



Farm Energy Audits

TOM MANNING, NEW JERSEY AGRICULTURAL EXPERIMENT STATION

INTRODUCTION

An energy audit is the process of assessing energy consumption of equipment or of a facility. Farm energy audits are a useful tool for operators to reduce energy consumption on the farm. The American Society of Agricultural and Biological Engineers (ASABE) developed a standard for agricultural energy audits that provides a general framework for conducting farm energy audits (ASABE 2009). 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 efficiency. This fact sheet explores the basics of conducting an audit and some specific places on the farm where energy use deserves examination.

Techniques for 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 uncover many opportunities for energy savings and improved efficiency. A review and analysis of energy records (e.g., fuel and electric bills) can be very informative for finding areas for improvement. When combined with building plans and basic information regarding mechanical systems and equipment, a detailed analysis of energy use and costs, preferably using data from one or more years, can often identify significant opportunities for energy savings.

An inventory and 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 can help identify specific features of an operation that sometimes uncover inefficient or wasteful energy use.

Comparing energy use to similar operations (benchmarking) can help identify potential areas for improvement.

An energy auditor may conduct on-site measurement and testing during a detailed audit or install longer-term data collection equipment. Measurement of performance over a period of time can help identify both short and longer term trends that are easily overlooked during a site visit such as seasonal energy use for irrigation. Similarly, idiosyncratic equipment performance that may only occur under particular conditions is more likely to show up in data recorded over a period of time. Additionally, 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 tool in validating estimates of energy performance and evaluating the impact of changes and improvements. 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. The building design, type of occupancy and range of environmental conditions are often too different from more typical commercial and institutional facilities for the models to produce reliable forecasts. On the other hand, there are models and simulation tools 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 AN ENERGY AUDIT

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 energy 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 an audit will often convert the more commonly used units of measurement into consistent energy units such as Btus or Joules.

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

Figure 1. Audits often convert all energy uses to a common unit of energy measurement, Btus.

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.



Figure 2. Motor nameplate (Photo Credit: Boston University)

ENERGY AUDITING 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 nameplate 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

A lighting systems evaluation includes taking inventory of lighting fixtures, noting the total wattage, bulb and ballast type, condition, and hours of operation. Further appraisal of lighting systems includes verification that light levels are appropriate and an assessment of lighting controls such as occupancy sensors.

In general, equipment energy use can be estimated by multiplying the energy use rate of the device (in watts) by the hours of operation. Note that this method is not reliable for equipment that has changing power use, such as motors controlled by 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, collect records 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. To determine fuel usage, top off a machine's fuel tank before an operation begins, and top it 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. Usage data can be compared to the Nebraska Tractor-Test Laboratory data (7).



Similarly, 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 that 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 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 important. 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

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.



Figure 3. Wellhead irrigation pump (Photo: USDA)

IRRIGATION

As with field equipment, energy use by diesel-powered irrigation equipment can be quantified by measuring fuel. 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 fueled by a particular source of energy such as natural gas, then the farm's fuel 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 heating 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

For single phase electrical service, estimate the energy use of fans by multiplying the nameplate amperage of motors by voltage and the annual runtime of the motors. 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 electricity. Because it is rare for lighting systems to be metered separately from other energy-consuming systems, lighting energy use can be quantified by multiplying the energy consumption rate (typically in watts) of all lighting fixtures by the total time those devices operate during a given period.

GREENHOUSES

Greenhouses tend to be very energy intensive. There are many readily available 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



Figure 4). Thermal curtain in greenhouse. (Photo credit: NRCS

REFERENCES AND RESOURCES

1. ASABE Standards. 2009. *S612: Performing On-Farm Energy Audits*, St. Joseph, Mich: ASABE.
2. Manning, Thomas O., “Agricultural Energy Audits: Compiling and Evaluating Energy Records”. New Jersey Agricultural Experiment Station, 2011.
3. Pedersen, Carl et. al., 2008. *Farmstead Energy Audit*, North Dakota State University Extension Service fact sheet AE-1366.
4. Friedman, D., *Clean Energy Farming: Cutting Costs, Improving Efficiency, Harnessing Renewables*, Sustainable Agriculture Research & Education.
5. United States Department of Agriculture, Natural Resources Conservation Service, Energy Tools available from <http://energytools.sc.egov.usda.gov/>.
6. United States Department of Energy. ENERGY STAR Challenge for Industry – Quick Converter. Excel-based tool for converting common energy units to Btus.
7. Nebraska Tractor-Test Laboratory. <http://tractortestlab.unl.edu/testreports.htm>

FURTHER READING

1. McLaughlin, M. B. et al. “Comparison of Energy Inputs for Inorganic Fertilizer and Manure-Based Corn Production”. *Canadian Agricultural Engineering*, Vol. 42, No. 1, 2000.
2. Miranowski, John. “Energy Consumption in US Agriculture”. *University of Iowa Staff General Research Papers*, 2004.
3. Reitz, H. J. “Energy Use In U.S. Citrus Production and Harvesting”. Pimentel, D.: Handbook of Energy Utilization in Agriculture. Boca Raton, Florida: CRC Press, 1980.

LINKS

NRCS NJ Energy page: <http://www.nrcs.usda.gov/wps/portal/nrcs/main/nj/energy/> (contains fact sheets and links to a greenhouse audit video).

This project supported by the Northeast Sustainable Agriculture Research and Education (SARE) program. SARE is a program of the National Institute of Food and Agriculture, U.S. Department of Agriculture. Significant efforts have been made to ensure the accuracy of the material in this report, but errors do occasionally occur, and variations in system performance are to be expected from location to location and from year to year.

Any mention of brand names or models in this report is intended to be of an educational nature only, and does not imply any endorsement for or against the product.

The organizations participating in this project are committed to equal access to programs, facilities, admission and employment for all persons.

