**Getting Off The Oil Cycle – The Critical Things You Need To Know About Alternative Energy and how you can implement them into your life**


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# Contents



# Chapter 1: Introduction

It's a measure of just how dependent the world has become on fossil fuels that we call any other form of energy production "alternative" energy. Ironically, humans relied on many of these so-called alternatives long before they learned to burn coal or refine petroleum into heating oil and gasoline, relying on the sun and the wind to keep themselves comfortable. Yet these Stone Age strategies, and many others, are today labeled not only alternative, but too often "experimental," "impractical" or "anti-progress"—and undeservedly so.

It is the aim of this book to provide an overview of energy sources and strategies beyond fossil fuels and along the way to dispel many of the misconceptions about them. Based on facts and figures rather than unsubstantiated claims and scare tactics, this book should inspire, inform and enlighten readers.

## Why Do We Need Alternatives?

To answer that question, we need to start by discussing fossil fuels—what they are, where they come from, how they are used and the advantages and disadvantages of each. Within this context, the pressing need for alternatives becomes quite clear.

### What are fossil fuels?

Most fossil fuels are formed from the remains of long-dead creatures and plants. Buried over the course of hundreds of millions of years, these carbon-based deposits have been converted by heat and pressure over time into such combustible substances as crude oil, coal, natural gas, oil shales and tar sands. A smaller portion of fossil fuels is the handful of other naturally occurring substances that contain carbon but do not come from organic sources.

To make more fossil fuels would require both the creation of new topsoil filled with hydrocarbons, and time—lots of time. Given estimates of current fossil fuel reserves worldwide, it's not possible we can wait out the problem, and continue our dependence on fossil fuels until new reserves are built. At current consumption rates, the reserves of oil and coal and other fossil fuels won't last hundreds of years, let alone hundreds of millions of years.

As for creating more, experts have pointed out that it can take close to five centuries to replace a single inch of topsoil as plants decay and rocks weather. Yet in the United States, at least, much of the topsoil has been disturbed by farming, leading still more experts to the disturbing conclusion that in areas once covered by prairie, the past hundred years of agriculture have caused America's "bread basket" to lose half of its topsoil as it erodes thirty times faster than it can form.

## The Advantages of Fossil Fuels in Energy Production

There are many reasons why the world became dependent on fossil fuels, and continues to rely on them. For example, it has so far been relatively cost-effective in the short run to burn fossil fuels to generate electricity at strategic centralized parts of the grid and to deliver the electricity in bulk to nearby substations; these in turn deliver electricity directly to consumers. These big power plants burn gas or, less efficiently, coal. Since so much electricity can be lost over long-distance transmission, when power needs to be concentrated more in one region than another, the fuels are generally transported instead to distant power plants and burned there. Liquid fuels are particularly easy to transport.

Thus far, fossil fuels have been abundant and easily procured. Petroleum reserves worldwide are estimated at somewhere between 1 and 3.5 trillion barrels. Proven coal reserves at the end of 2005, as estimated by British, were 909,064 million tons worldwide. Coal, furthermore, is relatively cheap.

Perhaps the simplest reason why the world continues to depend on fossil fuels is that to do anything else requires change: physical, economical, and—perhaps the most difficult—psychological. The basic technology for extracting and burning fossil fuels is already in place, not only in the large power plants but at the consumer level, too. Retrofitting factories would be cost-prohibitive, but perhaps even more daunting would be replacing heating systems in every home, factory and building. Ultimately, however, the true resistance may be our nature. We humans tend to resist change in general, and in particular those changes that require us to give up longstanding traditions, alter our ways of thinking and living, and learn new information and practices after generations of being assured that everything was "fine" with the old ways.

## Why Do We Need Alternatives?

If there are so many reasons to use fossil fuels, why even

consider alternatives? Anyone who has paid the least bit of attention to the issue over the past few decades could probably answer that question. If nothing else, most people could come up with the first and most obvious reason: fossil fuels are not, for all practical purposes, renewable. At current rates, the world uses fossil fuels 100,000 times faster than they can form. The demand for them will far outstrip their availability in a matter of centuries—or less.

And although technology has made extracting fossil fuels easier and more cost effective in some cases than ever before, such is not always the case. As we deplete the more easily accessible oil reserves, new ones must be found and tapped into. This means locating oil rigs much farther offshore or in less accessible regions; burrowing deeper and deeper into the earth to reach coal seams or scraping off ever more layers of precious topsoil; and entering into uncertain agreements with countries and cartels with whom it may not be in our best political interests to forge such commitments.

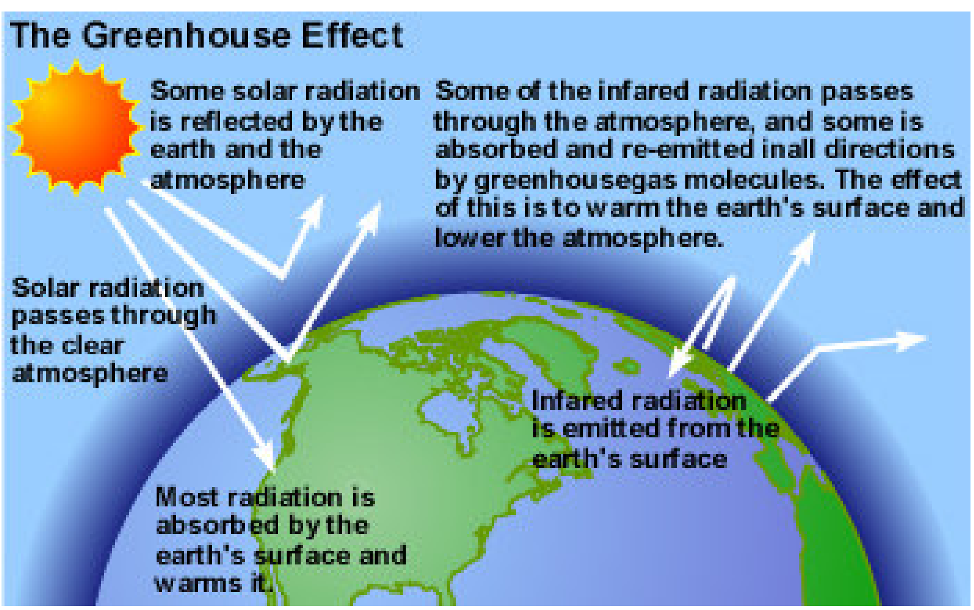
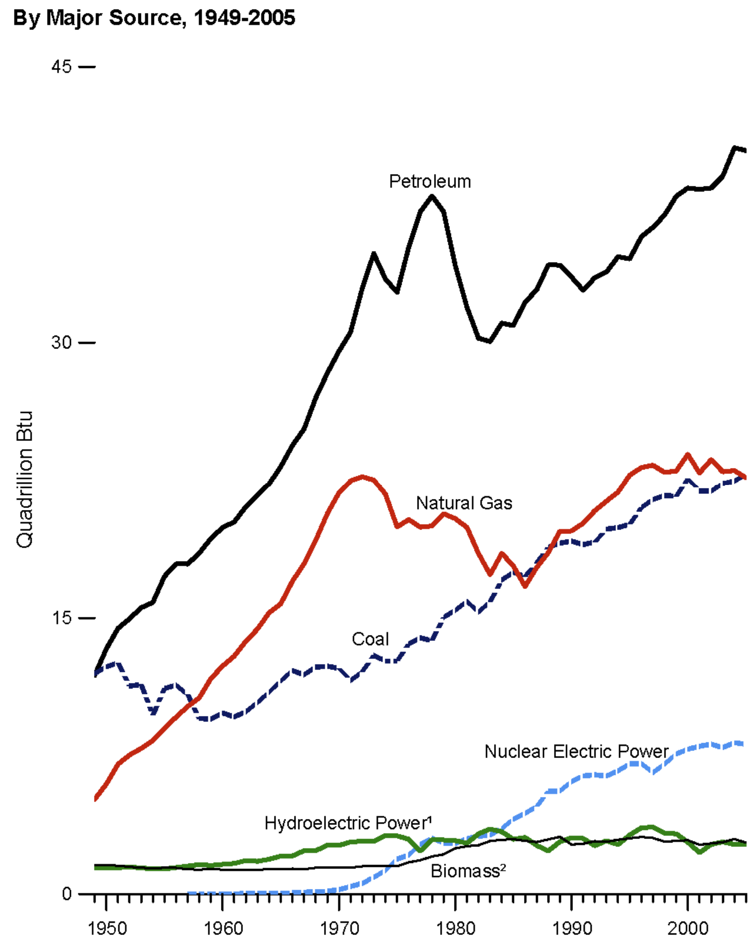



Illustration: EPA.gov




This graph shows energy consumption in the U.S. over the last half of the 20th century. The energy sources may change, but the trends stay the same: up, up,

Finally, there are human and environmental costs involved in the reliance on fossil fuels. Drilling for oil, tunneling into coalmines, transporting volatile liquids and explosive gases—all these can and have led to tragic accidents resulting in the destruction of acres of ocean, shoreline and land, killing humans as well as wildlife and plant life. Even when properly extracted and handled, fossil fuels take a toll on the atmosphere, as the combustion processes release many pollutants, including sulfur dioxide—a major component in acid rain. When another common emission, carbon dioxide, is released into the atmosphere, it contributes to the "greenhouse effect," in which the atmosphere captures and reflects back the energy radiating from the earth's surface rather than allowing it to escape back into space. Scientists agree that this has led to global warming, an incremental rise in average temperatures beyond those that could be predicted from patterns of the past. This affects everything from weather patterns to the stability of the polar ice caps.

## Conclusion

Clearly, something must change. As with many complex problems, however, the solution to supplying the world's ever-growing hunger for more energy will not be as simple as abandoning all the old methods and beliefs and adopting new ones overnight. Partly this is a matter of practicality—the weaning process would take considerable investments of money, education and, most of all, time. The main reason, however, is that there is no one perfect alternative energy source. *Alternative* will not mean *substitute*.

### What needs to change?

It seems simplistic to say that what really needs to change is our attitude, but in fact the basis of a sound energy plan does come down to the inescapable fact that we must change our way of thinking about the issue. In the old paradigm, we sought ways to provide massive amounts of power and distribute it to the end users, knowing that while much would be lost in the transmission, the advantages would be great as well: power plants could be located away from residential areas, fuels could be delivered to central locations, and for consumers, the obvious bonus was convenience. For the most part our only personal connection with the process would be calling the providers of heating fuel and electricity, and pulling up to the pumps at the gas station. And the only time we would think about the problem would be when prices rose noticeably, or the power went out.

There are people who have tried to convince us that there is no problem, and that those tree-hugging Chicken Littles who talk about renewable and alternative energy want us all to go back to nature. More often than not these skeptics' motivations for perpetuating this myth falls into one of two categories: one, they fear what they don't understand and are resistant to being told what to do, or two, they have some political or financial stake in enabling our fossil-fuel addiction. (And sometimes both.)

The reality is that except for altering our ways of thinking, there will not be one major change but a great many smaller ones. A comprehensive and successful energy plan will necessarily include these things:

- Supplementing the energy produced at existing power plants with alternative energy means, and converting some of those plants to operate on different "feedstock" (fuels)
- Shifting away from complete reliance on a few concentrated energy production facilities to adding many new and alternative sources, some feeding into the existing "grid" and some of supplying local or even individual needs
- Providing practical, economical and convenient ways for consumers—residences, commercial users, everyone—to adapt and adopt new technologies to provide for some or all of their own energy needs

- Learning ways in which we can use less energy now ("reduce, reuse, recycle"), using advances in technology as well as simple changes in human behavior to reduce consumption without requiring people to make major compromises or sacrifices

## Chapter 2: Alternative Energy Source Overview

If we say that alternative energy comprises everything that is not based on fossil fuel consumption, the number of optional resources is impressive. This chapter will provide an overview only of the ones in use or development now, with each being further explored in subsequent chapters. There are, no doubt, alternative energy sources not included here, either because they are not yet at anything beyond a theoretical stage or simply because no one has thought of them yet.

### Solar

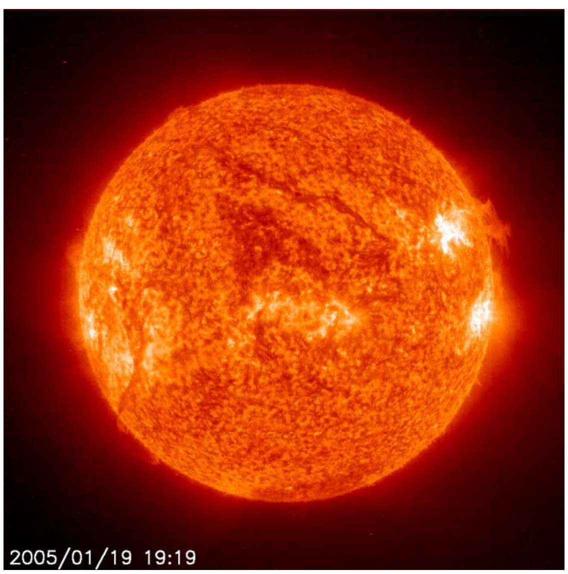



Photo: European Space Agency-

This is the original energy source. Before humans learned to make fire, we were dependent—as were all the plants and animals with whom we shared the planet—on the sun for heat and light. In fact, although there were likely many factors responsible, the radiant output of the sun (which may have been affected by variations in the Earth's orbital path or by the Sun's orbital path within the galaxy, as well as by activity taking place on the sun or in space) contributed to the first global energy crises: the ice age(s), when large portions of the Earth were covered with thick sheets of ice and sea level dropped precipitously. There are two types of solar energy: passive and active. The former involves simply making use of the position, duration, and intensity of the sun's rays to best advantage, using it to heat an area or induce air flow from one area to another, without the use of extra technology beyond what's needed to store the energy. The latter involves using mechanical and electrical technology such as collection panels to capture, convert and store the energy for later use.

## Wind

Photo: National Renewable Energy Laboratory, U.S.

Wind has been used for many centuries as a source of power. It has fueled many a sailing ship and made possible the exploration of and trade with distant lands. Single windmills have powered a family's needs for crop irrigation, electric lights and water pumping. These days, however, most of the discussions concerning wind power involve not one or two windmills dedicated to a specific consumer but many, many wind turbines arranged to capture large amount of power at once and feed it to the grid. These are known as "wind farms," and have been in use around the world for many years, with the United States one of the few industrialized nations to be slow to accept the concept.

## Biomass/Biofuel

Photo: National Renewable Energy Laboratory, U.S.

Biomass energy production involves converting biological material or wastes into substances that can be used as fuel for heating, transportation or power generation. Carbon-based materials that have been converted over time into fossil fuels are not considered "biomass" (although in their original states they would have been) for the simple reason that the carbon they contain has been isolated from the current carbon cycle and would therefore figure differently in their effect on the carbon dioxide levels found in the atmosphere.

## Hydrogen & Electric

Photo: National Renewable Energy Laboratory, U.S. Department of Energy

Hydrogen is not, in fact, an alternative producer of energy. Rather it is a means for storing energy produced by other methods and is thus considered by many to be a safer, easier and more efficient way to deliver energy. Since weaning ourselves from a steady diet of fossil fuels will involve many direct and indirect changes in the ways we think about and do things, we include it here, along with discussions of storage and transmission in general, and an important part of energy planning. Likewise, electricity is not an energy producer but a form in which energy can be stored and delivered.

## Nuclear

Nuclear power creates energy when its atomic structure changes. All the nuclear power plants in operation today are based on fission, in which the radioactive decay process is accelerated in a controlled chain reaction that splits an atom into two or more byproducts, including energy. Nuclear fusion involves the opposite—combining elements—for the same purpose. While fusion has enormous potential for energy production, the technology does not yet exist to instigate a controlled fusion reaction. Nuclear power has remained controversial worldwide for many reasons (discussed later), but its continued appeal lies in its ability to produce millions of times more energy than any fossil fuel of similar mass.

## Ocean and Earth Power

The Earth itself offers many promising sources of power. Like solar energy, **geothermal** resources have long provided humans with a source of heat, although harnessing the heat of the Earth to generate electricity dates back only to the turn of the last century. **Tidal power** involves capturing the kinetic energy of the incoming and outgoing tides, as well as the local difference between high tide and low tide. Similarly, there is energy in the **wave action** in the oceans. One alternate form of energy production for heating is already relatively common: the **heat pump**. They come in two basic forms: geothermal (see above) and air-source. Geothermal heat pumps use the ground temperature, and are 40 to 60 percent more efficient than air source heat pumps, which use the temperature difference between the indoor and outdoor air for heating and cooling. There are also systems for ocean thermal conversion.

Bjarnarflag Geothermal Station in northeast Iceland

# Chapter 3: Solar Power

For the most part, discussions about solar power relate to capturing and storing energy for stationary uses: home heating, water heating, powering something specific. As the technology improves, however, solar power can also be considered for powering (or at least supplementing the power for) vehicles or other means of transport, and for use in mass-capture solar farms. There are two kinds of solar power used in home heating: passive and active. These are discussed on the following pages.

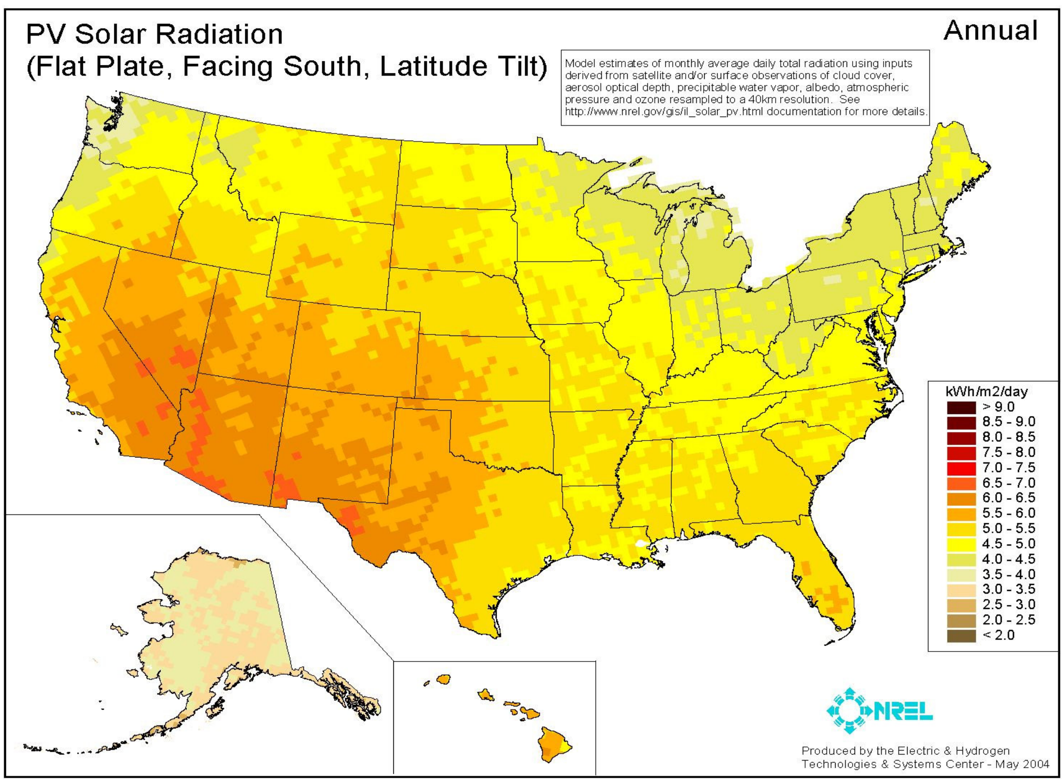
## Passive Solar

Every exposed part of a structure—walls, floors, windows, roofs—absorbs and stores or reflects away the heat radiated by the sun. Passive solar systems do this without any mechanical means (pumps or fans); they rely purely on design and positioning to work, which may include shutters or thermal curtains, dampers and vents, or other simple mechanisms.

While passive solar setups are rarely used as bulk collection units, the concepts behind passive solar have changed the way many architects and engineers approach designs. They are beginning to make profitable use of the sun's free energy by using to their advantage one or more of these principles: conduction (heat flows from molecule to molecule in solids; this explains why the handle of your tea cup will eventually be warmed by the hot tea in the bowl), convection (heat also flows through liquids and gases; this explains why you might swelter in the attic and shiver in the basement—heat rises), radiation (warm objects radiate heat away to cooler objects, which absorb it, reflect it, or transmit it along), and capacitance (this is a measure of how much heat a material will retain over time, and is a function of thermal mass).

## Passive solar space heating

Passive solar systems are used for space heating more often than active systems (see below). The most heat gains (in the northern hemisphere) come from windows oriented due south, but any window within 30° of that will show significant gains. The challenge, of course, it to avoid




overheating a space, a problem that can easily occur in rooms with substantial glass surface area facing south. The contained heat can be redistributed relatively easily with ceiling or other fans, or by making use of the blower and duct systems (with the heating elements off) of a standard furnace. Installing flooring with high thermal mass such as stone or tile can also absorb and store the heat to be radiated later when the ambient temperature becomes cooler than the floor. A well-constructed, well-insulated building with high-performance, airtight windows can generally meet up to a quarter of its own heating needs using passive solar strategies. That, along with its next-to-nothing operating cost, clean operation, and simple maintenance makes it a natural for any structure.

## Passive solar power cooling

This is more about reducing heat build-up than about taking it away. The obvious "technology" involved has been used for thousands of years: shading. You can do this with shutters, awnings, special "smart windows" (discussed later), curtains, and landscaping. Cross-ventilation will distribute the heat more evenly.

This house in Maine generates its own electricity from a 4.25-kW PV system beautifully integrated into the rooftop. A net-metering relationship with Central Maine Power lets the family export surplus electricity to the grid; they get it back in an even exchange at night and during periods of low sun if needed. Space heating and domestic hot water are provided by the solar thermal system with space heating distributed in a multizone radiant floor system. The house also uses passive solar heating and cooling,

## Building considerations

Even minor application of these basic principles can make a big difference in the overall climate control of a structure. Imagine that you have a room with large windows facing south. If you are in the northern hemisphere, that would mean that sunlight would shine into it all day. The windows are old clear glass, single-pane windows, which allow 80 to 90 percent of the heat to pass directly into the room. Now imagine that the sun coming in strikes a dark floor; this absorbs 40 to 95 percent of the heat. Obviously, that room will become extremely hot during the day. Depending on its intended use, this may be a good thing. The heat will flow from there, slowly but surely, into adjacent cooler spaces—a process that can be accelerated, of course, with fan systems. Remember, though, that since the heat does travel to cooler areas, at night it may leak back out those same inefficient windows to the outside unless you block the windows with some sort of thermal barrier.

Windows today are far different from those drafty single-pane versions in our grandparents' houses. Most new windows are constructed with two or even three panes (that is, they are "double-" or "tripled-glazed"), with insulating spacers and or inert gases between the panes, and have "low-e" (low-emittance) coatings of metal or metallic oxides that that reflect back much of the sun's heat without significantly reducing the light allowed in.

Additionally, there are also so-called "smart windows," which use varying technologies (electrochromic, suspended particles, liquid crystal) to alter a window's transmissive properties. Since these are operated electronically, one could debate whether they are "active" or "passive," but that's just semantics; the point is, they exist, and they work.

Ingenious placement and angling of windows was just one of the features that won the Dakin Building, in Brisbane, California, near San Francisco, an American Institute of Architects Design Excellence Award in 1992


In addition to optimal window placement, another way engineers, architects and even homeowners can use passive solar to greater advantage is through window pitch. Most windows are installed so that their surfaces and exactly vertical. It is possible, however, to calculate a different angle that will allow a more desirable amount of heat and light to penetrate; since this calculation concerns the position of the sun throughout various times of the day and year, the angle would of course be specific to particular locations.

The siting of a building plays a large role in its passive solar properties; builders generally take the sunlight into consideration when determining the size and orientation of a given façade, using the angle of a building to enhance or reduce the amount of sunlight that penetrates. The structure's overall shape, as well as how it fits into the landscape—substantial portions of a structure may be fully or partially below ground, for example—also makes a difference in how passive solar can be used to advantage. Architects and builders have been aided in recent years by the development of new materials designed to absorb or reflect varying amounts of radiated heat.

For a useful discussion of passive solar home designs, visit the Department of Energy's Energy Efficiency and Renewable Energy website:

http://www.eere.energy.gov/consumer/your_home/designing_remodeling/index.cfm/mytopic=10250

## Active Solar

Active solar builds on the same principles as passive solar but uses additional technology such as fans and pumps to maximize the desirable effects and minimize the undesirable ones. It is used to produce energy for heating and cooling spaces, to store energy for later use, and to heat water. Most active solar energy systems use specialized collectors to capture the rays and used the stored power and additional electricity as necessary to run pumps and fans for distribution.

### Solar collectors

The key to solar collection is the solar cell, or photovoltaic (PV), fashioned from semiconducting materials such as silicon, much like computer chips. As this material absorbs light, negatively charged electrons break free of their atoms and flow, or conduct, through the material. Through conduction, these electrons—electricity—are transferred to a fluid-filled metal tube; this is usually made of copper or aluminum, both of which are good thermal conductors. The tubes are fill with air, water or a solution of water and glycol (antifreeze). The direct current (DC) produced passes through an inverter and emerges as alternating current (AC), which is then shunted to the utility panel to be distributed as 12- or 240-volt power for lights, appliances and outlets, as well as for domestic hot water heaters, swimming pools, radiators, radiant floor heating systems—even car washes.

Some industrial and commercial architects are beginning to add solar heating systems to warm up fresh air from outdoors before it is drawn into the building's HVAC system, greatly reducing the amount of energy needed to heat the building conventionally.

Obviously, the percentage of your energy needs that you will be able to supply with a solar collector system will depend on several factors, including the efficiency of the system you install, and where the building is located. Ideally this will be somewhere that experiences cold temperatures but that also receives plenty of sunlight; that way, even if it cannot supply everything necessary, it can at least reduce the need for traditional heating and electrical sources. Although they cost more, photovoltaic arrays that move to track the path of the sun help take advantage of as many hours of sunlight as possible. Many states offer tax credits, deductions, and sometimes sales or property tax exemptions for approved solar energy systems. If you are thinking of selling the house or structure any time soon, however, be aware that you may not qualify for a loan from many banks or other lenders unless you have some form of traditional system in place as a backup.

## Solar Arrays

While small solar units can power such things as calculators and watches, to produce significant quantities of electricity photovoltaics are generally assembled into modules—self-contained in weather-resistant housings. The modules can easily be assembled into arrays of an appropriate size residential, commercial, scientific, and industrial installations.

The solar arrays of old were thick ungainly slabs of hardware, which made them unpopular with any but the most devoted enthusiasts. These days, however, solar arrays use a thin-film technology that allows them to be used in dozens of new ways, including as roof tiles and roof shingles that are as durable as traditional asphalt shingles but, of course, have the added benefit of doing more than keeping rain and snow out of the house. The efficiency has improved as well, although there is plenty of room for improvement. Although the first solar cells had efficiencies of less than 5 percent (they have been around

since the 1950s, believe it or not), today's solar cells are still capable of converting only 15 percent of the sun's rays to electricity.

This low efficiency is one reason that scientists have developed concentrating photovoltaic systems (CPVs). These use lenses or mirrors to focus more of the sun's rays into a single area—hence the word concentrate—as well as to use less silicon-type materials, a costly part of the system, in favor of higher-performance conductors such as gallium arsenide. There are three types of CPVs to date:

- **Parabolic-trough systems—**These use long U-shaped reflectors that focus the sunlight onto an oil-filled pipe in the center of the trough. The oil heats up, and can then be used to boil water to produce steam to turn a turbine.
- **Dish/engine systems—**These look a little like satellite dishes. Again, they focus the rays onto a receptacle that heats a fluid. As the fluid heats, it expands and either moves a piston or a turbine.
- **Power tower system—**This uses a large expanse of mirrors that focus the rays to a receiver on top of a tower. The receiver is filled with molten salt that, when heated, can power a conventional steam generator. Because molten salt holds onto heat for days, power tower systems can still be producing electricity even if the day is cloudy.

CPVs are not home-use systems. Because they are nearly always controlled by tracking systems to keep them aimed for maximum efficiency, they are used for large-scale solar plants—sun farms, in essence.

## Solar Energy Pros and Cons

Earlier we said that there is no single "perfect" energy producing technology. All have advantages and disadvantages—even solar power. Some of these are touched on below.

### Solar Energy Advantages

1. Solar energy is a renewable resource, for all practical purposes.
2. Except for the processes involved in manufacturing the materials, solar energy does not give off any harmful substances.
3. Sun, unlike fossil fuels, does not exist only in specific pockets of the earth: it is everywhere, although not in evenly distributed concentrations.
4. Sunlight is free.
5. While far from perfect, the technology required to use solar radiation as energy to produce heat, light, mechanical power and electricity already exists.
6. Small solar power systems are easily installed.
7. The systems are very low maintenance: they have no moving parts (except for fans and pumps, for example) and can last a long time.

8. Small systems require very little in the way of "monitoring" for routine operation.
9. Given the right data, it is almost always possible to predict

how much power a solar energy system will produce.

10. The systems are quiet and increasingly unobtrusive.

## Solar Power Disadvantages

1. The initial costs for components can be high.
2. Rarely efficient enough, predictable enough, or powerful enough to provide a substantial portion of a specific user's needs: needs efficient storage for "down" times.
3. Not every location is a feasible site for solar.
4. Solar "farms," like almost all large-scale building projects, are subject to the "NIMBY" syndrome ("Not in MY backyard!").

## Okay…What Can YOU Do?

Obviously you are not probably going to install a CPV in your back yard, but that doesn't mean you can't do something on a personal scale to take control of your energy production and consumption.

### If You are Building a Home…

No matter where you live, if you are planning to build a new home or other structure, you have the opportunity to design your home from scratch to make optimal use of the sun's rays as part of your overall personal energy solution with these simple steps:

- Hire a knowledgeable energy consultant to work with your architect to incorporate the technology.
- Orient your home (and/or garage or other outbuildings) on the site to allow maximum south-facing roof space for solar collectors, and use the energy to heat your home and/or your hot water; the angle of the panels should ideally be equal to your location's latitude.
- Take advantage of passive solar heating by concentrating windows on southern-facing walls, and reducing the number and size of windows on other walls.

- If you are installing a swimming pool, use solar power to heat it. Since these systems cost around $3,500 (with an average pay-back between 2 and 7 years), makes sure you and your energy consultant select the right size and type (and follow all local building codes).
- If you are truly beginning from scratch, it's possible to design your solar electricity system to be entirely independent from the grid.
- Install tubular skylights to use the sun's light—they let as much light in as regular skylights while reducing the heat lost and the excessive heat gain—to cut your electric bill.
- While you have the earthmoving equipment on sight, add a ground-source heat pump (these pipes must be buried well below the frost line)—an extremely effective and efficient way to heat your home by gathering heat from the subsoil.

## If You Own a Home…

If you already own a home and are looking for ways to take advantage of solar energy, here are some suggestions:

- Hire a knowledgeable energy consultant to help you plan the best way to retrofit your home to augment your traditional systems with solar-powered systems.

- Add a solar water heating system by installing flat panels or thin-film solar shingles.
- Retrofit your home with PVs to capture energy for electricity, and design the system to be either grid-connected or grid connected with battery backup. The energy you generate can be bought back or credited by your power company.
- If you have a swimming pool, covering the pool whenever possible can lead to considerable savings: 70 percent of the heat in an outdoor pool is lost through evaporation. Heating a single pound of water requires by 1 degree takes only 1 BTU, but every pound of 80°F water you lose from the pool takes 1,048 BTUs with it!
- Add a sunroom to gather heat, and distribute it throughout your home using a fan system.
- If you live in a hot, sunny climate, use landscaping, shutters, light-colored roofing and siding and reflective materials to minimize heat build-up.
- Run DC devices directly off your solar system before the current is converted to AC to gain efficiency. (Every conversion stage loses some usable energy.)

## Everyone

Even if you don't personally live somewhere that make uses of solar energy, you can still help by encouraging research, development and investment in solar energy and in energy storage and transport; by supporting "sun farms" where they make sense; and by supporting political candidates and initiatives that work toward increased solar energy use.

# Chapter 4: Wind Power

One of the fastest growing of the alternative energy sectors, wind power already provides nearly 75,000 megawatts of power worldwide—four times greater than in the year 2000—and yet still represents just 1 percent of the total. European and Scandinavian countries in particular have been a strong progressive force, both in developing and implementing the technology. Around 18 percent of Denmark's electricity needs, for example, are provided through wind power; as are 9 percent of Spain's needs and 7 percent of Germany's. The United States and India are the other two of the top five investors in wind power facilities.

Wind and solar power are inextricably linked, as somewhere between 1 and 3 percent of the sun's energy striking the Earth is converted to wind through a global convection system: air from the colder regions (the poles) flows to the warmer areas (the equator). Additionally, since land masses both absorb heat and release it back to the atmosphere more quickly than do the oceans, there is a constant shift of air from one to the other. The free, theoretically inexhaustible supply of energy holds great appeal, particularly since it is not limited by geographic and political boundaries: no one owns the wind, and every place receives it (to a greater or lesser extent, anyway).

## Harnessing the Power of the Wind

Historically, people used windmills to generate power. The first windmills, built in Persia in the 7th Century, used up to a dozen woven “sails” that filled with wind and caused a vertical shaft to turn; this mechanical spinning action was used directly to grind grain or pump water. Five centuries later the first horizontal-shaft windmills—what we picture when we think of “traditional” windmills—were developed in Europe.

Pitstone Windmill, a 17th C post-style windmill. Photo: Michael Reeve

In early versions, the main structure rotated on a massive central post to allow the sails to face the optimal wind direction, but later versions were refined so that only the top of the structure needed to be turned to face the wind. This allowed larger, heavier structures and greatly expanded their capacity and uses. By the late 16th Century windmills powered sawmills, grinding mills, irrigation systems and water pumps. In the Netherlands, where flooding has always been of grave concern, windmills arrayed in a series were used for centuries to pump water from low-lying land areas into successively higher reservoirs; before the advent of steam- and diesel-powered pumps, windmills played a crucial role in preserving the land.

The windmills that enabled farming and ranching in the pre-steam era in isolated, rural parts of North America used multiple-blade designs to allow them to turn slowly but easily in low winds and to withstand high winds. The rotary motion turned a crankshaft that fed into a gearbox converted the motion to a piston stroke that made it possible to pump water from considerable distances or depths.

## Modern Wind Power Machinery

Any machine that uses the kinetic energy of wind to produce mechanical energy is called a turbine. The turbines in use today are far more likely to be wind generators than windmills: windmills use energy directly, for grinding, pumping, etc.; wind generators convert the mechanical energy into electricity.
There are still two major wind turbine designs: **vertical-axis wind turbines** (VAWTs) and **horizontal-axis wind turbines** (HAWTs). Both have their good and bad points. VAWTs have the advantage of allowing the heavier components (generators, gearboxes) to be low to the ground, which makes maintenance easier. They have improved aerodynamics with decreased drag in high and low pressures, and need no yaw devices (these keep turbines facing into the wind). Smaller and lower, VAWTs can be easier to transport and erect, and may be used in areas with height restrictions. On the downside, VAWTs are generally only half as efficient as HAWTs, are really only useful in areas with steady prevailing winds, and their locations are limited by the size and steepness of a site.

VAWTs have many advantages. Most have torque levels that allow them to start up on their own. Since the towers are tall, they are better suited for sites that are steep, uneven, offshore, or above the treeline. The blades can “wing warp”—that is, twist or bend, a feature that is less desirable in “wings” intended for flight—to adjust for varying wind speed and direction. Their height and size can also cause problems, however: they are harder to transport, can interfere with low-flying aircraft and bird flight patterns, and require expensive crane installation.

## The Radar Debate

According to some factions, current radar technology apparently has trouble distinguishing stationary wind turbines from moving aircraft. Difficult and troubling as this is to believe, it has caused a number of applications for installations to be denied, particularly in the U.S. and the U.K. In 2006, more than a dozen wind turbines were halted by the Defense Department, but many believe that this can be traced to political rather than scientific concerns: legislation inserted into the 2006 Defense Authorization Act by a handful of U.S. senators (both Republican and Democratic) eager to block the offshore Cape Wind project in Nantucket Sound apparently has been used to delay and derail other wind farm projects across the country.

## Wind Energy Pros and Cons

We already touched on some of the good and bad sides to certain types of wind power. Here is a list of the pros and cons of the technology overall.

## Wind Energy Advantages

1. Wind energy is clean. It doesn't release pollutants, emissions or by-products into the air since there are no chemical processes involved, and modern turbines produce very little noise beyond a "whooshing" sound largely masked by the wind itself.
2. Wind energy, which is actually a component of solar energy, is "renewable" in the sense that there will

always be wind as long as the sun continues to heat the Earth unevenly, and the Earth continues to rotate.

3. Wind is not tied to geographic or political boundaries.
4. Although wind fluctuates over the course of a day, and from one day to another, the total output of energy varies by only a percentage point or two from year to year.

Wind turbines near Copenhagen, Denmark, where large, slow - moving turbines take advantage of moderate but steady winds to generate substantial power over 97 percent of the time.

5. The long-term predictability and availability of wind generation make it a reliable supplement to and backup for the overall energy supply grid.

6. Wind turbines can safely co-exist with other living creatures, which means that the land does not have to be restricted from other possible uses. The land on a wind farm can be used simultaneously for wind generation, crops growing, animal grazing, living and working space, and anything else. This also allows landowners to earn money by installing wind farms on their property to feed the larger electric grid.

> Wait a Minute…What About Birds?
> You may have heard people say that wind turbines, especially en masse as at a farm, represent a serious concern for birds. It is true that birds do fly into turbines—they fly into all sorts of tall structures, including buildings, cell towers, airport beacons and utility-line supports. Overall, the impact of wind turbines is very low—less than 1 in 30,000 bird deaths can be attributed to them as compared with other human-related causes such as structures and, well, house cats. And when you factor in the advantage that wind turbines add nothing noxious to the habitat, it's difficult to see why birds wouldn't agree that wind power is highly superior to any fossil-fuel based energy production source.

7. Wind generation can be done in remote areas on any scale from personal use to large-scale wind farms, which means that even places that might otherwise be "off the grid" can generate power.

8. At between 4 and 6 cents per kilowatt-hour, wind generation is currently one of the most affordable technologies in renewable energy. Additionally, local entities and cooperatives with equity positions in the

wind farms often qualify for federal tax benefits and subsidies.

## Wind Energy Disdvantages

1. The initial investment in wind energy is higher than for conventional fossil-fuel generators.
2. As man-made structures, the turbines may have a negative visual impact. In other words, many people find them to be a blight on the scenery. Beauty is, of course, in the eye of the beholder, and one must also weigh the alternatives: which would you rather see offshore, leaky flammable oil rigs, or a row of sleek turbines? Which would you rather live near, the cooling towers of a nuclear plant, a smoky coal-fired generator, or a wind farm?
3. The best places for converting wind to electricity aren't in high-density population areas, which often means that the electricity must be stored and/or transported over considerable distances.
4. Although annual yields are relatively predictable, hourly and daily wind-driven energy output levels are not.

## Okay…What Can YOU Do?

Wind is one of the few "alternative" energy resources that actually predates fossil-fuel power generation, so it should be fairly obvious that it can be used on a personal basis. Generations ago homesteaders depended on windmills to power their irrigation systems and to supply their modest power needs. But even if you live in an apartment in the city, you can still do something.

## On the Personal Level

Here are some options for things you can do to be a part of your own personal energy solution energy:

- If you have enough land and are in a location that makes it practical, consider installing one or two wind turbines. For assistance in doing this, there are a number of resources you can consult when you are just starting out:

    - http://www.eere.energy.gov/windandhydro/windpoweringamerica/index.asp
      Part of the U.S. DOE's Energy Efficiency and Renewable Energy Program, this site has information about and links to wind maps, state-by-state wind power programs, economic issues, and other invaluable data.

      http://awea.org/
      The American Wind Energy Association, an association of developers, manufacturers, service providers, utility companies, R&D groups and other wind-power advocates, has lots of information: wind projects in operation or in development; company links and resources; discussion about technology; and information about wind-power-related policies and legislation.

- Even if you can't install your own turbine, you may still be able to support wind power in one of three ways: green pricing, where a utility charges a small premium allocated to renewable energy; green marketing, where you choose to buy energy from a "green" supplier; or Renewable Energy Certificates (aka RECs, green tags, green certificates), which you buy in any amount (completely separate from the energy you buy) to "sponsor" renewable energy.

- If you have a large parcel of land, you could install a wind farm that would supply not only your needs but energy you could sell back to "the grid." For information about such a venture, start here:

  http://www.eere.energy.gov/windandhydro/windpoweringamerica/large_wind.asp

## On the Local/Community Level

- Join a cooperative or association to invest in or operate a wind farm.

- Encourage neighbors—your fellow voters—to support wind power projects, to buy green power and RECs, and to invest in green companies.

A wind farm with 195 "Vestas" turbines provides 320MW of power—and a profit—for

- Start a cooperative or association to install wind turbines in your town to power some highly visible project: irrigation for a community garden or park system, an outdoor sports field, or everyday and holiday street lighting.

### On the Regional/National Level

- Encourage research, development and investment in wind energy and in energy storage and transport.
- Support wind farms in locations where they make sense.
- Supporting political candidates and initiatives that work toward increased wind energy production.
- Write to your local, state and federal representatives in support of wind and other renewable energy resources.

## Chapter 5: Biomass Power

Biomass comprises all forms of biological matter, including plant matter both living (agricultural crops, wild plants, grains, grasses, trees, shrubs, brush, seeds, etc.) and in waste form (biodegradable materials, cellulose, garbage, compost, etc.), as well as animal matter and waste products. Biomass can be in solid form or, through a wide range of conversion and refining processes, can be made into liquids or gases; the solids, liquids and gases can then be used to produce electric power, heat, new chemicals, or fuels.

Skeptics like to claim it takes more fossil fuel energy to produce ethanol, for example, than ethanol itself can provide as fuel. Studies show that to be untrue. In the case of ethanol, it takes about 7 BTUs of energy by fossil fuels to yield 10 BTUs of ethanol fuel—a net of 3 BTUs—and efficiencies are increasing at a rapid pace. Even with today's modest conversion percentages, the Department of Energy and the Department of Agriculture estimate that the 1.3 billion tons of biomass the country could readily convert to energy could replace about 30 percent of the petroleum used in the U.S. annually. Considering that Americans burn though a whopping 7 billion barrels of oil each year, that's not an insignificant contribution.

## Biofuels

The potential of biomass as an energy source is enormous: experts have calculated that the planet produces eight times more biomass each year than its energy needs overall (though it currently puts only 7 percent of that available resource to use in energy production). It's not only a renewable resource, it's also a seemingly inevitable one; to paraphrase a common aphorism, biomass happens.

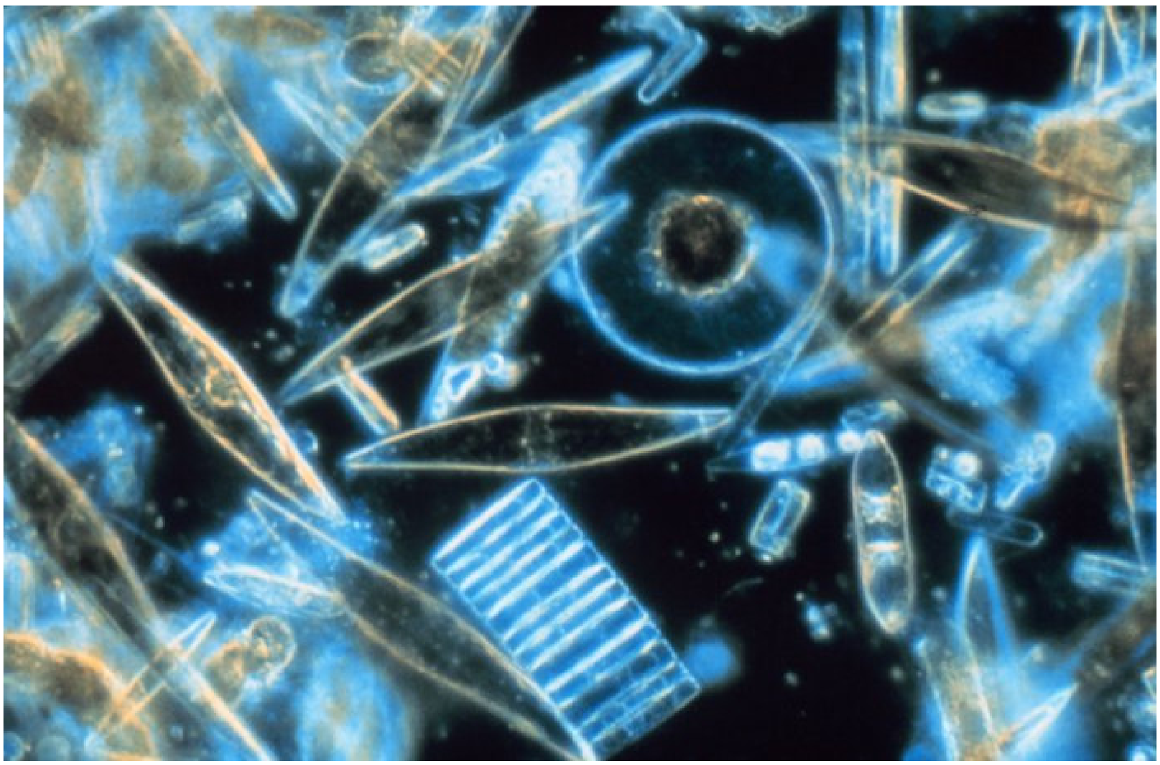
Any fuel created from biomass can be called biofuel, although the term gets the most media attention when used to denote biomass-based fuels that power internal combustion engines—especially cars. These include biodiesel, biobutanol, biogas and bioethanol. The fuels can be created from plant materials specifically grown for the purpose or from the recycling or re-use of other biomass resources.

### Energy Crops

Crops have long been grown to feed people and animals, but until recently were not raised specifically as energy sources. Even trees, which have been used for thousands of years as a heating source, were not "farmed" for just that purpose. Today there is even a term for trees and woody plants

A source of dendro-energy, wild rice grows well and in quantity in the Upper Great Lakes region of North America. It is the only major cereal grain native to the continent.

cultivated for the specific purpose of creating fuel: dendro-energy. The products of any agriculture dedicated to producing fuel of any sort are called "energy crops"—the high-falutin technical term would be "closed-loop biomass"—and are steadily becoming an important resource in global energy development.



These microalgae, photographed under a microscope by USC researcher Dr. Neil Sullivan, could be used to create a biodiesel fuel to power your car.

There are literally hundreds of different dendro-energy resources alone, from abies balsamea (balsam fir) to Zizania aquatica (wild rice) around the world. In countries with no proven reserves of fossil fuels, investments and research in dendro-energy resources have helped otherwise energy-poor nations such as Sri Lanka develop alternatives to costly and politically dependent imports, giving a whole new meaning to the phrase "power plant."

Some of the energy crops grown around the world include corn, soybeans, flaxseed and sugar cane. Additionally, biofuels are also manufactured frequently from the unused portions of crops grown for other purposes such as the chaff, stalks, shells, husks, and roots.

Energy crops add fewer emissions to the air and water supply than do petroleum products in general and coal in particular. Energy crops contain almost no sulfur and far less nitrogen than fossil fuels, so their combustion does not contribute to acid rain and smog (sulfur dioxide, or $SO_2$) and smog (nitrogen oxides, or NOx). And unlike fossil fuels, they do not have significant quantities of mercury to leach into the water supply. In general, energy crops do not release nearly the amount of volatile organic compounds (VOCs) as anthropogenic sources (that is, human-made concoctions such as natural gas, gasoline, solvents, pesticides, and paints).

Biotechnologist Susan Toon of the National Renewable Energy Laboratory examines a flask of lipids (oils) produced by microalgae that can be converted into

There are biogenic sources of VOCs, however, and these do represent significant contributors. Pine and citrus trees, for example, release large quantities of isoprene (a chemical compound found naturally in plants and animals, including humans, isoprene is nevertheless a pollutant, especially as it contributes to the production of ozone) and terpenes (a family of hydrocarbons that are the major components of resin and, not surprisingly, turpentine), although these trees are used as biomass.

One promising source of biofuels is microalgae, which can be grown on aquaculture farms. A pilot program demonstrated in during the 1990s showed that algae can be used to create diesel and jet fuel. This is particularly good news given the efficiency of algae relative to some other energy crops. For example, corn, which is a common energy crop, yields just 18 gallons of fuel per acre. Thanks to its fast growth cycle, algae can yield up to 10,000 gallons per acre. There's another benefit to algae, too. Some power plants are already using algae bioreactors to reduce $CO_2$ emissions by pumping the gas into a pond or tank for the algae to feed on.

## Recycled Energy

Another way in which biomass gets put to use as an energy source is through recycling biodegradable materials or water products. Industry and agriculture are major sources of biodegradable by-products, but every household generates potentially useful biomass. On a large scale, manufacturers and other industrial and commercial services generate biodegradable materials they no longer need.

### BIODIESEL

Any fuel made to drive a diesel engine is called diesel fuel. Most people are familiar with petrodiesel, and don't even bother to add the prefix. But advances in physical and chemical biomass conversion and processing have made the term biodiesel a term that may not yet be commonplace but has probably been heard by most adults in developed nations. The usual sources for biodiesel are oils and fats, which are mixed with a solution of methanol that contains sodium hydroxide (lye, an extremely caustic substance). Amazingly, the eponymous Rudolf Diesel demonstrated biodiesel at the 1900 Paris World Exposition using an engine that ran on peanut oil. Gasoline engines rely on a spark to fire, and can be quite finicky about fuel, but diesel engines depend on high cylinder compression to heat

and ignite the air/fuel mix, so many modern diesel engines can run on 100 percent biodiesel and others can run on petro-bio mixes. That's good news for the air: according to the Department of Energy, pure biodiesel emits 75 percent less $CO_2$ than petrodiesel, and mixes by anywhere between 75 and 15 percent.

There are many potential biomass sources for making biodiesel. For example, the Industrial Agricultural Products Center, which is part of the University of Nebraska at Lincoln, recognized that its home state leads the nation in commercial cattle slaughter. That process yields not only the steaks and burgers in your grocery store but also 1 billion pounds a year of tallow. Accordingly, the IAPC has developed a biodiesel that makes use of this largely unused material.

Food industry giant Perdue Incorporated (the chicken people) actually formed a BioEnergy group dedicated to biofuels. Oddly enough, Perdue is the twelfth-largest grain company in the United States and has three soybean crushing plants and a deepwater port, so the company works with biodiesel and ethanol producers to make feedstock (any raw material fed into an industrial process—in this case, for generating power).

Another food industry heavyweight, Tyson Foods, produces more leftover animal fat (from chickens, cattle, and hogs) than any other company in the U.S. The company recently announced a renewable energy division of its own to put to use the 2.3 billions pounds of chicken fat they create each year. That could make around 300 million gallons of pure biodiesel, or go into the most popular petro-bio mix, a B20 fuel—80 percent petrodiesel, and 20 percent biodiesel. Americans use almost 40 billion gallons of diesel a year.

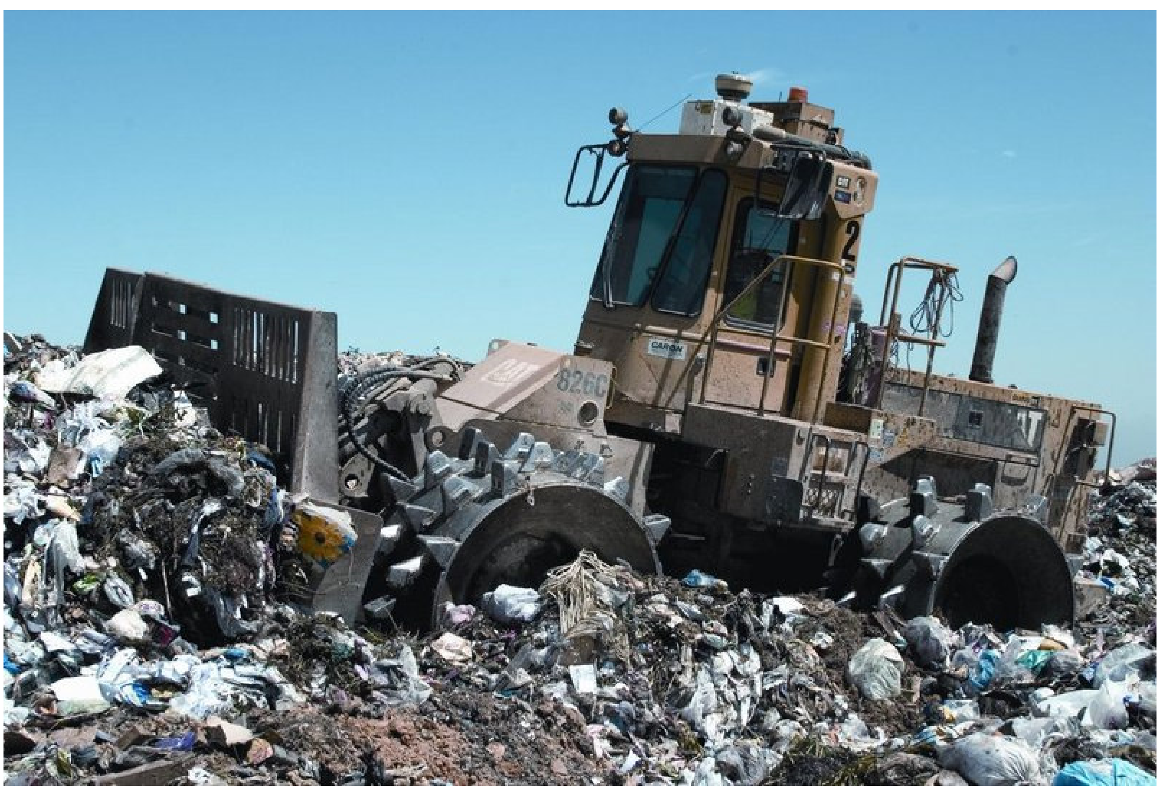
Biodiesel currently has a good news/bad news story. The good news is that it exists, it works, and it's getting easier: in 2000 there were 88 plants in the U.S. producing 250 million gallons of biodiesel. The bad news is that most of the biodiesel (and other biofuels) comes not from industry leftover but from energy crops such as soybeans, which require significant farm acreage that could otherwise be used to produce vegetables and grains for human consumption.

The Defense Energy Support Center, which handles securing fuel for the Depart of Defense, is the single-largest consumer in the U.S. of biodiesel (5.2 million gallons in 2003-2004; more recent figures are unavailable). The U.S. began using B20 in its non-tactical vehicles in 2003. The military consumes between 120 and 145 million barrels of oil in a single year; according to the Department of Defense, every $10 increase in the price per barrel of oil means another $1.3 billion the military needs to keep its fleets operational.

## BIODEGRADABLE & MUNICIPAL SOLID WASTE

While much of what goes into biodiesel could be considered biodegradable waste, the concept deserves its own section because of its enormous potential. As we said before, biomass happens. When the quantities were relatively low, few people considered waste management a problem—people used to burn trash in their back yards, or bury, or put it out for the trash truck without a thought. Industrialization, population growth, and dozens of other factors caused the amount of waste produced annually to skyrocket, and for a long time everything got dumped into old mines, quarries and other big holes: landfills.

Soon enough it became apparent that in solving the problem of what to do with the waste, other problems had cropped up. Before landfill developers thought to line the pits,



The number of new landfills in the United States and elsewhere around the world is decreasing, except in those few areas where low population densities and large amounts of available land, such as Australia (above). Countries with high population densities and small amounts of available land, such as Japan, contaminated water leeched into the aquifers. They attracted rats and other scavengers. “Landfill gas” (methane and $CO_2$) filled the air, killing surface vegetation and contributing in a major way to greenhouse gases (1.2 tons of $CO_2$ per ton of municipal solid waste, or MSW). And, quite simply, they stank.

Still, economics caused most MSW to end up in landfills. Then huge incineration plants called waste-to-energy facilities (WTEs) were built to take care of the problem. They do solve some issues: they reduce the volume of the MSW by 90 percent, and with 40 million Americans each producing an average of more than 1,600 pounds a year, that’s important. WTEs can convert a ton of garbage into 525 kilowatt-hours of electricity (and 300 to 600 pounds of ash). Today, 14 percent of the MSW in the U.S. get incinerated.

But as with landfills. WTEs were not without their own problems. What remains after incineration is ash—and much of it hazardous. High concentrations of the metals (e.g., lead, cadmium) in the MSW remain in the ash, from dyes, inks, batteries, ceramic materials and more. Pollutants

The Cesar Granda MixAlco process Pilot Plant any biodegradable material (municipal solid waste, biodegradable waste, sewage sludge, agricultural waste) into more than one useful chemical: carboxylic acids (e.g., acetic, propionic, butyric), ketones (e.g., acetone, methyl ethyl ketone, diethyl ketone), and biofuels, (e.g., ethanol, propanol, butanol, isopropanol, 2-butanol, 3-pentanol). It even shows promise in water treatment overall have decreased substantially—roughly 85 percent overall—since EPA introduced the Maximum Achievable Control Technology (MACT) standards in 1995 as part of the Clean Air Act. But U.S. facilities combine their fly ash (airborne) with their cleaner bottom ash, which brings the overall percentages of toxic materials into compliance standards for expanded reuse.

The newest development is converting the useful biomass energy stored in MSW to feedstock and ethanol in biorefineries. A number of processes are in the R&D and pilot stages, including one in Texas, that uses a biological/chemical process that anaerobically digests the biomass into liquid mixed-alcohol fuels.

## Biomass Energy Pros and Cons

What's not to love about biomass? All right, it does have some features that could be considered disadvantages.

### Biomass Energy Advantages

1. Biomass energy uses materials from all sorts of resources from industry to agriculture that would otherwise be considered waste.
2. Biomass is, in theory, a renewable resource; as long as there are living organisms, there will be biomass.
3. Biomass is not a geographic-specific resource. All countries produce some form of biomass.
4. Most of the technologies for creating and using biomass energy (with the exception of plain old incineration) have few or no negative environmental effects.

5. Some biorefinery processes produce not only energy products but other useful byproducts as well.
6. Biodiesel vehicles produce 20 percent less particulate matter than petrodiesel, 50 percent less carbon monoxide (CO) and 78 percent less carbon dioxide ($CO_2$) in terms of net gain over the carbon lifecycle since the carbon in the biomass is merely being recycled, not added.

7. Biodiesel is, itself, biodegradable. According to the DOE, biodiesel is less less toxic than table salt, and as biodegradable as sugar.
8. Blends using 80 percent petrodiesel and 20 percent biodiesel (a common mix known as B20) will run in most new diesel engines without any modifications. Pure biodiesel (B100) can be used as well but usually requires minor modifications.
9. Biodiesel contains lower amounts of polycyclic aromatic hydrocarbons (PAHs) such as benzofluoranthene (56 percent less) and benzopyrenes (71 percent less), chemicals that are harmful to humans.
10. Biodiesel is very low sulfur.
11. The distribution system for biofuels, especially biodiesel, does not change substantially from that used for petrofuels.

12. There is no performance compromise in the shift from petro- to biodiesel. Over 400 private and public transportation fleets use biodiesel today—and the U.S. military.

## Biomass Energy Disadvantages

1. Strict incineration of biomass produces much of the usual pollution as burning fossil fuels.
2. In the short term—and depending on what form biomass you begin with—creating liquid biofuels can be less cost-effective than fossil-fuel based production, making it a difficult "sell" to consumers and investors.
3. Some energy crops require vast amounts of arable land to produce a net energy benefit. However, recent focus has been on algae, some of which has a high oil content (over 50 percent) and fast growth cycles, as an ideal energy crop for biodiesel. Algae can yield as much as 250 times the amount of biofuel per acre as soybeans.
4. The higher gel and cloud points of biodiesel makes it necessary to heat the fuel to flow properly in colder climates.
5. Biodiesel can produce as much as 25 percent more nitrogen oxide ($NO_X$) than petrodiesel. Although at least on U.S. Navy researcher disputes the numbers, some skeptics say that although the $NO_X$ levels can be reduced using catalytic converters, they remain slightly higher than those of petrodiesel. Of high concern is the fact that biodiesels output levels of $NO_X$ and particulates remains higher than regular gasoline.

6. Deforestation for the purpose of turning the biomass into energy just substitutes one problem for another, and endangers flora and fauna if not dealt with as part of an ecologically sound plan.

## Okay…What Can YOU Do?

One of the best things about biomass is that everyone makes their own—literally—and everyone can potentially put it to greater use.

## On a Personal Scale

A quick search of the web will turn up hundreds of resources on personal-scale biomass energy, including information on products, procedures, energy loans, tax incentives, sources, energy providers and other important data. Here are some things you can do.

- Manufacture your own biodiesel. That's right. Using common feedstock, anyone in the U.S. can make a gallon of biodiesel for less than a buck. Where do you get feedstock? One common source is restaurants, which have gallons of used vegetable oils they have to dispose of anyway. There are many other sources. With a biodiesel manufacturing setup you can make enough biodiesel to run your car (say, 10 gallons per week) on about %5 to $7 per week—$300 to $400 a year. Buy a brand new diesel car—Volkswagen, for instance, promotes all of its diesels as biofriendly—and stop lining the pockets of the price-gouging, earth-raping, water-polluting oil companies (and you know who they are). For some excellent information on personal biodiesel production (and other whole host of green solutions) check out these websites:
    - http://www.journeytoforever.org
    - http://girlmark.com/
    - http://www.backwoodshome.com/articles2/yago101.html
    - http://www.diyfuel.com/

- Buy a diesel vehicle and run it with biodiesel or, at minumum, B20. Better yet, watch for the diesel/electric hybrids that manufacturers have been developing.

## On a Community/Regional Scale

- Just because you don't have any local biofuel makers nearby doesn't mean it has to stay that way. Biofuel is no longer a "fringe" product, so with a little research and an investment in human energy you can probably convince your town, or your school system, or a group of people interested in forming a cooperative, to do something along these lines:
    - Thanks to pressure to "clean up its act," a public utility in the state of New Hampshire converted a 50-megawatt power plant that had previously been run on coal to on now operating entirely on wood chips as a feedstock. Rather than burning130,000 tons of coal each year, it now uses 400,000 tons of wood scrap from local resources, and emits just a quarter of the $NO_X$ and only 2 percent of the $SO_2$ previously pouring into the air.

    - The Portland, Oregon, school system has long been a staunch supporter of the Reduce-Reuse-Recycle way of life. Now the schools system has convinced the local division of the largest waste hauler in the U.S.—Waste Management, Inc.—to run its fleet on B20 biodiesel.
    - Traveling in Hawaii? Visit http://www.bio-beetle.com/, a car rental site that uses biodiesel in its cars.
- For information on what might be happening (or not!) in your state, follow this link:
    - http://www.eere.energy.gov/states/

## Chapter 6: Energy Storage & Transport

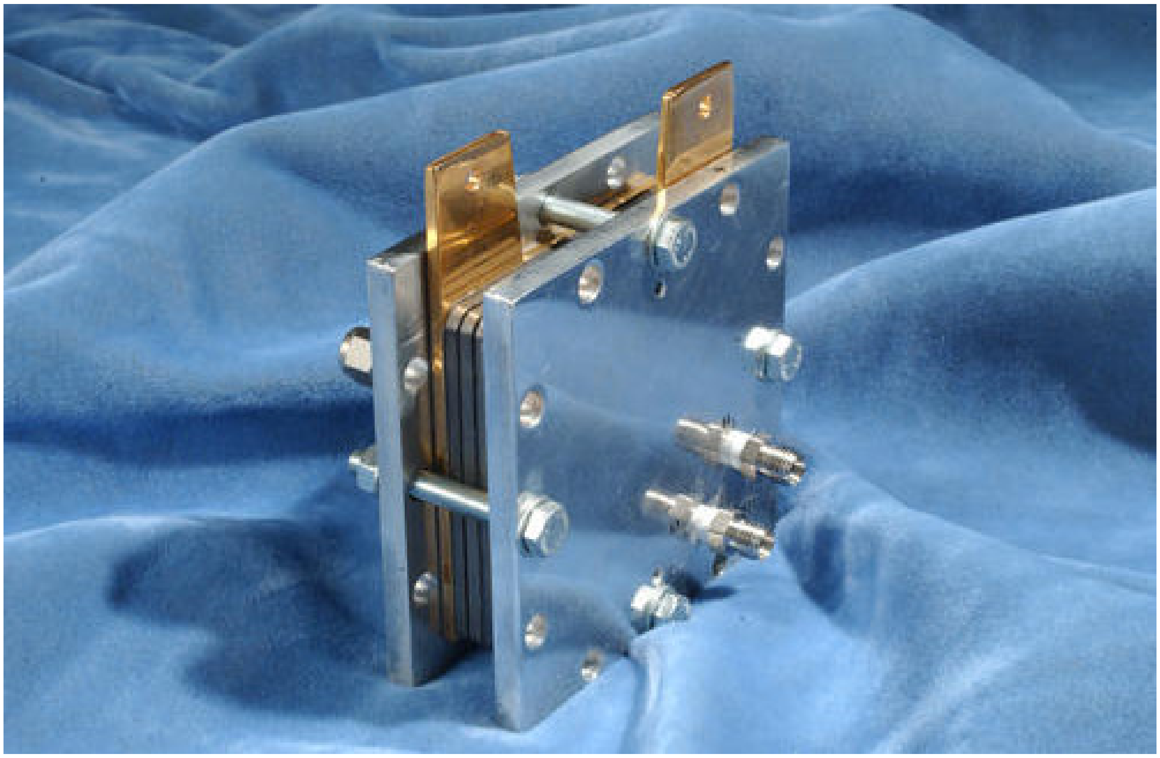
Until the advent of electricity, there wasn't much need for energy storage and transport. A great deal energy was used directly to power mills, or pump water, or aid some other mechanical action, and what wasn't was run by such easily stored fuels as petroleum products, whale oil, coal or wood. The constant and growing demands for power demanded new ways to store power.

There are many ways to store energy: electrochemical (batteries, fuel cells); electrical (capacitors, superconducting magnetic energy storage); mechanical (compressed air energy storage, flywheels, hydraulic accumulators, springs); potential gravity (hydroelectric, a boulder on a hill); and thermal (molten salt, cryogenic, bodies of water, stones/bricks/etc., steam).

In terms of electricity, there are two main processes. Transmission refers to transferring large quantities of power from one place to another, such as from the generating source to a substation. Distribution refers to delivering power to the end users. The interconnection, including redundant lines, is the "grid." The technology has had to change rapidly from the first high-voltage transmission as the voltages creep steadily higher: that first demonstration in 1891 was 25kV transmitted a little over a hundred miles, whereas today 1200 kV transmissions have been achieved. The farther electricity must travel, however, the more energy is lost, which is why so many densely populated areas have their own power plants. And where vehicles are concerned, there needs to be portable storage (or an infinitely long power cord)—a kind of superbattery. These are called fuel cells.

## Batteries and Fuel Cells

Technically, fuel cells aren't batteries at all, let alone superbatteries. That's because batteries by definition are closed systems that convert chemical energy into electrical energy, whereas fuel cells consume the materials that react and although they do not react and change directly, they must be replenished. Further, they do not store energy but must be coupled with electrolyzers, which do. The advantage that fuel cells have over batteries is that although a common battery might be able to return 90 percent of the stored energy, once the chemical process has run its course that's it. Fuel cells might create electricity, store it using an electrolyzer, and yield back only 30 to 50 percent, but it can do this over and over again.



Fuel cells work by electrochemically combining hydrogen or hydrocarbon fuels with oxygen using catalysts (platinum, nano iron powders, palladium) and electrolytes (ceramic, carbon membrane). The fuel splits into protons and electrons; only the protons can pass through the membrane, forcing the negatively charged electrons to travel around in an external circuit and this creates electrical current. The beauty of the system, in theory, is that when you burn hydrogen, all you get is heat, light and water. No carbon dioxide, no particulates—nothing. Thus, feeding hydrogen into specially designed engines could power a clean-burning vehicle. Hydrogen can be burned directly in a vehicle engine, but not as efficiently as running it from a fuel cell.

## Good News, Bad News

Nothing is ever that simple of course. Where does the hydrogen come from? We could strip it out of fossil fuels, but that doesn't help lessen our dependence on them. Researchers have also managed to extract hydrogen from ethanol. Ideally, we could remove hydrogen from water by passing electricity through it, then pipe all around using existing natural gas pipelines. Unfortunately, given the relatively small molecular weight of hydrogen gas, it would leak out of any existing natural gas pipelines like water through a soaker hose; the current pipes are porous where hydrogen gas is concerned. Storing hydrogen gas requires first liquefying it (which, of course, requires energy to do) or pressurizing it (ditto).

## Hydrogen-based Energy Advantages

- Hydrogen is colorless, odorless, and clean. It gives of heat, light, and water when combusted (with minimal $NO_X$).
- Having best energy-to-weight ratio because of its light weight, hydrogen could be economically competitive with petrofuels.
- When combined with electrolysis, fuel cells provide an efficient form of energy storage.
- Double-walled tanks can provide stable hydrogen storage, with the leakage reclaimed and restored.
- The sources for hydrogen are not as limited by geographical and political boundaries as fossil fuels.

## Hydrogen-based Energy Disadvantages

- So far the net energy after producing energy from hydrogen is negative. Therefore, the upshot of it all is this: hydrogen has the potential to be the ideal renewable energy source, providing we can solve make these three things cheaper, easier, and more effective: fuel cell technology and materials; hydrogen production from renewable—not fossil fuel—sources; and hydrogen storage and transport.
- The infrastructure for using hydrogen as a fuel for heating, electricity and transportation does not exist and would need to put into place—including building hydrogen plants, hydrogen fueling stations, and a hydrogen "grid."
- Storing and transporting hydrogen is difficult and extremely expensive.

## Where is My Electric Car?

In the late 1990s, the California Air Resources Board, an eleven-member body known for its stringent goals and regulations concerning air quality, issued a mandate that stated that any automaker that wished to continue operating in California would have to show that they were making and selling electric cars. Always resistant to any sort of regulation that might cause them to have to rethink or retool, let alone invest in something that wasn't already on the way to obsolete, automakers responded to this "Zero Emissions Vehicle" mandate in the way they do best: with lawsuits and lobbyists.

Meanwhile, some automakers did begin offering electric vehicles. The most well known was GM's EV1, a sporty little two-seater with a range of 55 to 150 miles per charge, depending on which battery was used (a full charge took eight hours), went from 0 to 60 in 8 seconds, and had a top speed of 80 mph. It featured many improvements not seen on other GM vehicles at the time (and in the case of most of them, since), aimed either at making the car more efficient or more attractive to consumers. It was almost completely silent. Other automakers that offered electric vehicles were Honda, Toyota, Chevrolet, Ford and Chrysler. If you'd like to buy one, you might occasionally see one up for sale, but you're more likely to run across one in a museum. For reasons that remain in dispute, of the hundreds of electric vehicles that hit the road, almost all of them have been destroyed. Not just recalled or dropped from production—destroyed.

## Why?

A documentary released in the summer of 2006 asks, and purports to answer, that very question. Not surprisingly, during the George W. Bush administration, CARB was persuaded to reverse its mandate. Since they no longer had to build and sell electric cars, automakers abandoned their research and production models. It is beyond the purview of this book to discuss the ulterior motives of those involved in canceling the electric-car programs. The movie, Who Killed the Electric Car?, does that with compelling reasoning and facts. Without going into too much detail, WHTEK? points to these “culprits”:

- Consumers—Since the early models would have required some degree of compromise in terms of performance, cost, and convenience, consumers who loved the idea of electric cars still preferred to wait until the technology improved. (Those who did lease or buy the vehicles, however, were for the most part so pleased that many of them mounted a protest to the mandatory return of the cars and managed to hold onto their cars—although without any promise of continued service or parts.)
- Batteries—the batteries in use at the time allow a more limited range and reliability than seemed practical, especially in cold-weather regions.
- Oil companies—Not too surprisingly, they were involved in the lobbying to kill the ZEV mandate. It has been reported that some oil companies have bought the patent rights to certain technologies, such as new types of batteries, to further ensure that the electric car does not become a reality any time soon.

- Automakers—None of the automakers that produced electric cars did so before the mandate, and none embraced the concept enthusiastically. In a nation that has seen millions of people buy such bizarre things as "pet rocks," it seems all but impossible to believe that the industry giants could not convince thousands of people to buy electric cars. They also ignored or downplayed the interest that was there, chased would-be buyers away with mandatory lease programs, and basically did all that they could to sabotage the electric car. The fact that so many of these cars were simply destroyed rather than adapted elicits a number of questions we just don't have time or space to answer here.

- The Federal government—The G.W. Bush Administration sued California for daring to try to control air pollution and minimum mileage standards. Need we say more?

- California Air Resources Board—they had a good idea, but they gave in to pressure. Not coincidentally, the head of CARB was given a plum job in the fuel cell industry.

- Hydrogen—By expanding the hype and disinformation about hydrogen and about fuel cells in general, it was easy to present a "green" façade even while derailing the more practical, proven and environmentally sound program.

## Will Electric Cars Make a Comeback?

In an ideal world, of course electric cars would come back, with high-capacity, fast-recharge batteries and a couple doze James Bondian accessories to boot. But unfortunately there doesn't seem to be enough incentive to convince the heavy hitters to work toward it, and R&D, legislation, emissions standards and p.r. all favor other technologies (hydrogen, of course) over electric cars.

With that said, it must be noted that there is at least one well funded private enterprise, Tesla motors, working on electric vehicles. Its website makes these claims about the Tesla Roadster: "100% electric; 0-60 in about 4 seconds; 135 mpg equivalent; 250 per charge; about 1¢ per mile." Not only that, it's gorgeous.

## Plug-in Hybrid Vehicles

These are vehicles that have both internal combustion engines and battery power. PHEVs can be recharged from an external electrical outlet virtually anywhere on the grid. There are also called "gas-optional" hybrids (GO-HEVs generally operate in an either/or capacity depending on the demand (highway versus city, e.g.). Since they reduce the amount of liquid fuel required to drive a car, they are even better at conserving

This Toyota Prius PHEV plugs into any 110-volt outlet to recharge the vehicle battery. A computer switches between fuels when run on biofuels. PHEVs driven on ethanol-petroleum mixtures can extend liquid fuel usage to as much as 500 mpg, although that figure reflects the petroleum component only; the ethanol and electric components would be a different number.

## Okay…What Can YOU Do?

People talk about hydrogen as the wave of the future…not the present. Regarding the so-called "hydrogen economy," the most we can do just now is keep up on the developments, follow the pros and cons, and encourage continues research and development. Someday there may be things you can do personally, but for now what you can contribute is not related to hydrogen:

- Drive an electric vehicle.
- Drive an electric-gas hybrid that continuously recharges its batteries.
- Drive a plug-in hybrid vehicle that you can recharge in your own driveway.
- Drive a plug-in hybrid vehicle that runs on biofuels.
- Write to your Congresspeople about the sharing the fuel cell research subsidies with for electric vehicles.
- Write to your Congresspeople about emission standards.
- Write to you Congresspeople about minimum mileage requirements.

# Chapter 7: Nuclear Power

Just including nuclear power in a book on alternative energy is a little frightening. Many of us recall the protests of last three decades of the 20th century over the safety of nuclear power generation (heck, some of us were even there, but we won't name names). No one questions that nuclear power works: France, for example, generates 80 percent of its electrical power from nuclear energy. The number of megawatts produced is enormous. But some of the worst-case short- and long-term consequences are enormous as well.

## What is Nuclear Power?

First, indulge us this simple lesson: If you are, say, a politician or the titular head of a superpower and want to downplay the seriousness of a situation, as well as to

appear folksy and at home with fission, you have to say "nuke-yuh-ler"—despite the fact that there is no such word. If you wish to be taken seriously as someone with knowledge of and fact-based opinions on fission, you should pronounce the word correctly: nuke-clee-er. Thank you.

## Fission

Nuclear power today is synonymous with fission, the process of splitting atoms to set off a controlled nuclear chain reaction. The energy comes when one element with a heavy nucleus (usually Uranium-235 or Plutonium-239) is split into two lighter elements; these can then set off another and another. When the reactions are self-sustaining, that's known as reaching "critical mass." Critical mass, uncontrolled, leveled Hiroshima and Nagasaki. Controlling (but sustaining) the chain reaction by slowing the neutrons delivers energy.

Unlike fossil fuels, the fissile materials used as fuels in fission plants are widely available. While concentrations vary by location, most rocks and soil contain at least a small amount of Uranium—mostly as Uranium-238, since only .72 percent of all naturally occurring Uranium is Uranium-235. Only Uranium-235 can sustain a chain reaction, so to generate power Uranium-238 can be used only if it is "enriched" to some extent. Enrichment is a kind of reprocessing, in which the spent materials are separated into re-usable fuels (Uranium, Plutonium) and fission products (every element from zinc, with the atomic number 30, to elements with atomic numbers somewhere between about 61 and 71 (the "mid- to late-lanthanides.")

Reprocessing removes up to 95 percent of the "leftover" Uranium and Plutonium for re-use in a mixed-oxide fuel.

Reprocessing also reduces the volume of “waste” materials by 90 percent, and effectively shortens the time the materials must be stored to contain the radioactivity since the remaining materials have shorter half-lives. Small wonder, then, that the larger countries creating energy through nuclear power reprocess their reactor fuel—Britain, France, Japan, and the United States, and eventually in China and India. It is this reprocessing, incidentally, that Iran announced it would begin doing, leading to much saber-rattling and recriminations from the U.S. and the Atomic Energy Commission. That’s because reprocessing can be used to produce Uranium and Plutonium for weapons.

## What’s the Catch?

As we mentioned, nuclear power plants can and do produce large quantities of relatively cost-effective energy. So why even bother with anything else? There’s enough Uranium to last several hundred years, three times as much Thorium (which can be converted to a form of Uranium) available, and breeder reactors to convert Uranium-238 to Plutonium for fuel—and an estimated 10,000 to 5 billion years’ worth of Uranium-238 around the world.

### NUCLEAR ACCIDENTS

The “catch” is safety, both short- and long-term. Let’s start with one of the most dramatic possibilities, a nuclear meltdown—known in the U.S. as the “China Syndrome” as people imagined the power plant burrowing all the way through the earth until it reached China. Nuclear power plants need to produce self-sustaining controlled chain reactions. When the core overheats and the chain reactions become un-controlled, that’s called a meltdown. The danger is that the containment of the reactor itself will then fail and release highly radioactive material into the environment.

In March 1979, a movie starring Jack Lemmon, Jane Fonda, and Michael Douglas—The China Syndrome—opened in theaters. “Experts” panned the movie’s premise, saying it could never happen thanks to all the fail-safes and backup contingencies in place. Less than two weeks later, the Three Mile Island nuclear plant experienced a partial core meltdown. Over the course of five days, a combination of equipment failures, design flaws, incorrect assumptions, and operator missteps wreaked havoc, leaking contaminated coolant into the plant and melting half the reactor core. The core containment itself was never breached, so there was no massive radiation leak, but once the reaction was finally under control there was still the matter of radioactive steam and hydrogen to deal with, as well as the system itself. Some of the steam was intentionally vented into the air, but there has been no conclusive evidence that there were any radiation-related health effects. Over the course of the next fourteen years, the nearly 100 tons of radioactive material were removed to the tune of $975 million in cleanup costs—and it still had to stay shut down since it was determined that radioactive coolant had leached into the concrete and made much of the site permanently unsafe.
Three Mile Island was not the first partial meltdown—the beginnings of one occurred in December of 1952 In Chalk River, Ontario (fortunately the reactions was halted within 30 seconds, and there was no radioactive contamination beyond the plant). There have been other partial meltdowns (Simi Valley, California, 1959; Detroit, Michigan, 1966; and Dumfries and Galloway, Scotland, 1967) as well as near-meltdowns Greifswald, East Germany, 1989; Forsmark, Sweden, 2006). For a complete list, follow this link:

- http://www.nucleartourist.com/events/part-melt.htm

## RADIATION ACCIDENTS

Experts divide possible accidents at nuclear power plants into nuclear (for example, meltdowns) and radiation accidents. Radiation accidents happen much more frequently, but since they are usually on a smaller scale there is rarely the same media attention paid as that given to Three Mile Island or the Chernobyl meltdown in 1986. However, the radiation accidents can be deadly.

For example, the International Atomic Energy Agency website includes a report on the "Preliminary Fact-Finding Mission Following the Accident at the Nuclear Fuel Processing Facility in Tokaimura, Japan." According to this report, workers at the plant made an "unauthorized" modification in procedures. On September 28, 1999, three workers were combining Uranium oxide with nitric acid to produce a Uranium solution. Instead of using the narrow container specifically designed and required by law, they poured the Uranium solution directly into the precipitation tank. Two workers—one pouring, one holding the funnel—were adding a seventh batch to the tank when the solution reached critical mass, and the resulting self-sustaining chain reaction gave off intense gamma and neutron radiation.

Over the next few days, monitoring showed intermittent changes in gamma radiation levels around the area, with evidence of several isotopes in soil samples 10 miles away; by October 2 the facility was surrounded by sandbags and concrete walls. No radioactivity was detected in the food chain or the water nearby.

The workers we mentioned, known in the report as A, B and C, were exposed directly. Seven construction workers and the three medical emergency service personnel were exposed with lesser doses, as were workers actively involved in fixing the problem. In all, 69 people were identified by October 15 as having been exposed. Patients A and B underwent emergency stem cell transplants, but died anyway. Patient C had bone marrow stimulants injected; his/her fate is not known.

Every power plant has accidents. Workers die in coalmine excavations, oil-rig disasters, and all manner of other power-related sites. Skeptics still say that nuclear power plants are foolproof thanks to their elaborate computer-controlled safety systems, but anyone who has spent a day rebooting a flaky PC or cursed a faulty idiot light on the dashboard should have some doubts about that. In any case, the point is not that nuclear power plants are more likely to have accidents but that the accidents they have are much more likely to have devastating, widespread, long-term effects. When a coal mine collapses and kills a dozen people, that's a terrible tragedy. If a reactor containment system is breached and radioactivity is released into the air and water supplies…that's a disaster.

Keloid scars formed over the thermal and radiation burns of many Hibakusha—survivors of the Hiroshima and Nagasaki bombings in

The Chernobyl disaster sent a 237 people to the hospital. Most of the 31 people killed were part of the emergency response team; 28 of the died from radiation poisoning. Incidences of childhood thyroid cancers jumped from about 150 in the four years before Chernobyl to almost 700 in the four years after, and are well over a thousand already. Radiation stays around a very long time, even for elements with short half-lives. The International Agency for Research on Cancer predicts that by 2065 there will be about 16,000 cases, with 25,000 cases of cancers in the areas affected by the fallout.

## RADIOACTIVE WASTE

Even if all proceeds according to plan at a nuclear power plant, there is the issue of the solid waste. By 2003, the U.S. had piled up 49,000 metric tons of radioactive material, most of it spent fuel—which is so in the beginning radioactive that a minute's exposure causes death. The radioactivity does break down over time. The EPA says that after 10,000 years, the material will be safe to handle.

In 1952, the 144-acre Radioactive Waste Management Complex (RWMC) was established near Idaho Falls, Idaho, to store—that is, bury—low-level radioactive waste. As early as 1954, unfortunately, not all the radioactivity was "low-level." Waste and sludge from Rocky Flats, Colorado, was also buried in the Subsurface Disposal Area (the pits) of the RWMC. After 1970, the high-level waste went elsewhere (the Waste Isolation Pilot Plant, or WIPP, in New Mexico), but nevertheless it has been documented that because of the way even low-level waste was handled in the past, radioactive contaminants got into the soil and groundwater. The information accompanying a 1975 photo released by the DOE reveals a little about this handling:

- "The waste is packed in specially constructed boxes or drums and is stacked on a sloped asphalt pad. During the stacking operation, an air support building covers the area. After stacking is complete, the air support building is removed and the area is covered with plywood, nylon-reinforced polyvinyl, and two to three feet of earth. It is planned to retrieve the TSA waste and transfer it to a federal repository when one is available. The SDA is an 88-acre, fence-enclosed portion of the RWMC. Various waste materials contaminated with non-transuranic radioisotopes are placed in pits and trenches in the SDA and buried directly in the soil."

## Fusion

Fusion is the practical opposite of fission; rather than splitting atoms, fusion combines them, releasing energy in the process. Still in the experimental stages, fusion has yet to produce a net energy gain although the largest experimental fusion reactor, the UK-based Joint European Torus (JET), has come closest. In 1997 JET hit a world record peak of 16MW. Fusion power plants would be inherently safer than fission plants since a fusion reactor chamber would contain at any given time only enough "fuel" to sustain a ten-minute reactions, whereas fission reactors contain enough for a year. Fusion is also cleaner, producing only helium (harmless) and small quantities of tritium (which can be a problem if enough accumulates but which has a half-life of only twelve years). The technical challenges in fusion, however, particularly containment, suggest that it will be years before fusion power plants can be developed.

## Nuclear Energy Pros and Cons

It works, it's here, and everybody's doing it. So how does nuclear energy balance out? According to the International Atomic Energy Agency, there are currently "435 nuclear power plants in operation with a total net installed capacity of 367.967 GW(e); 6 nuclear power plants in long-term shutdown; and 30 nuclear power plants under construction." Yet according to the World Nuclear Association as of 2006, "100 mines, 90 commercial power reactors, over 250 research reactors and a number of fuel cycle facilities have been retired from operation. Some of these have been fully dismantled." Although retirement is built into the plan for nuclear facilities, many countries have no plans to replace their decommissioned nuclear facilities.

## Nuclear Energy Advantages

1. Nuclear energy can provide huge amounts of energy from very little fuel.
2. Uranium exists in abundant quantities.
3. You can always take a $KIO_3$ (potassium iodate) "anti-radiation pill"—a thyroid blocker—to stave off radiation poisoning from the release of radioactive iodine (I-131, I-132). No, you shouldn't take it now "just in case," unless you want to set off a range of thyroid problems. And No, it won't protect you from any other form of radiation. It just prevents the radioactive iodine from building up in your thyroid. Here are the dosage recommendations for Iodine Prophylaxis that the World Health Organization says should part of nuclear event "preparedness":

| Age Group | Mass of Iodine mg | Mass of KI mg | Mass of $KIO_3$ mg | Fraction of 100mg tablet |
|---|---|---|---|---|
| Adults and adolescents (12+ years) | 100 | 130 | 170 | 1 |
| Children (3-12 years) | 50 | 65 | 85 | ½ |
| Infants (1 month-3 years | 25 | 32 | 42 | ¼ |
| Neonates (birth to 1 month) | 12.5 | 16 | 21 | 1/8 |

Table from World Health Organization's "Guidelines for Iodine Prophylaxis following Nuclear Accidents, Update 1999"

4. Proponents say that the rate of fission in a nuclear power reactor is not capable of triggering a nuclear explosion. Actually, the term used most often is "unlikely," and then usually when talking about plants in the U.S., which largely share a common design. The exact numerical value of "unlikely" remains…obscure.

5. Uranium-235 contains 3.7 million times as much energy as the same amount of coal. That means a single gram could generate the same amount of power as roughly four tons of coal.

6. Nuclear power plants are "cleaner" since they contribute no sulfur, mercury or much lower levels of "greenhouse gases" such as $CO_2$, even when you add in emissions during mining, enrichment and other processes. Power plants, followed closely by transportation, are the largest contributor of CO2: the two taken together represent almost three-quarters of the total.

7. Fusion power plants, which hold such great promises with far fewer disadvantages than fission, are not currently feasible.

## Nuclear Energy Disadvantages

1. Fission requires Uranium-235, but only .72 percent of the Uranium in the world is found as that isotope; almost all the Uranium around the world is Uranium-238.

2. Converting Uranium-238 to Uranium-235 to enable fission by thermal neutrons requires a processing step known as "enrichment"—the same process produces the critical components of nuclear weapons.

3. When the knowledge and technology required to create nuclear weapons—including the ability to enrich Uranium—spreads to people and places that have not previously had such capabilities, that is known as "nuclear proliferation." Many countries believe that the more nuclear weapons there are, the greater the chance of a nuclear war. And many countries believe that it is in their own best interest to possess the same level of weapons as others, and challenge the authority of the "haves" to limit the capabilities of the "have-nots." The most recent diplomatic crisis in this regard came when Iran announced its intention to enrich Uranium to fuel its civilian power plants; the United States, among other countries, immediately condemned this, asserting that Iran was intending to use the technology not for peaceful purposes but to create atomic weapons of its own.
4. While proponents say that the rate of fission in a nuclear power reactor is not capable of triggering a nuclear explosion, they ignore the unfortunate reality that there are other ways to trigger explosions, as we all witnessed during the tragic events of September 11, 2001.

   The following bullets are excerpted from the testimony of Dr. Gordon Thompson, Executive Director of the Institute For Resource and Security Studies, at the C-10 Research and Education Foundation, at a Public Forum On Nuclear Security held at Newburyport, MA, November 15, 2001, discussing a single plant—the Seabrook Nuclear Power Plant, located 40 miles north of Boston in Seabrook, New Hampshire:

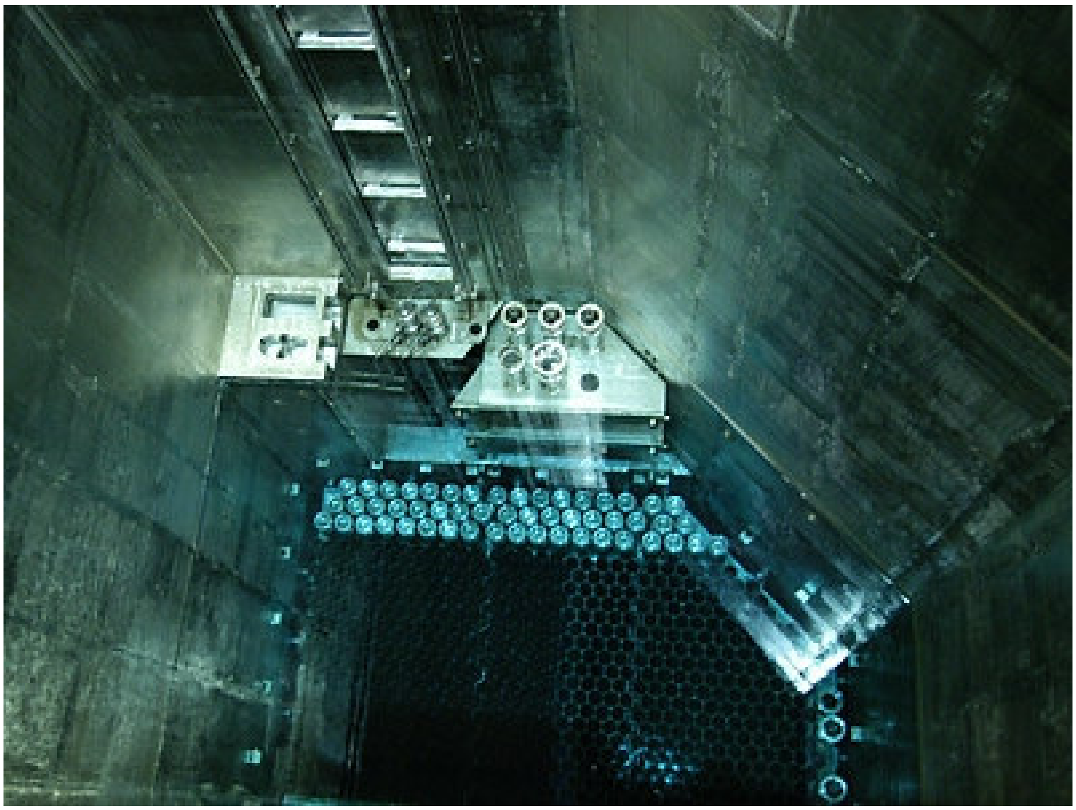
   - "Studies funded by the owners of this plant show that aircraft impact is a realistic and foreseeable event. Any aircraft over 37 tons in weight would rupture the containment dome on impact [as well as] the reactor cooling circuit. Impact on the control room or auxiliary building could be expected to lead to immediate initiation of a core melt accident. Examples of take-off weights for various aircraft follow:

Boeing 757 = 110 tons
Boeing 767 = 140-180 tons
Boeing 747 = 360-400 tons

Consequences of a 747 crash into the domes: A violent explosion could be expected if a 747 crashed into the containment domes. Aircraft contain jet fuel, and half of the fuel load contains chemical energy equivalent to 1000 tons of TNT. If the fuel accumulates in a confined space, such as exists between the inner and outer domes at Seabrook, and is ignited, then a violent explosion would occur."

"The accident at Chernobyl in 1986 released 2.5 million curies of Cesium-137. Large areas are still uninhabitable, health effects are becoming apparent and there are agricultural restrictions due to contamination 1,000 miles from the accident.… The spent fuel pool at Seabrook is approaching 20 million curies of Cesium-137 or 10 times the amount released at Chernobyl. After 40 years of operation, there will be 70-80 million curies of Cesium-137 in the spent fuel pool at Seabrook.… If [the water in the containment pools were removed, through accident or sabotage], we could have an accident 10 times greater than the Chernobyl accident."

> The Seabrook plant, incidentally, made headline news many times over the past few years with disclosures such as the head of security having no prior security experience, and a security fence that remained broken for months on end.



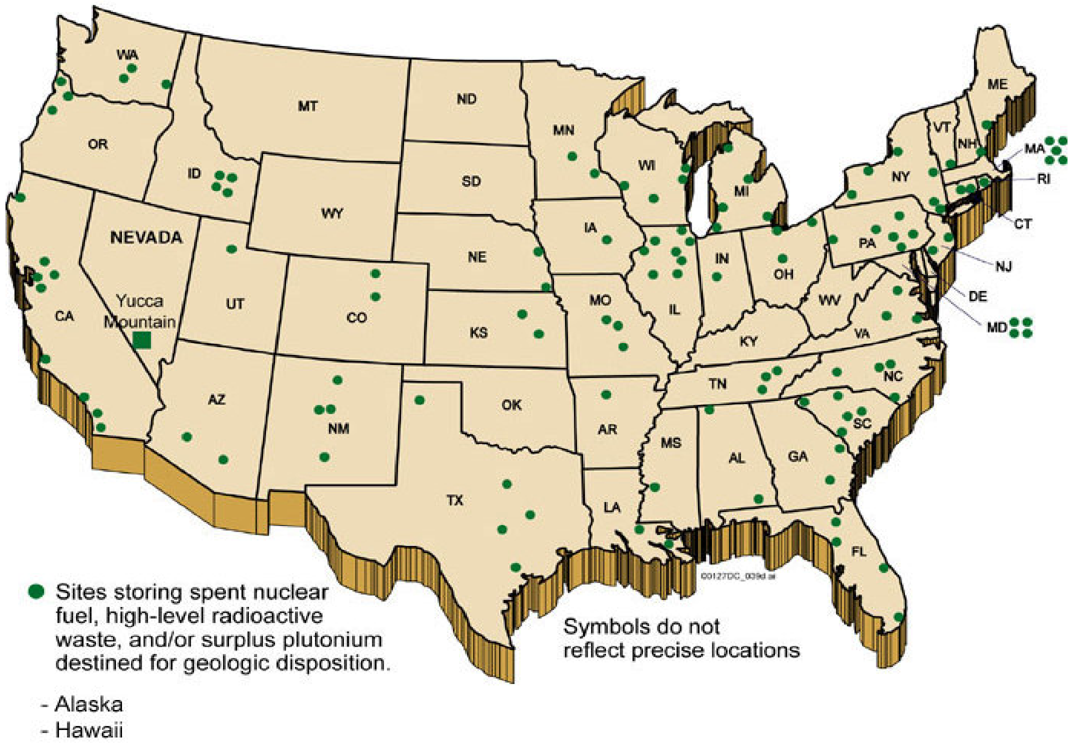
The spent fuel pond of reactor unit 2 at Mochovce Nuclear Power Plant. Levice, Slovakia, January 17-21, 2005. Photo: Dean Calma/IAEA. IAEA Image Bank

5. No one has yet solved the problem of what to do with the spent fuel. Although the DOE has its Waste Isolation Pilot Plant (WIPP) in Carlsbad, New Mexico, that will be for only low-to-medium-level transuranic waste—not spent fuel. In the United States, a single site has been proposed as the “final resting place” of the spent fuel from the country’s commercial reactors,

research reactors, nuclear subs, medical imaging sources, and private research sites: Yucca Mountain, Nevada. The site has been under evaluation and testing by the Department of Energy for two decades, but remains effectively blocked by people concerned with safety and environmental issues. Some of the issues concerned are these:

- The radioactive material will not, unfortunately, be beamed Star Trek-style to this site 90 miles from Las Vegas. Getting the spent fuel there will mean shipping it through at least 43 states, more than 100 of the largest cities, and 17 port cities—in all, an estimated 108,500 shipments over 38 years. Statistically, given the number of shipments, transportation experts say we can expect 130 trucking accidents and 440 rail accidents (oddly, the DOE's figures are significantly lower, at 66 and 10 respectively).

- The prime contractor for the proposed construction of the Yucca Mountain facility (and the current R&D associated) is none other than Bechtel Corporation, a company infamous for allegations of gross mismanagement on Boston's Big Dig project, for its financial links to the bin Laden family, and for its cozy relationship with certain people in the federal government. This last has caused widespread criticism since it has allegedly led to the awarding of no-bid contracts for rebuilding Iraq.




The Department of Energy's map as of 2007 of locations from which the spent fuel would need to be shipped to Yucca Mountain.

- There IS no rail access to Yucca Mountain. The proposed line would be "the largest federal transportation undertaking since World War I."

- Every shipment would be a viable terrorist target. Armor piercing weapons and, as we now know, aircraft could easily breach the shipping casks and instantly release radioactivity.

- The DOE's goal is to store the spent fuel in a single place so it can be better protected. Again, without the miraculous invention of instant travel, "all" the radioactive material will never be in a single location, especially since spent fuel cannot be moved immediately after being removed but must be placed in the spent-fuels pools to cool. Although expectations were that these pools would be temporary holding places, with the fuel there for only a few months or a year, many have become de facto long-term storage. So little of the spent fuel is removed for reprocessing that some pools could conceivably become full.

- The proposed shipping containers have only been tested in computer simulations (and declared safe), and there are no places by the Nuclear Regulatory Commission to determine whether they can actually withstand fire, sabotage, puncture, high impact, or submersion.

6. Nuclear power plants are extremely expensive to build, have a life expectancy of around 60 years, and the costs of disassembling (or, alternatively, entombing) the plants must be figured in as well.
7. Uranium must be mined, and this is done using traditional mining techniques and equipment, all of which do produce greenhouse gases, though in lesser quantities than coal mining.

## Okay…What Can YOU Do?

You can't build a nuclear power plant in your back yard. So what can you do?

## For Proponents of Nuclear Power

- Write to your Congresspeople.
- Find like-minded advocacy groups and get involved.

## For Opponents of Nuclear Power

- Write to your Congresspeople.
- Find like-minded advocacy groups and get involved.

# Chapter 8: Ocean and Earth Power

This chapter groups together a number of alternative energy sources that are powered in some way by the earth itself. One could argue that wind power should be here, or that tidal power should not, given that they are the product of such things as atmospheric conditions, solar input, and gravitational pull. Argue away. Nevertheless, this chapter covers hydropower, tidal power, wave power, ocean thermal conversion, and geothermal power.

## Hydro Power

Part of the beauty of hydropower lies in its simplicity. Moving water (kinetic energy) spins a turbine or wheel (mechanical energy), which drives a generator (electrical energy). Archaeologists have found evidence of water storage dams in Jordan, Egypt and elsewhere in the Middle East that date back 5,000 years to 3000 BC. One of the earliest designers to document his plans was Vitruvius (c.70 BC–c.25 BC), a Roman architect and engineer, who described an undershot waterwheel that could generate power. The Romans built many waterwheels, with the most ambitious being the one is Barbegal, France, in the 4th Century AD. Connected to a large aqueduct system that fed water to the city of Arles, Barbegal was a massive flour mill with not one but sixteen waterwheels in two parallel rows. The water turned the first pair of wheels, then flowed downhill to the second pair, then downhill again and so on until it had flowed through and turned all eight sets, after which it ran into a runoff pool at the bottom of the hill.

Today hydropower generates about 15 percent of the world's electricity (about 6 percent of the total energy supply). Rather than using waterwheels on a moving river or through a duct, most hydroelectric plants extract energy from the potential energy that comes from the vertical distance the water drops (the "head"). The water is channeled through a sluice or gate, or through enclosed pipes that funnel the water down to the turbines; these channels are called penstocks.

## Hydroelectric Plants

The typical hydroelectric plant needs four things to generate power:

- Dam—The dam holds back a river, raising the level, and controls the flow through the penstock(s). Dams create reservoirs that can be used for recreation, but it is the height difference between the stored water above and the turbines below that represents the potential energy.

- Turbines—The water behind the dam is channeled through the penstocks past the blades of turbines, which spin. This converts the kinetic energy to mechanical energy. 2. Turbine. The force of falling water pushing against the turbine's blades causes the turbine to spin. A water turbine is much like a windmill, except the energy is provided by falling water instead of wind. The turbine converts the kinetic energy of falling water into mechanical energy.
- Generator—The shafts of the turbines turn a generator, thus converting the mechanical energy to electrical energy.
- Transmission lines—The electricity is transmitted to substations and transported to consumers through the power lines.

## Microhydros

Hydroelectrical plants are big and powerful, but did you know that you can have your very own microhydro plant? All you need is a stream or a river with enough water running through it at the right pressure, and you can set up a system that feeds into turbines and generators—and into your home or business. Just as you can with your solar and/or wind systems, you can design a system that is grid-connected with battery backup, grid-connected, or standalone.

Microhydros come in two basic flavors: low-head and high-head. Head, you'll recall, is the height differential between the water and the turbine. That corresponds to pressure. Think of a high-head system as one running off a waterfall, and a low-head system as one running off a fast-moving stream, although that isn't always the case.

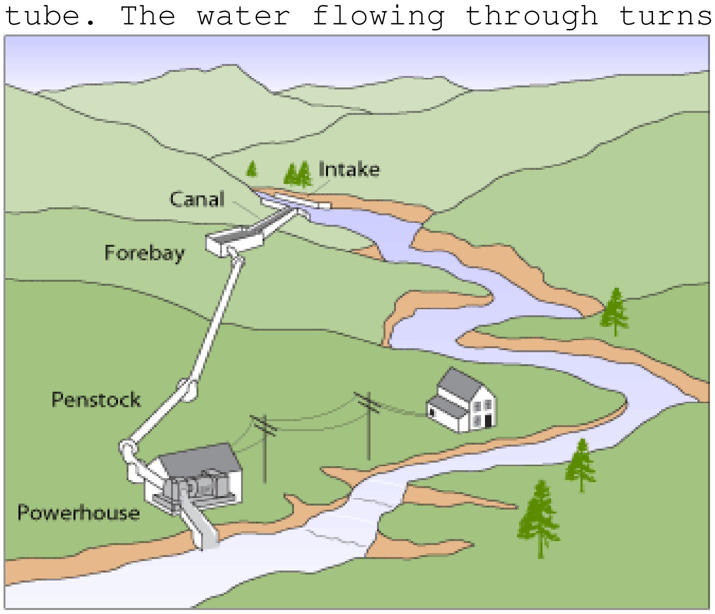
In a quick search online for microhydro resources, the names "Don Harris" and "HarrisHydro Systems" turn up over and over, with good reason: Harris is a well known pioneer in microhydro. He designs and manufactures turbine and generator systems in a shop that he powers with a microhydro system of his own. His designed feature a Pelton wheel, a highly efficient tangential-flow impulse turbine with spoon-shaped blades that capture a jet of water.

Impulse turbines transfer energy according to Newton's second law of motion, which is roughly paraphrased as "the momentum of an object, or force ("F"), is equal to the object's mass ("m") multiplied by its acceleration ("a"), or F=ma." It works like so: first, the water's potential energy (the head) is converted to kinetic energy by being funneled through a nozzle to form a jet. The jet of water moves at a given velocity, but when it strikes the spoons/buckets of the turbine, it loses velocity or acceleration, so the momentum changes. That change in momentum translates to an exertion of force that turns the shaft. The water pressure itself doe not change. Impulse turbines are the most commonly used turbines in domestic systems, and those with high heads.

Reaction turbines transfer energy according to Newton's third law of motion, which is roughly paraphrased as "for every action force there is an equal, but opposite, reaction force." The water moves through the turbine, losing pressure, which forces it to give up its energy. The turbines have to be either encased (to contain the water pressure or suction) or be completely submerged by the flowing water. Water wheels are reaction turbines. Most turbines are reaction-type turbines. They are used for systems with low and medium heads.

A typical microhydro system, then, needs a stream, an intake system, a penstock, and a powerhouse. Although the actual components are much more high-tech and specialized, you can envision a high-head microhydro system as this as a box or funnel at the top of a waterfall, a garden hose or a trough running downhill from the intake, the water from the hose/trough shooting onto a turbine (probably Pelton-style), and the turbine turning a generator. A low-head microhydro system is equally simple. They have a screened intake (or a mini-dam), and this feeds into a settling basin or forebay for any silt to precipitate out; this empties into a short canal that feeds into a ten-foot draft tube. The water flowing through turns a turbine (probably Turgo-style). Note that in neither case do you block or divert the stream (for which you would need a permit anyway, even if the water is on your property, and which may turn out to be prohibited in your area).



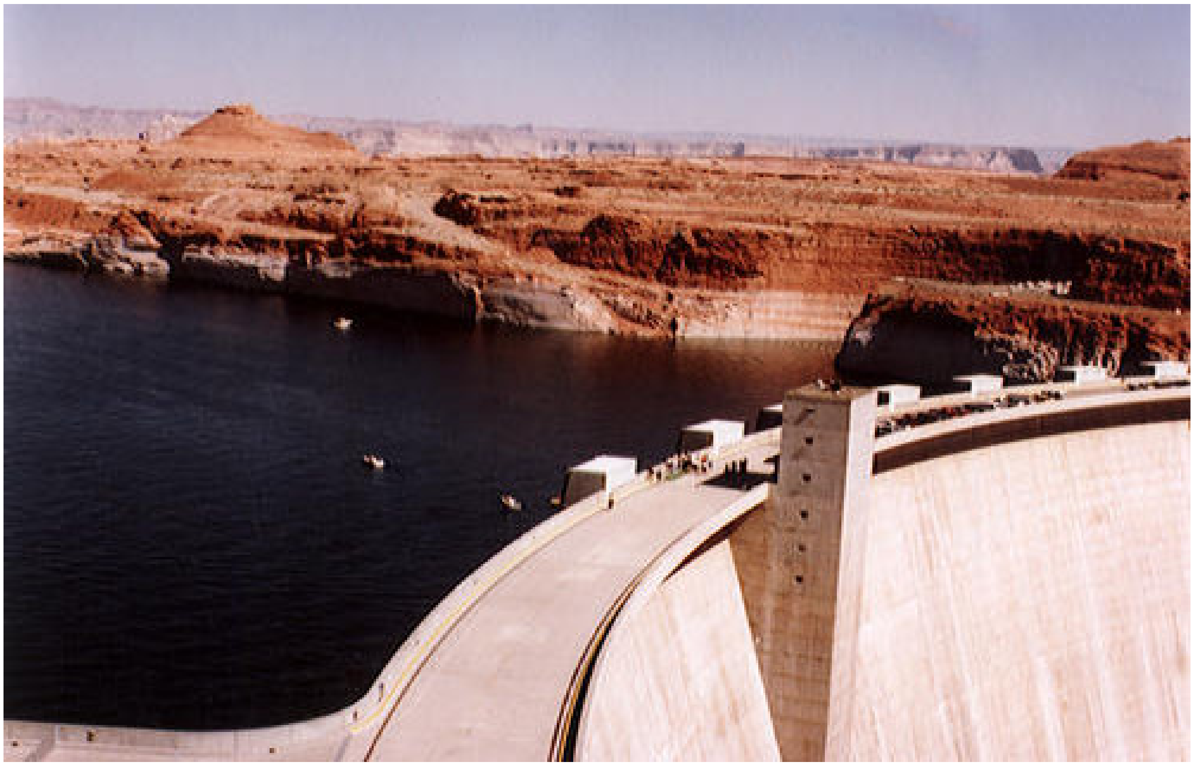
## Hydropower Advantages

1. As long as the water is there in sufficient quantity, hydro stations can generate power 24/7.
2. Large hydro stations can shift into maximum capacity to meet peak demands simply by controlling the amount of water released.
3. Microhydro systems produce no pollutants.
4. Hydropower is a renewable resource.
5. Most countries have access to waterways that can be used for hydro power.
6. Large dams can be useful for flood control.
7. Microhydro systems can provide power without affecting water quality, without affecting the habitat, and without altering the course of the river or stream. It leaves a very tiny footprint.
8. Large and mega-dams can create recreational lakes in areas where before there were none.

## Hydropower Disadvantages

1. Large hydro stations that create reservoirs actually dump huge amounts of methane and $CO_2$ into the atmosphere. When the area behind the dam is flooded, the trees and other plant material that get covered up rot and sift to the bottom where they continue to decompose without oxygen. This creates methane, which is released when the water flows through the turbines.
2. The reservoirs created by large dams and mega-dams destroy local habitats. When the area is flooded, plant life is submerged, and any animal—and human—life in the area must relocate or perish.

3. Large hydroelectric dams are expensive to build.
4. Large hydroelectric dams can only be used in a limited number of places—those with large water supplies.
5. Damming rivers and streams changes the natural waterways, diverting water from areas that depend on it.
6. Damming rivers changes the quality, quantity and even the temperature of the water that flows downstream. This can have disastrous effects on agriculture as well as potability.
7. Changing the path of a river can cause serious disputes between neighbors, from individuals to nations.
8. Water moving over a dam can pick up nitrogen, causing fish kills downstream.
9. Many small and medium dams built in the past to power industries such as mills and factories are no longer used, and are growing unstable. Allowing them to self-destruct rather than removing them in a controlled manner can lead to serious flooding, including loss of life and property.
10. Dams alter the spawning patterns of the fish, and often result in absenting entire species from an area.



Glen Canyon Dam, Lake Powell, Arizona, in 2002. Photo: Larry Gordon, Bureau of Reclamation.

11. When large amounts of water are released from a large dam or mega-dam the shores of man-made reservoirs naturally recede, leaving behind mud flats and reducing the surface area leaving less space for fish. Sometimes Mother Nature plays a role, as with Lake Powell, created by the Glen Canyon Dam. With reduced flow of the Colorado River, evaporation, and seepage back into the canyon banks, Lake Powell loses an average of 860,000 acre feet of water each year—about as much water as Los Angeles consumes annually. While it is perhaps one of the most beautiful lakes in the U.S. with its red-rock canyon sides, 150 feet below its 266 surface miles lie centuries of archaeological riches—as well as the canyon itself.

## Tidal Power

The tides are caused by the gravitational forces of the moon and the sun, which vary due to the elliptical orbits and thus cause the oceans to rise and fall in a continuous and predictable cycle, with all coastal areas having two high tides and two low tides within slightly more than 24 hours.

There are two ways that this phenomenon are used to generate power. The first captures of the kinetic energy of the ebbing and surging of the water, and there are currently several technological designs that make use of this powerful action. One type of design is with a tidal fence, in which vertical-axis "windmills" are strung together like giant turnstiles, usually between land masses, to capitalize on the currents created in coastal waters. With currents capable of reaching up 9 mph, and the fact that seawater is so much denser than air, these tidal fences can generate more energy than wind turbines with identical velocities.

Another design that uses the currents created by the ebb and flow depends on tidal turbines. These look very much like offshore, underwater wind farms—under 60 to 100 feet of water, in fact. In areas where the coastal currents run between 4 and 5½ mph, a 50'-diameter tidal turbine can generate as much energy as a wind turbine at the same speed and almost four times the size.

Built in 1632 on l'île de Bréhat, France, the Birlot tide mill is fed by the reservoir created by a 140-meter dyke that traps 30,000 cubic meters of the Kerpont Channel as "potential energy." The mill was still in use until 1920, at which time it apparently became cheaper to import

Beginning in the Middle Ages, one way people used the ebb and flow of the tides to generate power was the tide mill, in which a dam with a sluice gate stretches across a small tidal inlet or seals off a portion of an estuary. The tide flows through the gate into the reservoir created by the dam. The Birlot Mill on l'île de Bréhat, for example, ran on a "half-tide" schedule—it could only run for the first three hours of the rising tide and the last three hours of the ebbing tide. This gave the miller two six-hour stretches of continuous operation.

Another way to make use of tidal power is to take advantage of the potential energy of the head—the different between high tide levels and low tide levels. To harness this power, the head must be at least 16 feet, which limits the possible sites around the globe to 40. (While the U.S. currently has no tidal power plants, they would be possible in both the Pacific Northwest and the Atlantic Northeast coastal areas.) This method requires the construction of a barrage or dam equipped with gates and turbines. When the "head" is great enough, the gates are opened and water flows through the turbines from one side of the dam to the other, driving a generator. . While the engineering and specific designs have been greatly enhanced over the years, tidal fences have been in use since the 1960s. Construction on the Rance tidal power station, the first ever, began in 1960. Rance began operation in 1966 with a 240MW installed capacity. The Rance barrage can generate electricity on both the ebb and the flood tide, and can also be used for pumped storage depending on demand.

The 700-meter-long barrage on the estuary of the Rance River, Bretagne, France. The power-plant section is just under half that length. The bad news? There have been progressive silting issues. Sand-eels and plaice disappeared, but sea bass and cuttlefish returned to the river. The good news? Since it was connected to France's power grid in 1967, the project has finally paid for itself. Today it produces .012 percent of the

## Tidal Power Advantages

1. Once the technology is in place, operation is nearly free: tidal power consumes no fuel, and maintenance costs and human interaction and oversight are minimal.
2. Tides are predictable, which means power generation is predictable, too.
3. Tidal energy is renewable.

4. Of the three tidal power technologies, tidal turbines appear to have the least effect on sea life since they do not block migration paths.

## Tidal Power Disadvantages

1. Barrages and dams can affect the migration patterns of sea life—fish, sea mammals, and shorebirds—as can tidal fences.
2. Silt can build up behind dams and barrages, affecting the local ecosystem.
3. Construction costs are high, and the construction process can upset the local ecosystem temporarily. Additionally, the presence of a dam or barrage can have a negative effect on ecosystems up and downstream.
4. Active power generation takes place only about ten hours per day.
5. Dams and barrages can affect the patterns of fishing and recreational boats as well as commercial ships.

## Wave Power

For more than 200 years inventors worldwide have filed patents for wave-power technology of a dazzling variety of designs—bobbing objects ("ducks"), buoys, articulated rafts, floating bags, overspills, and many others. There has been no shortage of ideas. Many of these ideas are in fact technically feasible, so it seems a shame that this renewable energy resource has not been much used. The main challenge is building a system that is economically attractive when so many other forms of energy production (nuclear, fossil fuels) receive subsidies and already have infrastructure in place. There are some wave power systems in place around the globe: the Faroe Islands; Islay, Scotland; Oahu, Hawaii (providing power for the U.S. Marine Corps. base there); Santoña, Spain; Portugal; and even the world's first commercial "wave farm" in England.

The World Energy Council has estimated that wave power could produce as much energy in a year as 2,000 oil, gas, coal and nuclear power plants—twice the amount of electricity produced worldwide—by generating as much as 2 terawatts (that's 1 trillion watts).

Not every place is a candidate for wave power generation. Prime locations identified are Scotland, northern Canada, southern Africa, and the Atlantic Northeast and Pacific Northwest of the United States. Experts have estimated that wave-power systems in the Pacific Northwest alone could generate up to 70 kW per meter of coastline.

## Typical Designs

Wave-power systems can be located onshore or offshore, and come in a surprising range of designs. There are currently four basic "capture" methods: point absorbers (largely vertical, with a relatively small footprint on the surface); attenuators (horizontal footprint, arranged parallel to the waves to undulate with the flow); terminators (perpendicular to the waves); and overtopping (perpendicular to the waves, which break over the system). There are different power take-off systems including hydraulic ram (water hammer pumps water above the starting point); elastomeric hose pump (peristaltic, like your intestinal tract), pump-to-shore, hydroelectric turbine, air turbine, and linear electrical generator. Here are some systems already in operation, or close to it:

## OFFSHORE: POINT ABSORBER SYSTEMS

- The Salter "Duck"—In 1970 Stephen Salter ("the father of wave power"), a professor at the University of Edinburgh, designed a wave-power device that could both stop 90 percent of the wave motion and convert 90 percent of that into electricity, a standard that all other designed continue to be measured against. Ironically, the Duck itself never went into use. During the 1990s, a project based on the Duck and dubbed the OSPREY (Ocean Swell Powered Renewable Energy), commenced in the Clyde Estuary of the Scottish coast. Capable of generating 1 mW of power, the OSPREY was on its way to becoming an unqualified success until Hurricane Felix came along and sunk it (at great expense in terms of both money and confidence).

- The AquaBuOY® wave energy device—AquaBuOYs (Finivera Renewables) really do look like navigational buoys, and this is no coincidence. Obviously, maximum output from a wave-power device should be during those times when the waves are at their highest, but if the technology can't withstand rough seas (as with the OSPREY, above), they aren't much good. Operating on the premise that since navigational buoys can survive for decades in all sorts of conditions, the AquaBuOYs were designed to ride the waves for an estimated 100 years. The vertical wave action drives a two-stroke hose pump that directs pressurized seawater into a turbine connected to a generator; the resulting power is sent via an underwater transmission line. While at least four projects are in the permitting process (including one in Makah Bay, WA), as of this writing there are no AquaBuOY systems currently in operation.

- PowerBuoy®—Like the AquaBuOY above, the PowerBuoy resembles a navigational buoy, although one with long cylinder extending far below that houses the mechanics of the system. These PowerBuoys (Ocean Power Technologies) are placed from one to five miles offshore in 100 to 200 feet of water, and


A PowerBuoy floating off the New Jersey coast in the U.S. Photo: Ocean Power Technologies can be ganged together to form a "wave-power farm" such as the one to be installed off the coast of Santoña, Spain. That 1.39MW station will have one 40kW and nine 150kW PowerBuoys .

## OFFSHORE: ATTENUATOR SYSTEMS

- Pelamis®—Ocean Power Delivery, Ltd., developed world's first commercial offshore wave-power facility using its Pelamis Wave Energy Converter, a string of steel cylinders hinged to articulate. It lies half-submerged, like a 150-meter-long, bright red sea snake (pelamis is the genus for the sea snake), more or less facing into the waves. The cylinders contain hydraulic pumps activated by the wave action; the electricity comes as high-pressure oil gets pumped into generators. The first phase of the wave farm, located 5 km off the coast of Portugal, comprises three 750kW Pelamis "snakes" that combined

A single, moored Pelamis snakes across the ocean surface. Photo: Ocean Power Delivery to generate 2.25 MW; another 28 are expected to be added, bringing the total power generated to 22.5 MW—enough to provide electricity for more than 15,000 homes.

## OFFSHORE: TERMINATOR SYSTEMS

- Nearshore OWC—This is an offshore version of the Limpet, described below.

## OFFSHORE: OVERTOPPING SYSTEMS

- Wave Dragon—Overtopping systems work very much like hydroelectric dams, using the potential energy of water stored at an elevation higher than the turbines it drives. The Wave Dragon overtopping system funnels the waves into its own reservoir to create a head; the water is then released through channels that contain turbines. The Wave Dragon is moored 25 to 40 meters offshore in deep water, somewhat like a floating beach.



A Wave Dragon off Nissum Bredning, Denmark. Photo: Wave Dragon

## ONSHORE: OSCILLATING WATER COLUMN:

- Limpet (Land Installed Marine Powered Energy Transformer)—This an oscillating water column (OWC) system to convert the waves' kinetic energy to electrical power. Picture a box with the open end submerged but slightly tilted toward the incoming waves, with air trapped inside the box. Now imagine there is a narrow outlet for this air, and inside this tube is a turbine. As the waves raise the level of the water inside the box, the air rushing in and out of the tube powers the turbine. A Limpet system (WaveGen) in Islay, Scotland, uses an inclined oscillating water column (OWC) system optimized for the area's anverage annial wave intensity, and feeds a pair of 250kW generators. The Limpet power station in the Faroes is very similar. WaveGen also designs a near-shore oscillating water-column system.

The 500 kW Limpet power generator on Islay, the southernmost island of Scotland's Inner Hebrides.

There are many companies designing wave-power systems using these and other designs (such as the tapered channel system, an onshore system, and the pedulor system, an offshore device), and new ones seem to come along frequently as more countries come to recognize the potential of wave power.

## Wave Power Advantages

1. Wave energy is an abundant and renewable resource.
2. Even though not every country has coastline, the combined potential output of wave-power generation would meet all the electricity needs of the world.

3. Although the equipment represents a substantial investment, the “fuel” is free and not confined by geopolitical boundaries.
4. The effect on the environment is deemed to be minimal.

### Wave Power Disadvantages

1. These are most effective near coastlines, of which there is a finite supply.
2. Large scale systems are still in the early stages.

## Ocean Thermal Energy Conversion (OTEC)

Another way in which the ocean can shared its stored solar energy is through thermal energy conversion. Like a backwards refrigerator, OTEC takes advantage of the temperature difference of surface water and deep water. As long as there exists a difference of 38°F, OTEC can generate power.

Closed-cycle OTEC systems use a working fluid with a low boiling point, such as ammonia. Warm seawater is pumped though an evaporator filled with the working fluid. The vapor created by warming the working fluid drives turbines. Cold seawater from the depths is pumped through a second heat exchanger, which cools the vapor and returns it to liquid form for re-use. Open Cycle systems vary only in that they use seawater itself as the working fluid.
The Department of Energy developed a prototype OTEC facility on land at Keahole Point on the Kona coast of Hawaii. Partially funded by the Pacific International Center for High Technology Research in Hawaii, the 10kW

facility was never commercialized. India is currently testing a 1mW offshore OTEC. An 8mW power plant (with gas turbine backup) has been proposed for the a U.S. Navy base on an island in the Indian Ocean.

## Ocean Thermal Energy Conversion Advantages

1. OTEC has other uses besides power generation, including air conditioning, chilled-soil agriculture (allowing plants to grow in places that might otherwise be too hot), aquaculture (growing microalgae, which you may recall has excellent potential as biofuel), desalination, and mineral extraction.
2. It is a renewable resource.

## Ocean Thermal Energy Conversion Disadvantages

1. Offshore OTEC may be affected by the United Nations Convention on the Law of the Sea treaty (UNCLOS), which was refined in 1994 to cover the deep seabed area and define it as "the common heritage of mankind." That would affect mining activities in particular. As of this writing, 153 countries that have signed and ratified the treaty, in force since 1994. The United States has thus far declined to ratify UNCLOS, despite the fact that it is supported by a majority of the Senate, the Pentagon, and most scientific, international legal scholar, mining, and environmentalist groups.
2. It is limited to areas with the proper temperature differential.

3. With overall ratings of just 1 to 3 percent, current OTEC systems are not very efficient.

## Geothermal Energy

This means of energy production uses the heat of the earth to generate power. Currently around 8,000 MW of electricity, with 2,800 MW in the United States alone. As with many other alternative sources, geothermal shows great potential. In a report released last year, the U.S. Geological Survey estimates that the geothermal potential in the U.S. alone is between 95,000 and 150,000 MWe (megawatts of electric power). A report issued just last year by MIT estimates the world's geothermal potential using Enhanced Geothermal Systems (EGS) at more than to be over 13,000 ZJ (a zettajoule is $10^{21}$) of which over 200 ZJ would be extractable with current technology.

## Geothermal Technology

There are two basic types of geothermal power plants currently in use. Steam plants can use the hot water and very hot steam (over 300°F) to power a turbine that feeds a generator directly ("dry steam") or they can depressurize the very high-pressure and -temperature water to create steam ("flash steam"). The only emission in enough quantity to be significant is steam, although minute amounts of $CO_2$, $NO_x$ and sulfur are released (in amounts almost 50 less than the amounts emitted at fossil fuel plants). Currently steam plants can generate electricity for about 4¢ to 6¢ per kWh.

Binary plants can operate at locations with lower temperatures ((100° F to 300° F), which is more readily available. Hot water passes through a heat exchanger along with a working fluid that has a lower boiling point (e.g., isobutene, isopentane). The working fluid vaporizes, turning the turbines and powering the generators. Because this system is a closed loop, there are no emissions. Currently steam plants can generate electricity for about 5¢ to 8¢ per kWh. Because the lower-temperature geothermal locations are more plentiful, most plants are binary.

Geothermal energy can also be used a direct heat source. Nearly all the houses in Iceland are heated with water from hot springs, and the country generates more than half its energy from geothermal sources. If the heat is there but the water is not, energy can still be extracted. Pumping water through hot rock heats the water and can be used directly or to generate power.

Underground heat pumps are also a form of geothermal energy, these work like refrigerators in reverse. Believe it or not, you don't have to dig very deep to find the level of earth that stays at a fairly constant temperature—usually about 8 feet. Heat pumps use pipes (buried well below the frost line) that circulate a refrigerant through a cycle of condensing and evaporating between two heat exchangers. One heat exchanger evaporates at low pressure and absorbs heat. A compressor pushes the refrigerant vapor, now at high pressure, to other coil where the refrigerant condenses and releases the heat. Unlike refrigerators and air conditioners, heat pumps can work in both directions—heating and cooling. Energy cost savings with a ground-based heat pump are substantial.

## Geothermal Power Advantages

1. Geothermal energy produces little or no emissions.
2. In most cases, the “fuel” is free, although with the “hot rock” method water must be used, and may have to be transported there. Once the power stations are built they cost very little to operate.
3. Geothermal power plants usually have a small footprint, and very little environmental impact.
4. Ground-based heat pumps can be used almost anywhere. If you’re thinking that they won’t work in your snowy neck of the woods, consider that they are used extensively in Canada.

## Geothermal Power Disadvantages

1. Geothermal cannot be considered a renewable resource (although it is a sustainable one).
2. Not every area has accessible geothermal sources. The hot rocks and water must be within drilling range (except in the case of natural geysers).
3. Geothermal sites can run out of steam, as their temperatures drop to low. This can happen naturally or if a “hot rock” extraction method is mismanaged, and the water injected cools the rocks.
4. Along with the hot water and/or steam, geothermal sources can also yield up harmful gases and minerals.
5. Drilling deep into the ground, especially when water is then pumped into the holes, can set off “small seismic events” —earthquakes.
6. While research can suggest likely places for geothermal power plants, there is no guarantee a given

site will produce enough energy to offset the capital expenditure and operating costs.

## What Can You Do?

Ocean and earth power gives you a lot of options. We've collected the ideas from this chapter—hydropower, tidal power, wave power, ocean thermal conversion, and geothermal power—at the end to remind you of the variety, and to reinforce the idea that while there is no single perfect alternative energy source for the world, or even the country, there are many that in combination could be the perfect solution for you. Much depends on where you live and what resources you have.

- If you have a river, stream, brook, waterfall or some other running water nearby, look into installing a microhydro system to generate some or all of your electricity.

- If you live on a body of water that experiences tides, you may be able to use them to your advantage. Naturally you won't be damming up estuaries to power your house (your own personal tide mill), but it is possible that you could implement something on a much smaller scale that powers, say, your dock lights. Realistically, however, what you'll be doing is keeping up with the technology so you'll know when someone has developed something with a more personal application.

- While none of the wave power technologies are available as personal-size power stations, if you live somewhere that has strong, consistent waves, you may be able to adapt some of the techniques.

- While you probably don't have a geyser in your yard, you might be able to install a ground-based heat pump to heat and cool your house.

## Conclusion

"Energy" used to be an individual concern. If you wanted heat, you chopped wood or dug peat. If you wanted light, you put oil in a lamp. If you wanted water, you dug a well and used a hand pump or shared a community well and carried water in a bucket. Now most of us are connected through not one but many grids—power, water, telephone, internet, wireless phone, highway, sewer, etcetera. That has made many things faster, easier and sometimes cheaper, but it's also allowed many of us to be completely dependent on remote systems for our daily lives.

Few people beyond the oil and coal companies themselves would argue that it's time to reduce our dependence on fossil fuels, for many reasons: political, homeland security, environment, and scarcity, to name a few. When it comes to actually making changes, however, we are all much slower.

Part of this comes from the way those of us in recent generations have become accustomed to having large, centralized power sources that feed back to us as individuals. Thus, when others begin discussing alternative energy, we think of those on a grand scale, too: wind farms, solar farms, huge biomass factories.

And of course another reason we are slow to change is that we're human. Change is hard. Change is scary. Change is costly. Even when it doesn't require sacrifices, it still requires us to adapt our habits, create new systems, and sometimes even rewire our ways of thinking.

The message we hope you will take from this book is this:

- There are many options for alternative power generation that, when combined, have the potential to reduce our reliance on fossil fuels—and many of them work as well on a personal scale as they do when connected to the "grid."

That is, you can encourage your town to create treat its trash as biomass, and still set up your own biorefinery in the basement if you feel inclined. You can support sun farms on a grand scale, but you can also put PVs on your roof, or buy "green energy" from your local power plant. You can push for a geothermal power plant in your county, but you can still install a ground-based heat pump.

In other words, "think globally, but act regionally, locally, and personally."