


Sustainable Energy Solutions

For Small to Medium Sized Farms

This paper will explore a number of energy solutions, including alternative energy and efficiency best practices, for **small** to **medium sized farms**. It will present the advantages and disadvantages of various options, so that the reader can make an informed **sustainable energy** decision that best works for his or her farm. The paper will focus on farm operations, but does not consider the farm's residence, or "building envelope." Although the geographic focus of this paper is New York State, the solutions are applicable for other states and countries.

STRATEGIC SUSTAINABILITY CONSULTING

Contents

Why Do A Sustainability Assessment?

Research presented by Elizabeth Brown and R. Neal Elliott in their 2005 publication, *On-Farm Energy Use Characterizations*, concludes that the uses of energy on-farm that provide farmers with the largest savings potential include:

- **Transportation** including fuel use decisions
- **Machinery** including motors, lighting, and irrigation

While particular efficiency measures might be more useful to some farms based on their local climate and farming type, much of the following information is generally applicable to all farms.

Larger farms are certain to implement these techniques, which make it critical that smaller farms also consider them in order to remain competitive and sustainable. In addition, with more consumers focused on buying locally grown products that have been farmed with "green" practices, smaller farms that focus on energy efficiency also benefit because they can market their crops and products as being produced using energy efficient techniques.

This white paper is structured around the two largest contributors to farms' energy use: On-site transportation and machinery use. The average farmer spends 12% of his total energy budget on fuel for the tractors that plow or till the fields, the forklifts and trucks that move crops, or the combines and hay balers. It is important to note, however, that this statistic is formulated knowing that there is an enormous amount of unavailable information with regard to national energy use in agriculture.

The actual expenditures are likely to be much higher, which means the resulting savings will also increase.

On-site Transportation – Alternative Fuels

The tractor is one of the most important and heavily utilized tools on farms across America. It is not a surprise, therefore, that the tractor presents the largest savings potential for farmers. When reviewing ways to lower energy costs and reduce greenhouse gas (GHG) emissions, farmers must make two major decisions upon attempting to lower energy costs and reduce greenhouse gas (GHG) emissions. The first consideration is which fuel(s) to use.

Alternative fuels are sources of energy derived from resources other than petroleum-based products. Alternative fuel research has been conducted for many decades; this research is discussed with greater frequency during fuel shortages or a major price spikes. These fuels can come from many different forms, including agricultural products and waste. Fuels to consider include:

Ethanol is a fuel produced by the fermentation of starch or sugar in a wide variety of cereal grains.

Biodiesel is a fuel resulting from the conversion of vegetable oils or animal fats, or is created using pure vegetable oil.

Electricity that is produced by a renewable resource such as solar power, wind, or micro hydro.

Other fuels, including methane and hydrogen. The costs for these fuels are often prohibitive for a small or medium sized farm; therefore this paper will not discuss them in great detail.

Interested in learning more about sustainable agriculture?

Check out the info-packed **Sustainable Agriculture Research & Education** website:
http://www.SARE.org

ETHANOL

Ethanol (also called Ethyl Alcohol) is made by fermenting and then distilling starch and sugar crops such as maize, sorghum, potatoes, wheat, sugar cane, cornstalks, fruit, and vegetable waste. Recently, cellulose fiber sources have been used to make the fuel. New enzymes and production processes that convert cellulose to sugar can produce ethanol from almost any biomass, including agricultural wastes, straw, leaves, grass clippings, sawdust or old newspapers.

BENEFITS

- Cleaner than unleaded gasoline
- Renewable fuel made from plants
- Blends may be used in some engines without modifications
- Biodegradable

Ethanol is a renewable fuel that comes from agricultural feedstocks, and thus can be produced domestically. Combusted ethanol, particularly E85, an ethanol blend of 85% ethanol and 15% petroleum gasoline, also generates less pollution, reducing smog-forming emissions by as much as 50% relative to gasoline. Despite this improved performance, E85-powered vehicles also contribute to global warming, although experts disagree about just how much GHG is emitted by using ethanol.

Researchers at the University of California at Berkeley recently examined six major studies of ethanol production and concluded that corn-based ethanol generates a modest 13% less GHG emissions than gasoline. However, the researchers noted that **more dramatic reductions are possible if technical advances make economical production of ethanol from cellulosic materials** such as switchgrass, a crop currently grown by some U.S. farmers to control erosion on idle fields, feasible. They projected that the use of cellulosic ethanol could reduce GHG emissions by 88%.

DISADVANTAGES

- May be more expensive and provide less energy output than gasoline
- Few ethanol stations exist
- Can have difficulty starting in cold weather

Data on fuel prices from the U.S. Department of Energy (DOE) shows that E85 sells for nearly 30 cents less per gallon than conventional gasoline in the Midwest, where much of the country's ethanol is produced. On the West Coast, however, ethanol costs 35 cents more per gallon. In the Mid-Atlantic States, E85 had an even higher premium – 44 cents per gallon.

Ethanol contains less energy per gallon than gasoline. Your vehicle won't travel as far on a gallon of E85, and your fuel economy will decrease by 20% – 30%, then it would if you filled up with gasoline. This means that even if the price of E85 at the pump is cheaper than gasoline, using ethanol may not be less expensive in the end.

Check out the DOE website to see current ethanol prices:

http://www.afdc.energy.gov/afdc/price_report.html

A limited, but rapidly growing, number of public stations offering E85 currently exists. A table listing the stations in every state may be found here: http://www.afdc.energy.gov/afdc/ethanol/ethanol_locations.html
A corresponding map can be found here: http://www.afdc.energy.gov/afdc/locator/stations/

Engine ignition may be a concern when using E85 in colder climates. Alcohol is much less explosive and has a lower ignition point than regular gasoline, which prevents it from combusting well in a sub-freezing engine. Potential solutions to this include:

- Block and radiator heaters
- Using regular fuels during the cold season
- Using starter fluid
- Raising the compression ratio of the engine (to aid in explosion)
- Keeping a separate fuel tank with regular gas (and a switching valve)

Engine Requirements

There are many Flexible Fuel Vehicles (FFV) already on the road that can use E85. A list of car models currently available as FFV is available at:

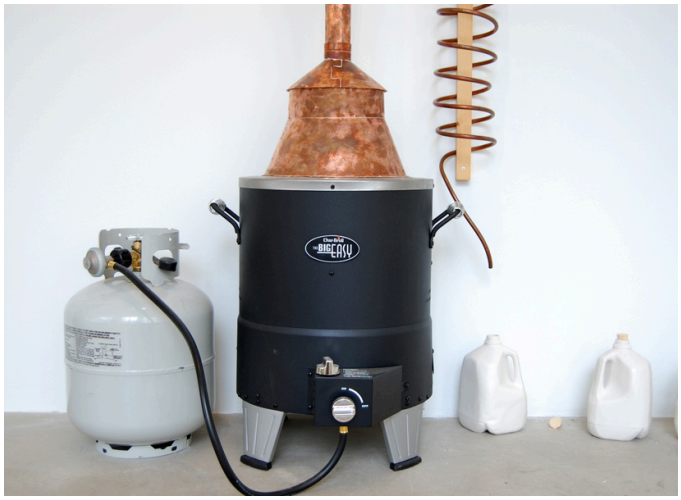
http://www.eere.energy.gov/cleancities/progs/afdc/search_type.cgi?1|E85_GSLN

If the vehicle is not a FFV, some carburetor or fuel injector and timing modifications may be necessary. Instructions for this modification were published by Mother Earth News in 1980. *How To Adapt Your Automobile Engine For Ethyl Alcohol Use* is available at: http://running_on_alcohol.tripod.com/id32.html. A modification system may also be useable on older carbureted gasoline engines (even for those found on tractors and other agricultural engines) since the system adds fuel through a separate injector plate and can be added easily to a carburetor system.

Professional mechanics can perform these modifications; one such service, located in New York, is: *http://www.flexiblefuelconversions.com/)*

Creating Your Own

In order to produce your own ethanol, a license must be obtained from the Bureau of Alcohol, Tobacco, and Firearms; you must purchase or build a still to generate the ethanol; the resulting 180 – 190 proof ethanol must be treated with a molecular sieve (such as Zeolite) in order to achieve the 200 proof required for blending with gasoline to become E85. A "how to" guide is can be found here: http://running_on_alcohol.tripod.com/id36.html



Ethanol stills can be purchased for under $1,000, but you need to obtain a license from the ATF

Check out the following sites for more information on E85:

http://www.afdc.energy.gov/afdc/ethanol/index.html
http://www.epa.gov/otaq/renewablefuels/420f10010.htm
http://www.transportation.anl.gov/fuels/ethanol.html
https://attra.ncat.org/attra-pub/farm_energy/ethanol.html

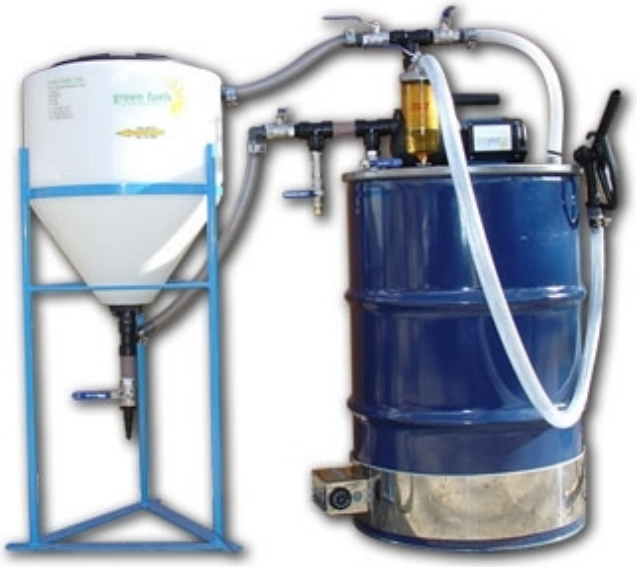
BIODIESEL

Biodiesel is an alternative fuel used in diesel engines and is derived from plant oils or animal fats. In the United States, most commercial biodiesel is made from soybean oil. In Europe, rapeseed (canola) oil is more commonly used. Biodiesel can be made from virgin oil, or from used cooking oil recycled from restaurants and food processing operations. This type of fuel should not be confused with Straight Vegetable Oil (SVO). SVO requires engine modifications before it can be used and has other disadvantages. Often biodiesel will be blended with petroleum diesel at commercial pumps. The blend B20 means that the fuel is composed of 20% biodiesel and 80% petroleum diesel.

BENEFITS

- Cleaner than unleaded gasoline
- Renewable fuel made from plant or animal fats
- May be used in diesel engines without modification
- Biodegradable
- Safer to transport and handle than gasoline
- Improved lubricity

Biodiesel is a renewable fuel that produces reduced GHG emissions. Additionally, biodiesel offers several criteria emissions benefits for the existing vehicle fleet – it reduces particulate matter (PM), sulfates, and carbon monoxide, hydrocarbon, and airborne toxic emissions.



A small biodiesel processor can produce up to 10.5 gallons of biodiesel per day, and can be purchased at websites such as www.NorthernTool.com

The U.S. Environmental Protection Agency (EPA) analyzed existing data and found that the nitrogen oxide (NOx) emission impacts of biodiesel are dependent on engine load, and thus vary by test cycle or application. On average, though, NOx emissions are expected to increase by about 2% for B20 blends. Recently, a number of test programs have examined the effects of B20 blends on

modern after-treatment devices (such as particulate filters, and NOx storage, and reduction devices), and none to date has shown biodiesel to degrade or impair device performance.

EPA studies confirm that blends containing small amounts of biodiesel (up to 5%) have greater lubricity; they more effectively lubricate components of the fuel system, such as injectors and fuel pumps.

Particularly when added to ultra-low-sulfur diesel fuel, biodiesel can play an important role in maintaining lubricity and extending the life of engine components. For this reason, most manufacturers of diesel engines in the United States approve biodiesel blends up to B5 for use in their vehicles. However, some manufacturers, Volkswagen in particular, have neither approved blends with higher amounts of biodiesel, nor approved the use of B100 in diesel vehicles. Currently, the use of biodiesel blends above B5 in a Volkswagen engine can void the manufacturer's warranty.

Austria's Institute of Agricultural Engineering tested 33 tractors from 12 different manufacturers, running them on rapeseed oil (now commonly called Canola oil), and found good performance and lower emissions. Other tests conducted in Sweden, France, Italy, and Spain show that soybean, rapeseed, and sunflower oil can give similar power, torque, mileage, and general performance in diesel trucks and other vehicle with no modification whatsoever.

DISADVANTAGES

- Produces less energy than gasoline
- Few filling stations exist
- Vehicle problems can result from use
- Handling and storage can be difficult

Biodiesel fuel contains 11% less energy than petroleum-based diesel fuel, resulting in power loss during engine operation. In turn, the engine adjustment required to compensate for power loss may violate the EPA's anti-tampering provisions. However, according to the EPA, fuel economy is only 2 to 8% less than petroleum diesel despite the power loss.

Case Study: Adirondack Biodiesel

Chris Arduini of Adirondack Biodiesel stands next to one of his company's settling tanks

Chris Arduini's company, **Adirondack Biodiesel**, has the capacity to produce up to 4,000 gallons of biodiesel a day, which it sells to farmers in a 90-mile radius outside of St. Johnsville, New York. Among his customers are farmers who use Arduini's B100 biodiesel: Robert Deere used B100 in his tractors and pickup truck for over two years with no ill effects, and Roger Lottman observed only a slight loss of engine power after using B100 in his excavators and bulldozers for a year.

Arduini recommends several measures to ensure that higher grades of biodiesel do not cause damage to biodiesel engines: Biodiesel can cause rubber to swell, which leads to leaks in the fuel lines and seals in older diesel engines. That problem can be remedied by replacing rubber fuel lines and return lines with synthetic ones. Biodiesel also dissolves old petroleum deposits in tank and fuel lines, so fuel filters should be changed after converting to biodiesel, after which the filters will remain clean. Installing heated jackets on fuel filters or using an additive to improve cold weather flowability will overcome the tendency of B100 to gel in cold weather.

Also, B100 will gel in cold weather. This can be remedied by installing heated jackets on the fuel filters, or by using an additive to improve cold weather flowability.

Very few filling stations currently exist. A table listing the stations in every state can be found here: http://www.afdc.energy.gov/afdc/fuels/biodiesel_locations.html
A corresponding map can be found here: http://www.afdc.energy.gov/afdc/locator/stations/

The use of biodiesel generally does not cause many maintenance issues. However, when used for the first time, biodiesel can release deposits accumulated on tank walls and pipes from previous diesel fuel, initially causing fuel filter clogs.

Therefore, vehicle owners should change the fuel filter after their first tank of biodiesel. Additionally, biodiesel can degrade rubber fuel system components, such as hoses and pump seals. This is especially true with higher-percentage blends, and in older vehicles. Many newer vehicles have biodiesel-compatible components, but it is best to consult your owner's manual or contact your vehicle manufacturers for specific information.

Biodiesel vehicles can also have difficulty starting in very cold temperatures, but this is more of an issue for higher percentage blends such as B100, and is easily solved by using engine block or fuel filter heaters or storing the vehicles in a building.

Engine Requirements

Diesel engines will run on biodiesel without modification.

Creating Your Own

Many farmers produce their own biodiesel, especially if they have access to a free supply of vegetable oil waste (which may be supplied by their restaurant customers). There are several books about biodiesel production, which involves mixing vegetable oil, alcohol, and lye, available for purchase. An online guide is available here: http://journeytoforever.org/biodiesel_make.html#1mixing

Case Study: SARE Learning Network

Used fryer oil on its way to Greengrow farms for conversion to biodiesel

In 2006, SARE (Sustainable Agriculture Research and Education), a grants and education program, established On-Farm Biodiesel 101, a series of workshops to show farmers in the northeast to establish and operate small-scale biodiesel operations. The objective of the workshops was to create a network of farmers who would disseminate knowledge about on-farm biodiesel production to other farmers. Between 2006 and 2009, participating farmers collectively produced $44,000 worth of biodiesel.

One participating farm, Greensgrow, in urban Pennsylvania, produces up to 200 gallons of biodiesel every week using grease from local restaurants. The farm's sustainability coordinator, Ryan Kuck, says the farm saves $200 a week on fuel costs, and earns an addition $50 a week by providing leftover diesel to a co-op.

More information about Biodiesel can be found here:

- www.afdc.energy.gov/afdc/fuels/biodiesel.html
- www.epa.gov/otaq/renewablefuels/420f10009.htm
- www.transportation.anl.gov/fuels/cleandiesel.html
- http://riley.nal.usda.gov/nal_display/index.php?info_center=2&tax_level=1&tax_subject=281
- https://attra.ncat.org/attra-pub/farm_energy/biodiesel.html

ELECTRIC

Electricity can be used to power all-electric vehicles and plug-in hybrid electric vehicles directly from the power grid. Vehicles that run on electricity produce no tailpipe emissions. The only emissions attributable to electricity are those generated in the electric power production process (emissions may be zero if electricity comes from solar, wind, or micro hydro systems).

BENEFITS

- Clean power
- Renewable with the appropriate source
- Many vehicles require no engine modification
- Lowers cost per mile

Electric vehicles generally cost less in total to operate than combustion-powered vehicles, even in cases when the initial purchase price is higher. Electric motors have very few moving parts and thus don't need fluids such as engine oil, anti-freeze or transmission fluid, so they require relatively little maintenance and are far less likely to leak. Excellent reliability means down time is less likely, too.

Case Study: Huguenot Street Farm

A converted G tractor at Huguenot Street Farm

The Huguenot Street Farm is a community-supported agriculture project in New Palz, New York. The farm staff designed a process for converting the Allis Chalmers G Cultivating and Seeding tractor, a model dating from the 1940s and '50s but still popular for seeding because the engine is in the back, which allows for an unobstructed view of the tractor's implements. In 2009, a grant from SARE funded the project, allowing both the sale of converted tractors in the range of $5000-6000, and the publication of an online how-to guide for farmers to convert their own G tractors. As of December 2009, the publishers had received word from over 100 other farms with stories of successful conversions.

Electric vehicles emit no pollutants from the tailpipe, so they're cleaner for the environment and better for everyone's respiratory health. They also run far more quietly than their combustion-powered counterparts, enhancing limiting noise pollution. Additionally, the overall emissions associated with using electric vehicles are typically far less. Most electric vehicles charge up at night when system wide demand for electricity is low. They tap existing generating capacity that is not fully used rather than increasing demand for new capacity.

DISADVANTAGES

- Reduced selection of available tractors
- Limited range and run time
- Higher up front costs

There are currently few electric options in the car market, and the tractor selection is even smaller. Small farms that don't need larger tractors may be able to implement this technology by purchasing an ATV or John Deere Gator electric vehicle. These vehicles can be outfitted with plows, cultivators, discs, post hole diggers, and bush hogs among others accessories. These vehicles are typically not very large, but could function well on a smaller farm.

The time required to recharge the batteries is a major disadvantage of electric vehicles. With lithium-ion battery technology, a fully charged electrical vehicle can travel a distance of about 100 miles before it requires recharging. At present, this means a drained electric vehicle will be out of service for several hours before it is fully recharged. This may not be a factor if the vehicle is recharged at night and the distance requirements are not as great. Faster recharging technology may become available in the future, but electric vehicles won't be viable for long trips in the near term. Even so, most driving is done relatively close to the farm and thus battery power will compete with gasoline power.

Some electric vehicles' initial cost may be another disadvantage. However, for the tractor and ATV mentioned above, the initial cost of about $10,000 is comparable to a gas powered vehicle

of the same size. Even where electric vehicles are more expensive than their counterparts, there are incentives described in the last section of this white paper to help offset this upfront cost.

Powering the Vehicle Using Renewable Energy

Ideally, a renewable energy resource should be used in conjunction with an electric vehicle. If on such resource presently exists, micro-hydro, wind, and solar power should be considered. All three of these technologies are very site specific and should be evaluated on a site-by-site basis.

Micro-hydro systems are often overlooked but can be a very cost-effective way of powering the vehicles. These systems require a combination of a year-round rapidly flowing stream and an elevation difference from one part of the stream to another (waterfalls are even better). Although these systems have very strict site requirements, they may be the most cost effective for the farm if available.

A micro-hydro system in action

Additional information for conducting feasibility studies and implementing micro-hydro may be found here:

http://www.oregon.gov/ENERGY/RENEW/Hydro/docs/MicroHydroGuide.pdf?ga=t

Small **wind turbine systems** are often confused with large, commercial wind farms, but their advantages and disadvantages may be very different. A small wind turbine system can be very cost effective for a farm depending on wind resources available and the local terrain. A wind resource map of the

United States may be found here:

http://www.windpoweringamerica.gov/wind_maps.asp

If these two systems are not viable options for your farm, and a view of the southern sky is available, solar power may be the solution. There are several solar calculator sites on the Internet including: http://rredc.nrel.gov/solar/calculators/PVWATTS/version1/

For all three of these solutions, it is important to understand how much energy is required in order to implement the correct size system. There are also incentives to support the purchase of these systems discussed later.

A small stand-alone wind turbine can provide significant energy savings on the farm

METHANE

Bio-methane, or methane produced from the natural breakdown of plant material, could supply enough natural gas for about 11 million natural gas vehicles according to the Natural Gas Vehicles for America (NGVA). One of the major benefits of using methane as a compressed natural gas is a significant reduction in emissions when compared to gasoline. Compressed natural gas is touted as the "cleanest burning" alternative fuel available, since the simplicity of the methane molecule reduces tailpipe emissions of various pollutants by 35 – 97%. The reduction in net GHG emissions is less dramatic; the improvement is about the same as corn grain ethanol (about a 20% reduction compared to gasoline).

Unfortunately, the capital costs of an anaerobic digester, which is required to produce bio-methane, can be very high, ranging from a few hundred thousand to a few million dollars, depending on the size. Payback periods can range from five to 16 years, depending on the conditions of operation. It is also important to keep in mind that the value

of the bio-methane produced will vary depending on the type of fuel that it is replacing. A general rule of thumb is that an anaerobic digester will not be cost effective for a farm with fewer than 300 head of livestock. For smaller farms, a cooperative operation used by multiple farms may be an option.

More information on biogas may be found here:
http://www.epa.gov/lmop/basic-info/index.html#a03

HYDROGEN

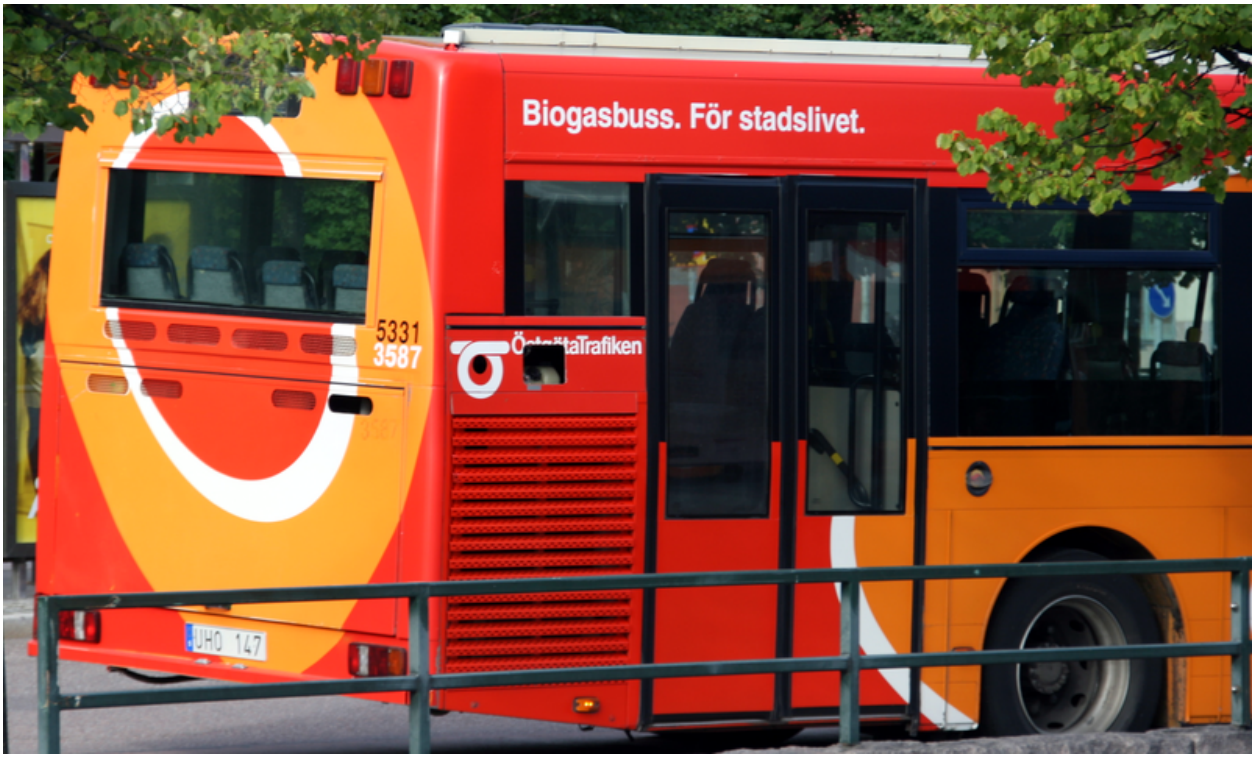
Interest in hydrogen as an alternative transportation fuel stems from its clean-burning qualities, its potential for domestic production, and the high output of a vehicle's fuel cell, which is two to three times more efficient than in gasoline vehicles. The Energy Policy Act of 1992 identifies hydrogen as a viable alternative fuel.

The energy in 2.2 pounds (1 kg) of hydrogen gas is about the same as the energy in one gallon of gasoline. A light-duty fuel cell vehicle must store 11 – 29 pounds (5 – 13 kg) of hydrogen to enable a driving range of 300 miles or more. Because hydrogen has a low volumetric energy density (a small amount of energy by volume compared with gasoline), storing this much fuel on a vehicle using currently available technology would require a very large tank – larger than the trunk of a typical car. Advanced technologies are needed to reduce the required storage space and weight.

Hydrogen should be thought of as an energy carrier rather than an energy source and can be produced from various domestic energy sources including geothermal, wind, water, and solar among others.

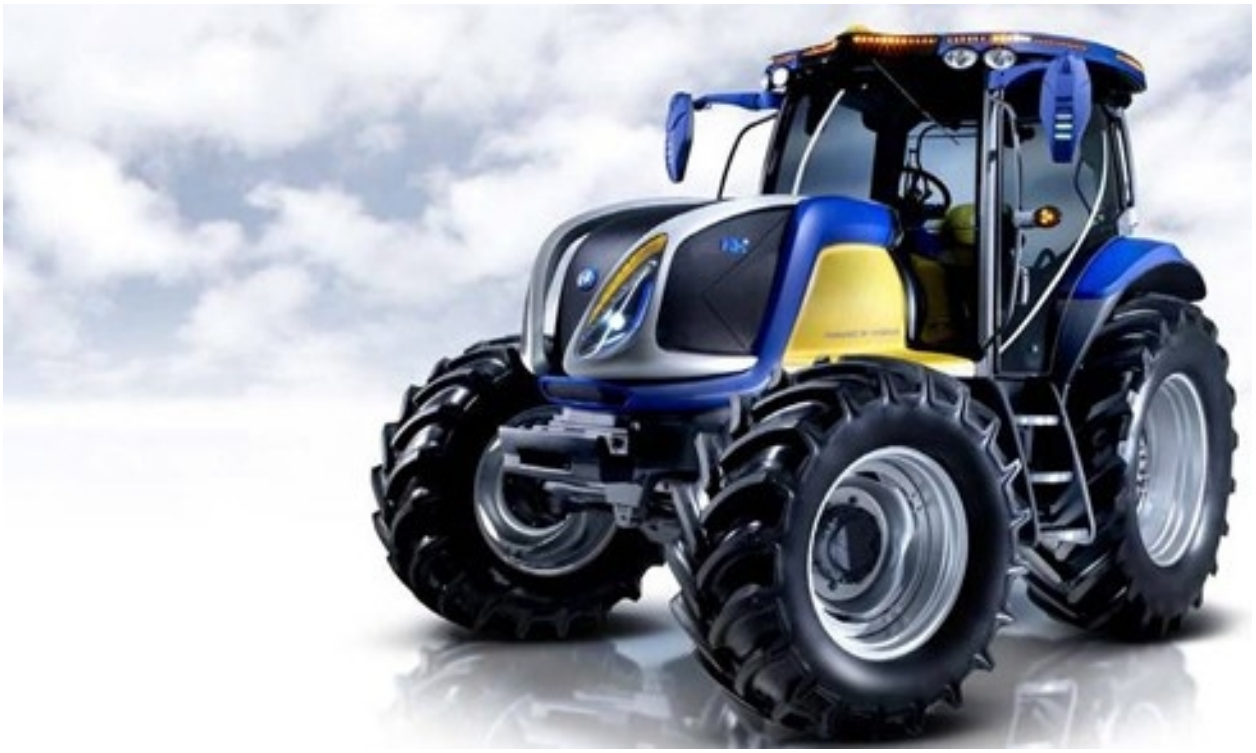
New Holland Agriculture has developed a new hydrogen powered tractor: http://agriculture.newholland.com/PublishingImages/cnhimg/we/Hydrogen/NH2_90014_INB.pdf. Unfortunately, the fuel cell itself costs more than $350,000. This is a technology to watch in the future, but it is currently cost prohibitive.

More information on hydrogen power may be found here:
http://www.afdc.energy.gov/afdc/fuels/hydrogen.html



ABOVE: Bio-methane, also known as biogas, is already in use in many countries around the world. Here, a public bus in Sweden runs on biogas.

BELOW: The New Holland NH^2 hydrogen-powered tractor is an impressive innovation, but the fuel cell enables fewer than two hours of operation and costs more than $350,000



On-site Transportation – Efficiency Best Practices

Besides choosing the fuel source and system that makes the most sense for your farm, it is also important to identify and use best practices in day-to-day operations.

GEAR UP AND THROTTLE DOWN

Running the tractor at the proper RPM is essential to fuel efficiency. In all cases, consult the factory-issued guidelines for your tractor. The engine should never be overloaded; all users should know the maximum loads. If the tractor is being used to haul hay bales or to pull a rake, consider reducing the engine RPM by "gearing up and throttling down."

TIRES

Tires should always be inflated to the proper pressure. Over-inflated tires decrease traction, create ruts in soft soil and can deteriorate sidewall tread. Also, be careful to not overinflate the tires. Overinflation can cause pre-mature tire wear, increased soil compaction, and greater fuel consumption resulting from increased rolling resistance. A University of California Study demonstrated that vehicles with correctly inflated tires required 20% less fuel than those with tires that were under- or over-inflated[8]. Always check the owner's manual or consult a local tire distributor for the proper inflation information.

MAINTENANCE

Make sure to perform general maintenance on all farm machinery, especially before and after harvest season. Properly lubricated tractors and equipment will result in better fuel efficiency. Also, be sure to change the filters in the air and fuel systems. Finally, use appropriate equipment ballast to keep wheels from slipping, which increases fuel consumption[9]. Ensuring that you follow the proper maintenance schedule will not only increase fuel efficiency, but will extend the life of the tractor.

TRANSPORTATION

Minimizing the use of heavy-duty pickup trucks when driving into town can surprisingly save hundreds of dollars a year on gas. Larger trucks and pickups are important to farm operations, but they should be saved for those tasks that require their power and hauling capacity. Also, remember to use air-conditioning selectively and consider combining trips to town so that one trip can accomplish multiple tasks.

FUEL

Because of the high use of machinery and on-site transportation on the farm, it is no surprise that making smart fuel energy choices is one of the biggest areas to ensure energy efficiency of the farm. Saving money on fuel is of primary importance to any farmer, especially to smaller farmers who need to do more with less. Fuel consumption varies widely due to variations in tractor efficiency, soil moisture conditions, crop yields, and other factors.

Here are ten ways a farmer can increase fuel efficiency of the farm:

1) **Reduce the number of trips associated with spring seedbed preparation.** With today's modern planter units, crop residue does not create the problems it used to with seed placement and depth control. For most field situations, one tillage trip over the field in the spring should provide adequate leveling of the soil and seedbed preparation.

2) **Change to a no-till planting system where field conditions permit.** This is especially true for soybeans, as no-till soybeans are an easy and proven way to maximize yields without doing any tillage.

3) **Reduce the depth of tillage associated with seedbed preparation if using a mulch-till or reduced-till system.** In most cases, spring seedbed preparation should be performed no deeper than three to four inches. This will reduce the power and fuel requirements needed.

4) **Combine trips across the field to reduce fuel usage.** Producers using

28 percent Urea and Ammonium Nitrate (UAN) solutions may be able to mix their pre-plant or pre-emergence herbicides with their fertilizer and apply with one trip over the field. Be sure to check with an agricultural product supplier regarding chemical compatibility of the herbicides and fertilizer products before mixing these together.

5) **Custom-apply either or both herbicides and fertilizer in the spring.** Although an application fee will be charged by the commercial company, they may be able to do it more cost and fuel-efficiently than an individual producer.

6) **Use post-emergence herbicides for annual grass and broad-leaf weed control.** By applying the post-emergence herbicides after the crops and the weeds emerge, producers know the crop's seedling plant population and the infestation of weed species present. In some cases, producers may only need to do "spot" treatments of either the broadleaf or grass herbicide in the field. Another tip: weeds can be controlled even better by waiting until after the crop and weeds emerge for treatment, weed control is usually improved.

7) **Avoid unnecessary use of the cultivator for weed control unless weed populations cannot be controlled with herbicides.**

8) **Match field equipment to the appropriately sized tractor.** If excess tractor horsepower is used for the job, fuel efficiency declines dramatically. Conversely, if a small horse-powered tractor is used and the tractor becomes overloaded for the job, fuel efficiency also suffers. In many situations, research studies show that a large front-wheel assist tractor or a four-wheel drive tractor may actually provide the best fuel efficiency if it is appropriately sized to a large field cultivator or other tillage implement. A good rule of thumb is to select the smallest and lightest tractor for the job that needs to be

done to enhance fuel efficiency and reduce soil compaction.

9) **Perform general tractor maintenance before going into the fields in the spring.** Take time to properly clean air and fuel systems, including replacing filters. Also be sure to properly lubricate tractors and equipment, as this will result in enhanced fuel efficiency and equipment operation when you get to the fields this spring.

10) **Examine use of your pickup truck and monitor your trips to town.** Studies show that the pickup truck is one of the largest users of fuel for many farms. Without a doubt, the pickup is an essential component of the entire farming operation. However, where possible, combine trips for equipment, seed, chemicals, and to arrange for other agri-business services. Also, using the telephone or the home computer may reduce a number of unnecessary trips to town.

MACHINERY

In addition to tractors and other vehicles, energy use is predominant in farm machinery, which also presents an opportunity for savings. Commercially available technology upgrades (combustion engines only), and changes in practices on the farm can result in potential savings from machinery. For example, certain changes in farming techniques reduce diesel fuel use as well as energy production costs to the farmer. The next two sections include recommendations for dairy type farms and farms with irrigation systems.

DAIRY FARMING

Dairy farms are also candidates for motor energy efficiency programs due to their large use of pumps on the farm. In Vermont, Wisconsin, and other states where dairy is the primary farm-type, upgrading motors can have a large impact on the energy efficiency of the farm and provide significant savings. In fact, in states where dairy farming is dominant, programs have been established to help

farmers achieve more energy efficient pumping on the farm.

For most dairy farms, the best way to improve energy efficiency is through the refrigeration system's design, operation, and maintenance. However, the farmer should address refrigeration system efficiency measures in a logical, step-by-step manner. If a farmer is planning a major expansion or renovation of his dairy farm refrigeration system, it may make sense to install multiple energy saving measures. These measures, in order of priority, include:

1) Refrigeration Heat Recovery (RHR) Units

2) Scroll Compressors

3) Plate/Pre-coolers

4) Variable Speed Milk Pumps

These measures can reduce refrigeration related energy costs substantially and maintain, or even improve, milk quality. They reduce refrigeration requirements and/or capture waste heat and use this excess heat energy to preheat water.

However, before installing one or more of these measures, farm refrigeration experts should be consulted, otherwise the energy usage may increase. For example, installing an RHR unit and a precooler may cause an increase in energy consumption if all factors are not considered when designing the new system. Experts can also help avoid damage to equipment or equipment failures. This factor is of greatest concern for farms with 120 cows or fewer, but all farms can benefit from expert advice

Companies like DeLaval (www.DeLaval.com/en) offer a full range of sustainable dairy farming equipment

before proceeding. Even if a major refrigeration overhaul is not expected, there are still some specific measures the farmer can take to improve the efficiency of the system that are addressed below.

Use Variable Speed Vacuum Pumps for Milking

The vacuum pump used for milking not only operates for long hours during the day, but it also tends to use a lot of energy. Standard pumps with single speed drives operate at a constant speed of seven to ten cubic feet per minute (CFM), per milking unit. On the other hand, by installing a variable speed drive on the pumping system, the pump speed can be lowered to two CFM per milking unit, yet additional power remains available if needed. The variable speed drive unit alters the vacuum power so that no more energy is needed than necessary, and the controllers on the pump are sensitive enough to prevent injury and milk back flow. The variable speed units, with corresponding controllers can lower the energy costs of a dairy vacuum system by half.

Use A Water Cooled Plate Cooler

Plate coolers, also known as plate heat exchangers, use well or spring water to lower the temperature of milk as it flows from the milking system to the collection tank. Using a plate cooler can speed the cooling process so that the milk is at a lower temperature, reducing the milk temperature by an extra 30 to 40 degrees. This means that the compressor does not have to expend as much energy as it would otherwise.

IRRIGATION

Irrigation Pumps

Irrigation presents great potential for saving energy and money for the agriculture sector. Irrigation energy savings are estimated at $436 million nationally, and represent 29% of the total potential motor savings. Motor energy use is the primary use of energy for all farm-types that use irrigation because of the energy it takes to pump water to and through the system[1]. It is important to

note that the benefits of increasing energy efficiency in irrigation are not solely (or even primarily) energy related[1]. Much of the benefit stems from the water savings that result from improving irrigation efficiency[1].

Irrigation Energy Saving Tips

There are several common sense guidelines a farmer can follow to improve irrigation efficiency on the farm:

First, **it is important to keep irrigation engines and motors serviced and well tuned.**

Second, make sure electric motors, switches, and control panels are clean and free of dirt, insects, or bird nests. These factors add to an inefficient motor.

Third, check connections to ensure they are tight, and lubricate moving parts that require it. For example, to avoid sprinkler system inefficiency, inspect the system regularly, and make minor repairs such as stopping leaks, replacing worn nozzles, and trimming the impeller, as necessary.

Fourth, to prevent over watering, consider using an irrigation scheduling method that times irrigation watering for more efficient fuel and water use. Such methods include starting irrigation before soils are completely dry and using larger amounts of water on fewer acres per irrigation to move water through fields quicker and more efficiently. Also, address watering methods to avoid patchy water distribution and inadequate pressure. Either of these problems will make it impossible to maintain correct soil moisture levels, leading to crop stress, reduced yields, waste water, runoff, soil erosion, and many other problems.

Addressing equipment and management efficiency together is critical to creating the most energy efficient irrigation system on the farm. In addition to these common sense tips, there are more specific measures a farmer can take to address equipment and irrigation management inefficiencies.

For example, there are publications that recommend irrigation system installations, explain how utilities charge

their irrigation customers for electricity, and describe common causes of wasted energy, as well as common energy-saving hardware improvements. Also, there are do-it-yourself methods to estimate the efficiency of electrically powered irrigation systems. In addition, visit an irrigation dealer or an extension agent to find information on the following:

- What is the net water application rate for my irrigation system?
- How do I calculate the number of hours the system should be operated?
- What are different methods to measure flowing water in an open channel or pipeline?
- What are possible suggestions for irrigating with limited water supplies?

Finally, all farms are encouraged to find publications that explain how to maintain irrigation pumps, motors, and engines for peak efficiency, including descriptions and diagrams of recommended installations, checklists for maintenance tasks, and a troubleshooting guide.

Other efficiency recommendations may be found here: http://www.wisconsinpublicservice.com/business/efficient_equipment.aspx

Incentives

FEDERAL INCENTIVES

RESIDENTIAL RENEWAL ENERGY TAX CREDITS

Consumers who install solar energy systems (including solar water heating and solar electric systems), small wind systems, geothermal heat pumps, and residential fuel cell and microhydro systems can receive a 30% tax credit for systems placed in service before December 31, 2016; the previous tax credit cap no longer applies.

FEDERAL PLUG-IN HYBRID TAX CREDIT

The American Recovery and Reinvestment Act of 2009 modifies the credit for qualified plug-in electric drive vehicles purchased between December 31, 2009 and December 31, 2011. The minimum amount of the credit for qualified plug-in electric drive vehicles is $2,500 and the credit tops out at $7,500, depending on the battery capacity. To qualify, vehicles must be newly purchased, have four or more wheels, have a gross vehicle weight rating of less than 14,000 pounds, and draw propulsion using a battery with at least four kilowatt hours that can be recharged from an external source of electricity.

The full amount of the credit will be reduced with respect to a manufacturer's vehicle after the manufacturer has sold at least 200,000 vehicles. The credit will then phase out over a year. See IRS Notices *2009-54: Qualified Plug-in Electric Vehicle Credit* (http://www.irs.gov/pub/irs-drop/n-09-54.pdf) and *2009-58: Qualified Plug-In Electric Vehicle Credit Under Section 30* (http://www.irs.gov/pub/irs-drop/n-09-58.pdf) for more information.

FEDERAL PLUG-IN HYBRID CONVERSION TAX CREDIT

The American Recovery and Reinvestment Act of 2009 provides a tax credit for plug-in electric drive conversion kits. The credit is equal to 10% of the cost of converting a vehicle to a qualified plug-in electric drive motor

vehicle and placed in service after Feb. 17, 2009. The maximum amount of the credit is $4,000. The credit does not apply to conversions made after December 31, 2011. A taxpayer may claim this credit even if the taxpayer claimed a hybrid vehicle credit for the same vehicle in an earlier year. See the IRS website for more information on *Alternative Motor Vehicle Credits* (http://www.irs.gov/businesses/corporations/article/0,,id=202341,00.html).

Low Speed & 2/3 Wheeled Vehicles

The Recovery Act also creates a special tax credit for two types of plug-in vehicles – certain low-speed electric vehicles and two or three wheeled vehicles. The amount of the credit is 10% of the cost of the vehicle, up to a maximum credit of $2,500 for purchases made after February 17, 2009, and before January 1, 2012.

To qualify, a vehicle must be either a low speed vehicle propelled by an electric motor that draws electricity from a battery with a capacity of four kilowatt hours or more, or be a two or three wheeled vehicle propelled by an electric motor that draws electricity from a battery with the capacity of 2.5 kilowatt hours. A taxpayer may not claim this credit if the plug-in electric drive vehicle credit is allowable. Please see IRS Notice 2009-58: Qualified Plug-In Electric Vehicle Credit Under Section 30 (http://www.irs.gov/pub/irs-drop/n-09-58.pdf) for more information.

The Volumetric Ethanol Excise Tax Credit (VEETC)

Also known as the "blender's credit", the VEETC is the primary federal tax incentive for the use of ethanol. The tax credit, which was created by the American Jobs Creation Act of 2004, provides blenders and marketers of fuel with a federal tax credit of 45 cents per gallon of ethanol blended with their gasoline. Through a market-based approach, VEETC enhances the sustained cost competitiveness of ethanol with gasoline, and provides long-term protection against a volatile petroleum fuel market. As such, VEETC has been a major factor behind the spectacular increase in ethanol use, production and continued innovation in the industry.

This tax credit is scheduled to expire on December 31, 2011.

SMALL ETHANOL PRODUCER TAX CREDIT

Under current law, small ethanol producers are allowed a 10 cents per gallon, production income tax credit on up to 15 million gallons of production annually. The credit, which is capped at $1.5 million per year per producer, is only available to small scale ethanol producers with an annual production capacity of no more than 60 million gallons per year. The credit can be claimed against the producer's income tax liability.

The small ethanol producer tax credit helps promote and encourage small businesses and farmer cooperatives that are involved in the production of ethanol. Given that small businesses are responsible for a large portion of our nation's job creation and economic growth, this tax credit is helping to revitalize our nation's rural communities, expand green job opportunities an and improve our overall economy.

STATE INCENTIVES

New York State has sales tax exemptions, property tax abatements and personal tax credits to encourage residential installation of energy savings measures, onsite renewable generation, solar and wind renewable energy systems and using alternative fuel for residential space heating and hot water heating.

Eligible onsite generation systems such as wind, solar, biomass, and fuel cells, must be grid connected and net metered to qualify for tax incentives.

Net metering in New York is available on a first-come, first-served basis to customers of the state's major investor-owned utilities, subject to technology, system size, and aggregate capacity limitations.

Publicly owned utilities are not obligated to offer net metering; however, the Long Island Power Authority (LIPA) offers net metering on terms similar to those in the state law. Below is listing of the system size limitations, organized by technology and eligible sector:

- Solar: 25 kW for residential, 2 MW for non-residential
- Wind: 25 kW for residential, 500 kW for farm-based, and 2 MW for non-residential
- Biogas: 500 kW (farm-based only)
- Micro-CHP and Fuel Cells: 10 kW (residential only)

Please see **Appendix: New York Tax Incentives Table** for more information

More information concerning federal and state incentives may be found here:

http://www.energy.gov/taxbreaks.htm
http://www.afdc.energy.gov/afdc/laws/
http://www.dsireusa.org/

References

Austrian Biofuels Institute (2004). Universtiy of Economy, Vienna, Austria; Federal Institute for Agricultural Engineering, Wieselburg, Austria. *Best Case Studies on Biodiesel Production Plants in Europe*. Feb 11, 2004. Retrieved from http://www.task39.org/LinkClick.aspx?fileticket=ZPi3yBsM8As%3D&tabid=4426&language=en-US.

Bonner, J., Thomas, J., Wilcutt, H. Mississippi State University Extension Service. *Reduce Energy Cost in Agriculture Information Sheet 1621*. Retrieved from http://msucares.com/pubs/infosheets/is1621.pdf.

Brown, E and Elliott, R. N. (2005). American Council for an Energy Efficient Economy. *15 Potential Energy Efficiency Savings In the Agriculture Sector*. Retrieved from www.aceee.org.

Brown, E and Elliott, R. N. (2005). On-Farm Energy Use Characterizations. Retrieved from http://www.agenergysolutions.org/site/index.php?page_id=178 - _edn1.

California Farm Bureau Federation. Fuel Efficiency on the Farm. Retrieved from http://www.cfbf.com/issues/energy/flex.cfm.

Environmental Protection Agency (2010). Biodiesel: Technical Highlights. EPA420-F-10-009, Feb. 2010. Retrieved from http://www.epa.gov/otaq/renewablefuels/420f10009.htm.

Environmental Protection Agency (2010). E85 and Flex Fuel Vehicles: Technical Highlights. EPA420-F-10-010, Feb. 2010. Retrieved from http://www.fueleconomy.gov/feg/atv.shtml.

Focus on Energy. Refrigeration Systems. Retrieved from http://www.focusonenergy.com/data/common/dmsFiles/B_GA_MKFS_BPRefrigerationSystems008.pdf.

The Institute for Energy and the Environment (2007). Energy Efficiency and Farm Equipment. Retrieved from http://www.agenergysolutions.org/site/index.php?page_id=178.

Kleber, P, Lancas, S.K., Upadhyaya, M.S., and Sayedahmad, S. (1996). California Agriculture 51(2). *Overinflated Tractor Tires Waste Fuel, Reduce Productivity*.

Sanders, R. (2006). University of California, Berkeley News, *Ethanol Can Replace Gasoline With Significant Energy Savings, Comparable Impact on Greenhouse Gases*. Berkeley, CA, Jan 26, 2006. Retrieved from http://berkeley.edu/news/media/releases/2006/01/26_ethanol.shtml.

Sustainable Agriculture Research and Education. On-farm Biodiesel 101. Retrieved on June 24, 2011 from http://www.sare.org/Learning-Center/From-the-Field/Northeast-SARE-From-the-Field/On-Farm-Biodiesel-101.

Triumpho, R. Farming: The Journal of Northeast Agriculture. *Biodiesel on the Farm*. Retrieved on June 24, 2011 from http://www.farmingmagazine.com/article-74.aspx.

United States Department of Energy, FuelEconomy.gov (2010). Advanced Technologies and Energy Efficiency. Retrieved from http://www.fueleconomy.gov/feg/atv.shtml.

University of Illinois Extension Service, Macon County. How Do You Save Fuel Expense? Retrieved from http://web.extension.uiuc.edu/macon/rr/i80_33.html.

Wisconsin Public Service Corporation. Vacuum Pump Technology, Handout. Retrieved from http://www.wisconsinpublicservice.com/business/vacuum_pump.aspx.

Appendix: New York Tax Incentives Table

CATEGORY	ELIGIBILITY PRODUCTS	TAX CREDIT AMOUNT
Sales Tax Exemption	Passive Solar Space Heat, Solar Water Heat, Solar Space Heat, Photovoltaic	100% State sales tax exemption. The exemption does not apply to solar pool heating or other recreational applications.
Property Tax Incentive	Equipment Insulation, Water Heaters, Furnaces, Boilers, Heat pumps, Central Air conditioners, Programmable Thermostats, Energy Mgmt. Systems/Building Controls, Caulking/Weather-stripping, Duct/Air sealing, Building Insulation, Windows, Doors, Solar Water Heat, Photovoltaic, Wind, Biomass, Geothermal Heat Pumps	100% of the value added to 1, 2, 3 or 4 family homes. The exemption includes general municipal property taxes, school district taxes, and special ad valorem taxes, but does not apply to special assessments.
Property Tax Incentive	Passive Solar Space Heat, Solar Water Heat, Solar Space Heat, Solar Thermal Electric, Solar Thermal Process Heat, Photovoltaic, Wind, Biomass, Solar Pool Heating, Daylighting, Anaerobic Digestion	100% exemption for 15 years installed before 7/1/1988 or between 1/1/1991 & 12/31/2014. This is a local option exemption where local governments are permitted decide whether or not to allow it.
Property Tax Incentive	Solar photovoltaic systems located in New York City	8/5/2008 to 12/31/2010: 8.75% per year for 4 years (total of 35%) 1/1/2011 to 12/31/2012: 5% per year for 4 years (total of 20%)
Personal Tax Credit	Biodiesel for residential space heating or hot water production within New York State.	$0.01/gallon for each percent of biodiesel $0.20/gallon
Personal Tax Credit	Grid connected and net metered Solar Water Heat, Solar Space Heat, Photovoltaic, Fuel Cells for Residential, Multi-Family Residential	25% for solar-electric (PV) and solar-thermal systems; 20% for fuel cells. Maximum $5,000 for solar-energy systems; $1,500 for fuel cells. 10 kW maximum for solar-electric systems, except 50 kW for solar systems owned by condominium or cooperative housing associations; 25 kW maximum for fuel cells