Farm Energy IQ

Farms Today Securing Our Energy Future

Farm Energy Efficiency Principles

Tom Manning, New Jersey Agricultural Experiment Station

NORTHEAST SARE Sustainable Agriculture Research & Education

Farm Energy IQ

Farm Energy Efficiency Principles

Tom Manning, New Jersey Agricultural Experiment Station, Rutgers University

---

Farm Energy Efficiency

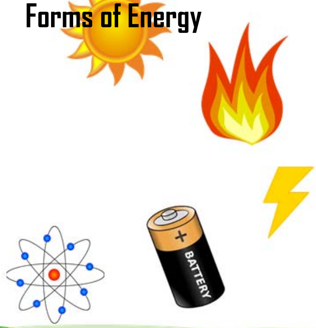
- Overview of energy and its uses
  - Basic energy principles
  - Forms of energy
  - Uses
  - Units and conversions
  - Thermodynamic principles
- Definitions of efficiency
- Typical conversion efficiencies and standards
- Principles of energy efficiency and methodologies
- Specific applications with examples
- Renewables and alternatives

Basic Energy Principles

- Energy can exist in different forms
- Energy can be converted from one form to another
- Every energy conversion process has its own efficiency
- Energy transfer should only be evaluated within a system defined by boundaries

Forms of Energy

- Kinetic
- Potential
- Thermal
- Light
- Sound
- Electric
- Chemical
- Nuclear
- Magnetic



Uses of Energy

- Heat
  - Space heating
  - Process heat
  - Water heating
  - Cooking
- Work
  - Transportation
  - Material handling
- Cooling/refrigeration
- Lighting
- Appliances and electronics

Energy Units

British thermal unit (Btu)	1	0.00095
Watt-hour	0.293	0.000278
Joule	1,055.06	1
Calorie (Cal)	252.164	0.239
Therm	1/100,000	9.48×10^{-9}

Power Units (Rates of Energy Use)

British thermal unit per hr (Btu/hr)	1	3,412
kilowatt (kW) or 1,000 Joule/sec	0.000293	1
joule/hour (J/h)	1,055.06	3,600,000
Horsepower – motor (hp)	0.000393	1.3410
Horsepower – boiler (hp)	2.99×10^{-5}	0.1019
Ton (refrigeration)	8.33×10^{-5}	0.2843

1 kilowatt (kW) = 1,000 watts (W)

Useful Energy Conversion Factors

From:	To:	Multiply by
hp (mech)	W	745.7
hp (boiler)	Btu/h	33,445.7
ft	M	0.3048
gal	L	3.79
lb	kg	0.454

Example: 2 lb = 0.908 kg

First Law of Thermodynamics

- Matter/energy can neither be created nor destroyed
- Or, you can't ever get more out of a system than you put in

Change in internal energy equals the heat transfer into the system minus the work performed by the system

Second Law of Thermodynamics

- Heat flows from a hot to a cold object
- A given amount of heat can not be changed completely into energy to do work

In other words…if you put a certain amount of energy into a system, you can not get all of it out as work.

What is efficiency?

- Generally, accomplishing a task with minimal expenditure (of time, effort, energy, etc.)
- The ratio of the useful output of a process to the total input

Energy Conversion Efficiency

- Efficiency is the ratio of the useful energy output to the source energy used (input)
- All conversion processes have maximum theoretical efficiencies less than 100%
- Many technologies are near or at their maximum theoretical efficiencies

Energy Conversion Efficiency Examples

Conversion process	Energy efficiency
Electric heaters	~100% (essentially all energy is converted into heat, however electrical generation is around 35% efficient)
Electric motors	70–99.99% (above 200W); 30–60% (small ones < 10W)
Water turbine	up to 90% (practically achieved, large scale)
Electrolysis of water	50–70% (80–94% theoretical maximum)
Wind turbine	up to 59% (theoretical limit – typically 30 – 40%)
Fuel cell	40–60%, up to 85%
Gas turbine	up to 40%
Household refrigerators	low-end systems ~ 20%; high end systems ~ 40–50%
Solar cell	6–40% (15-20% currently)
Combustion engine	10–50% (*gasoline engine 15 – 25%)*
Lights	0.7–22.0%, up to 35% theoretical maximum for LEDs
Photosynthesis	up to 6%

Source: *Wikipedia*

Typical Light Conversion Efficiencies

Lighting Technology	Energy efficiency	Lumens/watt
Low-pressure sodium lamps	15.0-29.0%	100-200
High-pressure sodium lamps	12.0–22.0%	85-150
Light-emitting diode (LED)	4.2–14.9%, up to 35%	28-100+
Metal halide lamps	9.5–17.0%	65-115
Fluorescent lamps	8.0–15.6%	46-100
Incandescent light bulb	0.7–5.1% (2.0-3.5% typical)	14-24 (typical)

Note: Lumens/watt is an indicator of efficiency, but most lighting technologies experience lamp lumen depreciation in which light output goes down over time. Therefore, retrofitting a 400-watt metal halide lamp with a 100 to 150-watt LED lamp is common and produces similar light output.

Source: *Wikipedia*

Heating Equipment Efficiencies

Heat energy source	Energy efficiency
Electric	95 – 100%
Natural gas or propane	65 – 95%
Oil	70 – 95%
Coal	70 – 80%
Biomass	65 – 90%
Wood	0 – 80%

Efficiency Standards

- AFUE (Annual Fuel Utilization Efficiency) – Estimated amount of heat delivered to the conditioned space during the year divided by the energy content of the fuel used in a fuel-fired heating system
- HSPF (Heating Seasonal Performance Factor) – Estimated amount of a heat pumps seasonal output in BTUs divided by the electrical energy consumed in watt-hours in a heat pump
- SEER (Seasonal Energy Efficiency Ratio) – Amount of cooling energy delivered during the season in BTUs divided by the electric energy consumed in watt-hours
- COP (Coefficient of Performance)

Basic Principles of Energy Efficiency

- Understand the energy issues
- Use functional and efficient controls
- Size equipment and structures appropriately
- Share resources
- Maintain equipment and facilities
- Increase production
- Pick good sites
- Use efficient architecture
- Adopt efficient technologies
- Insulate

Slide 14

JS1 Note what I added regarding electric heat. I don't like to say electric heating is 100% efficient b/c it doesn't consider source energy.
Jeannie Sikora, 1/11/2015

Understanding Energy Issues

- Energy audits provide snapshots of energy use
- Energy monitoring can provide a continuous record of energy consumption
- Utility bills provide a snapshot of energy consumption and usage patterns
- Guidelines, standards, and benchmarks help determine appropriate levels of energy use for specific applications
- Appliance and equipment efficiency ratings are to compare and determine efficiency
- Knowing how energy-using devices interact can help reduce energy waste

General Methods for Higher Efficiency

- Reduce losses
  - Reduce friction
  - Minimize resistive losses in electrical systems
  - Reduce leakage
  - Improve heat transmission
- Design to requirements
- Increase heat transfer capacity
- Use efficient equipment
- Use energy storage
- Reduce loads
- Improve conversion processes
- Use existing resources

Reducing Losses – Friction

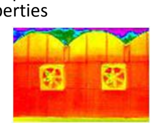
- 1/3 of a car's fuel consumption is spent overcoming friction
- Improved lubricants
- Design rolling elements to reduce rolling resistance
- Regular maintenance (e.g., tightening fan belts)
- Size ducts and piping to minimize pressure losses
- Select materials for pipe and ductwork that minimize friction
- Design plumbing and heating systems to minimize length of runs and direction changes

Reducing Losses – Electric Resistance

- Increase wire size
- Increase voltage
- Use direct current (sometimes appropriate)

Reducing Losses – Improved Heat Transmission

- Increase insulation
- Reduce surface area relative to production area or volume
- Reduce overall heat transfer properties
- Reduce infiltration losses
- Use materials with appropriate radiative properties



Photos: A.J. Both

Design for the Requirements

- Match equipment to the task
- Don't oversize heating and cooling systems
- Consider undersizing backup and secondary power sources
- Don't build space that you won't use

Energy Implications of Greenhouse Construction

Photos: A.J. Both, Rutgers University

Increase Heat Transfer Capacity

- Condensing boilers and furnaces
- Energy recovery and preheat systems
- On-demand water heaters

Using Efficient Equipment

- High efficiency lighting
  - LEDs, Fluorescent, HID
- Condensing boilers and heaters (90-98% efficient)
  - Operate on demand with no standby losses
  - Small footprint and low mass
  - Rapid response and quick heat delivery
- Variable frequency drive (VFD) motor controls
- High efficiency refrigeration and cooling equipment
  - SEER > 13 for central air conditioning
  - DOE standards for commercial refrigeration equipment

Landfill Gas Combined Heat and Power Plant

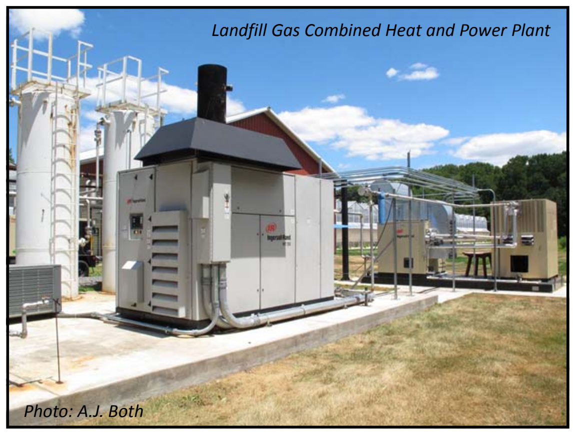


Photo: A.J. Both

Reducing Loads

- Optimize space utilization (for example, greenhouse benching layout)
- Adjust temperatures
- Lower illumination levels
- Adjust schedules

Using Existing Local Resources

- Ventilation and evaporative cooling versus air conditioning
- Using economizer cycles for air conditioning
- Ground source heating and cooling
- Take advantage of site characteristics
  - Wind breaks
- Burn waste oil

Other Opportunities…

- Understand the energy issues
- Energy storage
- Improved conversion processes
- Better controls

5,000 kW_{th} biomass boiler – Efficient combustion made possible by new designs and advanced electronic controls

Renewables and Alternatives

- Always start with improving efficiency
- Check that any new source of energy is suited for your location and site conditions
- Understand the performance potential of energy technologies without incentives

Summary

- Efficiency is a concern at every step of the processes of converting and using energy
- Overall performance depends on the specifics of the situation and processes. Optimum efficiency depends on matching the energy source to the end use and using the appropriate processes.
- The most efficient device may be the one that is switched off

Farm Energy IQ

Farm Energy Efficiency Principles

Questions?