Water and Biofuels; Implications for Michigan

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Producing ethanol, methanol, butanol, diesel, and gasoline from biomass requires water – lots of water. First, to grow the basic crops, and second, to process those crops. Michigan and other Great Lakes states, with abundant water and arable land, are ideally suited to host this alternative fuels industry.

This paper investigates the likely future of biofuels in Michigan and provides information about meeting the water needs of two Michigan biofuel plants. How much water is required, and how much wastewater must be disposed of, and what is its quality?

It is concluded that without a significant breakthrough in technology or increased governmental intervention to distort the economics, biofuels are not likely to represent a significant concern for Michigan's water environment. However, continued attention needs to be paid to this issue as new technologies arise, political realities change, and legislative changes are made.

INTRODUCTION

So what is a biofuel? A biofuel is a fuel (solid, liquid, or gaseous) derived from recently dead plant material, or waste organic material, such as fryer grease, as contrasted with so-called fossil fuels that are derived from long dead plant and animal organic materials.[1]

The principal driving force behind the current interest in biofuels is our dependence on foreign oil and in particular the dependence of our transportation system on liquid fuels. Also, the desire to reduce net carbon emissions plays a role in driving some biofuel development forward.

Many current and proposed methods of making liquid biofuels use significant quantities of water. This paper explores the issue of water use and disposal from biofuel facilities as a particular concern for Michigan. Michigan—having abundant biomass, water and proximity to large energy markets—is ideally situated to host biofuel facilities.

One or two biofuel facilities would not raise an issue. It is the potential for numerous facilities that raises concerns and causes an interest in this topic. Concerns such as:

- Pollution (air and water)
- Aquifer depletion
- Environmental degradation
- Community planning issues – traffic, noise, aesthetics, etc.

The biofuels of interest in this paper are liquid biofuels, since near term energy issues for the United States revolve around liquid fuels – especially the issues of availability and stability of sources. Solid and gaseous fuels are not as significant a short term concern, except as it relates to their carbon emissions.

This paper does not discuss the carbon emissions issue in any detail. If carbon emissions become a major issue, *vis a vis* cap and trade or carbon taxes, then certain biofuels are unlikely to become a major source of energy until the energy can be economically extracted without emitting carbon, or a viable process for offsetting

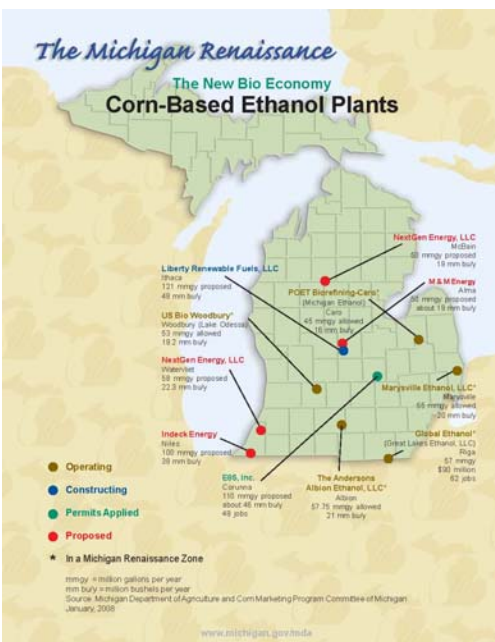
[1] Although, there is some scientific debate that some, or even a significant portion, of the oil found on earth has geochemical origins and is not simply the result of decaying plant and animal matter.

emissions, or sequestration is available. In this situation, nuclear, wind, solar, and geothermal are more likely to prevail. Hydroelectric is less likely because of environmental concerns.

Another limitation of this analysis is that many new technologies are being proposed and researched that may have implications for Michigan. However, at this time, their future is extremely uncertain. As we have seen with other technologies, there are often technical or economic hurdles that cannot be overcome or there are unforeseen consequences that derail a promising concept. Thus, this investigation only looks in detail at technologies that are either commercially viable or for which operating pilot facilities exist.

BIOFUELS IN MICHIGAN

Currently, there are five existing, large scale, biofuel plants in Michigan – all corn ethanol facilities. Only four of these are operational at this time. One more is under construction and another has applied for permits. The following map shows the location of those facilities.



Michigan Corn to Ethanol Plants[2]

The Woodbury, US Biofuel, facility was one for which our firm performed water supply engineering services. This facility, shown in the photo below, is typical of this generation of corn to ethanol facilities, and it required wells supplying 400 gallons per minute (gpm), but is permitted for 137,000 gallons of wastewater per day on average. This facility, when operating at capacity, generated approximately 3,400 barrels of ethanol per day. Actual water usage was approximately 100,000 gallons per day (gpd), most of which was non-contact cooling water that was discharged to a drainage ditch. The waste process water, estimated at approximately 30,000 gallons per day, is internally recycled, creating only a solid waste for ultimate disposal.

Aerial View, Woodbury, MI, Corn to Ethanol Plant

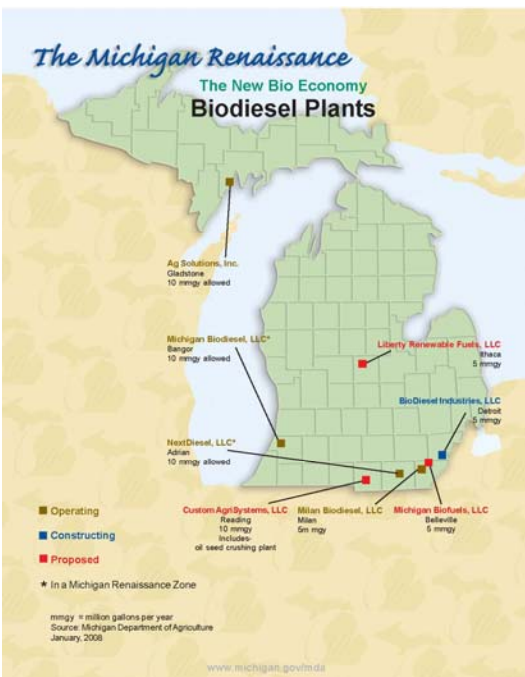
Williams & Works was also involved in the planning stages of the NexGen - Watervliet plant, which was cancelled in 2008. This plant was proposed to produce approximately 50 to 58 million gallons of ethanol per year or 3,300 to 3,800 barrels per day. They requested 600 gallons per minute of water or about 250 gallons of water per gallon of ethanol. Although it was expected that average use would be approximately 5% of this amount. The high water usage was because of once through cooling. The water did not require treatment. The plant was also proposed to produce 3 million gallons of corn oil per year. 16 million bushels of corn were required as feedstock.

In addition to these corn ethanol facilities, one, 2,400 barrel per day, cellulosic ethanol plant has been proposed in Kinross, near Sault Ste. Marie. This is a community that Williams & Works has provided water and wastewater engineering services for, and initial indications are that the cellulosic ethanol plant will require

[2] http://www.michigan.gov/documents /mda/EthanolMap_186353_7.pdf

approximately 2 mgd of water and generate approximately 200,000 gallons per day of wastewater. Most of the water is used for non-contact cooling and could be recycled if necessary. The process wastewater could also be treated on-site and recycled internally. Therefore, approximately 200,000 gallons of water per day will be used to produce just over 100,000 gallons of ethanol per day. It is anticipated that wood waste will be the primary feed stock of the plant and that irrigation will not be used to create the feed stock.

In addition, there are several medium sized biodiesel facilities in the state (shown on the following map) converting vegetable oils and waste products, such as wastewater scum and fryer grease. These are fairly small scale operations and no large scale facilities have been proposed of which we are aware.



Michigan Biodiesel Plants[3]

Algae to fuel facilities have also been proposed, but the technology does not exist to make this alternative commercially viable.

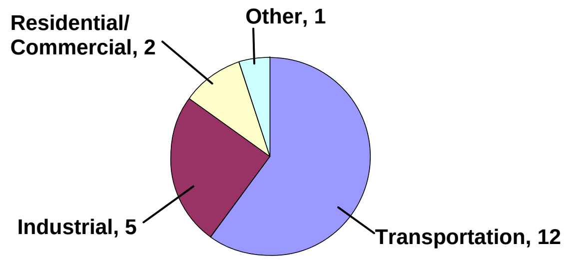
How real is the potential for numerous biofuel facilities, and what are they likely to look like?

[3] Ibid

In order to gauge this, we need to first gain an understanding of the potential demand for biofuels and the economics of biofuels.

THE BIG PICTURE – LIQUID FUELS

The United States consumes over 20 million barrels of oil per day[4] of which approximately 12 million barrels per day is consumed in transportation[5]. The following graphic shows approximately how the liquid fuel we put into our national fuel tank is used every day.



U.S. Crude Oil Usage, Million Bbls/Day

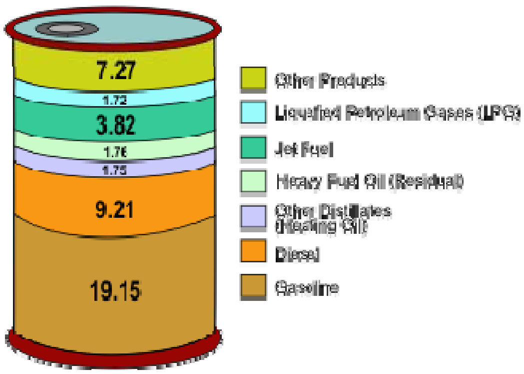
Our transportation system is built on using liquid fuels and conversion to another fuel state (solid or gaseous) is impractical in the near term. Although, T. Boone Pickens and others have argued that partial conversion of a substantial portion of our transportation fleet to compressed natural gas (CNG) is viable (CNG is technically not a liquid fuel, since it is not compressed to the extent that it is a liquid when it becomes known as LNG, or liquefied natural gas).[6] Therefore, alternative sources of liquid fuels have gotten increasing attention.

Of the energy used for transportation in the United States, approximately 65% is consumed by gasoline-powered vehicles. Diesel-powered transport (trains, merchant ships, heavy trucks, etc.) consumes about 20%, and air transport consumes most of the remaining 15%.[7]

It is important to note that a barrel of oil provides more than just gasoline and diesel. A barrel of oil, 42 gallons, actually yields more than 42 gallons of product, about 48 gallons, because of

[4] CIA, The World Factbook, United States, 2008
[5] http://www.eia.doe.gov/basics/quickoil.html
[6] http://www.pickensplan.com/theplan
[7] US Dept. of Energy, "Annual Energy Outlook" (February 2006), Table A2

other products added at the refinery, known as processing gain. The following graphic illustrates the typical products refined from a barrel of crude oil.



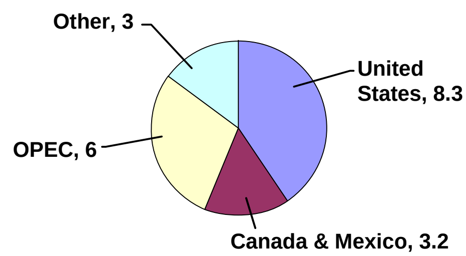
Products from a Barrel of Crude Oil, Gallons[8]

Transportation uses 29% of all energy consumed in the United States[9] and accounts for approximately 60% of all liquid fuel usage. Coincidentally, the amount of liquid fuel consumed by transportation is almost equal to the amount of liquid fuel imported.

As previously stated, the United States consumes approximately 20 million barrels of oil per day, but the United States produces only about 8 million barrels per day.[10] Our dependence on foreign sources of liquid fuels is a strategic weakness. And a great deal has been made of the assertion that this foreign oil is coming from countries that are less than friendly to the U.S. This is not exactly so and in order to understand our situation it is important to break our imports down.

Of the over 12 million barrels per day imported, about one quarter (over 3.2 million barrels per day) comes from Canada and Mexico. The other countries that we import from, for reasons of being unstable or unfriendly, are questionable as reliable suppliers (about 6 million barrels per day of this total is from OPEC). Each country exporting oil to the United States has a local economy dependent on this export. Therefore, while we may have political differences, we are interdependent in an economic sense, making the use of oil as a weapon difficult. The following graphic shows approximately where the liquid

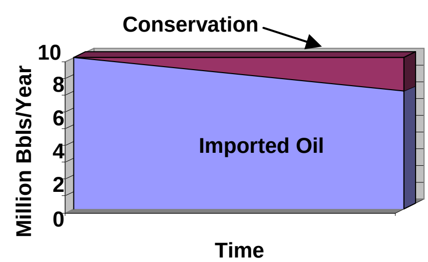
fuel used in the U.S. comes from to fill our 20 million barrel national fuel tank every day.[11]



U.S. Crude Oil Sources, Million Bbls/Day

Naturally, it would be desirable for the United States to be able to replace, or reduce the influence of, the unstable, non-free-market (cartel) or unfriendly suppliers. This will require something approaching 9 million barrels per day.

As environmentalists and conservationists have said, efficient use is often the least costly and most readily implemented means of reducing energy usage. However, this is not likely to reduce consumption more than 1 to 2 million barrels per day, without incurring exorbitant costs or drastically altering our standard of living. The shortfall is then still 7 to 8 million barrels per day, as you can see from the following graphic.



Effect of Aggressive Conservation on Imported Oil

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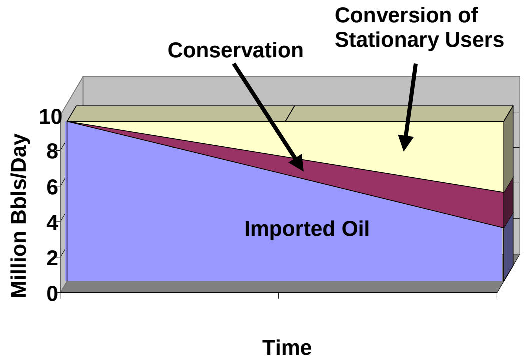
[8] http://www.eia.doe.gov/kids/energyfacts/sources/non-renewable/oil.html
[9] Weiss, Max, From FOG to Fuel, PM Engineer, October 2008.
[10] CIA, The World Factbook, United States, 2008;
[11] Energy Information Administration, Petroleum Navigator, U.S. Imports by Country of Origin

Also, it is interesting to note that diesel engines are the most efficient internal combustion engines followed by gasoline and then natural gas.[12] A barrel of oil can produce only about 9 gallons of diesel and 20 gallons of gasoline. Demand for these two main liquid fuels for mobile sources must be kept in balance or the relative price will change dramatically as we have seen in the last year or so. Just a few years ago, diesel was less expensive than gasoline. However, because of increased demand (more than 50% of new cars sold in Europe are now diesel[13]), the price of diesel has often exceeded that for gasoline. So switching to diesel for increased efficiency may not be an economical alternative without an alternative source of diesel.

Stationary sources consume approximately 6 million barrels per day of liquid fuels (mainly for space heating and for power generation). It is estimated that 4 million barrels per day of this demand could be fairly easily converted to other fuels given time and money.[14] Assuming this was done, the shortfall would be reduced to 3 to 5 million barrels per day as shown on the following graphic.



Effect of Aggressive Conservation and Conversion of Stationary Sources on Imported Oil

Also note that combined conservation and conversion of stationary sources would offset OPEC, but not the other countries from who we import that are of concern.

Thus, if conservation is aggressively pursued along with conversion of stationary sources that use liquid fuels to natural gas or coal, we would need to find alternative sources of about 3 to 5 million barrels per day of oil equivalents to be independent. Although, complete independence is arguably not necessary, or even necessarily a desirable objective, from the point of view of maintaining some economic/political interdependence between the United States and the petroleum exporting countries. Therefore, a reasonable goal seems to be increasing our domestic production (domestic oil or alternative fuels) by something like 2 to 4 million barrels per day or finding other ways to decrease consumption. However, energy usage is likely to grow as current U.S. sources of oil decline in output, while further exploration is opposed, and energy demands increase.

Our current heavy dependence on foreign sources of oil is the driving force behind developing alternative liquid fuel sources. And, therefore, the increased interest in biofuels.

BIOFUELS

Biofuels is a term generally applied to fuels derived from biomass that is grown, harvested, and replaced on a regular basis. Biofuels may take the form of liquid, gas, or solid fuels. Although, this term is primarily used for liquid

[12] As a side note, the primary reason that diesel engines are more efficient is that compression ignition results in more even combustion of the fuel than spark ignition. This has prompted researchers to look at methods of using compression ignition with gasoline and alternative fuels as a means of increasing efficiency.
[13] EU ECONOMIC REPORT, ACEA (European Automobile Manufacturers Association), February 2008
[14] Weiss, Max, From FOG to Fuel, PM Engineer, October 2008.

fuels. Ethanol, methanol, butanol and biodiesel alternative fuels from crops require water – lots of water. First, to grow the basic crops, and, second, to process those crops. Michigan and the other Great Lakes states, because of our abundant potential to create biomass and availability of water, are ideally suited to host this alternative fuels industry.

Liquid Biofuels

Currently available, commercial scale, technology uses food crop biomass to produce ethanol. The 2007 Energy Independence and Security Act established a national goal of increasing biofuel production to 36 billion barrels per year by 2022 of which 21 billion gallons per year of this is to be non-cornstarch based biofuel and 16 billion gallons per year of this 21 billion gallons is to be cellulose based biofuel.[15]

Production subsidies are being used to encourage the production of ethanol, with a $0.45 per gallon direct subsidy for food crop based ethanol and $1.01 per gallon for cellulosic ethanol.[16] In addition, agricultural subsidies are provided for crops that can be used in ethanol production. Because of ethanol's lower energy content than gasoline (76,000 btu/gallon versus 115,000) or diesel (128,400 btu/gallon)[17], the direct subsidy is closer to $0.50 per gallon on an equivalent energy basis for food crop based ethanol and $1.20 for cellulosic ethanol. This is important to understanding that the viability of ethanol biofuel is based on subsidies that can be eliminated at any moment.

An additional background issue to consider when thinking about ethanol biofuels is that the February 2008 issue of Science magazine has an article estimating that conversion to biofuels could double greenhouse gas emissions in 30 years.[18] This is a potential problem for ethanol, butanol, and biodiesel, since the 2007 energy act requires a net reduction in greenhouse gas emissions from those generated by gasoline to qualify as a renewable fuel. Initial studies indicate that many of the current pathways for producing these fuels would not qualify. For this reason and other environmental impacts, such as water use, environmental objections to crop based biofuels have been growing, as have concerns about the diversion of food crops to energy production. It has been argued that this diversion, at least in the short term, has resulted in higher food costs that have put many citizens of developing countries at risk of malnutrition. The counter argument has been that reduced pressure on oil supplies by ethanol production has resulted, or will result, in offsetting declines in energy prices.

Food Crop to Bioethanol

Currently, commercial technology only exists to convert simple carbohydrates and polysaccharides (mainly sugar and starch) to ethanol; and corn is the primary source of those carbohydrates in the Great Lakes region. Other food crops are also convertible, such as sorghum and sugar beets.

The ethanol created in this way is sometimes called bioethanol. It is not cost effective, when compared to fossil fuel, and many would argue not a net energy producer, at this time. But for political and strategic reasons, it has been subsidized to encourage commercial scale plant construction.

There are five plants in Michigan at this time (four are operational), producing about 0.7 million gallons per day of ethanol, or the energy equivalent of about 11,000 barrels of oil per day.[19] These plants consume about 95 million bushels of corn, which requires approximately 1,000 square miles of farmland. Growing, transporting, and converting the corn to ethanol requires about 10,000 gallons per day or more of fossil fuel or fossil fuel equivalents. Based on these assumptions, the net production is about 1

[15] Knowledge @ Wharton, An Earful on Ethanol: Rising Food Prices, Inefficient Production and Other Problems, May 28, 2008.
[16] Ibid.
[17] http://cta.ornl.gov/bedb/biofuels/ethanol/ Fuel_Property_Comparison_for_Ethanol-Gasoline-No2Diesel.xls
[18] Timothy Searchinger, Ralph Heimlich, R. A. Houghton, Fengxia Dong, Amani Elobeid, Jacinto Fabiosa, Simla Tokgoz, Dermot Hayes, Tun-Hsiang Yu; Use of U.S. Croplands for Biofuels Increases Greenhouse Gases Through Emissions from Land-Use Change, Science, February 2008
[19] http://www.michigan.gov/documents /mda/EthanolMap_186353_7.pdf

barrel of oil equivalent per day per square mile of farmland, or about 1,000 barrels per day. Some have calculated that there is a net energy loss.[20]

From the above analysis, it can be seen that without a breakthrough in efficiency (currently it is estimated that the process is somewhere between a net energy loser of 29%[21] to a net energy producer of 33%[22]), a dramatic change in oil availability or price, or even larger subsidies, this technology is not likely to be implemented on a larger scale.

Also, because of the enormous land area that would have to be dedicated to growing corn to produce meaningful amounts of corn ethanol, this technology is not likely, in and of itself, to generate significant amounts of biofuel. An acre of land planted in corn can yield about 375 gallons of ethanol per year. This is equivalent to approximately 250 gallons of gasoline per acre per year, since the energy content of ethanol is about two thirds that of gasoline. Assuming a net energy production of 10%, then an acre of corn can yield approximately as much energy as a half barrel of oil per year. If it is accepted that the amount of foreign oil that must be displaced is 3 to 5 million barrels per day or about 1,000 to 1,500 million barrels per year, achieving 5% of this amount would require over 100 million acres of land in corn. The total arable land in the United States is 400 million acres[23]. About 90 million acres are in corn today. It is clearly impossible for corn ethanol to make up more than a small fraction of our liquid energy needs.

Also, it is worth noting that by converting land to growing corn for fuel the price of food will be driven up, along with fertilizer and agricultural chemicals, further increasing the cost of this alternative fuel.

As to water needed in the starch/sugar to ethanol process, corn production requires 0 to 5,905 gallons of water per bushel.[24] Outside of those areas of the U.S. that require little or no irrigation to grow corn, which includes much of Michigan, a normal average is approximately 3,600 gallons per bushel. And an acre of land can yield from 100 to 200 bushels per acre. Conversion rates of corn to alcohol are approximately 2.5 gallons per bushel. Thus, a gallon of alcohol requires about 1,700 gallons of water to grow the corn. In Michigan most of this water is provided by precipitation and irrigation is relatively rare. A corn to ethanol plant requires approximately 12 to 13 gallons of water per gallon of ethanol produced (if a once through cooling system is used) and creates a waste stream of approximately 12 gallons of cooling water per gallon of ethanol. It also creates a small stream of high strength wastewater with a waste strength of 20,000 to 40,000 mg/l of BOD_5. The cooling water requirement can be reduced significantly through reuse, and typically is, to less than 2 gallons per gallon of ethanol, as can the process water. A typical corn to ethanol plant produces about 50 to 100 million gallons of ethanol per year or 137,000 to 274,000 gallons per day. Thus, the typical water requirement is about 100 to 200 gallons per minute and may be as high as 400 to 800 gallons per minute. From these numbers, it can be seen that corn based ethanol production presents significant questions about water supply and disposal, but not generally in Michigan where water is abundant.

Based on the above analysis, the proliferation of large scale corn to ethanol facilities in Michigan seems highly unlikely for the following reasons:

1. Little, or no, net fossil fuel energy reduction
2. Large amounts of land required
3. Higher food prices
4. Increased greenhouse gas emissions
5. Poor economics

[20] Pimentel, David and Tad W. Patzek, Ethanol Production Using Corn, Switchgrass, and Wood; Biodiesel Production Using Soybean and Sunflower, Natural Resources Research, Vol. 14, No. 1, March 2005.
[21] Ibid
[22] Brinkman, Norman, Michael Wang, Trudy Weber, and Thomas Darlington, Well-to-Wheels Analysis of Advanced Fuel /Vehicle Systems – A North American Study of Energy Use, Greenhouse Gas Emissions and Criteria Pollutant Emissions, Argonne National Laboratory/General Motors Corporation, May 2005.
[23] CIA, The World Factbook, United States, 2008.
[24] Committee on Water Implications of Biofuels Production in the United States, National Research Council, Water Implications of Biofuels Production in the United States, National Academies Press, 2008

The amount of water required for each facility is relatively modest. Therefore, water issues related to corn to ethanol, except on a limited, localized basis, are not likely to be a major issue in the future in Michigan. However, where those plants are sited water usage can be a local consideration.

Plant Cellulose to Bioethanol (Biological)

A second biological avenue for ethanol production is from non-food, plant cellulose (There is also a thermochemical avenue described in the next section.). The chemistry of this process has been well known for a long time, but a cost effective and rapid method of breaking down the cellulose to sugars and polysaccharides that microorganisms can ferment to alcohol has not been demonstrated on a commercial scale. It is also important to note that in addition to the previously mentioned $0.45 per gallon ethanol subsidy, there is an additional $0.56 per gallon subsidy for cellulosic ethanol, bringing the total to $1.01 per gallon. On an energy equivalent basis this is approximately $1.20 per gallon of gasoline equivalent for subsidies alone.

Pilot and pilot/production facilities are being constructed to work out the bugs – literally – of this process. The largest in Michigan is the Mascoma Corporation plant proposed in Kinross, which will couple the process expertise of Mascoma with the scientific expertise at Michigan Tech and Michigan State and the woodlot management expertise of Longyear, LLC. It is expected to produce 40 million gallons per year of ethanol.[25]

The National Renewable Energy Laboratory has estimated that cellulosic ethanol using a biological process will require 6 gallons of water per gallon of ethanol produced.[26] Thus, a plant the size of the Kinross plant will require approximately 750,000 gallons per day. Internal recycling is possible to reduce this quantity significantly.

[25] Mascoma Corp., Mascoma Corporation Announces $49.5 Million in DOE and State of Michigan Funding for Cellulosic Fuel Facility, Press Release, October 7, 2008.

[26] Aden, Andy; Water Usage for Current and Future Ethanol Production, Southwest Hydrology, September 2007

There is no known microorganism or enzyme in nature that will rapidly <u>and</u> cost effectively produce sugars from cellulose and then convert those sugars to ethanol. Mascoma and others propose to overcome this problem through bioengineering or improved chemical processes. Assuming this problem is overcome, cellulose, which is much more abundant than simple carbohydrates or polysaccharides and is often a waste product, can be used to create ethanol. Between the Department of Energy (DOE) and the State of Michigan, nearly $50 million is committed to this project[27], which, if it is successful, will put Michigan at the forefront of implementing this important technology. Mascoma is putting funding together for the approximately $200 million private investment required, and once that is in place, a date for groundbreaking is expected.

This alternative has significant promise, because much more energy can be potentially produced per acre, some estimates are in the 500 to 800 gallon per acre per year range[28], or two to four times that generated by corn. And the crop used does not need to be a food crop. However, without a commercially viable process and unknown net energy production statistics (current net energy estimates are negative to the extent of 50% to 57%[29]), this is only a hypothetical means of producing liquid fuel in commercial quantities.

A further impediment to implementing this technology is a restriction in the renewable fuel standards in the 2007 energy law that excludes wood from national forests (29% of all U.S. forests) and limits private land wood sources to only those from actively managed tree plantations. Ethanol developed from non-qualifying sources would not be eligible for the $1.01 per gallon subsidy.

[27] Ibid.

[28] Pate, Ron and Mike Hightower, Sandia National Laboratories, Overview of Biofuels from the Energy-Water Nexus Perspective and the Promise and Challenge of Algae as Biofuel Feedstock, Spring 2008

[29] Pimentel, David and Tad W. Patzek, Ethanol Production Using Corn, Switchgrass, and Wood; Biodiesel Production Using Soybean and Sunflower, Natural Resources Research, Vol. 14, No. 1, March 2005.

It is possible that a significant portion of the biomass required for this process can be supplied by low value by-products of food production, such as wheat straw and corn silage, as well as specifically grown crops, such as switchgrass or trees/woody biomass. These sources could avoid the limitations on forest usage imposed by the 2007 energy law.

Because of the uncertainties of technology and economics and the limited amount of readily available feedstock, it appears unlikely that many of these facilities will be built. And while they require more water than food-crop based ethanol plants, the amount is not a statewide concern, but may be a local concern.

Biomass to Gas to Liquid Fuel (Thermochemical)

Gasification of solid fuels through either partial pyrolysis, pyrolysis, or methanogenesis has been accomplished for many years. In pyrolysis or partial pyrolysis, which is essentially combustion in the absence of oxygen or reduced oxygen, with steam reformation, the product is syngas, a combination of mainly hydrogen and carbon monoxide. In methanogenesis anaerobic bacteria convert organic material to methane, carbon dioxide, and water vapor. The energy created in these processes is more costly than natural gas, unless the by-products can be sold.

Both of these processes can produce net energy but are relatively expensive to construct and operate. The syngas created in the pyrolysis process can be converted to biofuel through the Fischer-Tropsch process used by Germany in World War II and currently used by Sasol in South Africa. The Fischer-Tropsch process is a catalyzed heating process that results in the carbon monoxide and hydrogen in the syngas recombining as an alcohol, such as ethanol. This results in biofuels that may be substituted for oil. However, the capital costs of a Fischer Tropsch plant are very high, making the cost of this fuel quite high and the large scale implementation unlikely. The water use is expected to be on the order of 2 gallons of water per gallon of ethanol.[30]

[30] Aden, Andy; Water Usage for Current and Future Ethanol Production, Southwest Hydrology, September 2007

Range Fuels and others believe that they have found ways to reduce the process costs and have attracted investors, as well as government support, to build full scale plants. Range Fuels plant is in Georgia and should be in operation in the next year. Once it is online, the economics of these refinements to this process will be known.

Food Crops to Biodiesel

Soybeans and sunflowers, and other vegetable oil producing corps, have been used to produce biodiesel from the extraction of the vegetable oils and transesterification of those oils to biodiesel. The projected yield per acre is in the range of 40 to 80 gallons per acre, with the lower part of the range being soybeans and the higher portion being sunflowers.[31]

This avenue of biofuel production is also suspect in terms of net energy production with estimates ranging from a net energy loss of 8% to 18%.[32]

In Europe where biodiesel from food crops has been practiced longer, the industry has recently developed significant financial trouble and environmental resistance. The primary crop used to produce biodiesel in Europe, rapeseed, has nearly doubled in price, causing the price of biodiesel to rise to $4.80 per gallon in late 2007, and environmentalists there have turned against biodiesel saying that it puts too great a pressure on food prices and land.[33]

In May 2009 USEPA stated that vegetable based biodiesel reduced greenhouse gas emissions by only 22% when compared to petroleum based diesel. In order to qualify as a renewable fuel under the Energy Independence and Security Act of 2007 biodiesel must reduce greenhouse gas emissions by 50% or more. If USEPA's findings stand, biodiesel from vegetable oil may have a limited future.

[31] Ibid.
[32] Pimentel, David and Tad W. Patzek, Ethanol Production Using Corn, Switchgrass, and Wood; Biodiesel Production Using Soybean and Sunflower, Natural Resources Research, Vol. 14, No. 1, March 2005.
[33] Miller, John W., Europe's Biodiesel Drive Sputters, Wall Street Journal, December 27, 2007.

Water usage for this process is modest, approximately 0.5 gallons per gallon of biodiesel. Water is not a major concern for biodiesel facilities.

Algae to Biodiesel

A third potential commercial biofuel source is algae. Algae is an attractive crop, since it can be grown in areas not having arable land, is potentially highly productive in terms of energy potential per acre used (5,000 gallons of biodiesel per acre[34]), and a significant portion of their composition is lipids (fats) with an easily-converted, high-energy content. A further potential benefit is the relative ease in locating the growing facilities near sources of nutrients – CO_2 (think power plant exhaust) and organic wastes (domestic and industrial wastewater). And, interestingly, one company claims to be able to make gasoline from algae, not biodiesel. Algae to fuel plants have not been built on a commercial scale at this time, but several are proposed.

One attractive feature of this source of biodiesel is that it would not be a major consumer of water and could in fact use the nutrients in polluted water producing a cleaner effluent.

This means of biofuel production is only theoretical at this point, however, with several pilot facilities under construction.

In Michigan we are aware of a proposed facility in the City of Holland that would use the CO_2 emissions from the City's coal fired power plant and organic nutrients from the wastewater plant. Fortuitously, these two facilities are adjacent to each other.

Current costs for biodiesel from this source are from $10 to $100 per gallon.[35] Thus, a significant effort is required to reduce this cost through technological improvements and scale up before this alternative can be competitive. At this point in time, it is not likely that Michigan will see a significant number of these facilities for the reason of cost.

Biodiesel from Fats, Oils and Greases (FOG)

Food waste (mainly FOG) is another biofuel resource that is often mentioned. However, the quantity of food waste is too small to make a dent in petroleum importation – something like 0.05 million barrels of oil equivalent per day has been estimated.[36]

The real benefit to food waste conversion is reduced landfill costs and sanitary sewer overflows (SSOs) that result from congealed wastes plugging sewers.

There is an interesting side story to biodiesel from FOG, regarding chicken fat to biodiesel. In 2005, a congressman from Missouri, trying to help a local business that used turkey offal to fire its boilers, got the definition of biodiesel to include animal fat based products and thus qualify for the $1.00 per gallon tax credit. Tyson, the chicken company, realized that the chicken fat that Tyson produced was more valuable for biodiesel than for soap or other uses when the $1.00 per gallon tax credit was applied. Tyson teamed with Conoco to develop a facility to convert chicken fat to biodiesel. This drove the price of fat up, angering the soap industry, and the potential increased competition upset the vegetable biodiesel industry. Together, they lobbied Congress to drop the subsidy for animal fat and were successful in getting this provision into the Wall Street bailout bill. Tyson-Conoco dropped their plans. As the coup de grace, the USEPA ruled last month that animal fat biodiesel resulted in the highest level of carbon reduction of any commercially ready fuel.[37]

This side story illustrates the difficulty in advancing alternative energy sources when they are dependent on political actions.

SOLID OR GASEOUS BIOFUELS

While the primary focus of biomass energy has recently been on the production of liquid fuels, the potential for the use of biomass as a solid

[34] Pate, Ron and Mike Hightower, Sandia National Laboratories, Overview of Biofuels from the Energy-Water Nexus Perspective and the Promise and Challenge of Algae as Biofuel Feedstock, Spring 2008

[35] Ibid.

[36] Weiss, Max; From FOG to Fuel, PM Engineer, October 2008

[37] Carney, Timothy P., The mysterious death of the chicken-fat car, Washington Examiner, May 19, 2009

fuel or for the production of solid or gaseous fuels is significant. Syngas generated using biomass can be used to fuel stationary heating and cooling systems that would offset liquid fuel usage. It is also possible that it could be compressed and used in vehicles much like compressed natural gas.

Biomass Energy

Wood and other biomass can be burned directly, or as a supplement to coal, to create energy. It is estimated that in 1880 60% of the energy of the United States came from wood.[38]

Currently, the energy generated from burning biomass is heat and electrical energy, and using pyrolosis - syngas, and therefore, is not directly useful in addressing the liquid fuel importation problem as biofuel avenues. However, it can be used to offset some liquid fuel usage and natural gas usage that could assist in the liquid fuel importation issue.

Further, the State of Michigan enacted Public Act 295 of 2008 mandating that electrical utilities in the state generate 10% of their energy from renewable sources by 2015. Average electrical usage in the state is approximately 13,000 megawatts. The goal is therefore approximately 1,300 megawatts of renewable source electricity. Current renewable source electrical generation is estimated at about 4% of total, leaving a deficit of approximately 800 megawatts.

Currently, there are six wood fired utility power plants in the State capable of producing approximately 170 megawatts.[39] There are another nearly 200 megawatts produced by forest product industries and other businesses for use in their businesses[40] (since these industries are offsetting grid power, it is arguable that the portion of this energy used to generate electricity could count as renewable).

In the not too distant past Michigan had four large pulp mills that required 5,000 tons of pulp wood per day. The State now has only one. The pulp wood that was being grown for the closed pulp mills could generate approximately 200 megawatts of electricity. It is also estimated that the State could produce 5.8 million dry tons of scrap wood per year[41], which could generate 630 megawatts. The State has 19 million acres of timberland about one third of which is public and approximately one half of the private 12 million acres is not currently in production.[42] In addition urban wood waste is largely currently landfilled and could also be diverted to energy production (counted in the 5.8 million dry tons above).

Twenty to forty megawatts of capacity for each facility is typical. These facilities typically consume 25 tons per day of wood chips per megawatt of capacity, or about 1 ton per megawatt hour. Therefore, no new plants can probably be built without an increase in the fuel supply. Agricultural residues could more than double the amount of biomass and increased silviculture could also increase the amount of wood available. However, both of these sources result in higher costs than mill and forest residue from current forestry activities. Although, it is worth noting that selected harvesting of scrub, deadfall, and dense undergrowth in forest lands can reduce the risk and cost of fire.

It is estimated that the cost of electricity from these facilities is somewhat greater than the cost of coal or nuclear power at approximately $90 to $150 per mWh.[43] If, on the other hand, the biomass is used to supplement a coal fired facility the cost of this source of energy is $3.75 per million BTUs compared to approximately $4 for coal.

Pelletization of wood can be used by homeowners to fire boilers or heat air to displace the use of fuel oil, natural gas, or propane. To the extent that these other fuels can be used in transportation, this use of biomass energy can be a partial solution to our dependence on imported oil. Seventeen pounds of wood pellets equals the

[38] Clean Energy from Wood Residues in Michigan, Michigan Biomass Energy Program, Discussion Paper, June 2006.
[39] Ibid.
[40] Ibid.

[41] Freese, Robert E., Biomass, Biofuels and Bioenergy: Feedstock Opportunities in Michigan, Michigan Technological University, February 2007.
[42] Leatherberry, Earl C. and Gary J. Brand, Michigan's Forest Resources in 2001, USDA, North Central Research Station, Resource Bulletin NC-224
[43] Lazard, Ltd, Levelized Cost of Energy Analysis, Version 2.0, June 2008

energy content of one gallon of oil. To compete with oil at $2 per gallon, the pellets must cost less than $5 per 40 pound bag, or $10 at $4 per gallon oil. Current prices are about $4 per bag. Also, the average Michigan home will require four to five tons for a heating season. The logistics for many homeowners to deal with this many pellets, about forty pounds per day, probably works to prevent this option from being widely used at the residential level. Commercially, however, this option may be more widely implemented. The cost is competitive with oil, when oil is at a high price point.

Syngas/methane from Biomass

Gasification of solid biomass through either partial pyrolysis, pyrolysis, or methanogenesis has been accomplished for many years. In pyrolysis, which is essentially combustion in the absence of oxygen, the product is syngas, a combination of mainly hydrogen and carbon monoxide. In methanogenesis anaerobic bacteria convert organic material to methane, carbon dioxide, and water vapor. The energy created in these processes is more costly than natural gas, unless the by-products can be sold.

OTHER THINGS LEARNED ALONG THE WAY

Michigan Clean, Renewable, and Efficient Energy Act, Public Act 295 of 2008

This act, passed in 2008, requires Michigan electrical and natural gas energy providers to obtain 10% of their energy from renewable sources by 2015, with the rate paying public paying for the additional cost. This is likely to drive some biofuels development, but it will be limited if other renewable resources are less costly. Additionally, the law allows electrical energy producers to substitute clean energy (generally only up to 70%) or energy optimization credits for renewable energy credits. Clean energy is essentially defined as a low net carbon emissions system, but not conventional nuclear, and optimization credits are generated through load reduction, either average or peak.

A Calorie of Electricity does not Equal a Calorie of Coal

While in a physical sense a calorie is a fixed unit of measurement, the source of that calorie and the form that it takes are important in an economic sense. For instance a calorie of electricity is more versatile than a calorie of coal, as is a calorie of petroleum. To account for this disparity in value, it is estimated[44] that a calorie stored in petroleum is worth 1.3 to 2.45 times a calorie stored in coal and the multiplier for electricity is 3 to 4 times. This is due to the fact that a calorie of electricity is more versatile (versatility is a measure of the alternate ways in which the energy source can be used without further processing or inputs) and can be more precisely controlled by the user, reducing waste.

Another important concept is whether the energy is available on demand or is dispatchable to meet demand. Wind and solar electrical energy, without storage systems, is not as valuable as the electrical energy from a dispatchable source. The discount is approximately 30%.

Therefore, from an economic and societal perspective considering only the quantity of net energy derived from a particular source provides an incomplete picture. To compare alternative energy sources more accurately requires consideration of the quality of the energy as well.

Coal and Shale Oil

During World War II in Germany, and in South Africa today, alternative fuels had to be developed and coal and natural gas were extensively converted to liquid fuels. Fortunately, the United States has large supplies of both of these so-called fossil fuels. However, the environmental impacts of converting these to liquid fuels at this scale are, using current practices, not believed to be worthwhile. Tar sands and shale oil face similar obstacles even though they are plentiful. Thus, much attention has been directed to so-called biofuels.

Sasol of South Africa uses coal and natural gas to produce petroleum/diesel synfuel using the syngas/Fischer-Tropsch process. They are producing approximately 0.15 million barrels per day or nearly 5% of the amount estimated

[44] Cleveland, Cutler J., Robert Costanza, Charles A. S. Hall and Robert Kaufmann, "Energy and the U.S. Economy: A Biophysical Perspective", Science, New Series, Vol. 225, No. 465, August 31, 1984.

needed to replace most oil importation from unfriendly or unstable countries. At this time this avenue appears to be the most probable source of additional domestic liquid fuel, beyond increased exploration. Shale oil appears to be the next most probable source with a net energy production of somewhere around 5 to 1.

However, since Michigan does not have significant recoverable coal (small amounts in Saginaw formation) or shale oil resources (Antrim shale), these fuel sources will not have a significant direct impact in our state.

Wind

Wind energy costs approximately $90 to $150 per mWh, but it is intermittent (you may see numbers reported in the vicinity of $45 to $90, but these numbers are after tax subsidies are applied and before other costs, such as transmission and backup power are added). The problem of intermittency is significant, since the power demand does not coincide with output. Current estimates of storage systems (batteries, compressed air, molten metal/graphite) cost over $75 per mWh, increasing the cost to over $165 per kWh. For instance, a recently announced battery storage system is estimated to cost $3 million per megawatt of generating capacity. At an average output of 60% of rated capacity, this increases the battery cost to $5 million per megawatt. If the batteries are capable of lasting 5 years, the cost per megawatt-hour of storage alone is over $150 per megawatt-hour. Another approach is to build natural gas turbine generators, or other readily dispatchable power source, to replace the wind energy when the wind is not blowing.

However, pumped storage or compressed gas provides an opportunity in certain locations in Michigan to store wind energy as potential energy. The Ludington pumped storage is one such facility. Since this facility, and a few other storage systems, already exists the additional costs of storage are largely avoided. In these instances, wind energy may be a viable option.

The cost of coal generated electricity is in the vicinity of $40 per mWh.[45] One critic has said, tongue in cheek, that based on current technology the most economical wind energy system is to build a coal fired power plant and use the electricity to power large fans that would provide a constant wind for the wind turbines. If carbon emissions are a concern then the plant should be nuclear. The storage issue needs to be addressed in a more economical fashion to make wind energy viable on a larger scale. Also, transmission line extensions are usually needed, adding to this cost, because of the distributed nature of wind energy.

Europe has had a head start on implementing wind energy. Great Britain provides an interesting case study in that it is the windiest country in Europe with a well developed electrical grid. The average utilization factor for wind turbines in Great Britain for 2006 was 27.4%.[46] Thus, a 1 megawatt turbine actually produces 0.274 megawatts. Ofgem, which regulates the U.K.'s electrical and gas markets, estimates that the 1.3% of the electrical usage generated by wind power resulted in a nearly 30% increase in the cost of all electrical and natural gas energy to provide subsidies for the wind energy.[47]

This energy source is largely inapplicable to transportation and therefore holds little hope for having a significant impact on oil usage. Except to the extent that stationary uses of liquid fuel can be replaced.

The American Recovery and Reinvestment Bill of 2009 includes $8 billion in loan guarantees for renewable energy and transmission projects, largely expected to go to wind turbine projects. This, combined with the fact that the state has areas suitable for wind energy development as identified by the State's Wind Energy Resource Zone Board in its report in May 2008 and the states own initiatives, wind energy is likely to grow in Michigan.

Photovoltaic Solar Panels

Photovoltaic solar panels are beginning to be installed in large numbers. The energy generated

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[45] http://www.energy.gov.on.ca/english/pdf/electricity/cost%20benefit%20analysis%20dss%20report%20-%20executive%20summary.pdf

[46] Glover, Peter and Michael J. Economides, Wind Power Exposed: The Renewable Energy source is Expensive, Unreliable, and Won't Save Natural Gas, Energy Tribune, November 25, 2008.

[47] Ibid.

is not offsetting liquid fuel usage to any substantial extent, since the source of energy being displaced by this technology is largely coal and natural gas.

Significant improvements have been made to reduce the cost per unit of power produced by this technology. Some of these improvements have come from reducing production costs and some from energy efficiency improvements. Yet, the cost per unit of electricity is still approximately 2 to 3 times the cost of coal or nuclear power. Lazard Ltd. has estimated the cost of photovoltaic power, in areas where there is substantial sunshine, such as the southwestern US, as $244 to $405 per megawatt-hour[48] (this is higher than the $100 to $200 often reported that does not include subsidies). However, there are places in California where residential users are paying up to $360 per mWh for conventionally produced electricity.[49]

This energy source is largely inapplicable to transportation and therefore holds little hope for having a significant impact on oil usage. Except to the extent that stationary uses of liquid fuel can be replaced or the electrical energy can be used to create liquid fuels or even hydrogen.

Concentrating Solar Power

This use of solar power involves the use of mirrors to focus the solar radiation on a vessel in which water is boiled to power a turbine. Michigan because of its high degree of cloud cover is not well suited to this technology. However, large quantities of water are required for evaporative cooling, more than twice that per unit of power output than coal or nuclear power.[50] Ironically, those places with little cloud cover that, from an energy perspective, are best suited to this technology are also places where water is scarce. In those places, air cooling can be used, but the cost of the facility and the land required increases dramatically.

The Energy Policy Act of 2005 establishes the goal of 10,000 megawatts of electricity from this source on federal lands by 2015. To date, this effort has focused on the desert southwest. Even with the increased cost of air cooling, the energy availability in Michigan is too low to make this a viable alternative without a breakthrough in technology.

Waste Heat Recovery - Low-level Waste Heat and Cogeneration

There is a tremendous amount of energy that is not used, mainly heat energy, that is a by product of energy generation. In fact a lot of the water that is used in generating biofuels and generating electricity is used for cooling – ie removing heat from the process and discharging it into the environment.

The potential, in terms of Btu's, of this wasted energy is tremendous. However, technologies exist to economically recover only a small amount of this energy.

Recovery of this energy will not directly offset much liquid fuel usage, since most of the fuel used is either solid or gas. The Oak Ridge National Laboratory has published a report that indicates that doubling the amount of cogeneration currently in place would reduce energy demand by 5.3 quadrillion Btu's or the equivalent of 2.6 million barrels of oil per day.[51] If even a small fraction of this savings came from liquid fueled stationary sources the savings could be significant.

However, for recovery to be viable with current technology, the use of the cogenerated heat has to be adjacent to the electrical generating station and the user of the waste heat has to be an entity that can pay back the cost of the waste heat recovery equipment. These caveats reduce the probability that a large increase in these systems will be seen without some change in technology. Cogeneration has been aggressively pursued in the United States since the late 70's and most of the low hanging fruit has been picked. Yet there are still major opportunities in this area. Williams & Works is currently working with Veolia Energy on a project to recover waste heat from a district steam heating plant that will have an approximately two year payback.

[48] Lazard, Ltd, Levelized Cost of Energy Analysis, Version 2.0, June 2008

[49] Lorenz, Peter, Dickon Pinner, and Thomas Seitz, The economics of solar power, McKinsey Quarterly, June 2008.

[50] Glennon, Robert, Is solar power dead in the water?, Washington Post, June 2009.

[51] New York Times, National Lab Pushes Combined Heat and Power, December 3, 2008.

An area of research on waste heat recovery that has implications for liquid fuel consumption in the transportation sector is capture of engine waste heat. About 30% of the power generated by a spark ignited, internal combustion engine is dissipated as waste heat through the radiator and a similar amount through the exhaust pipe. Recovering half of this waste heat could allow fuel mileage to double. The potential is staggering and has drawn the kind of research interest that would be expected. However, this possibility must remain a long-term hope for a breakthrough in technology.

Coal

In 2007 a Federal court determined that EPA could regulate CO_2 and other greenhouse gases. In a decision in November 2008 the Environmental Appeals Board of EPA remanded a permit issued for a new coal fired power plant in Utah because they did not accept the reasoning for not regulating greenhouse gas emissions from the proposed plant. President Obama has said that he will direct EPA to quickly set standards for greenhouse gases. This is likely to stifle, if not eliminate, the development, in the near term, of coal fired power plants until those regulations are finalized. If the regulations are expensive to meet, this could be the end of new coal fired power plants until an economical means of controlling or offsetting the emissions is found. And depending on how onerous the regulation is, it is likely to have a similar effect on coal and natural gas synfuel plants, since the effect will be simply to move the CO_2 emissions from the plant to the vehicle or stationary user.

Nuclear

Nuclear power is a possible power source that could be expanded. The problems of economics and spent waste, however, must first be dealt with and are probably the core reasons that a new nuclear power plant has not gone into service in the United States for over a decade. Nuclear power is economically competitive with other sources of power – mainly coal and natural gas. However, the cost of insurance and waste disposal have been largely covered by the federal government and adding these costs in make this alternative marginally more expensive. And even if a carbon tax is implemented, making coal and natural gas more expensive, it is not certain that it would be the most economical alternative. Energy independence, however, could overshadow the economic disadvantage of nuclear power and lead to government subsidizing nuclear power to the extent that it is viable in the U.S.[52]

France generates approximately 80% of its electrical power using nuclear power plants and has some of the lowest electrical rates in Europe. How do they deal with the spent waste issue? They have built spent fuel reprocessing facilities to concentrate the radioactive waste and separate out isotopes that are useful for fuel and to the medical and industrial community. This recycling results in very little true waste that has to be disposed of. Why is the United States not doing this and why are we going down the road of attempting to develop a huge underground repository at Yucca Mountain? The answer lies in a decision that was made by the U.S. in 1976 to suspend reprocessing and made permanent in 1977. It was believed that in order to retard nuclear weapons proliferation that reprocessing should be banned. This was because the fuel produced through reprocessing could be used for weapons production. However, this was proven to be faulty logic as nuclear weapons continued to proliferate, and in 1981 the ban was lifted, but funding was not provided for a reprocessing facility. In 1993 the President reinstated the ban on reprocessing/recycling in the United States. Reprocessing, because of its potential to create plutonium for weapons, has been viewed as an activity that should only be conducted at a secure government facility. The US government has not agreed to build and operate such a facility for spent fuel reprocessing for commercial reactors. Most recently, though, a government task force recommended a policy of constructing reprocessing facilities run by the US and entering into treaties with other countries that wanted nuclear power to only reprocess in US owned facilities. This occurred in 2005 and no action was taken.

Having said all this, President Obama has said that he is in favor of expanded nuclear power and his support may result in the implementation, to

[52] As an aside energy independence, while it seems to portend a less violent world, could easily result in the exact opposite. The oil exporting countries would not have to be as concerned about the United States and could use their power over lesser developed countries who would be their primary customers.

some extent, of increased use of nuclear power. The key point being that this alternative is predicated on political support. Politicians destroyed the industry with the stroke of a pen and investors have a long memory in this regard.

Water is important to nuclear power for cooling and for steam. A 1,000 megawatt plant with once through cooling will need about 600 million gallons per day of cooling water and 10 million gallons per day of water for consumption (mainly evaporation). 1,000 megawatts per day is roughly equivalent to 16,000 barrels of oil per day, or 24,000 barrels of ethanol. Michigan, with abundant water and proximity to large energy markets, is potentially an excellent location for nuclear power generation. In fact, DTE has applied for a permit to construct a third reactor at its Monroe area Fermi complex.

Electrical Power Distribution – Smart Grid

Approximately 7% of the approximately 4.1 trillion kWh per year of electrical energy generated in the United States is consumed in transmission and distribution losses, amounting to over 250 billion kWh per year of energy.[53,54] Also, the existing electrical power distribution grid is being stretched to its capacity since the growth in demand for electrical power has far exceeded the investment in the distribution grid, with the result being increased reliability issues, such as outages or brown-outs. These two factors have caused a reevaluation of how we use the power grid. The conclusion has been that we can make better use of the existing grid through the application of controls and instrumentation as well as through some improvements to the grid itself. This combination has come to be known as Smart Grid and the American Recovery and Reinvestment Bill of 2009 promises $11 billion towards the effort of improving the nation's electrical grid.

One of the primary objectives of the Smart Grid is to make our current system of electrical power generation more efficient by getting more of the power to the customer and to incorporate existing distributed generation sources, such as emergency generators at water and wastewater facilities, into the grid. The end result is expected to be a reduction in the need for new power sources. Michigan has many back-up power generating facilities, such as those at many of our water and wastewater facilities that could be integrated into the grid. Both DTE and Consumers have programs in place for this purpose.

Hydrogen

The attraction of this alternative fuel source is its potentially relatively clean emissions. Particularly, if the hydrogen is generated using a low emissions method and used in a fuel cell with the result being mainly water vapor.

The drawbacks are the need to create a whole new hydrogen generation, distribution, and transportation system. Where many biofuels can be used in existing systems, with modest modifications, hydrogen requires a complete retooling of our energy system.

The key to the viability of this option is in how the hydrogen is generated. If oil or fossil fuels are used, it is very inefficient and simply moves the source of pollution from the tailpipe to the hydrogen generation facility. If nuclear, wind, or solar power is used to generate the hydrogen, it can be an extremely clean source of energy. However, the technology to make this economical is not currently available. Therefore, it is not likely that we will see any commercial scale facilities in Michigan in the near future.

CONCLUSIONS

The nexus of water and biofuels is only important if significant biofuels development takes place.

It is easy to see why there is interest in biofuels. The price of oil shot to the sky and much of it came from foreign sources. We were panicked and an unlikely political figure strode onto the national stage and said that he would bring about change. Very quickly a policy of conservation and alternative energy development was developed. However, this story is not about the last few years, but the early 1970's.

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[53] Staff Report: PRICE MANIPULATION IN WESTERN MARKETS DOCKET NO. PA02-2-000. United States Department of Energy Federal Energy Regulatory Commission. 2003-03-26. http://www.ferc.gov/industries/electric/indus-act/wec/enron/summary-findings.pdf.

[54] World Bank, World Development Indicators database, 2004

The unlikely figure was a nuclear engineer/peanut farmer – Jimmy Carter. It was the early 1970's and President Carter declared that 1977 would be the year that the U.S. would import the most oil ever and that imports would decline from there. He also said that at least 20% of our power would be solar by 2000.

The moral being that political desire is not enough, but it must coincide with economic and technical reality for change to occur. It is not wise to bet against these realities, and our assessment of the likelihood of numerous biofuel projects in Michigan needs to give significant weight to these realities.

Biofuels, as they are conventionally thought of, food crop or cellulosic, require proximity to crops, water, and energy markets for the fuel to be most cost effective. Michigan certainly is well suited to host this industry based on these criteria. But even under optimal circumstances food crop biofuel is not currently cost effective, nor does it produce a significant amount of net energy, if any. Cellulose based biofuel is not commercially viable at this time, so the true economics and energy balance are unknown. But based on the pilot scale facilities that are in operation, it appears that it could produce a significant amount of net energy, although at an unknown cost. This avenue of biofuel production appears most likely, but significant research and commercialization efforts need to be conducted.

Michigan has the requisite attributes for the development of a biofuels industry, but the technology is not sufficiently developed; that is, it is not cost effective and net energy productive, to make it viable. Also, there is no imminent resolution of these issues expected and environmental concerns about this source of energy are increasing. Therefore, the likelihood of significant biofuel development in Michigan in the near future appears slim at best, and the impact on water resources will not be significant.

Biomass energy, by comparison, is technically mature and viable, to a limited extent, in Michigan given the large amount of biomass available. Six wood fired generation facilities exist in the state generating 173 mW. None of these is newer than 12 years and one is 22 years old. In addition wood industry facilities have 195 mW of capacity on site, with cogeneration. The cost for new wood fired electrical generation facilities without cogeneration is relatively high compared to coal, although it is competitive when cogeneration is possible and at the residential level if the labor of stoking and maintaining the wood fired burner is ignored. Cofiring with coal is also cost competitive for waste wood, but not for wood harvested for fuel. Overcoming this cost hurdle is likely to impede any significant increase in the number of facilities beyond the six that currently exist. One way of overcoming the cost hurdle for this energy source is to cogenerate. But, of course, if cogeneration can be practiced with wood to lower its cost it can also be used to reduce the cost of other fuels.

Increased biomass energy development is also possible, but current economics do not favor it. Renewable energy requirements may, however, cause some development to occur, but probably only to the extent necessary to meet the requirement.

The Department of Energy recognizes the probability of a relatively small contribution to our energy supply from biofuels and even other alternative energy sources in the next twenty years. On their website, the DoE says, "It is likely that the nation's reliance on fossil fuels will actually increase over the next two decades." The DoE also states in its "Annual Energy Outlook 2009" report, "Dependence on imported liquids declines dramatically over the next 20 years." Reading between the lines, we can expect that natural gas (DoE predicts that 900 of the next 1000 power plants will be powered by natural gas), coal, and nuclear power will increase, but alternative energy will not be a substantial contributor of energy.