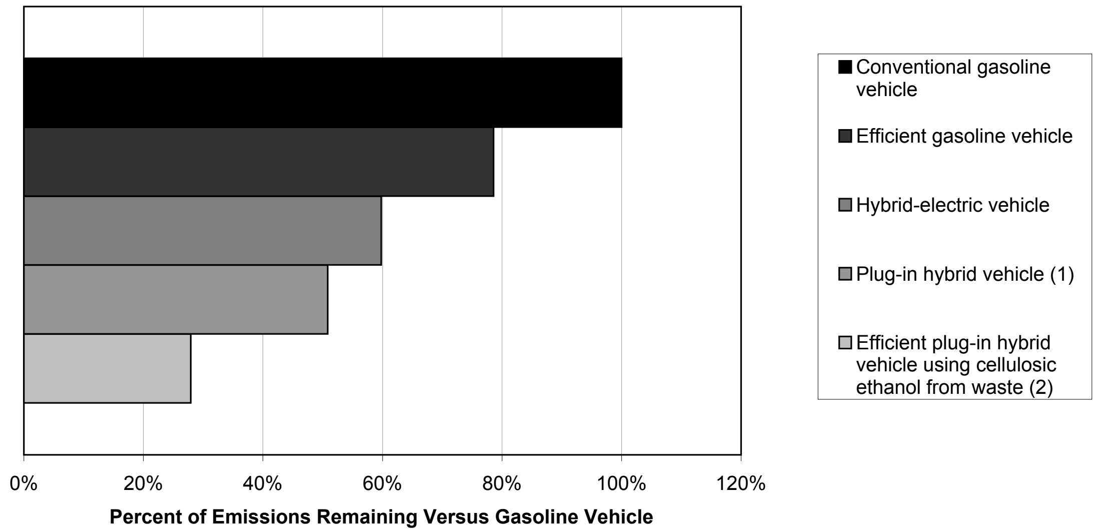
Three Principles for Transportation Fuel Development

1. Combine the most promising approaches to maximize environmental benefits.

A number of fuels have significant potential to reduce global warming pollution compared to gasoline. The greatest global warming pollution reductions, however, can be achieved by combining the cleanest technologies and fuels. Emissions from a conventional vehicle can be reduced by improving its efficiency and by powering it with a lower emission fuel. A vehicle that taps the best attributes of these options—better vehicle efficiency, use of a fuel that allows use of an efficient drivetrain, and by drawing on multiple clean fuels—can achieve the greatest reductions, as show in Figure 4-1.

Emission reductions gained through the use of alternative fuels, therefore, should be built on top of gains made through improved energy efficiency, and not substituted for them.

Figure 4-1. Life-cycle emissions achieved by combining the best vehicle technologies and fuels



Assumptions:

(1) Vehicle is recharged with electricity that has the same carbon emissions as the U.S. national average.

(2) Cellulosic ethanol produced from municipal waste. Electricity has same carbon emissions as U.S. national average.

2. Develop fuels with long-term potential.

Alternative fuels vary greatly in the short-term contributions they can make toward our energy and global warming challenges. They also vary greatly in their long-term potential.

Natural gas, for example, has the potential to reduce global warming pollution in the short term, but has little long-term potential as a transportation fuel due to limited domestic gas supplies. Hydrogen fuel has potential in the very long run, but that potential is decades away from being realized. Electricity is available today, but its potential will not be realized until automakers begin producing cars that can use electricity at a large scale.

Michigan's policy choices should emphasize the development of infrastructure to support promising long-term fuel options over those with only short-term potential. In some cases, that may mean developing policies that encourage the use of fuels, like electricity, with limited short-term benefits but greater long-term potential.

3. Set high environmental standards and mitigate environmental and social impacts.

Michigan will be more likely to reduce the environmental impacts of transportation fuels if we set strong environmental standards for those fuels. The first step should be to establish a low-carbon fuel standard (see next section) that encourages the development of fuels with lower life-cycle global warming emissions. Standards should also be developed and implemented to mitigate the potential impacts of alternative fuels on the quality of our air, water and natural ecosystems.

Significant research and study is necessary to accurately calculate the life-cycle global warming emissions of various practices for the production of fuels and to measure the impacts to our air, water and natural ecosystems.

Low-Carbon Fuel Standard: Michigan's Best Option to Grow Our Economy while Reducing Pollution from Transportation Fuels

If Michigan is to reduce global warming pollution and curb its dependence on expensive and polluting fuel, we will need policies to develop alternative transportation fuels that have long-term economic value for our state and the auto industry. These policies must promote clean fuels that can be used efficiently and that have the fewest environmental impacts.

The best such policy is a low-carbon fuel standard (LCFS), which encourages the development of alternative fuels that have lower global warming emissions. A well-designed LCFS ensures that the fuels that replace gasoline will be lower in carbon intensity and thus reduce emissions over time. By favoring lower carbon fuels, an LCFS provides significant incentives to increase the pace of development of low-impact cellulosic ethanol fuels as well as the electrification of vehicles, including both plug-in hybrid electric vehicles and pure electric vehicles. Michigan stands to benefit substantially from these incentives, particularly if Michigan helps set the standard for the rest of the country. Michigan will have to move quickly to play this role, as California has already adopted an LCFS, and approximately 11 other Northeast states are poised to move forward. Several Midwest states are also considering LCFS legislation, such as Minnesota and Wisconsin.

Michigan has been fortunate to have leaders who recognize the value of low-carbon fuels policy and of addressing climate change. The state has already adopted a number of policies to promote alternatives to gasoline, including biofuels and electricity.

After deciding that Michigan needed to make a focused effort to encourage the production and use of biodiesel and ethanol products, increase the viability of our agriculture industry, and reduce our dependence on foreign oil, Governor Jennifer Granholm established the Michigan Renewable Fuels Commission (RFC) to move Michigan towards renewable fuel development. In June 2007, the RFC made a number of recommendations to the Governor, including: 1) the development of a low-carbon fuel strategy for renewable fuels; 2) the establishment of a next-generation renewable fuels feedstock program; and 3) the creation of a "Green Retailers" program for encouraging retail renewable fuel sales.

Based on the RFC's recommendations, the Michigan Legislature passed 11 bills in December 2008 to advance renewable fuels in Michigan. The bills create tax incentives for machinery to harvest biomass and to convert fuel pumps to biofuels, establish tax-free renaissance zones for cellulosic ethanol plants, and provide basic alternative fuels funding mechanisms, standards and promotional materials. The bills also provide a tax credit to extend the life and expand the scope of the Renewable Fuels Commission.

To promote the development of vehicles that can operate on electricity, Michigan has used an aggressive economic strategy (see page 32) to successfully draw investment

Michigan Advanced Energy Policy Successes to Date

Tax Incentives

January 2009:

- Michigan passed $335 million in refundable tax credits for companies involved in the development and application of advanced-battery research, engineering, and manufacturing

April 2009:

- Added an additional $220 million in tax credits to the $335 million approved in January;
- Increased from $70 million to $90 million the maximum amount of tax credits for companies engaged in vehicle engineering to support battery integration, prototyping and launch expenses;
- Allowed the Michigan Economic Growth Authority (MEGA) to approve up to $300 million of the total $555 million in incentives for the construction of battery-cell manufacturing facilities; and
- Put Michigan in line to win up to $2 billion in battery development grants from the federal government

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Centers of Excellence

Purpose:

- Create partnerships between companies, academic institutions and the state to support cutting-edge research and development and pioneer new alternative-energy technology

2008-2009 Collaborations:

- Sakti3 & the University of Michigan (Ann Arbor) – will receive $3 million to establish a center focused on next-generation lithium battery technologies and processes, and creating the proprietary technologies to enable the manufacture of battery cells in Michigan instead of overseas
- Swedish Biogas International, City of Flint & Kettering University (Flint) – will utilize $4 million to launch a waste-to-energy/biomethane center at the city of Flint's wastewater treatment facility
- Mascoma Corporation, Michigan State University & Michigan Technical University (Kincross, Upper Peninsula) – will receive $20 million to establish a cellulosic ethanol center to use timber resources in the area to produce fuel from nonfood, cellulosic crops

from a number of battery manufacturing operations. Among the many projects are the following:

- A123 Systems will invest more than $600 million in a new battery plant in Livonia, which will create some 5,000 jobs;
- KD Advanced Battery Group LLC will build a $665 million, 800,000-square-foot battery manufacturing plant that will employ some 885 workers; and
- LG Chem and General Motors will build a 660,000 square-foot lithium-ion battery cell manufacturing facility and create up to 443 new jobs over the next five years.

While these bills and incentives are an important first step to promoting low-carbon, sustainable fuels for the 21st century, far more needs to be done to ensure that Michigan leads the nation in developing alternatives to gasoline. To achieve a successful low-carbon transportation strategy, we must adopt an LCFS and work with the Midwestern Governors Association (MGA) to establish a framework for our region. In particular, an LCFS is needed to require fuel providers to reduce greenhouse gas emission intensity. This approach would go a long way toward growing the market for new cellulosic fuels and electric vehicles, which hold the most promise for reducing global warming pollution and gasoline usage and growing Michigan's economy.

Governor Granholm also created the Michigan Climate Action Council (MCAC) to help Michigan develop a comprehensive climate action plan by providing recommendations for reducing the state's output of greenhouse gas emissions, lowering our overall energy consumption, and reducing our need to buy energy from out-of-state suppliers.

The MCAC also supports the adoption of a state LCFS, which is one of the policy options recommended in the group's final Climate Action Plan. The goal of MCAC's Transportation and Land Use Working Group's policy was to reduce the average "carbon intensity" of on-road transportation fuels sold within the state to achieve a 5 percent reduction of GHG emissions on a life-cycle carbon dioxide basis by 2015 and 10 percent reduction by 2025.

Moreover, Michigan can benefit by building upon, and encouraging, a regional coordinated approach such as that being recommended as part of the MGA's Energy Security and Climate Stewardship initiative. Earlier this year, the MGA adopted recommendations for the design of a Midwestern LCFS that would help states coordinate their efforts to encourage development of low-carbon fuels in their jurisdictions. The MGA has subsequently established a multi-stakeholder working group that will further study the issue and make recommendations to the governors on how such a policy could be designed and implemented to provide maximum benefit to the region.

Passage of an LCFS can build upon the federal Renewable Fuel Standard, or RFS, passed as part of the Energy Independence and Security Act of 2007. While the federal RFS takes an important step toward encouraging alternative fuels with lower greenhouse gas emissions, the standard only applies to new biomass-based fuels and does not ensure reductions from transportation fuels overall. This means, for example, that other low-carbon fuels like electricity and hydrogen get left out, thus putting them at a competitive disadvantage. It also leaves out other high-carbon fuels like tar sands or coal-to-liquids, potentially giving them an *advantage* over low-carbon biofuels, which are more heavily regulated, and undermining any gains made in lowering greenhouse gas emissions.

An LCFS is thus a necessary complement to the RFS because it advances other technologies—such as plug-in hybrids, natural gas, or hydrogen from natural gas—and, moreover, it *discourages* high carbon fuels like tar sands, oil shale, and coal-to-liquids. States that lead in LCFS policy will therefore be better prepared to benefit from an updated federal RFS as well as the advancement of new low-carbon fuel technologies. These states would also be better prepared for a national LCFS, an unlikely prospect in the short-term but likely in the long-term.

Designing an LCFS

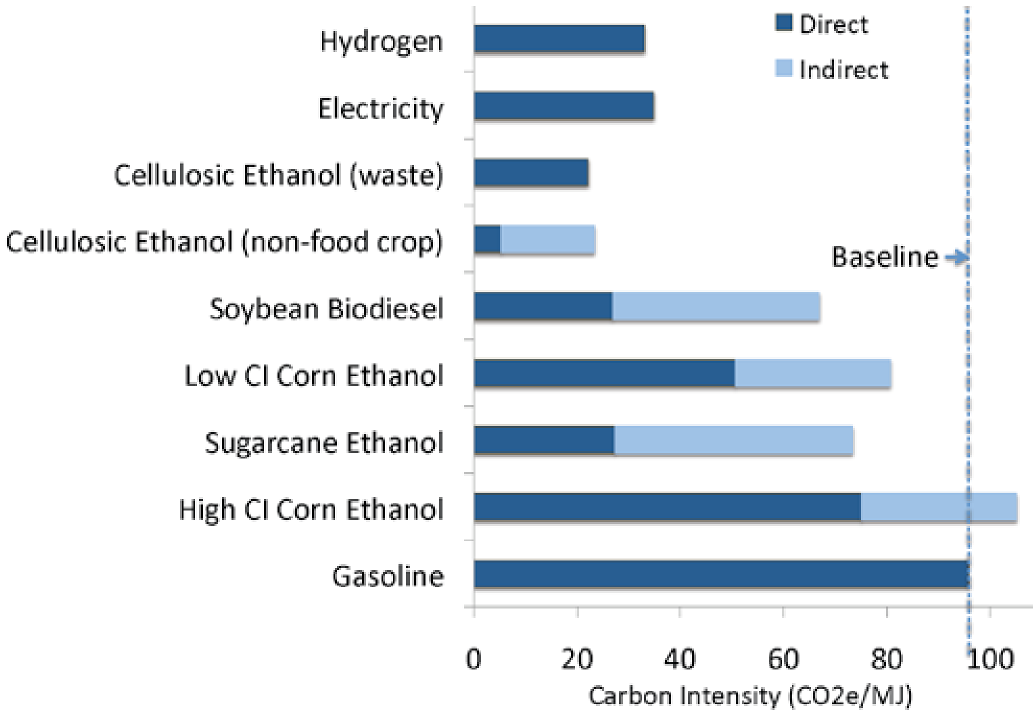
An LCFS could be implemented in several ways, but one of the easiest routes would be to require that fuel providers—those who refine, import, or blend fuel—sell fuel with a declining carbon content. A beginning point could be a requirement that transportation fuels be 10 percent less carbon-intensive by 2020, the standard adopted by the state of California.

Fuel providers would be required to report the full life-cycle global warming pollution of the fuels that they sell.[74] A default emission figure for each fuel should be established by the appropriate regulatory authority, but fuel sellers should have the option of presenting data demonstrating that their fuel is less polluting than the default fuel value. Life-cycle analysis of global warming emissions should include emissions from farming practices, land use changes here and worldwide, refining, shipping and use of the fuel. The efficiency of vehicles using non-petroleum fuels in high-efficiency electric drivetrains should also be factored. All global warming pollutants, including carbon dioxide, methane and nitrogen dioxide, from all stages of fuel production (including secondary land use impacts), should be considered.

As evident in the discussion of the life-cycle global warming emissions of different fuels in the *Evaluating Alternative Transportation Fuels* chapter and in the Appendix, many factors influence the environmental profile of biofuels. Accurately assessing the impact of fuels will not be simple, nor will it happen overnight. The California Air Resources Board (CARB) and the U.S. Environmental Protection Agency have begun the process. CARB, in particular, has completed its process, conducting a "carbon intensity" analysis of existing petroleum alternatives as well as advanced options that are not yet feasible at a commercial scale. CARB assessed the direct emissions—those associated with the production, refining, and transportation of the fuel—as well as indirect emissions, which result from the destruction of forest and grassland to account for the displacement of food crops. According to their results (see Figure 4-2), CARB found that cellulosic ethanol from non-food sources, electricity, and hydrogen were the most promising options for meeting their goal of a 10 percent reduction in carbon intensity of transportation fuels by 2020. CARB also found that lower carbon-intensity methods of producing traditional corn ethanol, as well as current sugarcane-based ethanol and soybean biodiesel, offered feasible pathways for helping meet the standard. A similar analysis is underway by the U.S. Environmental Protection Agency. Life-cycle analysis and indirect land use change have been hotly contested issues, and state or regional investment and participation in the analytical process will help Michigan participate in the national debate.

However, an LCFS could be implemented today, relying on estimates that

Figure 4-2: Sample CARB Carbon Intensity Values for Future Fuels



encourage the production of fuels with less carbon without favoring one vehicle technology over another. As better data becomes available—thanks in part to better tracking of production pathways and fuels once a standard is in place—the standard can be revised to offer greater precision about which fuels will provide the greatest benefit.

Current uncertainties should be dealt with conservatively. For example, researchers assisting with development of California's LCFS acknowledge that uncertainty remains regarding emission effects of land use.[75] However, uncertainty about land use impacts should not be an excuse to assume that there is no impact from land use: giving land use impacts a value of zero could facilitate counterproductive land use practices. Instead, a low-carbon fuel policy should include a best estimate of land use impacts, with the understanding that the estimate will be revised in the future as better data become available. A low-carbon fuels policy should be flexible enough to allow the addition of new information for establishing targets and enforcing requirements.

An LCFS allows fuel providers flexibility in deciding how to reduce the global warming emissions from the fuel they sell. Among their many options, providers could purchase and blend low-carbon biofuels (e.g., cellulosic ethanol) into gasoline products, purchase credits from electric utilities supplying low-carbon electricity for plug-in hybrid electric vehicles, or diversify into low-carbon hydrogen as a product. Fuel providers would also be encouraged to minimize the sale of high-carbon fuels (such as tar sands or coal-to-liquids). Businesses can also identify *new* technologies and strategies that meet the carbon reduction goals. Thus, the market will determine the least-cost and most consumer-responsive outcome for the fuel mix while ensuring decreasing greenhouse gas emissions.

A 10 percent reduction in global warming emissions from transportation fuels by 2020 is an ambitious, but reasonable, target. Also, by starting the low-carbon fuel standard with a fairly low requirement and increasing the target each year, farmers, researchers and investors can anticipate future demand, developing new energy sources and technologies.

Part of the value of an LCFS is its ability to promote the development of new technologies. Public policies that establish ambitious goals can help speed the evolution and production of cleaner technologies. Renewable Portfolio Standards (RPSs), for example, have been successful in stimulating new renewable energy capacity in many states, and Michigan recently embraced this strategy in legislation last year. A low-carbon fuel standard can help promote similar gains with the development of low-carbon vehicle fuels.

To avoid potential negative consequences from increasing production of low-carbon fuels, any LCFS should also include provisions to protect air quality, public health, and the environment.

Protecting air quality and public health

Because fuels such as ethanol blended with gasoline at certain concentrations can worsen air quality by raising emissions of toxic and smog-forming pollution and particulate matter, a fuel standard should include a requirement that low-carbon fuels at least maintain current air quality and that vehicle emission standards should not be relaxed. Operating a subset of vehicles on high blends such as E85 will allow a sector-wide reduction in global warming emissions without increasing air pollution.

Protecting ecologically sensitive areas

An LCFS should not result in the clearing and use of ecologically sensitive areas for feedstock cultivation. Environmental safeguards, such as the Michigan Woody Biomass Harvesting Guidelines and other best management practices should be established to ensure sustainable practices are used when complying with an LCFS. These practices should include current best management practices like inter-planting of perennial crops, riparian buffers and even possibly the development of a certification system based on sustainable harvesting guidelines for feedstock production and harvest.

If we design Michigan's LCFS efficiently and smartly, it will catapult Michigan into a leadership position in the development of homegrown, sustainable fuels and also assist our auto industry in the transition to vehicle electrification, while maximizing the domestic industry's competitive advantage in producing flex-fuel vehicles (to create a demand for homegrown cellulosic ethanol). Michigan's electric utilities are likely to benefit, since the utilities will get tradable credits for powering vehicles with electricity. Perhaps most importantly, an LCFS would leverage the significant investments the state has made in advanced battery technology for the automotive sector and in next generation biofuels. We must now help create the market demand for low-carbon technologies and fuels by enacting an LCFS and other complementary policies to push the market toward these technologies, instead of simply subsidizing particular fuels. These policies will help ensure that Michigan becomes a key leader in both the production and use of low-carbon transportation fuels.

By helping to set and push a national standard, Michigan would capitalize on its existing competitive advantage and the resources we have been leveraging to further advance battery technology, cellulosic ethanol and the future of our auto industry.

Complementary Policies & Solutions

Though an LCFS will provide the biggest driver for the production and use of low-carbon fuels in Michigan, additional policies will also help ease the transition to lower-carbon fuels. Several of the policies below have also been recommended by the Michigan Renewable Fuels Commission and the Michigan Climate Action Council.

1. Provide "Green Retailer" incentives to encourage the retail sale of low-carbon fuels.

To ensure a growing market for low-carbon fuels, establishment of a fueling infrastructure for many of these fuels will be necessary. While the legislature has already recognized this need by providing tax incentives for the installation of new biofuels dispensing systems, these incentives alone may not be enough. There is also a need for incentives to promote the retail *sale* of low-carbon biofuels, to help ensure retailers are able to offer pricing based on what customers find valuable.

The RFC recommended an alternative to the state's previous per gallon tax credit for biofuel blenders that expired last year. The proposed "Green Retailers" program would instead reward retail and wholesale fuel providers that sell a certain *percentage* of renewable fuels each year. The incentive could come in the form of a reduction in the motor fuel tax owed on all fuel sold at the facility. One option for funding the program is an increase in the motor fuel tax, initially starting at $0.01/gallon and increased as needed to achieve the program's goal. This is an innovative program that Michigan could be first to implement and could also be expanded to include other low-carbon fuel infrastructure needs such as electric and, perhaps eventually, hydrogen fueling options.

2. Support research and development for low-carbon fuels.

To succeed in developing low-carbon transportation fuels, Michigan also needs innovative collaborations like the Great Lakes Bioenergy Research Center (GLBRC), a joint research initiative between the University of Wisconsin and Michigan State University. With significant funding being provided by the Department of Energy, GLBRC scientists and engineers will conduct basic research toward a suite of new technologies to help convert cellulosic plant biomass — cornstalks, wood chips and perennial native grasses — to sources of energy for cars and electrical power plants.

Currently, the cost of converting cellulosic biofuel feedstocks into fuel limits the competitiveness of ethanol with petroleum products.[76] Research into easier and cheaper methods of refining cellulosic materials will thus help make those fuels more competitive. Cellulosic feedstock production also needs to be improved with research into better cultivation, including how to increase the yield of cellulosic material from food crops and cover crops.

Dedicated research and development is also needed for other low-carbon transportation fuels—specifically, vehicle electrification. Collaborations like the Advanced Battery Coalition for Drivetrains, announced by General Motors and the University of Michigan are essential to establishing the battery expertise and manufacturing skills necessary to make Michigan a leader in new transportation fuels. Research is also needed in many other areas as well, including "Smart Grid" systems, charging infrastructure, and generation capacity.

3. Encourage Sustainable Feedstocks.

There is also a need to develop and expand state programs to encourage landowners to grow new sustainable feedstocks, preferably in ways that target improvements in soil/water quality, wildlife habitat, soil erosion and carbon sequestration. Michigan should therefore leverage federal funding for voluntary land conservation programs such as conservation easements, open space programs or conservation reserve or working lands programs.

The legislature has already approved tax incentives for the use of agricultural machinery that can be used for harvesting biomass for alternative fuel production, and has created new renaissance zones for facilities involved in the production of cellulosic biofuels. The development of a "sustainable next generation renewable fuels feedstock program," as recommended by the state's RFC, would help to ensure the supply of sustainably-grown biomass needed to produce these new fuels.

Michigan should specifically look for opportunities to leverage federal programs and incentives. The Biomass Crop Assistance Program (BCAP), established in the 2008 Farm Bill, is one potential source of funding to boost climate-friendly and farmer-friendly energy crop production. BCAP supports the establishment and production of crops for conversion to bioenergy and assists with collection, harvest, storage, and transportation of eligible materials for use in a biomass conversion facility. Through programs like BCAP and the USDA's Conservation Stewardship Program, Michigan can provide farmers with the incentives and risk mitigation they need to produce crops for two synergistic markets—Sustainable Fuels and Green Chemistry. Programs that delineate energy crops and provide higher incentive payments for resource-conserving crop rotation also have the potential for bio-based chemical and materials co-production.

Progress Toward Low-Carbon Fuels in Michigan

Michigan has been fortunate to have leaders who recognize the value of renewable fuels and of addressing climate change. It is therefore not a surprise that significant progress toward a low-carbon fuels standard has already been made, providing a good foundation of legislation and administrative action. For Michigan to enhance its leadership in this area, however, the time is now right to take the next step in establishing low-carbon fuel policies that can further build the market demand for next-generation transportation fuels like advanced biofuels and low-carbon electricity for plug-in electric vehicles. As with Michigan's recent Renewable Portfolio Standard for the power sector, an LCFS would establish requirements for the transportation fuels sector that would stimulate the demand for these new fuels and technologies, helping to create new jobs while reducing global warming emissions.

It is also timely for Michigan policymakers to advance several complementary policies. Additional incentives for Michigan fuel retailers, for its research and development community, and for feedstock suppliers, would help to cement Michigan's leadership role in advancing low-carbon fuels. These measures will help to ensure that we have the infrastructure, the technical expertise, and the biomass feedstocks needed to maximize the state's potential. Michigan should also lead in the development of coordinated regional efforts, such as the Midwestern Governor Association's recommendations for development of an LCFS, and other recommendations to promote low-carbon fuels throughout the Midwest region.

Michigan has already invested significant public resources in the promotion of advanced battery technology, advanced cellulosic ethanol, and biogas. Now we must help create the market demand for these fuels by enacting an LCFS and other complementary policies. These policies help ensure that Michigan becomes a key leader in both the production and use of low-carbon transportation fuels. This is the state's best option for growing its economy while also reducing oil dependence and lowering greenhouse gas pollution from transportation fuels.

Appendix: Fuel Assessment

Ethanol

Ethanol is a nearly pure grain alcohol produced from the fermentation of plant material, most frequently corn, sugar cane, or cellulosic material. The conclusion that ethanol use reduces petroleum consumption is generally accepted by researchers, but, depending on the feedstock, the substitution of ethanol for gasoline may not provide any global warming benefit.[77]

Global Warming Impact

Conventional corn ethanol production generally results in a fuel with greater life-cycle global warming pollution than gasoline. Cellulosic ethanol from crop waste and other sources with limited land use impacts has greater potential for lowering global warming emissions than corn ethanol. Currently there is no large-scale ethanol production from energy crops such as woody biomass or crop residues such as corn stalks and rice husks; with technological advances these feedstocks could become major sources of ethanol production in the future. Restoring abandoned cropland by planting a mix of prairie plants including legumes and grasses increases the amount of carbon stored in the soil and in plant roots compared to previous use of the land.[78]

The estimate that corn ethanol produces twice the global warming pollution of gasoline is based on a scenario in which the U.S. produces 30 billion gallons of ethanol in 2016. Even if production volume were lower, the impact of worldwide land use changes would still cause corn ethanol to have higher emissions than gasoline. The study's authors estimate that even if actual production in 2016 is 25 percent lower than they postulated, emissions from worldwide land use change would decline by only 10 percent.[79]

Corn ethanol refining produces co-products such as distillers grains that can be used as animal feed and wastes that can be used as food. Lignin, found in plants used for cellulosic ethanol, cannot be fermented into ethanol but can be burned to create heat to power the refinery and even generate electricity to be sold into the grid.[80] These uses of co-products displace other processes—the manufacturing of animal feed or burning of fossil fuels for heat or electricity generation—that release global warming pollution. The savings can be credited to the life-cycle emissions from ethanol.

Were carbon sequestration ever to become a viable technology, the production of cellulosic ethanol from waste material could provide a means for reducing carbon dioxide levels in the atmosphere. Plants capture carbon from the atmosphere as they grow. Typically, that carbon is released again when the plant decays or is burned for energy. However, a refinery powered by waste biomass to produce cellulosic ethanol could capture its on-site carbon emissions and sequester them, thus effectively removing carbon from the atmosphere.

Corn grown and refined in the state where it will be consumed as ethanol has lower life-cycle emissions than ethanol shipped to a distant market. Shipping ethanol is more energy-intensive and thus produces more emissions than shipping gasoline the same distance. Ethanol is difficult to ship by pipeline, so it must be shipped by truck or rail, both of which are less efficient.[81] Furthermore, because ethanol has lower energy content per gallon, a tanker truck loaded with ethanol delivers less energy to fueling stations despite having expended just as much fuel as if the tanker had been full of gasoline.

Air Pollution

Ethanol, whether made from corn or cellulosic material, produces lower tailpipe emissions of some air toxins, such as benzene, though emissions of others, such as acetaldehyde, rise.[82] EPA estimates that under the requirements of the 2005 Energy Policy Act, benzene emissions will fall 1.8 to 4.0 percent and formaldehyde emissions will also decline.[83] This shift in the mix of emissions may or may not be a net public health benefit. Formaldehyde, which will decline, is a more potent toxin than acetaldehyde, but for vulnerable subgroups, acetaldehyde may prove more hazardous.[84] But mixing ethanol into gasoline allows gasoline to evaporate more easily and increases the difficulty of controlling emissions.[85]

The use of ethanol, particularly in low-percentage blends, can significantly increase emissions of smog-forming pollutants from vehicles because the presence of ethanol increases evaporative emissions.[86] U.S. EPA estimates that expanding the use of low percentage blends of ethanol could cause an increase in VOC emissions by 4 to 5 percent in some areas. Emissions of nitrogen oxides could increase by 6 to 7 percent.[87] Thus, fuels with high percentages of ethanol, such as E85, are preferable to low blends.

Water Pollution

Ethanol refineries can be large users of water, but proper wastewater treatment can allow the refinery to recycle its water. In addition, wastewater treatment allows the refinery to capture methane and use it for energy.

Deforestation and Land Use

Global land use decisions also have the potential to raise life-cycle emissions from switchgrass-based cellulosic ethanol. The scale of secondary land use changes on emissions can be seen from one life-cycle analysis model that examined the impact of growing switchgrass on land capable of producing corn. While this is a highly unlikely substitution that no farmer seeking to maximize profits would choose, the model suggests that it would cause life-cycle emissions of cellulosic ethanol to be 50 percent higher than gasoline.[88]

These are some of the first calculations that researchers have made of the global warming impact of indirect land use change from ethanol feedstock production. Newer and better data will become available about the indirect land use impacts of ethanol feedstock production as researchers create increasingly sophisticated models of worldwide changes triggered by biofuels production in the U.S.

Secondary land use change may not be of as much concern with cellulosic ethanol as for corn ethanol. Improved cultivation of cellulosic feedstocks may allow cultivation of crops for ethanol without requiring much new land.[89] Cellulosic feedstocks can be produced from abandoned or marginal cropland, which would trigger fewer, if any, changes in crop exports and overseas land use patterns. It may also become possible to increase production of cellulosic material as a byproduct of food production or through greater use of cover crops when land is not in use for food production. If this becomes possible, then life-cycle emissions of cellulosic ethanol could be much lower than gasoline.

Competition with Food Production

In the long term, higher prices for corn will encourage farmers to begin cultivating more acres of land, potentially bringing down food prices but also increasing emissions of global warming pollutants from land use. Using marginal or abandoned cropland means that cellulosic feedstock production will have less impact on global food markets, which can trigger land use changes in other countries and increase emissions from biofuels.

Oil Replacement

Corn ethanol can help reduce our dependence on imported oil and vulnerability to its price variations. Ethanol can be consumed at low concentrations (typically 10 percent or less by volume) in conventional gasoline-powered vehicles. If the auto manufacturer has made a few small changes to a vehicle's engine, it can consume ethanol at concentrations up to 85 percent by volume (e.g., flex-fuel vehicles). As with gasoline, a more fuel-efficient car will require less energy and produce less pollution when traveling a given distance.

Using corn ethanol can reduce America's dependence on petroleum. Some studies suggest that reductions in petroleum consumption from each energy-equivalent unit of ethanol can be as high as 95 percent.[90] Significant amounts of fossil fuels such as coal and natural gas are used to produce ethanol. As a result, ethanol reduces fossil fuel consumption by only a modest amount. Current methods of producing corn ethanol reduce total fossil energy by 5 to 26 percent versus gasoline, according to one estimate.[91] This conclusion is disputed by some researchers.[92]

Cost

Because a gallon of ethanol contains less energy than a gallon of gasoline, the price of the two fuels must be compared on an energy-equivalent basis. In January 2009, when a gallon of gasoline cost $1.86, an equivalent amount of energy in the form of E85 cost $2.56.[93]

Ethanol receives multiple subsidies but such subsidies likely are not necessary to ensure profitability of ethanol production. Currently, fuel blenders receive a federal subsidy of $0.51 per gallon of ethanol they blend with gasoline, which encourages ethanol production.[94] Total federal and state subsidies for ethanol reach $5.1 billion to $6.8 billion per year, but observers believe that ethanol production in 2006 and 2007 would have been profitable for producers even without subsidies.[95]

To increase the use of ethanol, gas stations may need to construct more tanks dedicated to E85 at an estimated cost of $100,000 to $150,000 each. Converting an existing gas tank to dispense E85 costs \$10,000.[96] In addition, automakers would need to increase their production of "flex-fuel" vehicles capable of running on both E85 and gasoline. The incremental cost of a flex-fuel vehicle is low: manufacturers often sell flex-fuel vehicles at no additional cost over a gasoline-only version.[97]

Biodiesel

Though both ethanol and biodiesel are produced from crops and natural products, the process to create each is different. Biodiesel often is derived from oil crops such as soybeans and canola, but also can be made from used vegetable oil and animal fats. The fat is mixed with an alcohol, triggering a chemical reaction that produces biodiesel. In addition, diesel substitutes can be produced from non-fatty biomass using the Fischer-Tropsch process, in which the biomass is converted to a gas and then to a liquid.

Global Warming Impact

Biodiesel may provide significant global warming pollution savings compared to conventional diesel, but these benefits are strongly dependent on how the biodiesel is produced. With respect to cultivation, transportation, and refining, soybean biodiesel is similarly situated to corn ethanol. Life-cycle emissions from soybean biodiesel are likely 52 to 158 percent higher than petroleum diesel.[98] Even accounting for the fact that biodiesel is less energy dense, biodiesel from waste cooking oil releases 98 percent less global warming pollution, but limited supplies of waste oil mean that not much waste oil-based biodiesel can be produced.[99] In the long run, should cellulosic ethanol technology move forward, wastes from that process could be used to produce larger quantities of diesel substitute.

Air Pollution

Biodiesel, more clearly than ethanol, reduces most types of air pollution. Biodiesel refining results in lower emissions of some pollutants compared to diesel. Use of biodiesel—from low-level blends to pure biodiesel—results in lower vehicle emissions of VOCs, carbon monoxide, particulate matter (PM_{10}) and sulfur dioxide.[100]

The impact of biodiesel on emissions of nitrogen oxide is less certain. A recent National Renewable Energy Laboratory (NREL) study found no increase in NOx emissions from 20 percent biodiesel fuel blend, contradicting earlier studies from EPA.[101] However, the EPA study involved older vehicles with less effective emission control systems and thus the NREL study may be more representative of current and future biodiesel emissions.[102]

Water Pollution

Crops grown for biodiesel have many of the water pollution problems of crops grown for ethanol. In addition, because biodiesel crops yield less energy per acre farmed, producing a gallon of biodiesel requires more cultivation and thus potentially more water pollution.

Deforestation and Land Use Impacts

Because canola and soybeans produce less energy per acre farmed, a dramatic increase in demand for oil crop-based biodiesel would require a very large increase in the acreage dedicated to fuel production. For example, even if the entire soybean crop in the U.S. were converted to biodiesel, it would replace only 6 percent of petroleum diesel used in the U.S.[103]

Thus, significantly increasing biodiesel production will conflict with other land uses, such as farming for food or maintaining forestland. Already, European demand for biodiesel has spurred the destruction of sensitive ecosystems in other parts of the world to make room for planting oil palm plantations for fuel. And as discussed above, these changes provoke huge increases in global warming pollution from biodiesel.

Competition with Food Production

Oil crops like soybeans produce far less energy per acre than cellulosic sources or corn.[104] Thus, dramatic expansion of biodiesel production could cause greater competition with food production than growing crops for ethanol does.

Oil Replacement

Biodiesel's potential to replace large amounts of current petroleum consumption is limited.[105] Canola and soybeans, the two primary crops that can be processed for biodiesel, do not yield as much energy per acre as corn or cellulosic material does for ethanol.[106] The low energy yield of biodiesel crops means that there simply is not enough land on which to grow crops to replace much petroleum diesel. Only a small amount of biodiesel can be made from waste cooking oil because feedstock supplies are so limited.

Cost

Biodiesel is slightly more expensive than petroleum diesel. In January 2009, when a gallon of diesel cost $2.19, an energy-equivalent amount of B20 biodiesel cost $2.43. Pure biodiesel cost $3.42.[107]

Electricity

Though electricity may not be the first vehicle fuel that comes to mind, it can be a low-carbon source of energy for transportation. Hybrid-electric vehicles, such as the Toyota Prius, are powered by both gasoline and electricity. The vehicle's battery is charged by the gasoline engine and through the capture of energy lost during deceleration. Plug-in hybrid vehicles have a larger battery that can be charged using power from the electricity grid, as well as by a regular gasoline engine as a backup. Extended range electric vehicles, like the much-anticipated Chevy Volt, use a lithium-ion battery with a gasoline-powered range-extending engine that drives a generator to provide electric power when the vehicle is driven beyond the 40-mile battery range. Full battery-electric vehicles operate solely on electricity.

Global Warming Impacts

Numerous studies have concluded that electric-powered vehicles produce lower global warming emissions than conventional gasoline-powered cars and trucks. For example, a plug-in hybrid electric vehicle with a 20-mile all-electric range is 62 percent less polluting than a gasoline vehicle, assuming that the vehicle is recharged from California's relatively low-carbon electric grid.[108]

Life-cycle analysis of the global warming emissions of electric vehicles typically includes an evaluation of how electricity is generated and the efficiency with which it is used in vehicles, but excludes mining and transportation of the fuel before it reaches the power plant. Adding these steps to life-cycle analysis of electricity would help ensure that electricity is evaluated on equal terms with other fuels.

Power Generation

Emissions from plug-in and full electric vehicles are heavily influenced by what fuel is used to generate electricity and how efficiently that electricity is generated.

Electricity in the U.S. is most frequently generated at coal-fired power plants, which have very high global warming emissions.

Coal-fired power plants release more than 2,000 pounds of carbon dioxide for every megawatt-hour of electricity generated. In contrast, the average natural gas power plant releases 1,100 pounds of carbon dioxide.[109] Electricity generated from wind or solar power releases no global warming emissions.

Charging electric vehicles with power from zero-emission renewable energy sources would result in vehicles with extremely low emissions. Unfortunately, the electricity grid does not allow picking and choosing between power sources on a day-to-day basis. To reduce emissions from electricity, the overall mix of generating facilities must be changed to retire dirty coal-fired power plants and replace them with cleaner natural gas or renewable generating capacity.

Developing renewable energy sources such as wind and solar power and reducing coal-fired generating capacity will make vehicles that rely on electricity even cleaner. Ultimately, as the amount of renewable generating capacity on the electric grid increases, a rising portion of the vehicle fuel will come from renewable energy.

Transportation to Market

As electricity is sent through power lines, thermal losses and other inefficiencies mean that a portion of the power never reaches consumers. To provide a kilowatt-hour of electricity to a customer requires generating more than a kilowatt-hour at the power plant. This inefficiency raises emissions from coal or natural gas-fired power plants.

Power that is generated close to consumers will incur almost no transmission loss and will therefore have lower emissions. And electricity generated from solar panels installed on the roof of a home will have no emissions and no transmission losses.

End Use

A major contributor to the reduced global warming emissions of electric vehicles is the inherent efficiency of an electric motor compared to an internal combustion engine. An electric drivetrain is five times more efficient than a gasoline internal-combustion engine.[110] This efficiency enables an electric-powered vehicle—even one using electricity generated in a coal-fired power plant—to have relatively low global warming emissions.

Drivers of electric vehicles who live in free-standing homes should be able to recharge vehicles at home. To facilitate re-charging at large apartment complexes or at workplaces, additional infrastructure may need to be built.

The time of day at which a plug-in hybrid or battery-electric vehicle is recharged will influence emissions (and cost, discussed later). During the day, power companies operate all their power plants to meet high demand; at night, the most expensive plants—typically natural gas plants—are turned off and just baseload facilities—currently coal or nuclear power plants—operate. This can result in higher night-time emissions. However, in coming years, as more wind generation capacity is installed, wind energy may provide a greater percentage of electricity generated at night. Additionally, because wind turbines can generate more power at night than during the day, charging vehicles with wind power overnight may become a convenient way of storing clean energy to feed back into the electric grid during the day.

In summary, even an electric vehicle that draws power from the national electricity grid, which includes many carbon-intensive energy sources, produces less global warming pollution than a gasoline vehicle. Research by the Argonne National Laboratory concludes that plug-in hybrids are 36 percent less polluting.[111] According to this same study, a plug-in hybrid recharged from California's grid would be 44 percent cleaner than gasoline.

Air Pollution

Should the widespread use of electric vehicles result in increased consumption of coal or natural gas, an increase in air pollution could result (although federal and state air quality regulations limit emissions of some pollutants from power plants). Coal-fired power plants release mercury, nitrogen oxides and sulfur dioxide. Mercury is a neurotoxin that delays development in children. Nitrogen oxides contribute to smog, which can lead to asthma, bronchitis, emphysema and other respiratory and cardiovascular problems. Sulfur dioxide is a component of fine particulate matter pollution, which can cause asthma, cancer and premature death. Modern coal-fired power plants control much of this pollution, but older plants have less effective pollution controls. Natural gas power plants are cleaner than coal-fired plants, but have higher emissions than renewable sources of energy.

Water Pollution

Waste material from a type of coal mining known as mountain-top removal is typically piled in valleys, blocking streams and leaching into water supplies. Other forms of coal mining also produce rock and dirt that is heaped in piles. When these piles are exposed to rain, they release toxins into streams and groundwater.

Drilling for natural gas creates sediment and toxic pollution, as well as large quantities of saline water that can degrade the quality of waterways or groundwater resources if improperly managed.[112] Other forms of electricity generation—including nuclear power and large hydroelectric dams—can also pollute or otherwise degrade water resources.

Fossil fuel power plants (and some central solar facilities) typically use water for cooling. If that water is released back into the river or lake from which it was taken, the higher temperature can cause fish kills and alter the ecosystem of the water body. If water is not released and is evaporated instead, it is no longer available to other users.

Land Use Impacts

Coal mining destroys habitat and pollutes land so that future uses are limited. In mountain-top removal coal mining, for example, entire hillsides are scraped away to expose the coal beneath. Material with concentrations of coal too low to be burned is discarded in giant waste heaps. Even when a mountain-top mining site is "reclaimed," the land remains tainted and the soil is inadequate to support the same forest as existed before mining.

Natural gas drilling offshore disturbs marine wildlife. Onshore, drilling infrastructure and pipelines create industrial sites within otherwise natural areas and fragment habitat. Pipelines for transporting natural gas extend hundreds or thousands of miles, cutting through ecosystems and fragmenting habitats.

Oil Replacement

Electricity can reduce oil consumption. Hybrid-electric vehicles do require gasoline but not as much as vehicles powered by a standard internal combustion engine. The Toyota Prius, for example, is EPA-rated to travel 46 miles per gallon of gasoline, compared to 27.5 miles per gallon for the average car. Plug-in hybrids require even less gasoline.

If electric vehicles are recharged at night, the U.S. has sufficient generating capacity to supply energy to many vehicles.

Daytime electricity supplies are more limited and for that reason, night-time recharging could be preferable.

Cost

Michigan retail electricity prices average 8.53 cents per kilowatt-hour, with the nationwide average at 8.9 cents per kilowatt-hour. Charging an electric vehicle or plug-in electric vehicle and operating it in all-electric mode would cost consumers 3 cents per mile, assuming a vehicle efficiency of 3 miles per kilowatt-hour.[113] This is a lower cost per mile than a gasoline or hybrid-electric vehicle (more than 6 cents per mile if gasoline costs $3 per gallon).

It costs less to charge a vehicle at night than during the day because cheaper (but often higher emission) power plants predominate at night. This price difference will matter to individual consumers only if they have a time-of-day pricing plan from their electric utility. However, all consumers will have to pay higher prices for electricity if vehicles are recharged during the day, driving up peak demand and requiring construction of more power plants.

Widespread use of electric vehicles offers new flexibility for the operation of the electricity system. Electric vehicles could be charged at night, when generating capacity is abundant and prices are lower. During the day, when vehicles are parked, the electricity stored in their batteries could be fed back into the power grid, thereby reducing the need for other sources of electricity to meet peak demand. Such an approach could reduce electricity costs by limiting the need to build new plants for times of high demand.

Natural Gas

Vehicles operating on natural gas are in widespread use throughout the U.S. in government and utility company vehicle fleets. Expanding natural gas vehicle use could reduce global warming pollution.

Global Warming Impacts

Compressed natural gas vehicles produce as much as 26 percent less global warming pollution over their life-cycle than gasoline powered-vehicles.[114] Natural gas drilling and processing, transport to consumers, compression, and end use all contribute to emissions.

Natural gas must be drilled and processed before it is fed into a pipeline, an efficient way to move fuel. However, the production process releases global warming pollution.

Also, a typical mile of natural gas pipeline leaks 1,360 pounds of methane, a powerful global warming pollutant, each year.[115]

The only commercially available light-duty vehicle that operates on natural gas is the Honda Civic GX, which is moderately efficient.[116] By one estimate, the Honda Civic GX averages the equivalent of 28 miles per gallon.[117] Natural gas has also come to be a common fuel in transit bus fleets.

Fueling a natural gas-powered vehicle requires compressing the natural gas so that more of it can be carried in the vehicle's tank. Most natural gas compressors in the U.S. are powered by electricity. Electric-powered compressors are marginally more efficient than those powered by natural gas.[118]

Finally, natural gas has lower emissions than gasoline. Analyses of natural gas's pollution using EPA's emission model calculate that it produces 18 to 26 percent less global warming pollution than gasoline.[119] Another, more conservative analysis estimates savings of just 5 percent.[120]

In the short term, natural gas may be a useful fuel for transitioning to lower emission fuels—particularly for vehicle fleets that are refueled centrally, such as transit buses. The California Energy Commission has identified natural gas as one of the fuels the state should use in transitioning to lower-emission transportation fuels, especially in the early years as other fuels are still being developed.[121]

Air Pollution

In terms of toxic and smog-forming pollutants, natural gas is a much cleaner fuel than gasoline. Natural gas vehicles release 56 percent less nitrogen oxide, 41 percent less carbon monoxide, and 84 percent less sulfur dioxide, but 68 percent more particulate matter.[122]

Fueling stations that rely upon electric compressors will not produce any on-site emissions, an important consideration for urban locations, though pollution will be released at the power plant. Natural gas compressors, in contrast, will release nitrogen oxides and other pollutants.

Water Pollution

Natural gas drilling releases sediment, toxics and saline water that can pollute groundwater and nearby waterways.

Land Use Impacts

As discussed with electricity, drilling for natural gas and building pipelines to transport that gas disturb thousands of acres of habitat.

Oil Replacement

Natural gas has limited capacity for replacing oil in the long run. The U.S. has small reserves of natural gas: 2006 levels of production can be sustained for only 11.3 years, given current knowledge of natural gas reserves.[123] Moreover, demand for natural gas in other sectors of the economy is on the rise, especially in the electricity sector, where natural gas is seen as a cleaner alternative to coal.

Internationally, natural gas supplies are greater, but importing natural gas is problematic on several counts. Natural gas has very low energy density that makes transport by tankers inefficient unless the gas is cooled to -256 degrees Fahrenheit, when it becomes a liquid. Once the gas is delivered to its destination, it must be warmed to return it to a gaseous state that can be fed into a pipeline. (This additional transportation and processing required for imported natural gas would raise life-cycle emissions of natural gas-powered vehicles.) Locating liquefied natural gas terminals near crowded coastal cities is potentially dangerous and building them in remote locations destroys delicate coastal ecosystems. All options for importing natural gas are expensive. Furthermore, replacing imports of petroleum with imports of natural gas does nothing to enhance our energy independence.

Cost

Compressed natural gas is significantly cheaper than an energy-equivalent amount of gasoline. Whereas a gallon of gasoline cost $1.86 in January 2009, an energy equivalent amount of compressed natural gas cost $1.63.[124]

However, building new refueling infrastructure to facilitate wider use of natural gas is costly. A residential refueling unit that compresses natural gas from a household natural gas line costs more than $4,000.[125] Residential refueling is relatively slow—adding enough fuel to drive 50 miles takes four hours.[126] New commercial refueling stations will not be cost-competitive with gasoline and diesel stations until natural gas achieves a 20 percent market share.[127]

Hydrogen

Global Warming Impacts

Hydrogen's impact on global warming depends entirely on how the hydrogen fuel is produced. Hydrogen is not a primary energy source—it exists on its own virtually nowhere in nature. Instead, hydrogen must be extracted from other compounds, either water (through a process called electrolysis) or fossil fuels. If hydrogen is generated from electrolysis powered by renewable energy, it can reduce global warming pollution per mile driven by more than 90 percent.[128] If, however, hydrogen is produced directly from fossil fuels such as natural gas, or created through electrolysis using electricity generated from coal, it produces far less reduction in global warming pollution.

Hydrogen can be produced from different sources, including natural gas, biomass, and water. All production methods are energy-intensive. Therefore, the choice of feedstock and how it is processed are important determinants of life-cycle global warming pollution from hydrogen.

The lowest-emission option is to use renewable energy to create hydrogen from water by electrolysis: exposing water to an electric current splits it into its constituent parts—hydrogen and oxygen. Electrolysis requires a large amount of electricity. Electricity generated by wind or solar energy results in hydrogen with essentially no global warming emissions, but electricity from coal or natural gas is much dirtier. In some parts of the country, scarce water supplies may limit the potential for producing hydrogen from water.

The next-lowest emissions are from hydrogen created (or "reformed") from natural gas or biomass. Reformation involves exposing the fuels to high-temperature steam in the presence of a catalyst. The result of the process is hydrogen and carbon dioxide. Gasification involves using a super-heated reactor to turn biomass or other fuels into a gas, which is then exposed to steam and oxygen to create hydrogen, carbon monoxide and carbon dioxide. (This method can also be used to create hydrogen from coal.)

Using natural gas as the power source to create hydrogen, according to a study by the National Academy of Sciences, would cut greenhouse gas emissions by 30 to 50 percent compared to hybrid-electric vehicles running on gasoline.[129] Hydrogen generated using biomass—such as plants, plant wastes or animal wastes—can reduce global warming emissions by 60 to 100 percent.[130] However, were coal to power the hydrogen production process, emissions from a hydrogen-powered vehicle would be equal to or greater than those from a hybrid-electric vehicle.[131]

Hydrogen can be distributed to consumers in two ways. Centralized distribution would operate much like the current gasoline distribution system. Hydrogen would be processed at large-scale facilities and then distributed to filling stations by pipelines and tankers. However, as with ethanol, hydrogen's low energy density means that a tanker truck hauling hydrogen will expend essentially the same amount of energy and produce the same emissions as if it were hauling gasoline.

A decentralized distribution approach means that hydrogen would be produced at filling stations from natural gas or water. Some of the basic infrastructure needed for this—pipelines for natural gas and power lines for electricity—already exists. The drawback is that such small-scale production of hydrogen could be less efficient and more costly.

Hydrogen can be used in vehicles with

fuel cells or internal combustion engines. Fuel cell vehicles use hydrogen to generate electricity, which powers an electric motor, allowing fuel cell vehicles to benefit from the drivetrain efficiency of electric motors. Many estimates of fuel cells assume a high level of efficiency for hydrogen vehicles. The National Academy of Sciences, for example, assumes that hydrogen fuel cell vehicles are as efficient as a conventional vehicle that can travel 65 miles per gallon of gasoline, or more than twice as efficient than the average car.[132] In contrast, hydrogen consumed in an internal combustion engine is only 23 percent more efficient than a gasoline vehicle.[133]

In summary, the global warming impact of hydrogen ranges from almost zero to greater than a conventional gasoline vehicle.

Air and Water Pollution

As with electricity, many of the air and water pollution impacts of hydrogen are contingent upon the fuel used to create hydrogen. Tailpipe emissions of toxic compounds would be minimal and per-mile emissions of nitrogen oxides would drop 47 percent compared to conventional vehicles.[134]

Land Use Impacts

Mining fuel to create electricity for hydrogen production will have the same impacts as discussed in the electricity section above. Hydrogen may also have other land use impacts if new pipelines are constructed to transport hydrogen from centralized production facilities or if new fueling stations are constructed to distribute the fuel.

Oil Replacement

Shifting large numbers of vehicles from gasoline to hydrogen certainly would reduce our dependence on foreign oil. However, greater hydrogen demand could cause natural gas consumption to increase, potentially requiring greater imports of natural gas. Assuming that hydrogen is produced from natural gas using current technologies, a study by the National Academy of Sciences suggests that converting half of the nation's vehicles to operate on hydrogen would increase natural gas consumption by 16 to 22 percent compared to 2002 levels.[135] Domestic reserves of natural gas are limited, so meeting this increased demand could require importing more natural gas.

Cost

Hydrogen is an expensive fuel to create and to use. Creating a generation and distribution system, whether centralized or decentralized, would require development of new infrastructure. A decentralized filling station that could serve 854 cars per week, for example, could cost $1.85 million to build.[136] While a centralized distribution system is more cost effective on a per-vehicle basis, cost-effectiveness relies upon widespread penetration of hydrogen vehicles into the marketplace. Decades will pass before such economies of scale can be achieved.

Consumers will pay an additional $6,000 to $11,000 for a hydrogen fuel cell vehicle compared to a gasoline vehicle in 2020, even if vehicle production reaches 100,000 vehicles annually.[137] On an energy basis, consumers likely will pay more for hydrogen than gasoline in 2020, though the greater efficiency of hydrogen fuel cell vehicles will mitigate this expense. The estimate assumes that 10 percent of fuel use is hydrogen.[138]

To achieve any of these price levels, industrial and governmental financing for research and development will need to continue at approximately $600 million to $1 billion annually.[139]

Coal-to-Liquid Fuel

Coal can be processed to create a liquid that serves as a diesel substitute. While coal-to-liquids has received much attention recently as a technology that can help reduce U.S. imports of oil, it creates so much global warming pollution that it is an unacceptable solution to our energy problems.

Global Warming Impacts

Liquid produced from coal creates more than twice the global warming pollution of gasoline and nearly twice the emissions of diesel on a life-cycle basis.[140] The fuel starts with a high-carbon energy source and requires heavy processing.

Coal-to-liquids production starts with the mining of coal, a heavy industrial process that requires petroleum-powered equipment that releases global warming pollution. Perhaps more importantly, coal mining can release methane, which is frequently trapped in coal beds. Methane is a greenhouse gas 16 times more powerful than carbon dioxide. When coal beds are opened for mining, the methane is released into the atmosphere.

Coal is typically transported by rail because rail lines have been built to serve mines. Coal-to-liquids processing facilities may be constructed near mines to reduce the distance coal must be transported.[141]

Coal-to-liquids fuel is not yet commercially produced in the U.S. but the federal Energy Information Administration (EIA) expects that production could begin within the next few years. At the refinery, coal will first be turned into a gas and then converted into a liquid using the Fisher-Tropsch process.[142] According to an estimate by EIA, just 49 percent of the energy in the original coal will remain in the final, liquid product. Twenty percent of the energy in the coal will be consumed to manufacture the liquid. If the facility has co-generation capacity and can generate electricity, then 30 percent of the energy will be sold into the power grid. However, if the plant is located near a coal mine, it likely will be a great distance from consumers who want to buy electricity.

The refined fuel could be moved to market via rail, truck or perhaps pipeline. Coal-to-liquids refineries built near coal mines will not necessarily be close to markets for fuel, so the product may have to be shipped a substantial distance.

Liquid fuel produced from coal can be consumed in place of gasoline or diesel in a conventional vehicle. As with ethanol and biodiesel, the overall efficiency of the vehicle and the inefficiencies of internal combustion engines will influence tailpipe emissions from end use.

In summary, extensive processing of a high-carbon fuel means that coal-to-liquids fuel has approximately twice the life-cycle global warming pollution of conventional gasoline.[143] Even if a coal-to-liquids facility were able to capture and sequester carbon released during the coal-to-liquids process, the liquid fuel itself still produces life-cycle emissions 4 to 8 percent greater than those of gasoline.[144]

Air Pollution

Coal-to-liquids processing facilities will produce air pollution. Operators of a proposed refinery in Gilberton, Pennsylvania, project that it will release 29 tons per year of sulfur dioxide, 70 tons per year of nitrogen oxides, 23 tons per year of particulate matter, and 54 tons per year of carbon monoxide.[145] Sulfur dioxide contributes to acid rain, nitrogen oxides are a precursor to smog and particulate matter, which can cause lung damage and worsen heart disease, and carbon monoxide can be toxic.

Water Pollution

As discussed regarding the use of electricity as a transportation fuel, coal mining creates significant water pollution. In addition, coal-to-liquids processing facilities consume large quantities of water. Producing one gallon of fuel requires 2.5 to 5 gallons of water for processing, resulting in very large total withdrawals.[146] The proposed coal-to-liquids facility in Gilberton, Pennsylvania, has received a permit to withdraw up to 7 million gallons per day.[147]

Land Use Impacts

Coal-mining irreparably destroys huge swaths of land, as discussed earlier.

Oil Replacement

Liquid fuel made from coal technically could replace all of the imported oil that we consume today. Domestic coal reserves are great enough to produce 800 billion barrels of liquid fuel, equal to 167 years of petroleum consumption at current levels.[148] However, this would require a huge increase in coal mining. To replace just 10 percent of current transportation-related petroleum consumption, coal mining would need to increase by 25 percent from current levels, worsening the water and air pollution impacts of coal mining.[149]

Cost

Coal-to-liquids fuel is technically feasible, but very expensive. Building a coal-to-liquids refinery can cost billions: one proposed facility in Ohio would cost $4 billion to construct.[150] Building enough refining capacity to replace 10 percent of current petroleum use would cost $70 billion, according to a study by researchers at M.I.T.[151] The researchers add a note of caution that historic projections of the costs of building synthetic fuel refineries have been "wildly optimistic," suggesting that the price tag could be far higher.

Compared to refining oil, converting coal into liquid fuel is costly. Even without carbon sequestration, refining coal into liquid costs three to four times as much as refining the same amount of oil.[152]

Because coal-to-liquids fuel is so expensive and private capital markets will not finance construction of such risky plants, a coalition of industry and labor groups has sought subsidies, federal loan guarantees and production tax credits to facilitate coal-to-liquids production, with some success.[153] In 2005, Congress agreed to provide funds for construction of coal-to-liquids plants, but has not yet allocated the funds. However, any production of coal-to-liquids is unlikely if the U.S. commits to reducing its global warming pollution and turns away from the most polluting energy sources.

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