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Energy Efficiency & Greenhouse Gas Mitigation Opportunities

Information Sheet #4

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Information Sheet #4 – OVERVIEW

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Fast Facts

- **Trends**: Nationally, energy efficiency on farms has increased dramatically, but there are still additional cost-effective opportunities that will increase profitability and reduce greenhouse gas (GHG) emissions.
- **An imperative to act:** Actions taken on farms to improve energy efficiency and energy conservation, particularly liquid fuel conservation, can increase profits and reduce GHG emissions.
- **Concerns for implementation:** It makes sense to start with actions that are simple and provide a quick payback. Also, improving energy efficiency is important before replacing equipment such as furnaces or boilers or implementing renewable energy systems, to avoid wasting money due to over-sized energy systems. However, some changes may require too long a return on investment to warrant implementation.
- **An opportunity for proactive change:** Energy conservation can be implemented through changes in habits and practices. Energy efficiency changes can be planned as the operation changes; equipment and buildings upgrades can be prioritized according to ease of implementation and potential financial and other assistance with implementation.

Introduction

Agriculture is a source of greenhouse gas emissions (GHG) but there are Best Management Practices (BMPs) to help mitigate these emissions. On-farm energy efficiency is a critical component of reducing GHG emissions while increasing farm viability into the future.

An ACEEE (American Council for an Energy-Efficient Economy, based on Energy Information Administration and USDA data in 2000 and 1999 respectively) report finds that in the US all on-farm energy use ranks sixth out of the total production expenses (6%) and costs over $9 billion per year. The US Energy Information Administration (US EIA, 2014) reports that US crop production in 2012 used almost 500 trillion BTUs compared to just under 300 trillion BTUs for livestock production in the same year (direct energy costs). In NYS, across all types of farms, about 8% of production expenditures were on energy, about 2% higher than the national average. NYS farmers spend about 1% above the national average on energy (Brown and Elliott, 2005a). A second ACEEE analysis indicates that diesel fuel energy efficiency could offer savings as high as 50% for NYS agriculture, including motors, on-site transportation, and machinery (Brown and Elliott, 2005b). The projected savings statewide were 1 million BTUs and 14 million dollars. A 2003 NYS electrical energy audit of 32 dairy farms statewide found that four categories (milk cooling, lighting, ventilation/cow cooling, and vacuum pumps) account for 88% of all electric energy (Ludington and Johnson, 2003).

Farmers have stewarded the land for decades, making incremental changes and active improvements in practices to protect environmental resources, such as installing riparian buffers to reduce nutrient loads to nearby surface water. Energy efficiency is a BMP for addressing local and global air emissions (particulate matter and greenhouse gases). Actions taken by the farmer will benefit the farm's bottom line, help to mitigate GHG emissions, and often have other environmental benefits.

Concerns

Currently most energy comes from fossil fuels. However, fossil fuel combustion releases carbon dioxide (CO_2) into the atmosphere and is the primary cause of climate change. Agriculture is vulnerable to the impacts of climate change, such as crop and livestock responses to temperature, increased pest and pathogen pressure, variation in seasonal precipitation, and changing precipitation and therefore soil water patterns. Irrigation may be required in regions where it has not been necessary. Late frosts and high-intensity storms are more likely to reduce productivity. Increased temperatures affect livestock production, including meat, eggs, and dairy, and increased need for cooling livestock will increase energy costs.

Agriculture is also vulnerable to fluctuations in energy prices. Improving on-farm energy efficiency and reducing use helps reduce risk from price fluctuation and climate change impacts on farms.

Summary of Regulation of GHG Emissions

While there are regulations on GHG emissions from the electric sector, there are no regulations of GHG emissions from agriculture. Action in this arena continues a tradition of stewardship and voluntary action by farmers.

Goal

This Information Sheet is intended to help educators and technicians assist farms in navigating voluntary methods for reducing GHG emissions from energy efficiency mechanisms.

Summary of Potential On-Farm Energy Efficiency Strategies

Description of Strategy	Opportunities	Considerations
Energy Audit (self)	Self-Audit. Collect your major energy expenses and identify top 3 energy uses.	Self-audits may miss opportunities with greater financial benefit, e.g. Increased cooling costs might be worth the increase in milking productivity.
Energy Audit (professional)	Get a professional energy audit. These generally prioritize opportunity based on financial return on investment.	While there are some grants for free energy audits, other cost money. Be sure to ask for a second-opinion for any improvements the audit suggests.
Re-Think Farm Operations	Assess your long-term goals to identify ways to improve efficiency of new infrastructure systems.	Oversizing infrastructure now, when expecting to 'grow' the size of your operations, can actually have greater energy and financial costs. However, sizing infrastructure to allow for increased capacity can be helpful.
Consider changing your fuel supply.	Farms are great sites to produce on farm energy to improve resiliency and long-term cost effectiveness and have great benefit on climate.	While fossil fuel is now cheap, energy prices are volatile, adding additional longer-term risk. That said, alternative energy can be costly, though there may be grants for on-farm energy projects.

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Information Sheet #4 – IN DEPTH

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Target Audience: Educators and technicians helping farmers planning for environmental quality, business, and facility upgrades such as building equipment, and expansions.
Target Greenhouse Gases (GHG): Carbon dioxide (CO_2)
Background Questions by Educator to Help in Farmer Planning

- What are the largest energy costs on your farm?
  - Are they seasonal? What are the patterns?
- What are the largest energy uses on your farm (independent of cost, e.g. gal diesel, kwh of electricity)?
- What are upcoming infrastructure changes you foresee?
  - Are they connected to other equipment or systems?
- Have you had a farm energy audit?
- Are you interested in making your own energy on-farm?
- Do you foresee any large changes to your operations (increase farm size, pass onto your children)?

Agricultural Production Concerns

The National Climate Assessment (2014) reports on a range of impacts to agriculture and discusses adaptation and mitigation strategies. Crop responses to temperature, variation in seasonal precipitation, and changing patterns of precipitation leads to changes in soil water availability. Irrigation may be required in regions where it has not previously been necessary. Increased frequency of late frosts and high-intensity storms will increase the risks of yield losses. The distribution and types of pests and pathogens is changing in response to weather and climate changes. Higher temperatures affect dairy, livestock, and poultry production, increasing the need for cooling and therefore higher energy costs. Farms need to know the cost-benefit of heat stress mitigation systems as part of making investment decisions.

Human Health and Environmental Concerns

Combustion of fossil fuels for energy releases carbon dioxide – a greenhouse gas -- and other pollution such as particulate matter to the atmosphere. Greenhouse gases trap heat from the sun in the Earth's atmosphere, increasing the temperature of the atmosphere and Earth's surface. This increased temperature results in changing weather patterns and long-term changes in climate (see Information Sheet #1). Higher temperatures are a concern for many people with health issues, such as heart disease; for certain regions of the world, such as coastal regions that are experiencing rising sea level with melting ice caps and glaciers; and for farmers, as temperatures rise above optimal ranges for livestock and traditional crops.

Finally, in looking at the life cycle of energy production and distribution, there are impacts from the extraction process (exploration, developing extraction sites, drilling or mining, for example), processing, and distribution (pipelines, trucking, for example). Reduction of on-farm energy use also reduces these life cycle impacts, many of which occur either "upstream" or "downstream" of the farm.

Potential GHG Mitigation Opportunities

Agricultural energy demands and accompanying GHG emissions can be categorized into the following:

- **Electrical energy:**
  - **Infrastructure**: buildings (including lighting and cooling/heating), fixed equipment such as fans, compressors, milk plate coolers, and pumps, and processes (such as milking or cooling milk).
- **Liquid fuel:**
  - **Machinery**: including vehicles and tractors.
  - **Practices**: agricultural practices including tillage, cropping patterns, nutrient management, and water management (see Information Sheet #5, Information Sheet #6, and other AEM guides). These are included under liquid fuel because many of the practices mentioned require use of vehicles/tractors and liquid fuel.

Greenhouse gas emissions from energy use can mitigated in the following ways:

- Energy conservation; only use energy when it is truly needed. Use available technologies to maximize return on use of electrical energy.
- Improved energy efficiency of equipment or infrastructure (the main objective of this document).
- Decreased demand by improved processes.
- Improved yield per unit of energy used.
- Increased nitrogen use efficiency (reduces costs, reduces energy-intensive synthetic N production, reduces N_2O-field emissions).
- Change from fossil fuels to renewable fuels such as solar, wind or bioenergy.

MITIGATION OPPORTUNITY 1: Energy Audit

A general approach to energy efficiency starts with an energy audit, conducted either by a certified auditor or by the farmer using audit procedures developed for agriculture. Often, energy efficiency grants will require that the audit be conducted by a certified auditor. However, some practices may not be eligible for assistance or cost-sharing, but represent "low-hanging fruit" (easily implemented with favorable return on investment). In a 2003 NYS electrical energy audit of 32 dairy farms statewide, Ludington and Johnson placed lighting second of the four categories (milk cooling, lighting, ventilation/cooling, and vacuum pumps) that account for 88% of all electric energy. "Low-hanging fruit", therefore, might include replacing lights with high efficiency bulbs or fixtures, particularly in shops and barns (versus greenhouses). A self-audit will help identify those changes that will gain early savings for the farmer and perhaps help subsidize more involved changes in practices or infrastructure.

Steps towards increasing electrical energy conservation:

- Only use electrical energy when needed.
- Install equipment to minimize electrical load when starting sizable electrical demands (e.g. grain drying blowers, silo unloaders, banks of ventilation fans, manure transfer pumps). For example, use ventilation fans with high cfm/Watt; illumination systems with high lumens/Watt, and be sure fans are kept clean.
- Install equipment to optimize the speed of large electrical motors based on the instantaneous demand of the motor.
- Ensure there are no leaks in pipes – leaks cause motors to run more frequently.

Steps towards increasing energy efficiency:

- Conduct an energy audit.
- Track energy use. Energy calculators can help estimate energy use if actual consumption is difficult to measure.
- Compare to other farms – what's different? This is called bench marking. Rather than being competitive, it is meant to alert farmers to ways that they could save energy by looking at other farmers with similar operations.
- Identify and prioritize "low-hanging fruit" (see list below).
- Plan a long-term approach. Some changes can be implemented more efficiently if they are built into other planned infrastructure improvements or expansions. Long-term plans for the operation should consider such issues as siting of new buildings (for light, cooling, and transportation/hauling purposes), insulation and ventilation, efficient lighting systems, and new and efficient pumps and fans. Consider cost-benefit ratios when making plans for energy efficiency. Some changes may not result in a short enough return on investment period to warrant implementation.
- Find financing. Financing can be entirely the farmer's responsibility, such as through a loan, or can involve an application for cost-sharing through the AEM process or potentially through New York State/NYSERDA incentive programs.
- Begin implementing according to the long-term plan for the farm.

MITIGATION OPPORTUNITY 2: Implement Energy Efficiencies Identified by Audit

Categories of efficiencies related to energy efficiency include:

- **Electrical energy:**
    - Lighting efficiencies,
    - Automation and controls for heating/cooling,
    - Motor and controls maintenance,
    - Vehicle and tractor operation and maintenance,
    - Building ventilation improvements,
    - Air compressor and refrigeration systems,
    - Heat exchangers to pre-heat water,
    - Grain drying
- **Liquid fuel energy:**

- Insulation,
- Fuel storage and used oil reuse,
- Pumping and conveyance.

Examples of common Energy Efficiency and Energy Conservation low-hanging fruit:

Lighting

- Replace incandescent lightbulbs with more efficient lighting such as fluorescent, halogen, or LED (see comparison chart below).
- Check that the fixtures will accept other forms of lightbulbs.
- In cold areas, check that the replacements will handle cold starts.
- In areas such as shops that are not used 24-hours, consider timers that turn off lights at a reasonable hour or even motion detectors that turn them on and off when people arrive and leave.
- And as always, housekeeping and maintenance are important -- clean lighting fixtures to increase illumination.

KEY PERFORMANCE FEATURES FOR VARIOUS WHITE LIGHT SOURCES

Light-source type	Luminous efficacy (lm/W)	Usable output (lm/W)*	Lifetime (hours)
Incandescent lamp	17	10-17	3000
Halogen lamp	20	12-20	10,000
Cree XLamp 7090 XR (color and white)	47	47	>50,000
T12 fluorescent lamp	60	45-50	20,000
Metal-halide lamp	70	<40	5000-15,000
Cree XLamp 7090 XR-E (white)	71	71	>50,000
T8 fluorescent lamp	74	55-60	20,000
High-pressure sodium lamp	91	<50	20,000-24,000
T5 fluorescent lamp	100	80	20,000
Low-pressure sodium lamp	120	65-70	18,000

* Conventional lighting technology wastes up to 50% of the lumens generated in fixture losses. (courtesy of Cree Inc.)

Source: http://electronicdesign.com/boards/white-power-led-lights-way-160-lumen-output

Note: Use of LED (light-emitting diode) lighting is expanding beyond research greenhouses and similar settings, although their high cost requirements for fixture designs that provide good lighting uniformity, function in the greenhouse environment, and uncertainty about long term performance still may limit their adoption (NRCS, 2012). The USDA National Institute for Food and Agriculture project, Developing LED Lighting Technologies and Practices for Sustainable Specialty-Crop Production provides some additional information about LEDs for greenhouse performance (http://leds.hrt.msu.edu/; Runkle, 2014).

Insulation

- Heating and cooling pipes and ducts can be insulated relatively easily and inexpensively.
- Seal openings or gaps where pipes penetrate walls.
- Inspection of buildings (infrared scanning can be used to detect gaps inside walls) might reveal local gaps or damage to insulation that can be repaired fairly easily.
- If using spray-in foam insulation, be sure to follow manufacturer's recommendations for breathing apparatus and ventilation while installing to prevent health and safety risks. – Some types of spray foam are going to increase the fire insurance or be precluded from getting fire insurance.

Operation efficiency

- Cleaning apparatus such as fans and motor cooling vents will increase efficiency and can be integrated into other building cleaning schedules. Clean light fixtures to allow maximum illuminance.
- If relying on natural light, clean windows regularly, as well.
- Consider sensors and timers that turn equipment on and off as needed (heating, cooling, fans, lights, etc.).

BMPs for crop systems

Field equipment: ACEEE analysis indicates that diesel fuel energy efficiency could offer savings as high as 50% for NYS agriculture, including motors, on-site transportation, and machinery (Brown and Elliott, 2005b). The projected savings statewide were 1 million BTUs and 14 million dollars. For example, as shown in the Colorado State University table below, while the individual planting and harvesting activities are relatively little per acre, multiple passes of the tractor multiply the efficiency or inefficiency of your tractor. Therefore, improvement in the efficiency of the single tractor is multiplied across each pass of a field times all fields. Conservation or reduced tillage can reduce liquid fuel use.

- Idling vehicles can use up to 20% of total fuel use, so turn off machinery when not in use.
- If there are fuel tanks on the farm, locate under shade structures to keep them cool – this reduces evaporation of fuels. Regularly inspect for leaks.
- Regular maintenance of farm machinery including tune-ups, replacing filters, changing oil, and keeping tires inflated and balanced will help machinery last longer and save fuel.
- Remove unnecessary weight from vehicles to reduce fuel use.
- Use an appropriately sized tool or machine for the job so as not to waste fuel.
- Too much or too little horsepower will reduce fuel efficiency.
- Drive tractors in higher gears and at lower rpm or throttle setting to reduce fuel use but not so slow as to produce black smoke or a sluggish response.
- Consider purchasing an ATV so as not to use a full sized truck for some smaller on-farm tasks.

Average Fuel Use of Farm Activities in Gallons per Acre*

Activity	Gasoline	Diesel
Plow 8 inches deep	2.35	1.68
Chisel plow	1.54	1.10
Cultivate field	0.84	0.60
Planting row crops	0.70	0.50
No-till planter	0.49	0.35
Combine	2.24	1.60
Baler	0.63	0.45
Sprayer	0.14	0.10
Grain drying	8.40	6.40

*Estimates from Colorado State University Extension, https://ag.umass.edu/fact-sheets/reducing-energy-use-on-dairy-farm

Grain Drying: The table above also indicates that grain drying, as a single entity, is significant energy demand. If your operation does grain drying, you might want to consider targeting that process first. In some situations, more purchased energy is used to dry a crop than to grow it. Also note that the data is from a drier climate than we generally find in New York State.

- Planting early maturing corn varieties allows for more time to field-dry the crop.
- When using a moisture meter to ensure dryness of grain, make sure it is calibrated correctly by comparing the reading with another meter.

Field Practices: Switching to no-till or minimum tillage can reduce fuel use by 86% but may increase the farmer's dependence on herbicides to control weeds.

- Several conservation tillage methods exist such as zone or strip tillage where only the seeding area is plowed, or ridge and mulch till which require fewer trips across the field.
- Combining field tasks such as applying starter fertilizer and planting simultaneously or zone tillage and manure application can reduce the number of passes over a field.
- Manage manure to reduce dependence on costly fossil fuel based fertilizers.

BMPs for dairy systems

In general, dairy farms use between 800 and 1,200 kWh/cow-year of electricity, but in one study the range was from 424 to 1,736 kWh/cow-year –both in freestall operations. Data from the Center for Dairy Profitability indicates that utility costs on the average dairy farm account for less than 2% of milk production costs on all sizes of farms although utility costs per cow decreased as farm size increased. A recent study indicated that 46% of the electrical use was for milk harvesting (vacuum pump, milk cooling and water heating), another 46% was used for lighting and ventilation and the remaining 6% was for feeding, manure handling and other miscellaneous uses. Milk cooling accounted for the largest block of electrical usage at 25%, and lighting was the second largest user of electricity: 17% for tie stall barns and 26% for freestall barns.

Refrigeration and Vacuum Pumps: Dairy farms have several options for improving the efficiency of refrigeration and vacuum pumps used for milking.

- Plate coolers capture heat from milk and transfer it to cool water, partially cooling the milk before it reaches the storage tank. This can reduce cooling time by as much as 15 to 30 minutes, and the warmed water preheats hot water for other uses.
- A refrigeration heat exchanger is another energy saving device that transfers the excess heat from the milk cooler to preheat water for use in the barn.
- Another option is a variable frequency pump or drive which adjusts the pump's speed to meet the milking/pipeline washing need, resulting in energy savings of 50-80%. It is recommended that variable frequency drives be used for varying loads such as milk pumps, vacuum pumps and sometimes for ventilation fans.
- Consult with a qualified energy auditor before making any new 'energy saving' purchases to make sure they will be appropriate for your needs. Lists of auditors may be obtained from NYSERDA.

Ventilation Fans: Increased temperatures affect dairy, livestock and poultry production efficiency and ventilation/cooling will likely become a larger portion of energy costs. Therefore, investigate different types of ventilation/cooling systems:

- Tunnel ventilation
- Cross ventilation
- Slotted air inlet
- Tube fans
- Circulation/cooling fans

(See: < http://www.uwex.edu/energy/dairy_V.html>)

Selecting the most energy efficient fan may not be the best fan for the application. It is important that the fan be selected also based on achieving the goals of ventilation/cooling.

MITIGATION OPPORTUNITY 3: ReThink Farm Operations

Think strategically:

Beyond the "low-hanging fruit", what are the items revealed by an energy audit? Are there improvements that could be incorporated with other planned changes in the farm?

For example, if a building is being enlarged, renovated, or replaced, it may be cost-effective and efficient to improve insulation and heating/cooling systems at the same time. Could siting of a new building reduce cooling demands, improve natural lighting, or offer better natural ventilation?

Temperature directly impacts livestock and milk production, so ventilation and heating/cooling will be increasingly important as temperatures rise due to climate change. This interaction of temperature impacts on production with the bottom line of the operation is one example of a strategy for prioritizing improvements. Will the capital costs of ventilation and heating/cooling upgrades be recovered more quickly than other improvements that are not tied as closely to production?

MITIGATION OPPORTUNITY 4: Consider Generating Renewable Energy

While not covered in these information sheets, farms have great capacity to create their own energy. It can be in the form of biodiesel, solar, wind, anaerobic digesters, or biomass for heat or electricity, etc. Generally these renewable fuels will reduce farm GHG, but their financial viability is still subject to current fossil fuel markets, net metering rules, and infrastructure development.

Resources and Tools

- **Farm Energy Calculators**: Tools for saving money on the farm, 2008, Holly Hill, A Publication of ATTRA – National Sustainable Agriculture Information Service.
- **Grain Drying Systems**. http://alliantenergy.com/docs/groups/public/documents/pub/p010003.hcsp (see references below).
- **Energy-Efficient Agricultural Lighting**. http://learningstore.uwex.edu/assets/pdfs/A3784-14.pdf (see references below).

To learn more about opportunities to reduce GHG emissions, see other information sheets in this series:

Tier II Worksheets	Identifying Farm & Forest GHG Opportunities
Information Sheet	**Topic**
IS#1	Intro to Farm & Forest GHG
IS#2	Dairy Manure Storage
IS#3	Planning for Quantitative Methane Capture and Destruction from Liquid Dairy Manure Storage
IS#4	Energy Efficiency
IS#5	Nitrogen Fertilizer Management
IS#6	Soil Carbon Management
IS#7	Forest Management
AEM Technical Tools	Water Quality BMPs http://www.nys-soilandwater.org/aem/techtools.html

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