Chapter 10
Energy for Tomorrow: Solar and Other Renewable Energy Resources

Earth’s Ultimate Energy Source
- Provides more energy than we need to solve all of our energy needs...
- But at low concentration

- Fossil fuels are hard to beat for concentrated energy content.

Hydroelectric Power
- Considered to be a form of solar energy
- Clean, efficient, renewable
- Major limitation: small number of dammable rivers in the U.S.
  - 42% already have dams
- Also threats to marine life, potential dam failure, impact on the river as a whole
- Main areas for growth: developing nations
Wind Power

• Another indirect form of solar energy.
• The Sun heats air which expands and rises; cooler air rushes in to fill the void, creating wind that can turn a turbine.

Advantages and Disadvantages

• Price is competitive with coal
• Clean
• Efficient
• Renewable
• Releases nothing into the atmosphere
• Unattractive
• Uses lots of land
• Winds are intermittent and uncontrollable
• Secondary energy source or storage mechanism is necessary
Solar Thermal Energy

- Concentrating and focusing the sun’s rays with mirrors generates enough heat at the focal point to produce steam and turn a turbine, generating electricity.

- Three designs:
  - Solar power towers ($0.12/kwh, $0.05 for coal)
  - Parabolic troughs ($0.12 per kwh)
  - Dish/engine ($0.15 per kwh)

- Prices continue to drop as technologies improve.
- The cost per kilowatt hour of coal is $0.05.

Solar Two/Solar Power Tower

Parabolic Troughs

- Troughs trap and focus sunlight onto a receiver pipe through which flows synthetic oil.
- In a heat exchanger, water is heated to steam to turn a turbine.
Dish/Engine

- Dish-shaped reflectors focus sunlight onto a central receiver which becomes the heat source for a conventional engine or turbine.
- Can be hybridized to use other fuels when sunlight is insufficient for operation.

Photovoltaic Energy

- PV cells found on watches and calculators are the most familiar of solar technologies.
- The ultimate energy source (besides the sun) since there are no moving parts, no noise, and no pollution
- They are made from controllable semiconductors.
Method of Operation

• An n-type silicon sample is brought in contact with a p-type in what is called a p-n junction.
• Light excites electrons and allows them to flow from the n-side to the p-side.
• These mobile electrons are forced to travel through an external wire, powering an appliance.
• Presently expensive and inefficient, but cost is dropping dramatically and they have found a number of commercial applications.

Energy Storage

• Storage in the form of heat is easiest but of short duration.
• Batteries quickly increase the cost of the energy production method.
• Every conversion means a loss of energy to surroundings.
• It is always more efficient to use electricity as it is generated.

EXAMPLE 10.2

Square Meters of Solar Cells

Suppose you are installing 1 MW solar panels in a remote location and want to run 300 W of lights, a 500 W refrigerator, and two 100 W fans. If the efficiency of the PV cells is 8.5%, how many square meters of PV cells are needed?

Solution

Because the cells are 8.5% efficient, the input power must be:

\[ P_{in} = \frac{P_{out}}{0.85} \]

The total area of PV cells required is:

\[ A = \frac{P_{out}}{P_{in} \times \text{Efficiency}} = \frac{300}{1000 \times 0.85} = 35 \text{ m}^2 \]
### Energy Storage

- Energy can be stored in chemical bonds.
- Solar energy can be used to decompose water and the resulting hydrogen and oxygen gases stored.
- The combustion of hydrogen can be used at a later time to liberate the energy.
- Nature's heat tax will take some of this energy.

\[
2\text{H}_2\text{O} + \text{energy} \rightarrow 2\text{H}_2 + \text{O}_2 \\
2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O} + \text{energy}
\]

### Biomass

- Energy stored in plant material during photosynthesis can be liberated when the plants are burned.
- Plants can be burned
  - Directly (fast-growing plants)
  - After fermentation (typically as ethanol)

\[
\text{C}_6\text{H}_{12}\text{O}_6 \rightarrow 2\text{CH}_3\text{CH}_2\text{OH} + 2\text{CO}_2
\]

### Geothermal Power

- Heat from Earth’s interior is used to generate steam to turn a turbine.
  - In rare cases, steam from the earth is used directly.
- Disadvantages include:
  - Limited availability
  - Spent-steam disposal
  - Contains sulfurous gases and ammonia
Nuclear Power

- Heat from controlled fission can be used to heat water and turn a turbine.

Advantages and Disadvantages

- No smog production
- No CO₂ emissions
- Radioactive waste
- Supply of U-235
- Public fear of accidents and concerns over waste disposal have halted growth in the U. S.

Breeder Reactors/Fusion

- Can solve the problem of U-235 supply

\[
\begin{align*}
^{238}\text{U} + {}_{0}\text{n} & \rightarrow ^{239}\text{U} \\
^{239}\text{U} & \rightarrow ^{239}\text{Np} + {}_{0}\text{e} \\
^{239}\text{Np} & \rightarrow ^{239}\text{Pu} + {}_{0}\text{e}
\end{align*}
\]

- Development of controlled nuclear fusion would make nuclear a very attractive source of energy.
Efficiency and Conservation

- Conservation efforts coordinated with developing energy technologies will help stabilize energy costs.

### Table 2-1

<table>
<thead>
<tr>
<th>Use</th>
<th>Baseline Values</th>
<th>Percent of Baseline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Space heating</td>
<td>6.80</td>
<td>94</td>
</tr>
<tr>
<td>Air conditioning</td>
<td>4.60</td>
<td>0</td>
</tr>
<tr>
<td>Water heating</td>
<td>1.00</td>
<td>47</td>
</tr>
<tr>
<td>Electrical end-use electricity (including water)</td>
<td>0.94</td>
<td>30</td>
</tr>
</tbody>
</table>

More natural gas now used to meet energy and space heating needs. Gas is more efficient. Transfer of waste reduces the need for additional fuels. See tables for complete data.  

Natural gas powered appliances are more efficiently used than electric ones.
The 2050 World

- Who is the real winner with respect to new energy technologies?