Electrical Systems

Lighting

Lighting uses about 1/4 of all electricity in the U.S. [1]

- Standard incandescent bulbs produce 10-20 lumens per watt
- Fluorescent lights produce 30-110 lumens per watt
- 90% of the power inputted to incandescent bulbs is lost as heat
- compact fluorescent (CFL) bulbs can screw into regular light sockets
- CFLs last 13 times longer than incandescent bulbs and use only 1/4 the energy
- CFLs provide about 13 lumens per watt
- Each CFL saves $25-$50 over the lifetime of the bulb depending on the energy rate
- CFLs should be installed in locations where they will be used for at least 2-3 hours per day to achieve the best return on investment
- See http://www.rmi.org/hebs/heb1/cheaper.gif for a cost comparison of CFLs with incandescent bulbs
- Halogens are about 10% more efficient than incandescent bulbs
- The use of large windows to allow for day lighting can greatly reduce the lighting load of a building
- Day light can be maximized by using wide window sills, light coloured walls, and atria to help the light penetrate into the building
- Occupancy sensors help to eliminate excess lighting
- The use of low level ambiance lighting combined with specific task lighting can greatly reduce the lighting load while making areas more productive at the same time
- High-pressure sodium lamps provide 150 lumens per watt
- Metal halide lamps provide 65 lumens per watt
- A standard 40W incandescent bulb lasts 1000 hours
- A 40W fluorescent bulb lasts 8000 hours
- A 35W high-pressure sodium lamp lasts 16000 hours
- A 50W high-pressure sodium lamp lasts 24000 hours
- Thought should be given to the use of sensors to automatically adjust lighting levels based on occupancy and the level of natural light reaching an area. This will help to ensure proper lighting levels and save money by reducing the number of unnecessary lights being left on.

Solar Electric Energy

- Photovoltaic cells convert sunlight directly into electricity
- Flat plate photovoltaic (PV) arrays can be mounted at a fixed angle facing south, or they can be mounted on a tracking device that follows the sun
- PV energy systems can be as small as a few solar cells or as large as an array of PV modules
- About 10-20 PV arrays can provide enough power for a household [2]
- For large electric utility or industrial applications, hundreds of arrays can be interconnected to form a single large PV system
- Typical commercial PV cells have an efficiency of approximately 15%, or in other words, 1/6 of the sunlight that strikes the cell generates electricity [3]
- Most modules are about the size of a coffee table top, but it is possible to manufacture them in many different sizes
- State-of-the art PV technology is known as Building-Integrated Photovoltaics (BIPV)
- BIPV is a construction material, such as a roof shingle or a sheet of glazing, with PV cells directly laminated onto it

Bioenergy

- Bioenergy is the use of organic matter to produce electricity, transportation fuels, or chemicals
- Sources of bioenergy include agricultural, forestry residues, and the organic component of municipal and industrial wastes
- If burned efficiently, oxygen from the atmosphere combines with the carbon in plants to produce carbon dioxide and water
- Burning new biomass contributes no new carbon dioxide to the atmosphere, as long as harvested biomass is replanted
- The total annual production of biomass is estimated at 2740 Quads (1 Quad = 10, 000, 000, 000, 000, 000 Btu's) [4]

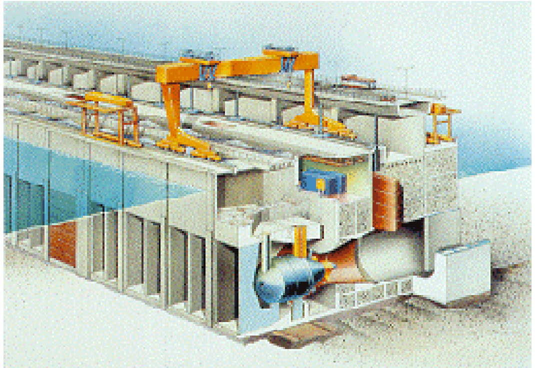
- Biomass production is about 8 times the total annual world consumption of energy from all sources
- Currently, the world population uses only about 7% of the annual production of biomass – only partially exploiting natures abundant renewable resource [5]

Hydrogen

- Hydrogen is non-polluting, abundant, and a clean source of electricity for lighting, heating, and cooling
- Hydrogen gas is not found in its natural state on earth and therefore must be manufactured. One method of producing H_2 is through electrolysis – splitting water into its basic elements. This process involves passing an electric current through water to separate the atoms.
- This process costs approximately 10 times as much as natural gas, however technological advances in renewable electricity could make electrolysis more affordable in the future

Ocean Energy

- Power can be produced from either the movement of waves and tides (mechanical energy) or the temperature differences that exist in the ocean (thermal energy)
- Oceans cover more than 70% of the earth's surface making them the worlds largest solar collectors
- Ocean thermal energy is used for electricity generation. There are three types of electricity conversion systems:
  - Closed-Cycle: The ocean's warm surface water is used to vaporize a fluid, which has a low boiling point (such as ammonia). The vapor expands and turns a turbine. The turbine then activates a generator to produce electricity
  - Open-Cycle: Seawater is boiled while operating at low pressures. This produces steam that passes through a turbine/generator and produces electricity
  - Hybrid: Combination of both open and closed cycles
- Ocean mechanical energy uses tides (driven by the gravitational pull of the moon) and waves (are driven primarily by the wind) as sources of energy
- Electricity conversion of both tidal and wave energy usually involves mechanical devices. A barrage (dam) is typically used to convert tidal energy into electrical by forcing the water through turbines, activating a generator and producing electricity



Cross section of a tidal barrage [6]

- For wave energy conversion, there are three basic systems:
  - Channel Systems: Funnel waves into reservoirs
  - Float Systems: Drive hydraulic pumps
  - Oscillating Water Column Systems: Use waves to compress air within a container
- The mechanical power created from these systems either directly activates a generator or transfers to a working fluid, water, or air which then drives a turbine or generator

Wind Energy

- Small wind energy systems can be used in connection with an electricity transmission and distribution system (grid-connected system) or in stand alone applications (not connected to a utility grid)
- A grid connected system can reduce the amount of utility-supplied electricity for lighting, appliances, and electric heat Conditions for Stand - Alone Systems [7]:
  - You live in an area with average annual wind speeds of at least 9 miles per hour
  - A grid connection is not available
  - The cost of running a power line to a remote site to connect with the utility grid is costly ($15000 to $50000 U.S.). This depends largely on terrain.
  - You are interested in being independent from your electricity company

  - You would like to reduce the environmental impact of electricity production

- Conditions for a Grid Connected System [8]:
  - You live in an area with average annual wind speeds of 10 miles per hour
  - Utility supplied electricity is expensive in your area
  - The utilities requirements for connecting your system to the local utility grid is not overly expensive
  - Local building codes allow you to legally erect a wind turbine on your property
  - You are comfortable with long term investments

Additional Considerations

- Research potential, legal and environmental obstacles
- Obtain cost and performance information from manufacturers
- Perform a complete economic analysis
- Understand the basics of a small wind turbine system
- Review possibilities for combining your system with other energy sources, backups, etc.
- Find out if some utility companies offer rebates or other incentives that can offset the costs of purchasing and installing a wind system
- Other considerations include maintenance costs and the time required to maintain the system. All wind systems consist of a wind turbine, a tower, wiring and the balance system components (controllers, batteries, etc.)

- Wind Turbines:
  - Home turbines consist of a rotor, a generator, and a tail
  - The rotor captures the kinetic energy produced by the spinning blades and converts it to rotary motion to drive a generator
  - Rotors can have two or three blades. The best indication of how much energy a turbine will produce is the diameter of the rotor (the larger the rotor, the more energy produced)
  - The tail is required to keep the turbine facing in the direction of the wind
- Towers:
  - Wind speeds increase with height in flat terrain, thus the turbine is mounted on a tower
  - Generally, when the tower is mounted higher, the wind system can produce more power
  - A general rule is to install a wind turbine on a tower with the bottom of the rotor blades at least 30 ft (9m) above an obstacle that is within 300ft (90m) of the tower [9]
  - There are two types of towers: self supported (free standing) and guyed tower
  - Most home models use a guyed tower as they are less expensive
  - This system consists of guy cables, earth anchors, and a relatively inexpensive framework (made of metal strips)
  - The guy radius must be 1/2 to 3/4 of the tower height. Therefore sufficient space is required to install these systems [10]
- Balance of System
  - Stand-alone systems require batteries to store excess power for use when there is little or no wind. To keep the batteries from overcharging, a charge-controller is required.
  - Deep-cycle batteries (i.e. used to power golf carts) can discharge and recharge approximately 80% of their capacity hundreds of times
  - In small systems, direct current appliances operate directly off the batteries
  - Standard appliances require conventional alternating current and in this case, an inverter must be installed to convert direct current to alternating current

Case Study 1: Wind Power Economics of a Home System

Note: This case study was taken directly from the web site below. To learn more about wind energy systems and to see a list of manufacturers, please visit: http://www.eren.doe.gov/erec/factsheets/wind.html

In this analysis, we have assumed a certain set of conditions, such as wind regime, maintenance costs, etc. Your analysis will differ for your set of circumstances. This case study is for illustration purposes only.

A New England homeowner is considering taking out a 20-year loan to purchase a $10,000 wind system (turbine, tower, inverter, and battery storage) for generating her own electricity, instead of paying her full electricity bills for the next 20 years.

Assume that the wind turbine she has chosen is rated at 3 kilowatts with the turbine 80 feet (24 meters) above the ground. She lives in a Class 4 wind regime (average wind speed of 12.5 to 13.4 miles per hour [5.6 to 6 meters per second] measured at 33 feet [10 meters] above the ground).

Given these assumptions, the turbine can produce an estimated 9000 kilowatt hours (kWh) per year, or 750 kWh per month. Also assume for the sake of simplicity, that she will use all of the electricity herself and will not sell any back to the utility. Therefore, the value of the electricity to her is equal to the retail price she pays the utility; in this case, 12 cents per kWh.

If she continues to pay her electricity bills without the wind turbine, the retail value of the electricity is $1,080 the first year. In later years, the price of electricity increases. For this analysis, we assume that the cost of electricity increases at the same rate as inflation—3% a year. Thus, the 9000 kWh will cost $1,112 in the second year, $1,146 the third year, and so forth, until the total inflation-adjusted cost of electricity for 20 years is $29,020.

She can obtain the least-expensive loan by taking out a second mortgage on her home. She can borrow $10,000 at 8%, and make payments of $1,019 for 20 years. But she can deduct the portion of her payments that go toward interest at her 30% combined federal and state tax rate. Thus, after taxes, her annual payment is $779 for the first year, and increases to $996 as the interest deduction decreases in later years.

However, there are other costs to owning a wind turbine. Her property taxes will be higher because the wind turbine increases the value of her property. She will pay additional insurance since her standard homeowner's policy does not cover liability from the wind tower. And she will hire a local mechanic to climb the tower and grease the bearings every year. Altogether, she figures these operations and maintenance (O&M) costs will be about 1 cent/kWh or $100 per year in today's dollars. Let us assume for this analysis that taxes, insurance, and labor rates increase at the same rate as inflation. Thus, annual O&M costs increase to $175 in the 20th year. So, over 20 years, her total inflation-adjusted cost for buying a wind system is $19,678.

However, our example is still not complete. Economists tell us that future dollars are worth less than present dollars. It is better to have money now, rather than in the future, so we can use it to invest and earn more money. Even though inflation increases her annual electricity payments after 20 years to $1,894, those are future dollars, so they are worth less than today's dollars. Economists refer to this devaluation as the net present value factor, the rate at which future dollars are discounted compared to present dollars. This discount rate is equal to the rate of return that she could make on an investment of equivalent risk and liquidity to a wind turbine. In this evaluation, assume her opportunity for return on investment with today's dollars (i.e., the discount rate for her future dollars) is 10% a year.

Therefore, projecting her electric utility payments into the future to, say, the end of the first year, the dollars are worth 90% of what they were at the beginning of the year. At the end of the second year, the dollars are worth 90% of what they were at end of the previous year. (Notice the value of her future dollars depreciates at a compounded rate.) Considering these adjustments, her annual electricity payment in the 20th year is actually worth only $156 in today's dollars. Thus, her total cost of buying electricity for 20 years, adjusted for inflation and present value factors, is only $8,927 in today's dollars.

Another way to think of it is that her payment in the 20th year is really a deferred payment. She does not have to pay $29,020 today. Since the utility company allows her to pay her bills as she uses the electricity, she does not have to make any large capital expenditures. So she has more of her money to invest for 20 years. This would not be true if she had to pay for 20 years of electricity up front.

But net present value factors also apply to purchasing a wind system, because she is making deferred payments on her loan. Her payments of $1,154 in year 20 are really worth only $95 in today's dollars, for instance. Therefore, her total cost for buying a wind system, adjusted for inflation and net present value, is only $6,426 in today's dollars.

So in real terms, she saves $2,501 over 20 years by purchasing a wind system, as opposed to continuing to pay her electricity bills. An added benefit is that she would avoid the release of 40 tons (40 metric tons) of carbon dioxide, 800 pounds (363 kilograms) of nitrogen oxide, and 280 pounds (127 kilograms) of sulfur dioxide into the atmosphere. The amount of pollution that a utility company in the Northeast would emit to supply her electric load for 20 years, on average.

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