

ALTERNATIVE FUELS

Standard fuel sources include non-renewable energy sources such as petroleum based products, natural gas, coal, propane and nuclear power. Alternative fuels on the other hand refer to any non-conventional source materials that include biofuels (e.g., biodiesel, ethanol), hydrogen, wind power, hydroelectricity, geothermal energy, and solar power. The energy from alternative fuels may also be stored for later use using chemical storage systems (e.g., batteries, fuel cells). Alternative fuel sources are non-fossil fuel based and are an integral part of a renewable and sustainable energy practice. Although fossil fuel substitutions have notable drawbacks, the development and implementation of alternative fuel technologies coupled with extreme conservation measures may provide industrialized nations a means to wean their historical dependence on fossil fuels without comprising economic prosperity.

The inexpensive fuels of the previous century are no longer and high fossil-fuel consumption among western nations show trends of declining. In 2008, global oil consumption decreased by 0.6 percent, the largest decrease in nearly three decades that was driven primarily by 2 to 3 percent declines in traditionally major oil consuming nations such as the United States, Canada, and western Europe. However, the oil consumption decline of western nations is being countered by increasing consumption by developing world economies, particularly China and India. The world has already consumed about half of the recoverable fossil fuels since the modern industrial age, remarkable given fossil fuel development requires millions of years and specialized biological, geologic and climatic conditions. For instance, oil forms from the decomposition of marine life deposited in sedimentary basins that undergoes compaction from the increasing pressure of the overlying materials, thus trapping the hydrocarbons and the gas byproducts from the organic breakdown deep into the Earth's crust. The majority of oil and natural gas worldwide ~~are-is~~ found in sedimentary rock layers of the Cenozoic Era about 50 million years ago. The process of oil and natural gas creation took millions of years while the process of extraction is on the order of a couple centuries.

Although uncertainty exists about when world oil production will peak and when viable oil reserves will cease, experts generally agree supplies will be severely limited within the next generation and a fossil fuel energy crisis may be unavoidable. The ratio of oil consumption to oil availability is nearly 3:1. Based on 2009 global consumption and production levels, British Petroleum (BP) estimates 42 years are left before current oil reserves are completely depleted. However, the BP estimate does not incorporate several key parameters that can influence oil consumption, such as: consumption pattern changes, including those stemming from population increases; conservation measures; alternative fuel usage; increased oil extraction costs from less accessible reserves; pricing and production strategies from oil producers; (e.g., the Organization of Petroleum Exporting Countries, OPEC); or new oil reserve discoveries. Whether or not current oil reserves will be sufficient to meet demand for the next decade or several decades or the whether or not world oil production has climaxed is largely immaterial. The global energy crisis will begin when oil production is growing more slowly than the amount demanded by the population coupled with volatile pricing. As such, energy consumption

habits will alter as petroleum-based products gradually become more expensive and alternative energy solutions are sought.

Concerns over oil reserves and exorbitant prices in the early 21st century have led to increased consumption of other fossil based fuels, particularly coal that has become the mainstay electrical energy source of developing world economies. As with oil, coal is derived from the decomposition of organic material on a geologic time scale. Coal forms from decaying plant material that accumulated near low-lying swamps during warm, humid climate conditions and then undergoes physical transformation as the material is subjected to increasing temperature and pressure below the surface of the Earth. The majority of world's coal was formed during the Carboniferous period approximately 300 to 360 million years ago during a period of high sea-level and extensive tropical vegetation. Since coals are derived from carbon-based organisms, the combustion of coal produces large quantities of carbon dioxide (CO₂) as well as other air pollutants such as sulfur dioxide (SO₂), nitrogen oxides, and particulate matter. Anthracite, the highest grade coal, provides the highest energy content per unit mass while producing smallest amount of pollutants compared with the lower and more abundant coal grades of bituminous, sub-bituminous and lignite. Based on current consumption patterns, coal reserves will last at least five times longer than oil; however, coal as with other fossil based fuels is not a sustainable energy option.

In order to stave off the impending energy predicament, some have turned to increased fossil fuel extraction using unconventional methods and sources. Oil (or tar) sands are being exploited for bitumen, a viscous black oil that requires multiple extraction, separation and dilution processes before the oil can be used as a viable fuel. Canadian oil sands, such as the Athabasca fields in Alberta, are particularly rich, producing nearly one million barrels per day with plans to triple that production. Oil sand extraction has significant environmental consequences (e.g., increased greenhouse gas emissions, diminished water quality, wildlife habitat loss) with minimal energy gains. Two tons of tar sands are needed to produce one barrel of crude oil. Other unconventional sources include oil shales and liquefied coal, but the economic and environmental impacts are cost prohibitive and widespread adoption is not likely it has been impossible so far to gain more energy from burning the resulting fuel than was used in producing it. Consequently, fossil fuels are gradually being substituted with alternative energies.

Biofuels

Alternative energy fuels comprise renewable energy resources such as biofuels, solid, liquid or gaseous fuels derived from living or recently living organic material or biomass, or hydrogen made from wind, solar or geothermal energy. The energy from biomass is used as a fuel for domestic heating and cooking, running power generators for electricity production, and transportation fuels. Biofuels include long-exploited sources such as wood and grass that produce heat directly when burned.

Liquid biofuels are increasingly being developed as substitutes for gasoline for the transportation fuel market. The most touted substitutes are ethanol (also known as ethyl alcohol or grain alcohol) from fermented plant starches and sugar-based feedstocks and biodiesel from oil-based crops. In the United States, ethanol derived from corn is the

leading fuel alternative, devoting 14 percent of the annual national corn crop for ethanol fuel production. Since pure ethanol provides only one-third of the energy of produced from gasoline, ethanol is often blended with gasoline to increase the energy efficiency; a common ethanol blend for vehicles is E85, a high-octane mixture of 85 percent ethanol and 15 percent gasoline. Ethanol production and demand in the United States has increased significantly in the past decade, but gasoline consumption has paralleled those increases. Ethanol production technologies are inefficient, consuming as much energy during production as ~~that~~ is released during combustion. Corn-based ethanol currently meets only about 4 percent of the total U.S. fuel needs; distilling the entire corn crop would only satisfy less than one-fourth of that demand. Ethanol from corn remains a viable alternative fuel in the United States due to the relative abundant corn supplies, an established infrastructure and, perhaps, more importantly, a 51 cents per gallon federal subsidy.

Similar energy efficiency problems—consuming almost as much energy as it releases— occur with ethanol originating from other plants. In non-grain crops, the material being converted to liquid fuel is the cellulose biomass, a plant material comprised of complex sugar polymers found in agricultural and food processing byproducts (e.g., wood chips, corn husks, household garbage). Cellulose could be grown in greater quantities than grain with less environmental impact, but converting ~~them-it~~ into ethanol is more difficult than distilling the starches in corn because the chemical bonds holding the cellulose together must be broken first. This step requires additional energy, thus making cellulose-based ethanol no more energy efficient than corn ethanol. Energy is further expended during collection and transportation of the dispersed crop to a distillery for refinement, especially given that only 3 percent of the biomass eventually becomes ethanol. Although ethanol technologies may improve over time, the energy efficiency of ethanol is limited by the energy available from the input product.

In contrast to corn and cellulose-based varieties, ethanol made from sugarcane can achieve a positive energy balance because sugar yields more calories per acre than any other crop. Sugarcane based ethanol yields eight times more energy than the fossil fuel inputs to its production. Several low-latitude countries produce sugar ethanol on a large scale, using the non-sugar parts of the cane plant as fuel for the distillation process. In particular, Brazil devotes enormous tracts of land for sugar production that are used for generating 8 percent of the national total fuel supply, a remarkable percentage especially when considering the per capita energy usage by Brazilians is about one-fifth of that of Americans.

Another path to biofuels is growing oil crops and plant oil-based sources for use in diesel engines. Plant oil undergoes a process called esterification, joining two organic molecules together. Alcohol and a catalyst (a substance that enables a chemical reaction) convert the oil into an ester fuel called biodiesel. The process is more efficient than alcohol distillation, and many crops grow seeds that are rich in oil. Soybeans are a premium choice in the United States because they are grown on an industrial scale, but the amount of fuel obtainable per acre is even less than with corn ethanol, making the product viability difficult. In Europe, biodiesel stems chiefly from palm plantations in the tropics. The plantations are environmentally destructive and clearing land for them produces more carbon dioxide than the oil saves from not using fossil fuels. Other oil crops face similar problems, balancing energy acquisition with negative consequences

such as environmental degradation and food production limitations. Biodiesel is also being made from oil-based plant substances that have been processed, such as vegetable and other cooking oils discarded by restaurants and food processors. As with other oil crop biofuels, the problem is scaling, as only a very small proportion of the world has ~~ve~~ the technological infrastructure to utilize biodiesel and the amount available would not be sufficient for residential and commercial energy needs.

Hydrogen

Hydrogen is a light weight gas derived in large quantities from the chemical breakdown of hydrogen-based sources (e.g., water) or as a byproduct of other chemical processes. The two most common techniques for hydrogen production are steam production and electrolysis. The steam production method separates carbon atoms from methane (natural gas, CH₄); however, the process results in the increase of greenhouse gas emissions linked to recent global climate change. Electrolysis involves the splitting of hydrogen from water, an expensive process without global climate implications if the required electricity comes from renewable sources. Although often publicized as the fuel of the future, hydrogen is technically not a fuel source but serves as an energy carrier for moving energy in a practical form between mediums. Hydrogen batteries or fuel cells are then used to produce electricity. Fuel cells have been primarily utilized for industrial applications (e.g., metal refinement, food processing) as well as for remote and portable electricity generation from powering portable electronic devices to space shuttles. Increasingly, hydrogen is being sought as a viable alternative fuel for vehicles.

While hydrogen has the advantage of producing considerably less pollution than fossil-based fuels, hydrogen has some significant downsides. Hydrogen is particularly volatile substance, making transportation and storage difficult. Even though hydrogen has the highest energy content of any fuel by weight, the energy density is about quarter ~~than~~ that of gasoline. Hydrogen creation is expensive and the renewable energy sources that might produce hydrogen on a large scale, such as wind electricity for hydrolysis of water, can be used more efficiently to power motors directly.

Other Alternative Fuel Sources

The generation of electricity by multiple mediums (e.g., solar, water, wind) is another major alternative fuel group. In the transportation industry, gasoline-electric hybrid vehicles like the Toyota Prius are finding recognition as a means of fossil fuel energy conservation rather than complete fuel replacement. Petroleum-electric hybrid vehicles use highly efficient internal combustion engines, fueled by gasoline or diesel, to turn a generator that the powers the batteries ~~and/or supercapacitors~~ used for propulsion. Completely electric vehicle models powered by onboard battery packs have waxed and waned in popularity in the United States, but have seen a marked increase in adoption in Europe and Asia. A single battery charge can power electric vehicles for 40-50 miles, making them practical for the majority of routine daytrips, and can be recharged during the night when electricity usage is typically in lower demand. Other alternative transportation fuel development includes creating solar-powered vehicles powered by

rooftop photovoltaic panels; however, current technology is only able to produce about one-tenth of one horsepower (i.e., less than the power generated from riding a bicycle).

Much of the more promising alternative fuel options come from electricity generation by renewable sources, primarily hydroelectric. The movement of water from higher to lower elevations, often using water held in a dam, creates kinetic energy as the water flows downstream. A hydroelectric power plant can convert this energy into electricity by pushing the water through hydraulic turbines that are connected to generators. In the western United States, huge dams produce large quantities of electric power, enough to drive, for instance, the San Francisco mass transit system. Hydroelectric power has also become an increasingly large fuel source for the developing world, most notably China that has undertaken some of the largest dam construction projects in the world (e.g., Three Gorges Dam). The environmental costs for such megadams are high, including ecological habitat loss and increased river sediment load that must be weighed against power generation by other means.

Electricity generated from solar energy has become more widespread in recent years with advances in photovoltaic (PV) technology. Photovoltaics are sunlight sensitive semiconductors composed of silicon-based materials ~~like silicon~~ that are capable ~~for of~~ converting sunlight into electricity. In addition to electricity conversion, PV technology is being used to develop ways to harness the solar energy into fuel cells. In terms of viability as an alternative fuel, solar energy derived fuels remain relatively inefficient and expensive and as a consequence, often require the support of government subsidy programs to sustain their development. At present, solar panels require nearly three years to generate power equal to that energy inputs made during the manufacturing process. Solar power is most economical on the smaller, residential scale (e.g., home water heating) in certain climate zones. Large-scale solar electricity plans are well into the future, and may include heat-based solar electric plants in the deserts that are still in their experimental phase.

Wind power has become highly developed in Europe ~~and~~, generatings electricity less expensively than solar panels, and has already become cost-competitive with fossil fuels in some locations. Modern wind power generation utilizes large three-four blade wind turbines (with heights 60 to 1200 meters and blade spans of 20 to 40 up to 100 meters ~~or more~~) to harness the kinetic energy of the wind and convert it into mechanical energy for electricity. The maximum power generated by a single wind turbine is dependent on rotor diameter, tower height, and wind speed; for example, a rotor diameter of 40 meters and a maximum wind speed of 15 meters per second (or 33 miles per hour) can produce about 500 kilowatts. The largest turbines generate up to 5 megawatts. For large-scale power generation, multiple turbines are clustered together into wind farms. Approximately 200 of the largest ~~wind~~ turbines are needed to equal the output of a single fossil-fuel power plant, a figure reliant on moderate winds blowing.

See Also: Biodiesel; Ethanol, Corn; Ethanol, Sugarcane; Fossil Fuels; Hydrogen; Hydroelectric Power; Renewable Energies; Solar Energy; Wind Power.

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