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Types of Renewable Energy

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Types of Renewable Energy

Credits: 4 PDH

Course Description

This course provides a brief overview of various alternative energy technologies. Topics covered include: solar, wind, biological fuels, hydrokinetic and marine energy; as well as fuel cells, Biohydrogen, coal gasification, and alternate nuclear technologies.

Topics

- Carbon neutral and negative fuels
- Photovoltaic based solar energy
- Passive and active solar systems
- Types of concentrated solar plants
- Marine energy - tidal and wave energy
- Ocean Thermal Energy Conversion (OTEC) technology
- Biological fuels
- Algae (green diesel)
- Biogas digestion
- Biohydrogen
- Biomass
- Geothermal and enhanced geothermal
- Onshore and offshore wind farms
- Hydroelectric
- Coal gasification
- Fuel cells
- Thorium nuclear power
- Liquid Fluoride Thorium Reactors (LFTR)

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Chapter 1: Introduction

Section 1: Intro

Alternate Energies

Throughout civilized history, there have been several key periods of change and transition from existing energy sources to newer and more practical alternatives.

> **Fossil Fuels**
> The term "fossil fuel" refers to hydro-carbon fuels which are extracted from beneath the Earth's surface. These fuels are derived from prehistoric deposits of organic material transformed over time into solid, liquid, and gaseous hydro-carbons. Coal, crude oil, and natural gas, are all forms of fossil fuels.

The main cause of these transitions has historically come from the imminent depletion of the existing fuel sources. However, with the present situation with the widespread consumption of fossil fuels, there has also been the need to limit environmental damages caused by this fuel source.

Coal as an Alternative to Wood Burning

In the early medieval centuries, Europeans lived in the midst of a vastly forested terrain. However, with increasing human populations came deforestation, where by around 1500 AD the supplies of wood for heating, lighting and cooking began to run out.

On the brink of total deforestation there was a shift to the use of soft coal for heating and cooking needs. By the late medieval period, coal had become the new "alternative fuel" to save the European society from its overuse of the previously dominant fuel source, which was wood.

Petroleum: an Alternative to Whale Oil

In the early 19th century, whale oil was the main source of lubrication and lamp oil fuel (lighting).

However, the depletion of the whale populations by the middle of the century caused whale oil prices to soar, bringing about the move to petroleum-based lighting and lubrication products.

Modern Transition away from Petroleum

The modern day need to develop energy sources as alternatives to hydrocarbons has come about both for environmental necessities, (principally the limitation of carbon dioxide emissions and other greenhouse gases), as well as for the long term, future sustainability of our energy supplies.

In planning a future for humanity, converting to sources of energy which do not cause damage to the environment, has become the present day challenge.

With a world population of nearly seven billion people with ever-increasing appetites for power, we must find energy sources that will never become depleted.

Various Types of Alternative Energy:

- ***Hydroelectricity*** – generating energy from the falling of water, using hydrodynamic turbines
- ***Nuclear energy*** - uses nuclear fission to release energy stored in the atomic bonds of heavy elements
- ***Wind energy*** - generation of electrical power from wind, by the use of various forms of aerodynamic turbines
- ***Solar energy*** – use of sunlight as thermal (heat) energy to power steam turbines, or sunlight to be converted directly into electricity using photovoltaics.
- ***Geothermal energy*** - use of the earth's internal heat to generate direct heating or to generate steam for electrical power
- ***Marine energy*** – wave, OTEC and tidal

- ***Hydrokinetics*** – energy in moving water
- ***Biological fuels*** - plant-derived gasoline substitutes for powering vehicles, or fueling steam turbines
- ***Hydrogen*** - can be used as a carrier of energy, produced by various technologies such as cracking of hydrocarbons or water electrolysis
- ***LFG (landfill gas)*** – captured natural gases from landfill (municipal solid waste) decay
- ***Coal gasification*** – conversion of coal to syngas and other products

Section 2: A Need for Clean and Renewable

Both Clean and Renewable

When it comes to alternate energy sources, not all clean energy is a renewable source and not all renewables are clean-burning and 100% efficient.

Finding ever-replenishable energy resources, which will not cause irreparable damage to our environment, is the ideal goal.

Clean vs. Polluting Energy

Certain types of renewables still possess a rather large carbon footprint when consumed. Typically, resources which require combustion in order to generate energy output will create some form of greenhouse gas byproduct.

Renewable vs Non-renewable

- ***Renewable energy*** - is generated from naturally occurring resources, such as sunlight, wind, rainfall, tidal movements and geothermal heat. All sources which can be continually replenished.
- ***Non-renewable energy*** - is generated from inground resources such as fossil fuels (long decayed organic matter), coal, inground natural gas resources, and nuclear energy resources.

Use of Natural Gases

Natural gas is considered a clean gas, because it generates 50% less CO2 output than coal. Though it still does not have a near zero carbon footprint as with solar and wind technologies.

Natural gas is made up mostly of methane, and methane, when unburned, is roughly 70 times worse than carbon dioxide as a greenhouse gas.

To perceive natural gas as a semi-clean source of energy, it would have to be burned with a near complete efficiency, consuming 100% of the gases taken from the ground.

Studies have found that if as little as 3 percent of the methane which is produced escapes, we may as well be burning coal, from a climate perspective.

Types of renewable/sustainable energy sources:

- Biomass such as wood, etc. - polluting
- All types of solar - clean
- All types of wind - clean
- Tidal and Wave - clean
- OTEC (Ocean Thermal Energy Conversion) - clean
- Hydroelectric - clean
- Geothermal – minimally polluting
- Coal gasification - polluting
- LFG (landfill gas) - polluting
- Biological fuels - polluting

Types of non-renewable energy sources:

- Fossil fuels - polluting
- Coal - polluting
- In-situ natural gas - polluting
- Nuclear - polluting

Section 3: Carbon-neutral or negative fuels

Carbon-neutral or Negative Fuels

Carbon neutral and negative fuels are synthetics such as methane, gasoline, diesel, jet fuel or ammonia which are produced by:

- hydrogenating waste carbon dioxide recycled from power plant flue-gas emissions
- recovered from automotive exhaust gas
- derived from carbonic acid in seawater

Why Carbon Neutral?

Such fuels are considered carbon-neutral or negative, because they do not result in a net increase in atmospheric greenhouse gases.

Commercial fuel synthesis companies have suggested they can produce synthetic fuels for less than petroleum fuel when the costs exceed $55 per barrel of crude.

Carbon negative fuels - Greenhouse Gas Remediation

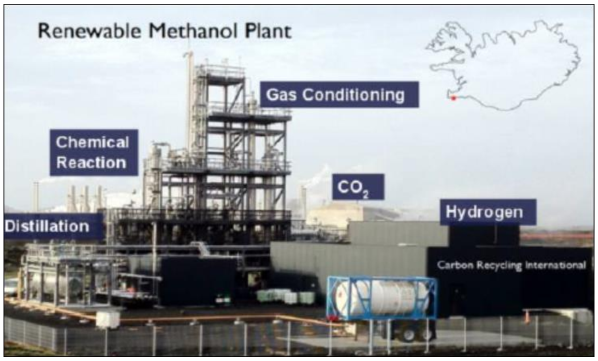
To the extent that synthetic fuels displace fossil fuel sources, or are produced from waste carbon or seawater carbonic acid, and their combustion is subject to carbon capture at the flue or exhaust pipe, they result in negative carbon dioxide emission and net carbon dioxide removal from the atmosphere, and thus constitute a type of greenhouse gas remediation.

Producing Synthetic Fuel using Wind Power

Utilizing wind power at night is considered the most economical type of electrical power with which to synthesize fuel, because the load curve for electricity peaks sharply during the day, but wind tends to blow slightly more at night than during the day, so, the price of nighttime wind power is often much less expensive than any alternative.

Methanol - Most Energy-efficient Fuel

The most energy-efficient fuel to produce is methanol which is made from a chemical reaction of a carbon-dioxide molecule with three hydrogen molecules to produce methanol and water.



Renewable methanol (RM) is produced from hydrogen and carbon dioxide by catalytic hydrogenation where the hydrogen has been obtained from water electrolysis. It can be blended into transportation fuel or processed as a chemical feedstock.

Dimethyl Ether

Researchers have also suggested using methanol to produce dimethyl ether. This fuel could be used as a substitute for diesel fuel due to its ability to self-ignite under high pressure and temperature.

It is already being used in some areas for heating and energy generation. It is nontoxic, but must be stored under pressure. Octane and ethanol can also be produced from carbon dioxide and hydrogen.

Chapter 2: Solar Energy Tech

Section 1: Photovoltaic Solar Systems

Applications for Photovoltaic (PV) Cells include:

- ***Off-grid applications*** - in developing countries and off-grid rural conditions: for use in rural power, water pumping, irrigation, lighting, and agricultural purposes.

- ***Grid-connected applications*** – grid-connected applications for PV systems, can be divided into two groups: those which form part of the centralized grid system, and those which form the sub-section of building integrated photovoltaic systems (BIPV).
- ***Industrial applications*** – applications such as the powering of low voltage communication units in remote locations where the requirement for reliable, maintenance-free, independent power is required.

Principles of PV Technology

When light strikes certain semiconducting materials such as silicon, gallium arsenide or cadmium sulphide, fabricated in the form of a p-n junction, an electric current will flow through an externally connected circuit.

About 80% of PV cells presently manufactured are based on a crystalline silicon structure (image).

Electrical contact is made via the busbars (the larger silver-colored strips) and fingers (the smaller ones) which are printed on the silicon wafer.

Section 2: Passive Solar Thermal Systems

Passive Solar Design

In passive solar building design, proper use is made of the building's materials along with creative design principles, to heat and cool an environment.

By combining energy efficiency measures with passive solar design techniques for energy collection, storage and distribution, energy requirements for a building can be greatly reduced.

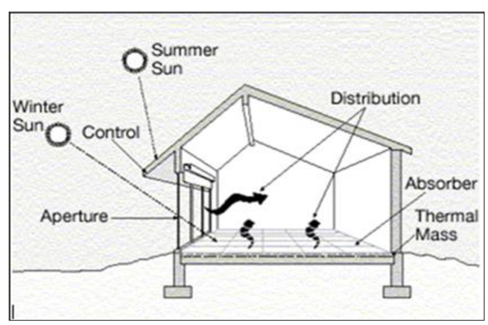
Direct Gain Passive Systems

This type of system is the simplest passive design technique. Solar light enters a building through the aperture (collector), usually south-facing windows with a glazing material made of transparent or translucent glass.

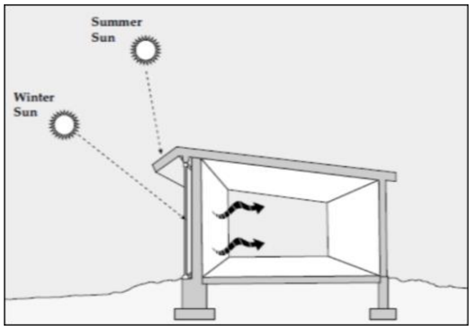
The sunlight then strikes dark colored masonry floors or walls, which absorb and store the solar heat.

Indirect Gain Passive Systems

An indirect-gain approach uses a thermal storage space between the south-facing windows and the living environment.



Using a Trombe wall is the most common indirect-gain approach.



The wall consists of an 8 to 16 inch-thick masonry wall on the south side of a house. A single or double layer of glass is mounted about 1 inch or less in front of the wall's surface. Solar heat is absorbed by the wall's dark-colored outside surface and stored in the wall's mass, where it radiates into the living space. The Trombe wall can release warmth over a period of several hours.

Isolated Gain (Sunspaces)

A sunspace, solar room or solarium, is a versatile approach to passive solar heating. A sunspace can be built as part of a new home or as an addition to an existing one.

The simplest and most reliable sunspace design is to install vertical windows with no overhead glazing. Sunspaces may experience high heat gain and high heat loss through their abundance of glazing.

The temperature variations caused by the heat losses and gains can be moderated by thermal mass and low-emissivity windows.

Physics of Heat Movement

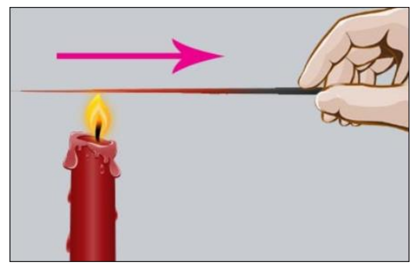
As a fundamental law of thermodynamics, heat moves from warmer mass to cooler mass until the temperatures are equalized. A passive solar building uses this principle with three heat movement mechanisms, to distribute heat throughout a living environment.

Heat Movement Mechanisms:

- Conduction
- Convection
- Radiation

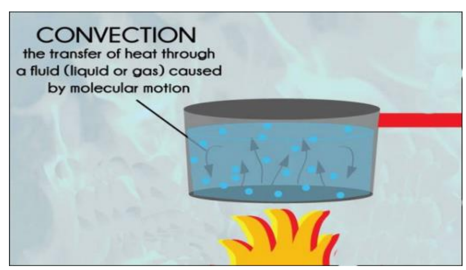
Conduction

This is the way heat moves through materials, traveling between adjacent molecules. Heat causes the molecules close to the heat source to vigorously vibrate. These vibrations spread to neighboring molecules, thus transferring heat energy. For example, a frying pan conducts heat through its handle, and into the hand of the cook.



Convection

This is the means in which heat circulates through liquid or gas mediums. Lighter, warmer fluid rises, while the cooler, denser fluid sinks. Warmer air will rise, being lighter than the cold air.



This is why warmer air accumulates on the second floor of a house, while the basement stays cool. Some passive solar homes use air convection to carry solar heat from a south wall into the building's interior.

Radiation

When radiation strikes an object, it is absorbed, reflected, or transmitted, depending on certain properties of that object.

Thermal radiation moves from a warmer surface to a cooler one. Roofs receive the majority of the radiation delivered to a house.

Two types of radiation relative to passive solar design:

- solar radiation
- infrared radiation

Section 3: Active Solar Thermal Systems

Active Solar Design

Active solar energy systems operate on the same principles as passive systems except that they use a transfer fluid (such as water or glycerin) to absorb and transmit the heat.

A solar collector located on the roof heats the fluid, and then pumps it through a network of piping to warm a structure with radiant heat, or to heat domestic water.

Absorbers

The most commonly used active method to convert solar energy into heat is by the use of flat plate collectors.

These consist of:

- the absorber plate
- tubes or channels integrated with the collector absorber plate, carrying the transfer fluid
- an absorber plate which is normally metal and with a black surface
- insulation to minimize heat losses
- casing for protection against the weather
- pumps or fans for the circulation of the heat

Collectors

Collectors come in a variety of designs, with combinations of flat, grooved or corrugated shapes to transfer the absorbed solar radiation from the surface.

Heat can be removed by circulating the lower levels of water through a heat exchanger without disturbing the upper layer. Advanced collectors are necessary for temperatures above 212 F because of the large heat losses of simple flat plate collectors.

Solar ponds with a blackened bottom can also be used as a collector to potentially reach water temperatures near to boiling temperatures with a collection efficiency of 15 to 20% using salt concentration to ensure that the density of water increases towards the bottom, thus preventing circulation by convection.

Section 4: Concentrated Solar Plants

Concentrating Solar Power (CSP)

Concentrating solar power (CSP) plants use mirrors to concentrate the energy from the sun to drive traditional steam turbines or engines that create electricity.

The thermal energy concentrated in a CSP plant can be stored and used to produce electricity when needed, even in the nighttime hours.

Areas of high direct normal solar radiation are required, in order to concentrate the sun's energy. Areas with cloudy, diffused sunlight are not compatible with these types of solar energy systems.

Production potential in the U.S. Southwest is exceptionally higher than the remainder of the country.

Parabolic Trough Systems

These systems use parabolically-curved mirrors

(image) to focus the sun's energy onto a receiver tube that is centered at the focal point of the cross sectional parabola. In the receiver tube, a high-temperature heat transfer fluid (such as a synthetic oil) absorbs the solar energy, reaching temperatures of 750°F or higher, and passes through a heat exchanger to heat water and produce steam.

The steam drives a conventional steam turbine power system to generate electricity.

A typical solar collector field contains hundreds of parallel rows of troughs connected as a series of loops, which are placed on a north-south axis so the troughs can track the sun from east to west. Each collector module is typically 15-20 feet in height and 300-450 feet in length.

Compact Linear Fresnel Reflector (CLFR) Systems

CLFR systems (see image) use the same principles in their design as curved-mirror trough systems,

but with long parallel rows of lower-cost flat mirrors.

These modular reflectors focus the sun's energy onto elevated receivers, which consist of a system of tubes through which water flows. The concentrated sunlight boils the water, generating high-pressure steam for direct use in power generation and industrial steam applications.

Power Tower

Power tower systems utilize a central receiver system, allowing for higher operating temperatures and greater efficiencies. Computer-controlled flat mirrors (heliostats) track the sun's rays along two axes and focus solar energy on a receiver at the top of a high tower.

The focused energy is used to heat a transfer fluid (over 1,000° F) to produce steam and run a central power generator.

When using molten salt as a transfer fluid and thermal energy storage medium, energy storage can be efficiently incorporated with these projects, allowing for full time, 24 hr. power generation.

Stirling Dish-Engine

Mirrors are distributed over a parabolic dish surface and arranged to concentrate the sunlight onto a receiver fixed at the focal point.

Unlike other CSP technologies that employ steam to create electricity using a turbine, a dish-engine system (Image below) uses a working fluid such as hydrogen that is heated to 1,200° F in the receiver to drive an engine such as the Stirling engine. Each dish rotates along two axes to track the sun.

Chapter 3: Hydrokinetic and Marine Energy

Section 1: Marine energy

Marine Energy

Large bodies of water such as the oceans, seas, and lakes offer nearly unlimited access to untapped energy. Some potential sources of marine-based energy are: wave action, tidal action, oceanic thermal differentials, and ocean or river currents.

Types of Hydrodynamic Devices:

- ***Wave energy converter*** - machine able to exploit wave power
- ***Tidal barrages or dams*** – these capitalize on the potential energy within basins such as estuaries; relying on the predictable ebb and flow of coastal tides to drive the turbines.
- ***In-stream turbines*** – these capitalize on the kinetic energy in fast-moving rivers or channels to drive the turbines
- ***Ocean current turbines*** – uses the kinetic energy in regions of strong oceanic currents
- ***(OTEC) Ocean thermal energy converters*** – relies on the thermal differentials between cooler deep and warmer shallow or surface seawaters to run a heat engine and produce electricity.

Waves

Wind-driven waves, or surface waves, are created by the friction between wind and surface water. As wind blows across the surface of an ocean or lake, the continual disturbance creates a wave crest, which transmits energy, not water.

Waves can also be caused by the gravitational pull of the moon and the sun; these are called tides. However, waves are most commonly caused by the wind.

Tides

Tides are long-period waves that roll around the planet as the ocean is "pulled" back and forth by the gravitational pull of the moon and the sun as these bodies interact with the Earth in their monthly and yearly orbits.

Spring Tides

During full or new moons, which occur when the Earth, sun, and moon are in near alignment, average tidal ranges are slightly larger. This occurs twice per month.

The moon appears new (dark) when it is directly between the Earth and the sun. The moon appears full when the Earth is between the moon and the sun.

In either case, the gravitational pull of the sun is added to the gravitational pull of the moon on Earth, causing the oceans to bulge a bit more than usual. This means that high tides are a little higher and low tides are a little lower than average. These are known as spring tides.

Spring tides, derived from the concept of the tide "springing forth," occur twice each lunar month all year long, without regard to the season.

Neap Tides

Seven days after a spring tide, the sun and moon are at right angles to each other. When this occurs, the bulge of the ocean caused by the sun partially cancels out the bulge of the ocean caused by the moon.

This produces moderate tides known as *neap tides*, meaning that high tides are a little lower and low tides are a little higher than average. Neap tides occur during the first and third quarter moon, when the moon appears "half full."

Section 2: Tidal Energy

Tidal Energy

One of the more promising sources of marine-based energy is tidal energy. Tidal energy is derived from harnessing the energy from the movement of the marine currents.

Two types of technology involved in extracting energy from the tides:

- The capture and use of the potential energy (stored energy) within a storage basin
- The conversion of the kinetic energy (energy of motion) of tidal streams

Tidal Dams or Barrages

One of the simplest means to extract tidal energy is to construct a dam (or barrage) across an estuary channel or inlet.

Tidal barrages are one of the oldest types of tidal power generation, with projects dating back to the 1960s, such as the 1.7 megawatt Kislaya Guba Tidal Power Station in Russia.

Within the dam are multiple turbines used to generate electricity (see image, below). Instead of damming water on one side as with a conventional dam, a tidal barrage first allows water to flow into a basin (bay or river) during high tide, and then releases the water from the basin during low tide.

This is done by measuring the tidal flow and controlling the sluice gates at key periods of the tidal cycle. Turbines are placed at the sluices to capture the energy as the water flows in and out.

Ebb Generation

The storage basin is filled through the sluices until high tide; then the sluice gates are closed. At this stage additional pumped water may be required to raise the level further. The turbine gates remain closed until the sea level drops enough to create sufficient head across the barrage.

The turbine gates are then opened so that the turbines generate until the head is again low. Then the sluices are opened, turbines disconnected and the basin is refilled to repeat the cycle. Ebb generation or outflow generation, is so named because the generation occurs as the tide changes tidal direction.

Flood Generation

The storage basin is filled through the turbines, which generate at tide flood. This is typically less efficient than ebb generation, because the volume contained in the upper half of the basin, where ebb generation operates, is greater than the volume of the lower half (filled first during flood generation).

Therefore, the available level difference, important for the turbine power produced, between the basin side and the sea side of the barrage, reduces more quickly than it would with ebb generation.

Rivers flowing into the basin may further reduce the energy potential, instead of enhancing it as in ebb generation. This is not an issue with the "tide lagoon" model, without river inflow.

Environmental Issues

The construction of large tidal plants alters the flow of saltwater in and out of estuaries, changing the hydrology and salinity Marine life that use the estuaries as their habitat can also be adversely affected.

Potential Issues resulting from the Construction of a Tidal Barrage:

- ***Turbidity*** - (the amount of matter in suspension in the water) decreases as a result of the smaller volumes of water being exchanged between the basin side and the ocean side. This allows sunlight to penetrate the water at a greater depth, improving conditions for the phytoplankton. This propagates up the food chain, causing a general change in the ecosystem as a whole.
- ***Salinity*** - As a result of less water exchange with the sea, the average salinity inside the basin decreases, also affecting the ecosystem. Tidal Lagoons do not have the same issues.
- ***Sedimentation*** - Estuaries often have high volume of sediments moving through them, from the rivers to the sea. The introduction of a barrage into an estuary may result in sediment accumulation within the barrage, affecting the ecosystem and also the operation of the barrage.

- ***Marine life*** - Fish may move through sluices safely, but when these are closed, fish will seek out turbines and attempt to swim through them. Also, some fish will be unable to escape the water speed near a turbine and still be sucked through. Even with the most fish-friendly turbine design, fish mortality rates per pass are approx. 15%.

La Rance Plant - 20 year case study in ecosystem damage from tidal barrage structures

The La Rance plant (see image), off the coast of northern France, was the first and largest tidal barrage plant project in the world. It is the only site where a full-scale ecological evaluation of the impact of a tidal power system has occurred.

In studying the effects of the tidal barrage on the ecosystem, French researchers found that the isolation of the estuary during the construction phases of the tidal barrage was detrimental to flora and fauna. However after ten years, there appears to have been a variable degree of biological adjustment or adaption to the new environmental conditions.

Some species lost their habitat due to construction, but other species colonized the abandoned habitats, causing a shift in the biodiversity of the estuary. Also as a result of the construction, sandbanks disappeared, the local beach was badly damaged, and high-speed currents have developed near the sluice gates.

Section 3: Wave Energy

Wave power is the transport of energy by wind waves, and the capture of that energy to perform work (electric power generation, water desalination, or the pumping of water into reservoirs.) Once the wave energy is captured at a wave source, power must be carried to the point of use or to an electrical grid connection using transmission power cables.

Wave power differs from the diurnal flux (pattern that recurs every 24 hours) of tidal power and the consistency of an ocean gyre (large system of circulating ocean currents.)

Wave-power generation is not currently a widely utilized commercial technology, although there have been attempts to use it dating back to 1890 or further.

Wave power devices

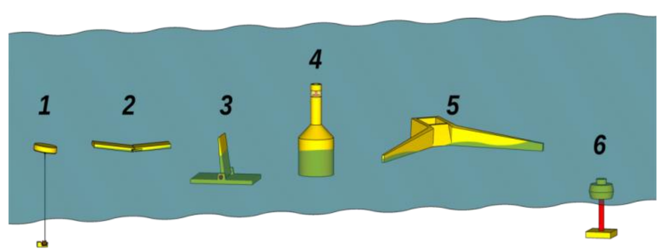
A machine able to exploit wave power is generally known as a wave energy converter (WEC). Wave power devices are generally categorized by the method or approach used to capture the energy of the waves, by location and by the power take-off system.

System locations are either:

- shoreline
- nearshore
- offshore

Common approaches to capturing wave energy:

- 1) point absorber buoys
- 2) surface attenuators
- 3) oscillating wave surge converter
- 4) oscillating water columns
- 5) overtopping devices
- 6) Submerged pressure differential



Types of power take-off include:

- hydraulic ram
- elastomeric hose pump
- pump-to-shore
- hydroelectric turbine

- air turbine
- linear electrical generator

Point Absorber Buoy

This wave energy device floats on the surface of the water, secured by cables connected to the seabed. Buoys use the rise and fall of swells to drive hydraulic pumps to generate electricity.

The EMF generated by electrical transmission cables and acoustics of these devices may be detrimental to marine organisms.

The presence of the buoys may affect fish, marine mammals, and birds as potential minor collision risk and roosting sites.

Potential also exists for entanglement in mooring lines. Energy removed from the waves may also affect the shoreline, resulting in a recommendation that sites remain a considerable distance from the shore.

Surface Attenuator

These wave energy devices work in a similar manner as point absorber buoys, with multiple floating segments connected to one another, oriented perpendicular to the incoming waves.

A flexing motion is created by swells that drive hydraulic pumps to generate electricity.

Environmental effects are similar to those of point absorber buoys, with an additional concern that organisms could be pinched in the joints.

Oscillating wave surge converter

These types of devices usually have one end which is fixed to a structure or the seabed while the other end is free-moving.

Energy is collected from the relative motion of the body compared to the fixed point. Some of these designs incorporate parabolic reflectors as a means of increasing the wave energy at the point of capture.

Oscillating wave surge converters often come in the form of:

- floats
- flaps
- membranes

Environmental concerns with this type of device include:

- minor risk of collision
- artificial reefing near the fixed point
- EMF effects from subsea cables
- energy removal effecting nearby sediment transport

Oscillating Water Column

These devices can be located on shore or offshore. With an air chamber integrated into the device, swells compress air in the chambers forcing air through an air turbine to create electricity.

Environmental concerns include the significant amount of noise produced as air is pushed through the turbines, potentially affecting seabirds and other marine organisms within the vicinity. There is also concern about marine organisms getting trapped or entangled within the air chambers.

Overtopping Device

These are long structures that use wave velocity to fill a reservoir to a greater water level than the surrounding ocean.

The potential energy in the reservoir height is then captured with low-head turbines. Devices can be either on shore or floating offshore.

Environmental concerns of floating devices:

- the mooring system can affect benthic organisms
- organisms may become entangled
- EMF effects produced from subsea cables can affect marine life
- low level turbine noise
- wave energy removal can affect the nearfield habitats

Submerged Pressure Differential

Submerged pressure differential based converters are a newer technology which utilizes flexible reinforced rubber membranes to extract wave energy.

These converters use the difference in pressure at different locations below a wave to produce a pressure difference within a closed power take-off fluid system. This pressure difference is usually used to produce flow, which drives a turbine and electrical generator.

Challenges

In terms of socio-economic challenges, wave farms can result in the displacement of commercial and recreational fishermen from productive fishing grounds, can alter the pattern of beach sand nourishment, and may represent hazards to safe navigation.

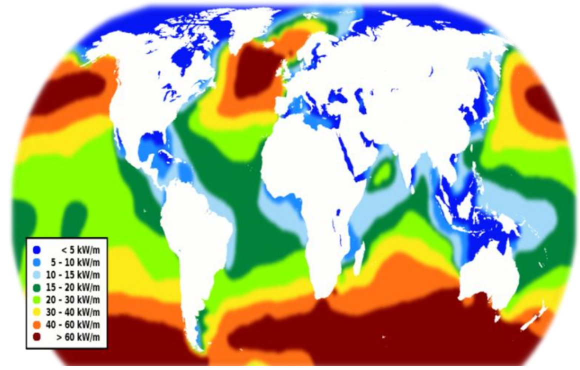
Common environmental concerns associated with marine energy developments include:

- risk of marine mammals and fish being injured by device mechanisms
- EMF effects and underwater noise emitted from operating marine energy devices
- presence of marine energy projects and their potential to alter the behavior of marine life, and seabirds with attraction or avoidance
- potential effect on nearfield and farfield marine environment and processes such as sediment transport and water quality

Global Potential

The worldwide resource of wave energy potential has been estimated to exceed 2 TW (see map image below). Locations with the most potential for wave power include the western seaboard of Europe, the northern coast of the UK, and the Pacific coastlines of North and South America, Southern Africa, Australia, and New Zealand.

The north and south temperate zones have the best sites for capturing wave power. The prevailing westerlies in these zones blow strongest in winter.



Section 4: Ocean Thermal Energy Conversion (OTEC) Energy

OTEC Technology

Ocean thermal energy conversion (OTEC) uses the thermal differential between the cooler deep and the warmer shallow or surface seawaters to run a heat engine and produce work, usually in the form of electricity.

OTEC is a base load electricity generation system. (The base load on a grid is the minimum level of demand on an electrical grid over a span of time.

Base load power sources are those which can economically generate the electrical power needed to satisfy this minimum demand.

Among ocean energy sources, OTEC is one of the continuously available renewable energy resources that could contribute to base-load power supply.

The resource potential for OTEC is considered to be much larger than for other ocean energy forms. Up to 88,000 TWh/yr of power output could be generated from OTEC without affecting the ocean's thermal structure.

Closed or Open Systems

Systems may be either closed-cycle or open-cycle. Closed-cycle OTEC systems use a working fluid that are typically thought of as refrigerants such as ammonia or R-134a.

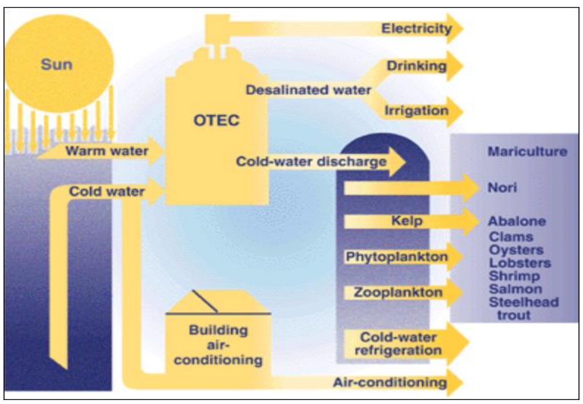
These fluids have low boiling points, and are therefore suitable for powering the system's generator to generate electricity.

The most commonly used heat cycle for OTEC to date is the Rankine cycle, using a low-pressure turbine. Open-cycle engines use vapor from the seawater itself as the working fluid.

Cold and Fresh Water Byproducts

OTEC can also supply quantities of cold water as a by-product. This can be used for air conditioning, refrigeration, or the nutrient-rich deep ocean water can feed biological technologies (see image, below).

Another by-product is fresh water distilled from the saline seawater, to be used for human consumption or irrigation purposes.



OTEC diagram and applications

Hawaiian Test Facility

OTEC theory was first developed in the 1880s and the first bench size demonstration model was constructed in 1926.

In 1974, The U.S. established the Natural Energy Laboratory of Hawaii Authority (NELHA) at Keahole Point on the Kona coast of Hawaii.

Hawaii is the most suitable location for a US OTEC facility, because of its warm surface water, access to very deep, very cold water, and high electrical costs. The laboratory has become a leading test facility for OTEC technology in the US.

Chapter 4: Biological fuels

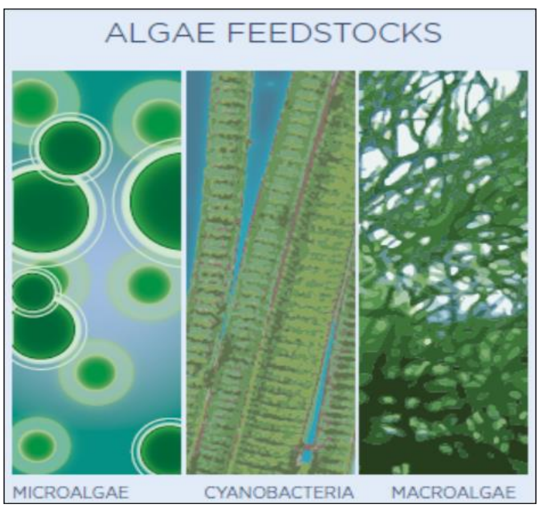
Section 1: Algae Fuel

Algae as a Fuel

Algae fuel, as the name implies is a biofuel derived from algae. During photosynthesis, algae and other photosynthetic organisms capture carbon dioxide and sunlight and convert them into oxygen and biomass. The process usually entails growing the algae between two panes of glass.

Algae as it applies to a feedstock for bioenergy, refers to a diverse group of organisms that includes:

- microalgae
- macroalgae (seaweed)
- cyanobacteria ("blue-green algae")



Types of Algae Feedstock
Image Source: US Dept. of Energy

Algae occur in a variety of water and land habitats ranging from freshwater, brackish waters, marine, and hyper-saline environments, to soil, and in symbiotic associations with other organisms.

The understanding, management, and proper utilization of the biology of algal strains selected for use in production systems is the foundation for processing feedstocks into fuel, products, and by-products. Isolating new strains directly from various unique environments will promote versatile and robust strains for mass culture needed in biofuels applications.

The algae create three forms of energy fuel:

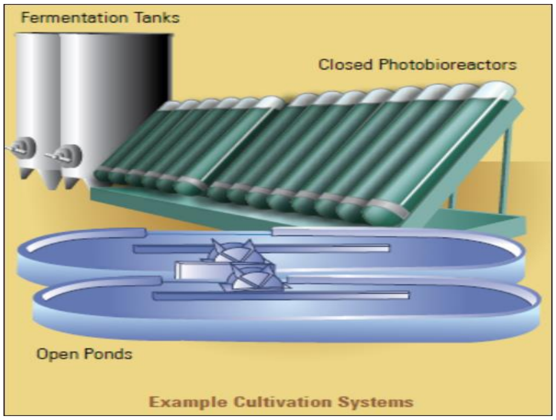
- ***Heat*** – created by the growth cycle
- ***Biofuel*** - the natural "oil" extracted from the algae upon maturity. This is used to create energy similar to the use of biodiesel.
- ***Biomass*** – created by the algae's mass, as it is harvested upon maturing

Some of the desirable aspects of algal biofuel production (that have generated the interest of researchers and entrepreneurs), are:

- high per-acre productivity
- non-food based feedstock resource
- use of otherwise non-productive, non-arable land for the production facilities
- utilization of a wide variety of water sources (fresh, brackish, saline, marine, produced, and wastewater)
- production of both biofuels and valuable co-products
- potential recycling of CO2 and other nutrient waste streams

Cultivation of Algal Feedstock:

- ***Microalgae and cyanobacteria*** - can be cultivated using photoautotrophic methods (where algae require light to grow and create new biomass) in open or closed ponds or via heterotrophic methods (where algae are grown without light and are fed a carbon source, such as sugars, to generate new biomass).
- ***Macroalgae (or seaweed)*** - requires open off-shore or coastal cultivating facilities.



Example of three types of cultivation systems

Designing an optimal cultivation system involves balancing the biology of the algal strain used, and integrating it with the best suited downstream processing options.

The choices made for the cultivation system will have an effect on the affordability, scalability, and sustainability of the algal biofuel system.

Section 2: Algae Processing Stages

Algae harvesting and Dewatering Process

Some processes for the conversion of algae to liquid transportation fuels require pre-processing steps such as harvesting and dewatering.

Algal cultures are mainly grown in water, requiring process steps to concentrate harvested algal biomass prior to extraction and conversion. These steps can be energy-intensive and can entail siting issues.

Extraction Process

Three major components can be extracted from algal biomass:

- ***lipids*** – these include triglycerides and fatty acids; are fuel precursors (gasoline, biodiesel and jet fuel)
- ***carbohydrates*** – are also a fuel precursor (gasoline, biodiesel and jet fuel)
- ***proteins*** - can be used for co-products (animal and fish feeds)

Most issues in the extraction process deal with the industrial scale up of integrated extraction systems.

While many analytical techniques exist, optimizing the extraction system to consume less energy than contained in the algal product is a challenge due to the high energy required in handling and drying algal biomass as well as separating out the desired end products.

Bypass Extraction

Some developers of innovative algal biomass production processes are investigating ways to bypass extraction; though these are also subject to a number of unique scale-up challenges.

Conversion to fuels and products is predicated on a basic process decision point:

- Conversion of whole algal biomass
- Extraction of algal metabolites
- Processing of direct algal secretions

Conversion technology options include:

- Chemical processes
- Biochemical processes
- Thermochemical processes
- A combination of these approaches

The end products vary depending on the conversion technology used. Focusing on biofuels as the end product poses challenges due to the high volumes and relative low values associated with bulk commodities like gasoline and diesel fuels.

Section 3: Biogas Digestion

Biogas Digestion

Biogas digestion concerns the harnessing of the methane gases that are released as waste matter decays. This gas can be collected from sources such as landfill garbage or sewage systems.

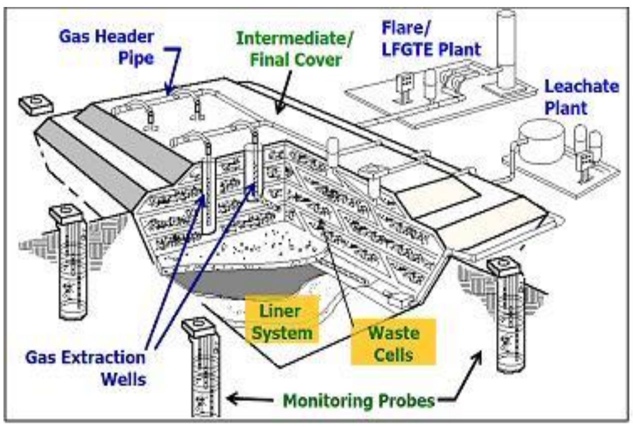
Aerobic (oxygenated) conditions generate mostly CO2 emissions, while in anaerobic conditions as is typical of landfills, methane and CO2 are produced in a ratio of roughly 60:40.

Biogas digesters process the methane gas portion by using bacteria to break down biomass within the anaerobic (non-oxygenated) environment. The methane gas that is collected is refined and used as a combustible energy source.

MSW and Landfill Gas

Landfill gas (LFG) is generated from the degrading of municipal solid waste (MSW) and other biodegradable waste matter, by anaerobic microorganisms.

As organic matter will decompose aerobically in the presence of oxygen to produce carbon dioxide, the exclusion of air by means of an impermeable cap ensures anaerobic decomposition to produce water, and a flammable mixture of carbon dioxide and methane.



Landfill gas collection system

Landfill sites are built according to strict guidelines to reduce their negative impact on the environment, with impermeable capping and internal lining, drainage control, in situ refuse compaction and ventilation, (see image, above)

Gas Composition

The composition of landfill gas varies depending on a number of factors. The rate of gas production depends on the rate of MSW decomposition, with a half-life for the waste-to-gas decomposition typically in the ranging from 3 to 10 years.

The rate of decay is dependent on the physical and chemical conditions occurring within the MSW mass, namely the level of moisture.

Typical gas yield for a Landfill Site

Not all landfill gas is retrievable, with 25 to 50% being typical of a properly designed site. A landfill site taking in an average of 300 tons of degradable waste per day for a ten year period, could potentially generate around 4 billion cubic meters of gas spanning a period of forty years.

Generating Power from the Methane

Spark ignited gas engines, a form of internal combustion engine, are a popular means of generating electricity from landfill gas, with the turbo-charged gas engine offering the best compromise in terms of capital cost, efficiency, performance and reliability.

Gas Turbine Efficiencies

Gas turbine engines usually meet an efficiency of 20 to 28 percent when operating at full load and using landfill gas as a fuel source.

Efficiencies drop when the turbine is operating at partial load. Also, gas turbines require high gas compression, which uses more electricity to compress, further reducing their efficiency.

Gas turbines have relatively low maintenance costs and low nitrogen oxide emissions, when compared to the reciprocating piston style of engine.

Gas turbine engine designed to use LFG

Microturbines

Microturbines are able to produce electricity using lower amounts of LFG than gas turbines or RP engines. They can operate between 20 and 200 cfm and emit less nitrogen oxides than the RP engines. Also, they can function with less methane content, with amounts as low as 35 percent.

Microturbines cost more per kW generated than gas turbines, but have smaller annual operating and maintenance costs.

Example:

- ***Microturbine (less than 1 MW)*** - typically cost $5,500/ kW with annual costs of $380/kW
- ***Gas turbine (greater than 3 MW)*** - can typically cost $1,400 per kW with annual costs of $130/kW

Section 4: Biological hydrogen (biohydrogen) production

Biohydrogen

Biohydrogen is defined as hydrogen produced biologically, and is typically produced from:

- algae
- bacteria
- archaea or archaebacterial (primitive bacterial microorganisms)

Biohydrogen is a potential biofuel which can be obtained from either cultivation or waste organic materials. Hydrogen gas is totally clean burning; with the only by-product being (H_20) or water.

It contains a relatively high amount of energy in comparison with other fuels due to its chemical structure.

Large Demand for Hydrogen

Presently, there is an enormous demand for hydrogen, with future needs being even higher. Refineries are large-volume producers as well as consumers of hydrogen.

Nearly all hydrogen produced today is derived from fossil fuels, with 48% from natural gas, 30% from hydrocarbons, 18% from coal, and about 4% from electrolysis.

Oil-sands processing, gas-to-liquids and coal gasification projects require a huge amount of hydrogen and are expected to increase the demand for hydrogen significantly within the next few years.

Environmental regulations which have been implemented in many countries increase the requirement for hydrogen at refineries for their gas-line and diesel desulfurization processes.

Biohydrogen as an alternative fuel source

One future application of hydrogen could be as an alternative to fossil fuels. This application is however dependent on the development of storage techniques to enable proper storage, distribution and combustion of hydrogen.

If the cost of hydrogen production, distribution, and end-user technologies decreases, hydrogen as a fuel could be entering the market by 2020.

Hydrogen production using Fermentation

The main biochemical technologies used to produce hydrogen are dark and photo fermentation processes.

Fermentation Types:

- ***Dark fermentation*** - with this process, carbohydrates are converted to hydrogen by fermentative microorganisms including strict anaerobe and facultative anaerobe bacteria. A theoretical maximum of 4 mol H2/mol glucose can be produced and, besides hydrogen, sugars are converted to volatile fatty acids (VFAs) and alcohols as by-products during this process.
- ***Photo fermentation*** - Photo fermentative bacteria are able to generate hydrogen from VFAs. Hence, metabolites formed in dark fermentation can be used as feedstock in photo fermentation to enhance the overall yield of hydrogen.
- ***Combined fermentation*** - Combining dark- and photo-fermentation has shown to be the most efficient method to produce hydrogen through fermentation. The combined fermentation allows the organic acids produced during dark-fermentation of waste materials, to be used as substrate in the photo-fermentation process. Many

independent studies show this technique to be effective and practical.

Industrial Fermentation

For industrial fermentation of hydrogen to be economical feasible, by-products of the fermentation process have to be kept to a minimum. Combined fermentation has the unique advantage of allowing reuse of the otherwise useless chemical, organic acids, through photosynthesis.

Industrial fermentation of hydrogen, or whole-cell catalysis, requires a limited amount of energy, since fission of water is achieved with whole cell catalysis, to lower the activation energy.

This allows hydrogen to be produced from any organic material that can be derived through whole cell catalysis since this process does not depend on the energy of substrate.

Section 5: Biomass

Biomass Fuel Types

Biomass energy or "bioenergy" **(**the energy from plants and plant-derived materials**) has been around since fire was first discovered; when humans began using wood for cooking and heat.**

Wood is still the largest biomass energy resource today, but other sources of biomass can also be used.

These include:

- food crops
- grassy and woody plants
- residues from agriculture or forestry
- oil-rich algae
- organic component of municipal and industrial wastes

Even the fumes from landfills (which are methane, the main component in natural gas) can be used as a biomass energy source.

Biomass can be used for fuels, power generation, and products that would otherwise be produced from fossil fuels.

Biomass briquettes are an
example of a fuel for power production

Balancing Carbon Footprint thru Growth

The use of biomass energy has the potential to greatly reduce greenhouse gas emissions. Burning biomass releases slightly more of carbon dioxide than the burning of fossil fuels.

However, fossil fuels release carbon dioxide captured by photosynthesis millions of years ago, while biomass releases carbon dioxide that is largely balanced by the carbon dioxide captured in its own growth.

This balance depends on how much energy is needed to grow, harvest, and process the fuel.

Also, studies have found that clearing forests to grow biomass results in a carbon penalty that takes decades to recover from, so it is best if biomass is grown on previously cleared land, such as on under-utilized farm land. Additionally, the use of biomass can reduce our dependence on foreign oil.

Feedstocks for Biomass Energy

Biomass energy supports U.S. agricultural and forest-product industries. The main biomass feedstocks for power are paper mill residue, lumber mill scrap, and municipal waste.

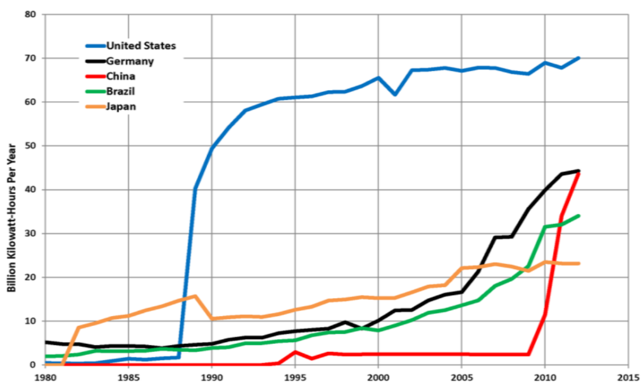
For biomass fuels, the most common feedstocks used today are corn grain (for ethanol) and soybeans (for biodiesel).

In the near future, agricultural residues such as corn stover (the stalks, leaves, and husks of the plant) and wheat straw will also be used.

Future Development

Long-term plans include growing and using dedicated energy crops, such as fast-growing trees and grasses, and algae. These feedstocks can grow sustainably on land that will not support intensive food crops.

One vision is to develop technology for biorefineries that will convert biomass into a range of fuels, chemicals, materials, and products, similar to products from present oil refineries and petrochemical plants.



Trends in the top five countries generating electricity from biomass

Switching from Coal to Biomass

Biomass has become popular among coal power stations, which switch from coal to biomass to comply with the law.

Biomass most often refers to plants or plant-based materials that are not used for food or feed, and are specifically called lignocellulosic biomass.

As an energy source, biomass can either be used directly via combustion to produce heat, or indirectly after converting it to various forms of biofuel.

Conversion of biomass to biofuel can be achieved by different methods which are broadly classified into: thermal, chemical, and biochemical methods.

Chapter 5: Geothermal, Wind, Hydro and Other

Section 1: Geothermal and Enhanced Geothermal

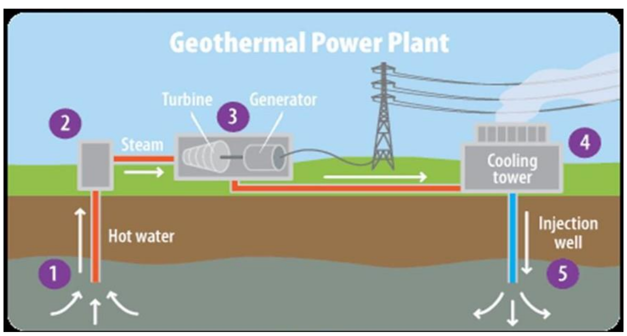
Geothermal Energy

This is heat energy generated and stored within the Earth. Thermal energy is the energy that determines the temperature of matter. Earth's internal heat is thermal energy generated from radioactive decay and continual heat loss from Earth's formation.

Geothermal Power

Geothermal power is cost-effective, reliable, sustainable, and environmentally friendly, but has been limited to areas near tectonic plate boundaries in the past.

Recent technological advances have expanded the range and size of viable resources, especially for applications such as home heating, opening a potential for widespread exploitation.



Releases Greenhouse Gases

Geothermal wells release greenhouse gases trapped deep within the earth, but these emissions are much lower per energy unit than those of fossil fuels.

As a result, geothermal power has the potential to help mitigate global warming if properly deployed in place of fossil fuels.

Geothermal Resources

The Earth's internal thermal energy which flows to the surface by conduction is more than double humanity's current energy consumption from all primary sources.

However, most of this energy flow is not recoverable. Even so, the Earth's geothermal resources are theoretically more than adequate to supply humanity's energy needs, but only a very small fraction may be profitably exploited. Drilling and exploration for deep resources is very expensive.

Forecasts for the future of geothermal power depend on assumptions about technology, energy prices, subsidies, plate boundary movement and interest rates.

A geothermal heat pump can extract enough heat from shallow ground anywhere in the world to provide home heating, but industrial applications need the higher temperatures of deep resources. The thermal efficiency and profitability of electrical generation is very sensitive to temperature.

The most demanding geothermal applications would benefit the most from a high natural heat flux, such as from a hot spring.

The next best option is to drill a well into a hot aquifer. If no such aquifer is available, an artificial one may be built by injecting water to hydraulically fracture the bedrock.

This last approach is called hot dry rock geothermal energy in Europe, or enhanced geothermal systems in North America. Much greater potential may be available from this approach than from conventional tapping of natural aquifers.

Enhanced Geothermal Systems

Enhanced geothermal systems (EGS) actively inject water into wells to be heated and pumped back out. The water is injected under high pressure to expand existing rock fissures to enable the water to freely flow in and out.

The technique was adapted from oil and gas extraction techniques. However, the geologic formations are deeper and no toxic chemicals are used, reducing the possibility of environmental damage. Drillers can employ directional drilling to expand the size of the reservoir.

Geothermal Gradient

Geothermal gradient is the rate of increasing temperature with respect to increasing depth in the Earth's interior. Away from tectonic plate boundaries, it is about 1 °F per 70 feet of depth near the surface, in most of the world.

Section 2: Onshore Wind Farms

What is a Wind Farm?

A wind farm is a grouping of wind turbines in the same location used to produce electricity. A large wind farm may consist of several hundred individual wind turbines and cover an extended area of hundreds of square miles, but the land between the turbines may be used for agricultural or other purposes.

A wind farm can also be located offshore where the wind currents are considerably stronger and more predictable.

China's dedication to Wind Energy

Many of the largest operational onshore wind farms are located in China, the US, and Germany.

The largest wind farm in the world, Gansu Wind Farm in China has a capacity of over 6,000 MW as of 2012, with a future goal of 20,000 MW by 2020. Eight of the ten largest wind farms are located in China.

In five short years, China surpassed the rest of the world in wind energy production, going from 2,599 MW of capacity in 2006 to 62,733 MW at the end of 2011. However, the rapid growth outpaced their electrical infrastructure, slowing new construction significantly in 2012.

At the end of 2009, wind power in China accounted for 25.1 gigawatts (GW) of electricity generating capacity, and China has identified wind power as a key growth component of the country's economy.

With its large land mass and long coastline, China has exceptional wind resources. Researchers from Harvard and Tsinghua University have found that China could meet all of their electricity demands from wind power by 2030.

Wind farm in the Gansu province of China

Micro-siting

Onshore turbine installations in hilly or mountainous regions tend to be on ridgelines generally three kilometers or more inland from the nearest shoreline.

The purpose of this is to exploit the topographical acceleration as the wind accelerates over a ridge. The additional wind speeds gained in this way can increase energy produced because more wind goes through the turbines.

The exact position of each turbine matters, because a difference of 30m could potentially double output. This careful placement is referred to as "micro-siting."

Opposition to Wind Farm Construction

One of the biggest factors suppressing wind farm construction in the US is human opposition and public perception.

The placement of turbines nearby to residents may increase their uncertainty and concern of the wind turbines and overshadow any positive inclination they may have toward the farm's development.

In addition, some legislators and grass roots organizations in the US have attempted to discredit and undermine the renewables agenda based on partisan biases and alternate agendas which have nothing to do with the viability of a potential energy source.

The Environmental Impact of Wind Farms

Compared to the environmental impact of traditional energy sources, the environmental impact of wind power is relatively minuscule. Wind power consumes no fuel, and emits no air pollution, unlike fossil fuel power sources.

The energy consumed to manufacture and transport the materials used to build a wind power plant is equal to the new energy produced by the plant within a few months.

While a wind farm may cover a large area of land, many land uses such as agriculture are compatible, with only small areas of turbine foundations and infrastructure made unavailable for use.

Aviary Mortalities

There are bird and bat mortalities which occur at wind turbines, just as they occur around other artificial structures. The scale of the ecological impact may or may not be significant, depending on one's point of view.

From one perspective: the estimated number of bird deaths caused by wind turbines is between 140,000 and 328,000 annually, whereas deaths caused by domesticated felines are estimated to be between 1.3 and 4.0 billion birds annually and over 100 million birds are killed annually by impacting windows.

Concentrated solar plants (CSP's) have also faced this type of negative public and special interest scrutiny from bird mortalities.

Section 3: Offshore Wind Farms

Offshore Wind Energy

Offshore wind energy has the potential for significant environmental and economic benefits on a global scale. It provides a non-exhaustive domestic energy resource, with no carbon footprint.

Offshore wind farms can be located close to major coastal load centers, providing an alternative to long-distance transmission or development of power generation facilities in areas with limited available land.

Once built, offshore wind farms can produce energy at low, long-term fixed costs, which can reduce electrical prices and improve energy security by providing a hedge against the volatility and uncertainty of fossil fuel pricing.

Critical challenges to offshore wind farm development:

- lowering the costs and associated with domestic offshore wind development
- technical risks associated with the corrosive coastal saline environments, and issues with transmitting the power to shore
- providing long term supervision, maintenance and support through conflicting political cycles
- establishing regulatory oversight
- mitigating the potential environmental risks of offshore wind development
- increasing the public understanding and support of the benefits of offshore wind energy
- reducing "visual" pollution (spoiling of the ocean view from the coast)
- accommodating fishing and shipping lanes

Offshore wind farms are similar in design to land-based wind farms, but require special foundation design considerations.

Traditional offshore wind turbines are founded to the seabed in the nearshore, shallower waters while floating systems are tethered to deep seabed anchoring structures.

Offshore wind farms can be erected in areas with water up to 130 ft. deep, while floating wind turbine systems can operate in areas with water depths up to 2,300 ft. deep.

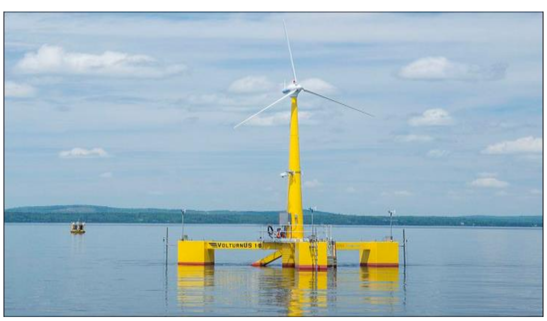
Floating Wind Farms

Floating wind farms are able to harness the much more desirable wind currents from the open ocean. With no obstructions in inhibit the winds; wind speeds found in the open ocean can be considerably more than those found in near coastal areas.

The image above shows World's first full-scale floating wind turbine, "Hywind" being assembled in 2009, before being deployed to the North Sea.

Significant generation of offshore wind energy already contributes to electrical demand in European and Asian countries and now the first offshore wind farms are under development in U.S. waters.

While the offshore wind industry has seen serious growth over the past decades, especially in European regions, there is still much to learn concerning how the construction and operation of these wind farms affects the surrounding marine life and environment.



The image above shows the Volturn US 1:8, the first North American grid-connected offshore wind turbine.

First Offshore Wind Turbine in the Americas

The Volturn US 1:8, was designed and built at the University of Maine, It was assembled in Brewer Maine, then successfully towed nearly 30 miles from Brewer by a Maine Maritime Academy tugboat, and anchored off the coast of Castine, Maine in 90 ft of water.

On June 13, 2013, the turbine became energized and began delivering electrical power through an undersea cable to the Central Maine Power electricity grid.

This made the Volturn US 1:8 the first grid-connected offshore wind turbine to be put into operation in North or South America.

Section 4: Hydroelectricity

Hydropower

Hydropower is one of the oldest sources of power, generating power as water drives a turbine. Hydropower is a renewable energy source and produces no air pollution or toxic byproducts.

When we think of hydropower, huge facilities such as the Hoover Dam or Three River Gorge in China come to mind. However small-scale, micro-hydro power plants exist as well.

These can take advantage of water streams in municipal water facilities or irrigation ditches. They can also use diversions or run-of-river facilities to channel a portion of a stream through a powerhouse before the water rejoins the main river.

Impoundment Type

The most common type of hydroelectric power plant is an impoundment facility. An impoundment facility is usually a large hydropower system. It uses a dam to store river water in a reservoir upstream of the dam structure.

Water released from the reservoir flows through and drives a turbine, which then drives a generator to produce electricity.

The water may be released either to meet changing electricity needs or to maintain a constant reservoir level. Hoover Dam (see image) is a prime example of the type of hydropower facility.

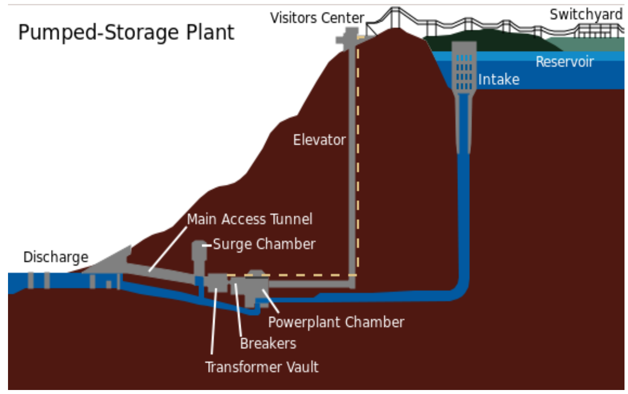
Diversion Type

A diversion or run-of-river facility, channels a portion of a river's flow through a canal or penstock. It may or may not require the use of a dam.

The image above shows a diversion type of hydropower plant, the Chief Joseph Dam near Bridgeport, Washington. This is an example of a major run-of-the-river station without requiring a sizeable reservoir.

"Pumped-storage" Type

Another type of hydropower called pumped-storage, works like a battery, storing the electricity generated by other power sources like solar, wind, and nuclear for later use. It stores energy by pumping water uphill to a reservoir at higher elevation from a second reservoir at a lower elevation.



When demand for electricity is low, the pumped-storage facility stores energy, by pumping water from a lower reservoir to an upper reservoir.

During periods of high electrical demand, the water is released back to the lower reservoir and turns a turbine, generating electricity.

Sizes of Hydroelectric Power Plants:

- ***Large Hydropower*** - large hydropower facilities have a capacity of more than 30 megawatts (MW).
- ***Small Hydropower*** - small hydropower facilities generate 10 MW or less of power.
- ***Micro Hydropower*** - micro hydropower plants have a capacity of up to 100 kilowatts. A small or micro-hydroelectric power system can produce enough electricity for a home, farm, or small community.

Section 5: Coal Gasification

Coal Gasification

This is the process of producing synthetic natural gas (SNG), or syngas, from cheap and abundant coal resources.

The following image shows a coal gasification plant.

Syngas is a mixture consisting mainly of:

- carbon monoxide (CO)
- hydrogen (H2)
- carbon dioxide (CO2)
- methane (CH4)
- water vapor
- air and/or oxygen

Uses of Coal Gasification

In the past, coal was gasified using early technology to produce coal gas which is a combustible gas traditionally used for municipal lighting and heating before the advent of industrial-scale production of natural gas.

In the present, large-scale instances of coal gasification are primarily used for:

- electricity generation, (such as in integrated gasification combined cycle power plants)
- for production of chemical feedstocks
- for production of synthetic natural gas

Hydrogen and Methane Products

The hydrogen obtained from coal gasification can be used for various purposes such as making ammonia, powering a hydrogen economy, or upgrading fossil fuels.

Coal-derived syngas can be converted into transportation fuels such as gasoline and diesel through additional treatment via the Fischer-Tropsch process or into methanol which itself can be used as transportation fuel or fuel additive, or which can be converted into gasoline by the methanol to gasoline process.

Methane from coal gasification can be converted into LNG for use as a fuel in the transport sector.

Concerns with Coal Gasification

But there are two big issues when considering large scale coal gasification. First, coal gasification actually produces more carbon dioxide than a traditional coal plant.

Secondly, coal gasification is one of the more water-intensive forms of energy production, requiring a great deal of nearby water.

Section 6: Fuel Cells

Basic Operation of a Fuel Cell

A fuel cell is an electrochemical energy conversion device, which is two to three times more efficient in converting fuel to power, than an internal combustion engine.

- A fuel cell produces electricity, water, and heat using a fuel source (typically hydrogen) and the oxygen in air.
- Water is the only emission when hydrogen is the fuel.
- As hydrogen flows into the fuel cell on the anode side, a platinum catalyst facilitates the separation of the hydrogen gas into electrons and protons (hydrogen ions).
- The hydrogen ions pass through the membrane (the center of the fuel cell) and, again with the help of a platinum catalyst, combine with oxygen and electrons on the cathode side, producing water.
- The electrons, which cannot pass through the membrane, flow from the anode to the cathode through an external circuit containing a motor or other electric load, which consumes the power generated by the cell.

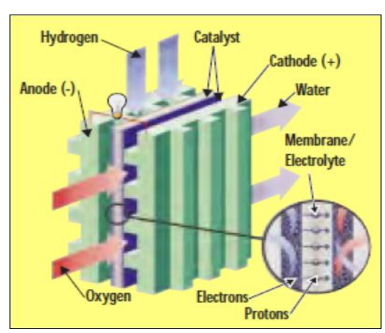


Diagram of a fuel cell

Voltage Output

The voltage from one single cell is about 0.7 volts, just about enough to power a light bulb. When the cells are stacked in series, the operating voltage increases to 0.7 volts, multiplied by the number of cells stacked.

Types of Fuel Cells

There are many types of fuel cells, but they all consist of an anode, a cathode, and an electrolyte that allows positively charged hydrogen ions (protons) to move between the two sides of the fuel cell.

Types usually vary based on the design, operating temperature and the electrolyte used.

Various Types of Fuel Cells:

- Proton exchange membrane fuel cells (PEMFCs)
- Phosphoric acid fuel cell (PAFC)
- Solid acid fuel cell (SAFC)
- Alkaline fuel cell (AFC)
- Solid oxide fuel cells (SOFCs)
- Molten carbonate fuel cells (MCFCs)
- Phosphoric acid fuel cell
- Molten phosphoric acid (H3PO4)
- Solid acid fuel cell
- Tubular solid oxide fuel cell (TSOFC)
- Protonic ceramic fuel cell
- Direct carbon fuel cell
- Planar Solid oxide fuel cell
- Metal hydride fuel cell
- Proton exchange membrane fuel cell
- Reformed methanol fuel cell
- Direct-ethanol fuel cell
- Direct methanol fuel cell
- Direct borohydride fuel cell
- Regenerative fuel cell
- Upflow microbial fuel cell (UMFC)
- Microbial fuel cell
- Direct formic acid fuel cell (DFAFC)
- Electro-galvanic fuel cell
- Enzymatic Biofuel Cells
- Magnesium-Air Fuel Cell

Section 7: Thorium Nuclear Power

What is Thorium?

Element 90, which is found in nature as Thorium 232, is 4 times more common than Uranium and about 200-400x more common than U-235, the fuel used in Light Water Reactors (LWRs) in the US and much of the world.

Thorium reactors can have several potential advantages over a uranium-based fuel cycle, such as thorium's greater abundance, superior physical and nuclear fuel properties, and reduced nuclear waste production.

(LFTR) Liquid Flouride Thorium Reactors

An LFTR is a different type of reactor than those presently used throughout the world, using molten salt as a heat transfer medium.

Invented during the 1950s and 1960s in Oak Ridge Labs, this design was quickly abandoned as the nuclear reactions from LFTR's were found to be incompatible with bomb production.

Since the focus was on bombs and Uranium originally, the LWR (light water reactor) technology proliferated, while the promising Thorium technologies such as LFTR, were abandoned.

Safer than conventional nuclear reactors

This kind of reactor can't "melt down" as the fuel source is already in a liquid state. Operating temperatures run around 1300°F giving them far superior thermodynamic efficiency.

High pressure is kept away from the core, as a hot salt loop transfers the heat to the generators.

The reactor incorporates a "salt plug" in its base, cooled by a fan. If power is ever lost, the system fan would shut down (due to lost power), and the plug would melt, draining the fuel into a storage container where fission stops.

The fuel would also cool and solidify. If there were ever a breach in the reactor, material would drain into the same tank. Even if the tank broke, the fuel would simply solidify on the floor.

More Efficient Use of Fuel

A LWR (Light Water Reactor) in the US, burns roughly 0.5%-5% of its fuel source. The remainder is disposed of as unburned fuel (radioactive waste).

A LFTR on the other hand, running from Thorium could burn 100% of this fuel. Likewise, it could burn the stockpiles of radioactive waste which are stored from the many years of using conventional nuclear power processes.

The byproducts of a LFTR are radioactive, but contain few "transuranic" elements – which would be radioactive for a very long time.

Instead, much of the "waste" could be recycled into useful products after a month or a few years of cooling off, and by about 100 years, much of the radioactivity is gone.

China is already working on LFTR technology and stockpiling Thorium, while India is working on Thorium for solid fueled reactors, but will likely transition to LFTR.

Negative Aspects of Thorium:

- ***Limited operational experience with Thorium*** – Thorium-based power generation has a limited operational history, making it less desirable than the more proven nuclear technologies.

- ***Thorium fuel is more difficult to prepare*** – The melting point for Thorium dioxide is 550 degrees higher than traditional Uranium dioxide, thus requiring more extreme temperatures to produce high-quality solid fuel. In addition, Thorium is an inert substance, making it difficult to chemically process.

- ***Irradiated Thorium is more dangerously radioactive in the short term*** – Thorium-based power generation produces some U-232, which decays to Tl-208, which has a 2.6 MeV gamma ray decay mode. These gamma rays are very hard to shield, requiring more expensive spent fuel handling as well as fuel reprocessing.

- ***Thorium doesn't work as well as U-Pu in a fast reactor*** - For reactors that require excellent neutron economy (such as breed-and-burn concepts), Thorium is not ideal.

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