Alternative Energy

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Objectives:
1. Gain a fundamental understanding about alternative energy;
2. Be able to discuss about advantages and disadvantages of each alternative energy
source;
3. Comprehend the close connections between biofuels, food production, and agriculture.
4. Capable of explaining the hope imbedded in the so-called economy of scale.

Terms and Concepts:
Relative quantities of potential energy resources, Solar constant, Economies of scale

Alternative Energy: Introduction

As we have discussed, fossil fuels are not sustainable, and burning fossil fuels has caused
global warming and other environmental impacts. Nuclear power has various issues and
difficulties for further development. It is in this context that we explore alternative energy
sources. These alternative energy sources include solar, wind, hydroelectric, and
geothermal power, and biofuels. We will briefly discuss each one in the following
subsections.

Quantities of potential energy from alternative sources:
(a table here)

US energy consumption
(a figure here)

The estimated amounts of potential energy sources in the table above tell us that solar
energy has the largest capacity and that wind energy has the second largest capacity. The
rest kinds have limited capacities.

How much alternative energy is used?
Globally, as of 2005, alternative energy production only contributes approximately 8% of total energy production.

According to the data given by the Energy Information Administration, alternative energy consumption in the U.S. only contributes 6.8% of total energy consumed, as of 2007, but is projected to grow faster than other energy sources.

You may wonder why alternative energy has not become the main source of energy, even though it has been in the horizon for several decades now. Hopefully, you will find some information which may help you to formulate an informative answer to this question.

**Solar Energy**

The huge potential:  (web link here)

Solar constant: $1.366 \text{ kW m}^{-2}$.

Total solar power reaching the Earth's surface: $78 \times 10^{15}$ W or 78 quadrillion W or 78 petaW ($3.14 \times 6371 \times 2 \times 1000000 \times 1366 \times 0.45$) with 3-5% variability. This amount of energy is equivalent to 6000-7000 times the total global energy use now (as of 2008). Therefore, solar energy has the highest potential among all alternatives.

Passive use of solar energy has a long history with us such as in building designs, sun drying, and greenhouses.

However, recent increase in solar energy use is in two primary forms: solar thermal collection and photovoltaics. The installation of solar water-heating systems in the US has been increasing at an annual rate approximately 15-40%, while photovoltaics are being installed in the US at a similar rate of increase in recent years. So an optimistic person can say that the age of solar energy is surely coming. But, the reality is, though, less than 1% of our energy use in the US is from direct solar sources.

Pros of solar energy: (1) sustainable; (2) relatively low environmental impacts (e.g., no greenhouse gas emissions).
Cons of solar energy: (1) temporal and spatial variability; (2) manufacture-associated pollution and old-equipment recycling; (3) economic concerns.

Wind Energy

Wind power originates from solar radiation, and drives air circulation locally and globally. Wind power has the second highest potential among all alternatives.

Using wind power has been part of our history such as windmills-driven water pumps. Our recent increase in wind power conversion has been primarily in the form of electricity generation. In recent years, wind-generated electricity has been increasing at approximately 30% per year.

(figures here)

The pros of wind energy: (1) sustainable if there would not be real climate change; (2) relatively low environmental impacts.

The cons of wind power: (1) even higher variability than solar energy; (2) windmills may kill birds; (3) use large land area; (4) degrade scenic value.

Hydroelectric Power

Quantities of potential energy from alternative sources? (Web link here)

No exception, hydropower also originates from solar radiation and stored as gravitational energy. In the US, the total hydroelectric power is about 80,000 MW, which is close to 10% total electricity used in the US. Most suitable sites for hydropower have been developed in well-developed nations than underdeveloped nations. Overall, global hydroelectric power has been increasing at a relatively steady rate (see the figure below).

(figures here)

Pros and cons of hydroelectric power:

The major advantage is that it is “clean” and can be sustainable if there would not be any climate change in the region. However, Building dams inevitably floods a lot of land which is a major impact to the local communities. The built dam alters water ways and influence aquatic ecosystems. Sediment accumulation in the dams is a common issue. Larger dams can have other big problems such as induced earthquakes, safety issues, and large capital required.
Geothermal Energy

Quantities of potential energy from alternative sources (link here).
(figure here)

Based on the data shown above, geothermal energy only contributes a small fraction of total energy use in the U.S. However, it has been on the rise as indicated by the data shown in the following two figures:

(figure here)

U.S. Capacity of Geothermal Heat Pump Shipments (1 ton = 12,000 Btu/hr):

(figure here)

Because of the “spotty” nature of geothermal energy, it is limited to some special locations, and is exposed to the dangers of plate tectonic activities and volcanic eruptions. But the good thing is that thermal electricity generation only produces approximately 10-15% of the CO2 and other pollutants from coal burning.

For example, the Geysers in California:
(photo here)
The Geysers, comprising 30 square miles along the Sonoma and Lake County border, is the largest complex of geothermal power plants in the world. Calpine, the largest geothermal power producer in the U.S., owns and operates 15 power plants at the Geysers with a net generating capacity of about 725 megawatts of electricity - enough to power 725,000 homes, or a city the size of San Francisco.

Biomass Energy and Biofuels

U.S. energy consumption 2007:
(Figure here)

As commonly known, wood and other biomass have been the main source of energy throughout human history until the discovery and extraction of fossil fuels. The current attempts to produce liquid fuels or electricity using biomass have encountered several difficulties. One of them is the relatively low energy density of biomass as compared to fossil fuels (typical heating values of coals of 25,000-35,000 kJ/kg as compared to biomass of 13,000-21,000 kJ/kg).

Producing liquid fuels from land: Liquid biofuels:
The recent fast increase in crude oil price has stimulated a new round of interest in developing liquid biofuels. However, there are numerous issues and difficulties associated with liquid biofuels.

It is a very complex process as shown by the following figure:
(a figure here)

Given all the stimulus actions around the world, the production of liquid biofuels is still limited in quantity.
(a figure here)

It becomes apparent that the potential for liquid biofuel production is small, because it is part of agriculture and competes with food production.
(a figure here)

With all given subsidies, the economic outcome of liquid biofuels is still challenging.
(figures here)

Further more, the commonly hoped reduction of greenhouse gas emission by liquid biofuels remains a big question, if the extra emission associated with land use changes is included in the analysis (Read this article for more information--Searchinger et al. 2008).
(a figure here)

More serious is the competing nature of biofuels with food production and consumption. It becomes a moral issue.
(a figure here)

In general, special configuration is required for long-lasting and economical production of liquid biofuels at a relatively constrained scale in the world.

**Summary: Economies of Scale**

As commonly believed, the relatively high costs of alternative energy sources have been regarded as the main holding factors before faster development and replacing fossil fuels. One mechanism of hope is that, as time and market goes larger, the so-called "economies of scale" will bring the costs down. This is shown by these figures here:
(Figures here)
Source: Mark Hammons, International Energy Agency

However, it is clear that policy and people's will ultimately determine how fast alternative energy can replace fossil fuels.
Questions for the video:
1. What are the main approaches being advocated in the video as ways of producing renewable energy?
2. What are the advantages and disadvantages associated with each approach?