ENERGY CONSERVATION SERIES:

Conducting an Energy Audit

New Jersey

An energy audit is the process of assessing energy consumption, equipment or ~~a~~ facility. Farm energy audits are useful to help operators reduce the total energy used on their farm. The American Society of Agricultural and Biological Engineers (ASABE) has developed a standard for agricultural energy audits that provides a general framework for audits on farms (ASABE Standard S612, see Appendix 1). In conducting audits, energy used in all forms is quantified and evaluated to identify seasonal trends in energy use, inefficient energy use and specific opportunities for conservation.

NRCS standards and programs differentiate between the *farm headquarters* and *landscape* agricultural energy management plans. The farm headquarters plan assesses energy use and conservation opportunities related to the processing and storage of agricultural crops, feeding, housing, and processing of farm animals and animal products. Landscape plans address problems and opportunities on the working land. This fact sheet will explore the basics of conducting an audit and some specific places on the farm where energy uses should be examined.

Audit Techniques

The techniques used in conducting an audit vary according to the scope and complexity of the survey, but can include:

- Visual inspection / walk-through
- Compilation of energy records
- Characterization of equipment and systems
- Interviews
- On-site measurement and testing
- Simulation and modeling

A walk-through of a building or facility is an opportunity to quickly appraise the condition and operation of energy using systems. By itself, a walk-through audit can often identify serious shortcomings, but will not readily uncover opportunities for energy savings and improved efficiency. A review and analysis of energy records (e.g. fuel and electric bills) can be very informative in finding areas for potential improvement. When combined with building plans and basic information regarding mechanical systems and equipment, a detailed analysis of energy use and costs, preferably over a period of a year or more, can often identify significant opportunities for energy savings.

An inventory that includes a detailed description of equipment and systems within a facility often helps provide a clear picture of the overall condition and performance potential of an operation. Interviews and discussions with owners and operators may also uncover inefficient or wasteful energy use.

Checking air cleaner on equipment
PHOTO: IOWA STATE UNIVERSITY

On-site measurement and testing is often an essential aspect of a detailed audit, and can serve several purposes. Measurement of performance over a period of time can help identify both short and longer term trends that are easily overlooked in a site visit. Similarly, idiosyncratic equipment performance that may only occur in particular circumstances is more likely to show up in data recorded over a period of time. Direct measurement of equipment or system performance is often more reliable and accurate than manufacturer's data or engineering analyses. Examples of measurement and monitoring methods that might be part of an audit include using a blower door to estimate infiltration in a building, monitoring electrical power over time for a facility or individual systems or equipment, and using infrared imagery to identify poor thermal performance of building components or equipment.

Simulation can be a valuable for validating estimates of energy performance and evaluating the impact of changes and improvements. The building design, type of occupancy and range of environmental conditions in agricultural buildings are often too different from more typical commercial and institutional facilities for the models to produce reliable forecasts. Many of the general simulation tools, particularly those designed for evaluating heating and cooling energy use in buildings are not always applicable to agricultural buildings. There are models and simulation tools, however, developed for specific applications in agriculture that can be useful. Both USDA-NRCS (5) and the Sustainable Agriculture Research and Education (SARE) program (4) have online tools that can assist in verifying and projecting energy use in farm operations.

Purpose of Energy Audits

The main purpose of an energy audit is to characterize the energy use profile of a facility or operation and develop prioritized opportunities for reducing energy consumption and associated costs. An energy audit should produce at least some of the following:

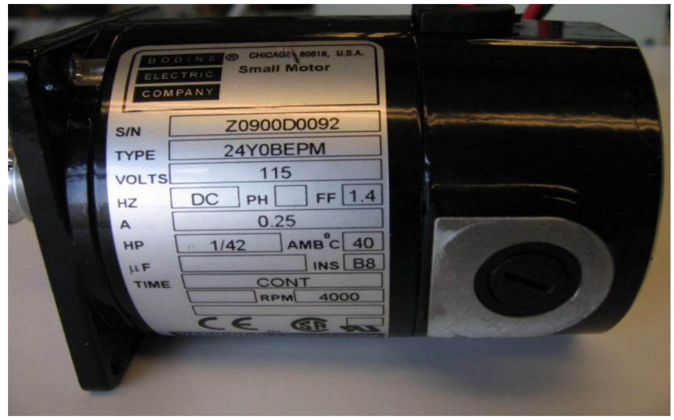
- Summary of energy use by energy resource
- Summary of use by application or location
- Identification of peak demands
- Compilation of energy use per unit
- Identification of trends
- Summary of energy costs
- Inventory of equipment and systems
- Comparison to established norms
- Identification of conservation opportunities

Energy resources include electricity as well as a variety of fuels. The table below presents the approximate energy content of different energy resources in common units. For a comparison of the relative importance of different energy resources in a particular operation it is generally useful to convert the more common units of measurement into consistent energy units such as BTUs or Joules. Although in most cases electricity is supplied to the end user by a regional electric grid, electricity can also come from on-site solar photovoltaics, generation or combined heat and power systems using conventional or other fuels such as biomass, wind or other sources. Energy for heat and other uses can also come from solar thermal systems, biomass combustion, direct use of geothermal energy, waste heat, etc. Accounting for these energy inputs can be more complicated than for energy resources purchased directly from utilities.

Energy Conversion Factors

Source: US EPA (5)

Form of Energy	Input Unit	Multiply by to Calculate kBTU
Electricity	kWh	3.41
Natural Gas	Cubic Foot	1.03
	Cubic Meter	36.34
Fuel Oil Nos. 1-4	Gallon	135.00
Fuel Oil Nos. 5,6	Gallon	149.69
LP Gas	Cubic Foot	2.52
	Gallon	91.65
Coal (anthracite)	US Ton	25090.00
Wood	US Ton	15380.00



Motor faceplate

PHOTO: BOSTON UNIVERSITY

Methodology

The following sections discuss specific techniques and methods for evaluating energy use in farm operations.

Electrical Supply: Determine the type of electrical supply, including number of phases, main current capacity in amps and main voltage. Inspect main panels to determine their condition and capacity for supporting current and future needs. Summarize monthly electrical use, including cost, usage (kilowatt hours or kWh) and demand (kilowatts or kW). For each month, calculate the average cost of electricity in cents per kilowatt-hour.

Fuel Resources: Identify the types of fuels used, storage capacity (where applicable) and condition of fuel storage and distribution equipment.

Major Equipment: Inventory large equipment, both electrical and combustion driven. A detailed inventory will include manufacturer's identifying information (make and model) and faceplate data for all major equipment. Where possible, determine the efficiency of motors, heaters, air conditioners, refrigerators, freezers and other machinery. Evaluate the condition of equipment and identify all immediate and near term maintenance needs.

When building energy is a significant portion of total operating expenses, consider an audit by a professional or, where available, auditing services provided by utility companies. A self-audit of building heating systems may include an appraisal of the following:

- Insulation (attic/ceilings, walls, basement, pipes and ductwork)
- Condition and insulating properties of windows and doors
- Weatherization (caulking, weather-stripping, seals and astragals, etc.)
- Leaks (in steam or hot water systems and ductwork)
- Temperature controls (use of electronic thermostats, temperature settings, setbacks, etc.)
- Age and condition of heating and cooling equipment.
- Equipment maintenance needs
- Efficiency of heating and cooling equipment
- Lighting

Seeding a field
PHOTO: NRCS

Evaluation of lighting includes an inventory of lighting fixtures, noting the total wattage, bulb and ballast type, and condition. Further appraisal of lighting systems includes verification that light levels are appropriate and an assessment of lighting controls.

In general, energy use for specific equipment can be estimated by multiplying the energy use rate of the device by the hours of operation. Note that this method is not reliable for equipment that has changing power use, such as variable frequency drives. Various forms of energy monitoring may be useful in situations where energy consumption rates are determined by the load. The following sections explain how to quantify energy use in particular areas around the farm.

Field Operations

The production of any crop in the field requires the use of cultivation machinery as well as chemical inputs. The energy used by machinery is primarily in the form of diesel fuel and gasoline. If the farm has a fuel storage tank with a metered outflow, records should be kept for an entire year of the total use each month. In quantifying the energy used in specific field operations, the fuel used by a specific piece of machinery must be established. The machine's fuel tank should be topped off before the operation begins, and topped off again after it ends. Record the total volume of fuel used in all fill-ups during the operation and in the last fill after it, along with the acreage covered and the hours operated by the machine. This can be compared to the Nebraska Tractor-Test Laboratory data (7).

Fertilizer, pesticide and other chemical inputs can be quantified by recording the total acreage to which a particular product was applied and, as accurately as possible, the total pounds or gallons of chemical applied.

Grain Drying

Energy used in grain drying can be quantified by calculating the total cubic feet or gallons of fuel used in the drying process, along with the total volume or weight of product dried. Where drying systems are not supplied by their own gas meter, the manufacturer's specifications for specific fuel consumption can be useful in quantifying fuel use. Multiply the total time that burners operate by the specified fuel consumption rate to estimate total usage.

Fuel use in drying can be affected in several ways. Timing of crop maturity and harvesting is significant. If grain is dried earlier in the year, temperatures tend to be warmer, which maximizes natural drying and reduces the temperature difference between ambient air and optimal drying temperatures.

Harvesting hay
PHOTO: NRCS NEW JERSEY

As with field operations, the condition of drying equipment is significant. Verify that flues and air intakes are properly adjusted and that airflow is not restricted. Equipment should be designed so that hot air is distributed evenly throughout storage systems, which is generally accomplished by the use of a generous space for air to diffuse into before entering storage vessels. Insulating exposed air ductwork and plenums can be beneficial.

Verify that burners are adjusted to manufacturers' specifications, with orifices cleaned annually. Check that thermostats are placed to accurately measure the average temperature of the volume of grain being dried as opposed to the coolest portion of it. Check thermostats for accuracy monthly. Moisture testers should be calibrated properly. Thermometers and other measuring equipment should be compared to a standard at the start of the season.

The most significant opportunity for energy conservation in grain drying, however, remains outside the mechanical drying system. As artificial drying of grains is often more energy-intensive than their production, crop harvest times should be adjusted to maximize drying in the field.

Wellhead irrigation pump
PHOTO: USDA

Irrigation

As with field equipment, energy use by irrigation equipment can be quantified by measuring fuel use where such equipment is diesel-powered. The energy use of electrically-powered equipment can be quantified as with ventilation motors, multiplying the nameplate amperage by line voltage and time the motor is estimated to be running.

Farm Heating

As with grain drying, the energy used by heating devices is often difficult to quantify. If heating systems are the only devices on the farm fired by a particular source of energy, such as natural gas, the farm's natural gas bill can be used. Similarly, individual tanks of Liquid Petroleum Gas (LPG) tanks powering only heating devices can be checked for fluid level on a monthly basis and the total gallons of LPG calculated. Otherwise, calculate the energy use by multiplying the specified energy consumption rate of the device by the time it has been in operation. Keeping records of weather during the operation of heating systems will help differentiate energy attributable to weather-related conditions from other energy uses.

Ventilation

Estimate the energy use for fans and ventilators by multiplying the nameplate amperage of motors used by voltage and the time these motors run. Where possible, checking for proper voltage at the motor terminals during motor operation can help to identify significant losses due to poor wiring.

Lighting

Farm lighting can be a large consumer of energy. Because it is rare for lighting systems to be metered separately from other energy-consuming systems, quantification of energy used in lighting can be estimated by multiplying the energy consumption rate (typically in watts) of all lighting devices by the total time those devices are on during a given period.

Greenhouses

Greenhouses tend to be very energy intensive. There are many available audit checklists that can be used to conduct detailed evaluations of greenhouse operations. Depending on the type of greenhouse, an evaluation may include any or all of the following:

- Basic Greenhouse Information (dimensions, type, location and orientation)
- Cropping information (crops, schedules, temperature settings and growing methods)
- Leakage and weather tightness (insulation, weatherstripping and condition)
- Glazing, Insulation and Heat performance (type and condition of glazing)
- Shade/Thermal Curtains (configuration, type and condition)
- Heating System and Maintenance (type of equipment, capacities and condition)
- Ventilation and Cooling Systems and Maintenance (type of ventilation, fan sizes and condition)
- Control Systems (type and capabilities)
- Insect Screening (type, installation method and condition)
- Supplemental Lighting (type, layout and total wattage)
- Electricity, general maintenance and miscellaneous

Thermal curtain in greenhouse
PHOTO: NRCS

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FURTHER READING

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This publication was developed by Rutgers Cooperative Extension, for USDA Natural Resources Conservation Service in support of Agreement No. 68-2B29-11-150.

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Appendix 1- ASABE Standard S612

Source: ASABE (1)

Major Activity	Components	Dairy	Swine	Poultry	Beef/veal	Field Crops	Fruit/ Vegetables	Aquaculture	Nursery/ Greenhouse
Lighting	Lamps, timers, sensors	X	X	X	X		X	X	X
Ventilation	Fans, control systems, variable drives, humidity control	X	X	X	X		X	X (aeration)	X
Refrigeration	Compressor, evaporator/ chiller, motor, insulation	Milk, products		Eggs			Commodity	X	Vegetables/Cut Flowers
Milk harvesting	Pumps, motors, controllers	X							
Controllers	Master system automation	X	X	X				X	X
Other motors, pumps	Types, compressors	X	X	X	X	X	X	X	X
Water heating	Heater, energy source, insulation, recovery, waterers	X	X	X	X				
Air heating/ building environment	Heater, energy source, insulation, recovery, variable drives	X	X	X	X		X		X
Drying	Energy Source, airflow, (motors/fans), control systems, handling equipment					X			
Waste handling	Collection and dispersal equipment/ methods	X	X	X	X			X	
Air cooling	Energy source, airflow, (motors/fans), control systems, evaporative cooling systems	X	X	X	X			X	
Cultural practices	Planting, tilling, harvesting, engine-driven equipment					X	X		
Crop/ feed storage					X	X	X	X	X
Water management	Wells, reservoir, recycled	X	X	X	X	X	X	X	X
Material handling	Equipment, motors, pumps	X	X	X	X	X	X	X	X
Irrigation	Motors, engines, pumps, power source					X	X		X

A check placed in an enterprise's column indicates further ASABE standards concerning the major activity listed, are availalbe for that enterprise.
See Reference (1) for further details.