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Energy Basics for Water and Wastewater Treatment

a presentation by

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The Schatz Energy Research Center

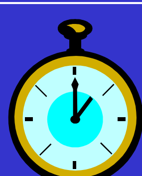
- Based at Humboldt State University
- Founded in 1989
- Mission: to promote the use of clean and sustainable energy

First, let’s define a few terms

Energy = the ability to do work

Units of energy include

- kWh (electricity)
- Therms (natural gas)
- BTU (heat)



Power = the *rate* at which work is performed

Units of power include

- kW (electricity)
- BTU/hr or BTUH (heat)

So energy is a *quantity*, while power is a *rate*.

Some common quantities and rates:

Quantity	Rate
Miles	Miles per hour (MPH)
Gallons	Gallons per minute (GPM)
kWh	kW
BTU	BTUH (BTUs *per* hour)

BTUs are not something you see on utility bills, but they're widely used for comparing energy content of different fuels or different systems of units.

100 cubic feet of natural gas = 1 therm = 100,000 BTU

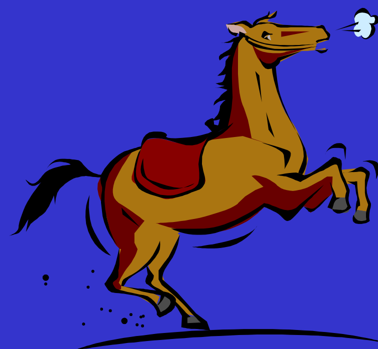
1 kWh = 3,413 BTU

1 gallon of gasoline = 125,000 BTU

1 barrel of crude oil = 5,100,000 BTU

1 cord of firewood = 30,000,000 BTU

How do you convert kilowatts to horsepower?

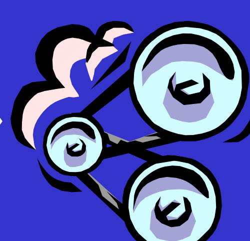


1 HP = 746 W = 0.746 kW

1 kW = 1.34 HP

Let’s do a few quick calculations

$$\text{Energy efficiency (\%)} = \frac{\text{Energy out}}{\text{Energy in}} \times 100$$

Energy in →  → Energy out

For a pump that requires 7.6 kW of electric power and produces 5 HP of thrust to the fluid:

$$\text{Efficiency} = \frac{5\ \text{HP}}{6.7\ \text{kW}} \times 100 = \frac{5\ \text{HP}\left(\frac{0.746\ \text{kW}}{1\ \text{HP}}\right)}{6.7\ \text{kW}} \times 100$$

$$= 0.56 \times 100 = 56\%\ \text{efficient}$$

Ohm's Law:

Volts X Amps = Watts

Example:

240 V X 3.2 A = 768 W = 0.768 kW ≅ 1 HP

Energy Cost Reduction Strategies

5 Basic Types

Conservation: use less energy

Efficiency: improve (increase) ratio of energy out to energy in

Load shifting: change equipment use schedules to reduce peak demand or avoid high time-of-use rates

Fuel switching: find a less expensive type of energy to get the job done

Rate shopping: change rate schedule or energy supplier to pay less per unit of energy

Conservation Example

Imperial Lighting Maintenance Company

Take half the tubes out of fluorescent fixtures in an area that's overlit

Efficiency Example

Replace a 72% efficient pump with an 80% efficient model

Load Shifting Example

Reschedule some daytime pumping operations to take advantage of time-of-use utility rates.

Fuel Switching Example

Replace electric space heaters with propane- or natural gas-fired radiant heaters.

Rate shopping

Ask PG&E for an electric rate comparison and switch rates if the analysis shows an advantage.

Energy Use at Water and Wastewater Facilities

- Water and wastewater pumping and treatment use about 4% of all electricity consumed in the U.S. ($^4/_5$ for pumping, $^1/_5$ for treatment)
- The EPA estimates that water and wastewater treatment plants will need to increase their capacity by 5-8% over the coming decade to keep up with demand.

Energy Use at Water Treatment Plants

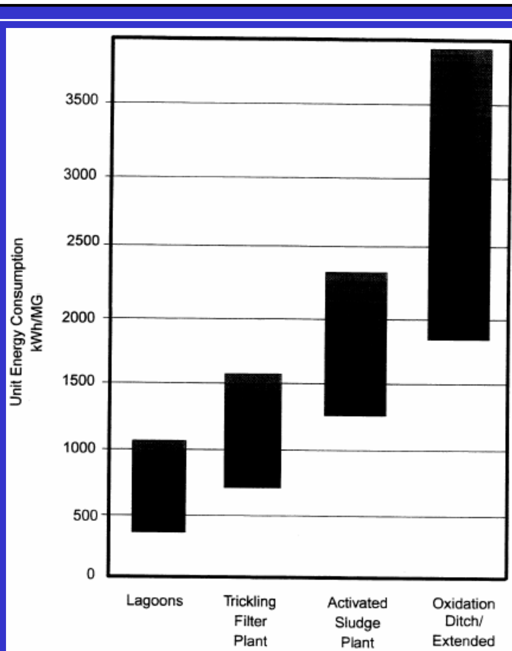
- In surface water systems, most energy is used for treatment.
- In ground water systems, most energy is used for pumping.
- Overall, ground water systems use ~20% more total electric energy than surface water systems.

Source: EPA

Energy Use at Wastewater Treatment Plants

- Wastewater treatment is the single biggest electricity use for most local governments.
- At the plant, energy makes up 25-40% of total operating costs, second only to labor.

Source: EPA



RANGES OF UNIT ENERGY CONSUMPTION FOR SECONDARY WASTEWATER TREATMENT PLANTS

Source: EPRI, Energy Audit Manual for Water/Wastewater Facilities

Types of WWTPs and Their Energy Use

- Lagoon: low energy use, but slower process and need lots of space
- Trickling filter: most appropriate for smaller plants
- Activated sludge: most common technology, uses lots of energy for aeration

Pumps, Blowers, and Motors

Pumps and Blowers are the main energy users at WWTPs: ~86% of total electricity use

- 46% for pumping
- 40% for aeration

U.S. National Archives and Records Administration

Main end uses of electricity:

- •Wastewater, sludge, and scum pumping
- •Aeration (blowers)
- •Stirring or agitation (clarifiers, RBCs)

Common Cost-Effective Opportunities for Reducing Pump, Blower and Motor Energy Costs

✓Replacing old and inefficient equipment

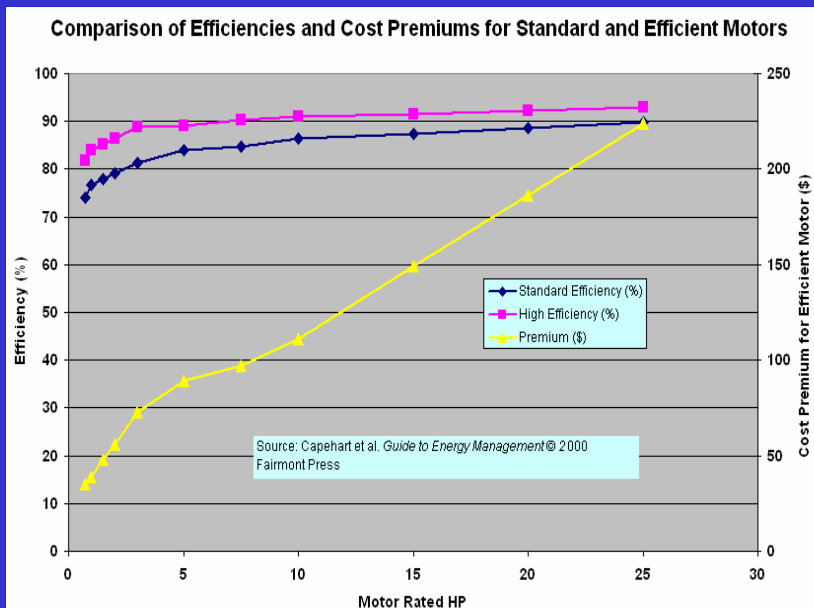
✓Matching equipment to loads

✓Using variable frequency drives (VFDs)

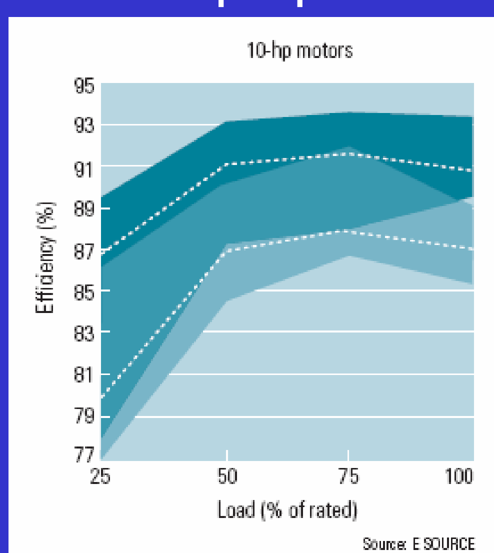
✓Measures to improve efficiency of whole drive system

- •Belts
- •Lubrication
- •Maintenance

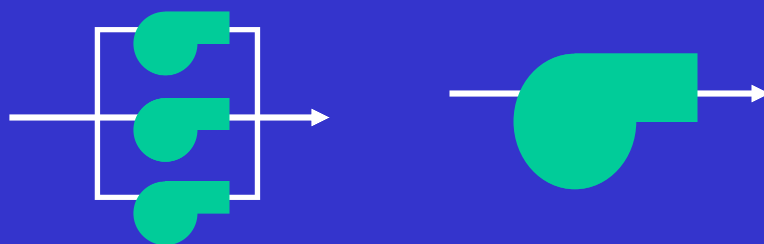
Specify efficient motors at replacement time



Match Equipment to Loads (don't oversize pumps or blowers)



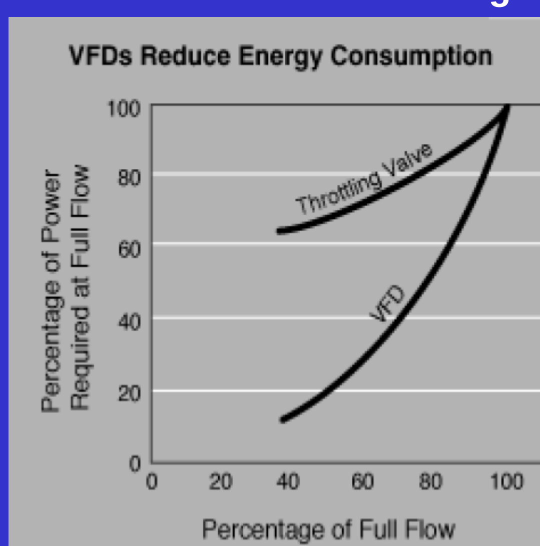
Staged Pumps



Multiple small pumps in parallel vs. 1 big pump

- More redundancy for greater security
- Higher operating efficiency at all flow levels

VFDs are a much more efficient way to control flow than throttling



California Energy Commission

Other Opportunities to Reduce Plant Energy Costs

- ✓Load shifting
- ✓Fine-pore aeration
- ✓Renewable electric generation
  - Solar photovoltaics (PV)
  - Wind
- ✓Biogas recovery
  - Thermal use to speed biological processes
  - Electricity generation
  - Both (cogeneration)

Energy Economics

To perform a basic economic analysis of any energy saving project, consider costs and savings.

Costs

- Materials
- Labor
- Administrative costs (procurement, permits, etc.)
- Recurring costs (maintenance)

Savings

- Energy savings (kWh, therms)
- Demand savings (kW)
- Labor savings, if any
- Equipment savings, if any

} Convert all to $/year

Economic Tests

- Simple Payback
- Return on Investment
- Life Cycle Cost

Simple Payback

$$\text{Simple Payback (yrs)} = \frac{\text{cost}}{\text{annual savings}}$$

Return on Investment

$$\text{Simple ROI (\%)} = \frac{\text{annual savings}}{\text{cost}} \times 100$$

Life Cycle Cost

Neither Simple Payback nor Simple ROI takes into account the changing value of money over time.

Life cycle cost (LCC) of a measure is the *net present value* of all future costs and savings. LCC requires more calculation, but it gives a more complete and "real" economic evaluation that considers time value of money.

LCC is a great tool for comparing alternatives.

To learn more about LCC, download:
www.oit.doe.gov/bestpractices/pdfs/pumplcc_1001.pdf

Utility Rates

Saving energy and saving money aren't always the same thing:

- Switching rate schedules may allow you to save $ without making any change in total energy use or treatment volume.
- Reducing peak demand for any demand-metered account can cut demand charges. Strategies may include staggering operations to reduce the number of pieces of equipment being run at any given time.

Please contact me if you have any follow-up questions:

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