Uncommon Alternative Renewable Energy Sources

Cristián Cárdenas-Lailhacar†, Ph.D., Alex Epstein

Jeff Escarra, Scott Moody, Adam Rosenberg, Adam Wright

Dept. Industrial & Systems Engineering, University of Florida, Gainesville, FL 32611, USA
cardenas@ise.ufl.edu

Abstract

In this work we address the current world wide energy problem by providing some insight on the use of uncommon but renewable energy sources. The current world addiction to oil mostly, is generating problems of yet unknown consequences. Countries in Latin America and the Caribbean are not free of these problems and one of its main associated consequences: global warming. The sources investigated here can currently have an impact in the society, and mainly in industry which, on the average, uses approximately 35% of the energy of the countries in the region. On the other hand, droughts are a constant threat to power supply since Latin American and Caribbean countries have a great dependence on rains, which in turn have a greater impact on agriculture and water supply to cities and for human consumption in general. In this work we discuss germane background information about some uncommon and yet renewable energy sources. We explore their current and potential uses, operational constraints, advantages, and disadvantages, and each fuel source potential capacity for energy generation and fuel savings. The quantitative section analyzes the amount of power that these uncommon renewable energy sources can provide, according to generation methods. In a separate section, we analyze potential fuel savings through direct application to some industries. We explore these values using several examples, and show financial analysis of selected alternative fuel projects. Lastly, an overall analysis of the uncommon alternative renewable energy sources presented is made, and concludes that there exists great potential for fuel and cost savings, and for the protection of the environment.

† To whom all correspondence should be addressed.

Keywords

Energy, Alternative Energy Sources, Environment, Sustainability, Global Warming.

Introduction

Today, with energy prices at record highs, the need for non-traditional and renewable energy sources has increased dramatically. The market for alternative energy sources is extremely large because the cost of energy has increased so much. It is extremely important to find alternatives to coal and oil as a means to provide power and transportation to the public. Some non-traditional energy sources like wind and geothermal power have case studies which prove their worth as an alternative energy source for providing power to the grid. In addition, biofuels and fuel cells have some significant results that show their potential in replacing oil as a means for fueling transportation. The requirements for a good alternative to traditional energy sources are that the energy source leaves little to no environmental footprint, is economically feasible (good ratio of Dollars to kilowatt), and have the ability to support large populations of users. One our goals is to examine and identify which non-traditional energy sources could be part of the solution to the energy problem.

In the next section we review some non-traditional energy sources starting with known ones (solar and wind) and continuing with ones that are more obscure (bio-fuels and wood oils/resins). Corresponding current widely used standards background are presented. Each energy source is examined to determine their respective costs and benefits. We conclude with a comparison of the studied sources to help determine which of these non-traditional energy sources have the potential to become a traditional energy source to the next generation, or to solve current specific situations. An Appendix with a Case Study Analysis on the possibilities of using Bio-gas is presented.

1. Solar

Photovoltaics could literally be translated as light-electrical energy [1]. It produces no air pollution or hazardous waste, and it doesn't require liquid or gaseous fuels to be transported or combusted. Its energy source, sunlight, is free and abundant. Individual photovoltaic cells, are electricity-producing devices made of semiconductor materials. They typically produce about 1 or 2 watts of power. To boost the power output of the photovoltaic cells, they are often connected together to form photovoltaic modules arrays of different sizes and power output.

Other components are needed to take the direct current (DC) and convert it to alternate current (AC) electricity. Batteries can be used to save the electricity for later use. These items are referred to as the balance of system (BOS) components. Photovoltaic systems are classified into two general categories: flat-plate systems and a concentrator systems.

These panels respond to sunlight that is either direct or diffuse. Even in clear skies, the diffuse component of sunlight accounts for between 10% and 20% of the total solar radiation on a horizontal surface. On partly sunny days, up to 50% of that radiation is diffuse. On cloudy days, 100% of the radiation is diffuse. The primary reason for using concentrator photovoltaic systems is to be able to use less solar cell material in the photovoltaic system. Photovoltaic cells are the most expensive components of the system, on a per-area basis. The concentrator makes use of inexpensive materials such as plastic lenses and metal housings to capture the solar energy shining on a large area and focus that energy onto a smaller area, where the solar cell is. One measure of the effectiveness of this approach is the concentration ratio: how much concentration the cell is receiving. Concentrator systems increase the power output while reducing the size or number of cells needed. An additional advantage is that a solar cell's efficiency increases under concentrated light.

Solar heating on the other hand, harnesses the power of the sun to provide solar thermal energy for solar hot water, solar space heating, and solar pool heaters. The fluid or air then transfers solar heat directly to use [1]. Solar water-heating systems for buildings have two main parts: a solar collector and a storage tank. Heated water is then held in the storage tank ready for use, with a conventional system providing additional heating as necessary. The tank can be a modified standard water heater, but it is usually larger and very well insulated. The most common collector used in solar hot water systems is the flat-plate collector.

Integral collector-storage systems (ICS), or batch systems, are made of one or more black tanks in an insulated glazed box. Cold water first passes through the solar collector, which preheats the water, and then continues to the conventional backup water heater. ICS are simple, reliable solar water heaters. The most common solar water heating systems are active systems. Active solar water heaters rely on electric pumps, and controllers to circulate water, or other heat-transfer fluids through the collectors. Direct-circulation systems use pumps to circulate pressurized potable water directly through the collectors, this is one type. The other systems is Indirect-circulation systems pump heat-transfer fluids through collectors. Passive solar water heaters rely on gravity and the tendency for water to naturally circulate as it is heated. Passive systems are generally more reliable, easier to maintain, and possibly have a longer work life than active systems because they contain no electrical components.

For solar space heating, the two basic types of active solar space-heating systems use either liquid or air as the heat-transfer medium in their solar energy collectors. Liquid-based systems heat water or an antifreeze solution in a hydronic collector. Air-based systems heat air in an air collector. Both of these systems collect and absorb solar radiation, then transfer the solar heat directly to the interior space or to a storage system, from which the heat is distributed.

Finally, for solar lighting, hybrid solar lighting systems collect sunlight and routes it through optical fibers into buildings where it is combined with electric light in "hybrid" light fixtures. Sensors keep the room at a steady lighting level by adjusting the electric lights based on the sunlight available [1].

In a solar lighting and power system, the roof-mounted concentrators collect sunlight and distribute it through the optical fibers to hybrid lighting fixtures in the building's interior [1]. The light in a fiber-optic cable travels through the core by constantly bouncing from the cladding, a principle called total internal reflection. Because the cladding does not absorb any light from the core, the light wave can travel great distances. Some of the light signal degrades within the fiber due to impurities in the glass and the wavelength of the transmitted light [1].

1. Geothermal

To harness geothermal energy a power plant must drill into underground geothermal reservoirs. The steam or hot water is brought up to the surface and used to spin turbine generators and create electricity. The water is then returned down into the reservoir and reheated in order to sustain the reservoir. There are three types of geothermal reservoirs in which electrical energy can be created. The first are called "dry" steam reservoirs. These produce steam and a minimal amount of water. The steam is then directly used to turn turbines. The Geysers, a geothermal plant north of San Francisco, is the largest dry steam field in the world. The plant was opened in 1960 and is considered "the most successful alternative energy project in history" [2].

Another type of geothermal reservoirs is called a "hot water reservoir". The reservoir releases mostly hot water and this water is used in a flash power plant. When the water is brought up to the surface and released from the pressure of the reservoir some of the water flashes into steam which is used to drive a turbine. The last type of geothermal reservoir is the Binary Cycle Plant has lower temperatures than the others (250ºF-360ºF) and cannot be flashed into steam, but can be used to heat into a second liquid with a lower boiling point. The vapor from the second liquid is then used to turn a turbine and is then re-condensed and used again. This "binary" system is a closed system and does not emit any chemicals into the air [2].

2. Tidal

Tidal Power or Tidal Energy is a form of hydropower that utilizes the movement of water caused by tidal currents [3]. This is a form of energy that that is completely re-useable and will not run out in the foreseeable future. There are many ways to harness energy from the tides, though some have more range than others. Tides comes with several limitations.

Tidal Barrage is a popular way to harness tidal power. It works with a high tide and low tide with a difference in height of about 5 meters. This system collects water in the basin as the tide goes high. At the tides highest point The Basin is closed off and the system will hold the water until the tide goes low again. Once the tide goes low the basin is emptied through a turbine which will generate energy. The effects on the environment can be hard to predict. Though calmer waters will be created (which will be good for recreation) the difference in water level will affect local vegetation and wildlife. Other factors that will affect the environment are the quality of water in the estuary that the barrage is created in, and the sediment concentrations. The animals that will be mostly affected by this system are local fish and birds, the birds will most likely migrate to a more favorable environment.

Another form of Tidal Energy comes from Tidal Streams. In this case, tidal turbines act just like wind turbines but with a much denser fluid. Water is 800 times denser and has a much slower flow rate which will make the turbine endure greater forces and moments. One of the draw backs of this is that the turbines must be able to either generate energy on both ebbs (directions) of the tide or withstand the strain of the opposing flow [3]. The solution to the problem of the much denser fluid and slower flow rate is smaller diameter turbines. The environmental impact of implementing tidal turbines is pretty small because this system works best in sea heights between 20 and 30 meters.

3. Eolic

Wind is a form of solar energy. Winds are caused by the uneven heating of the atmosphere by the sun, the irregularities of the earth's surface, and rotation of the earth. Wind flow patterns are modified by the earth's terrain, bodies of water, and vegetation. The terms wind energy or wind power describes the process by which the wind is used to generate mechanical power or electricity. Wind turbines convert the kinetic energy in the wind into mechanical power. This mechanical power can be used for specific tasks (such as grinding grain or pumping water) or a generator can convert this mechanical power into electricity [4].

Modern wind turbines fall into two basic groups: the horizontal-axis variety and the vertical-axis variety. Horizontal-axis wind turbines (HAWT) have the main rotor shaft and electrical generator at the top of a tower, and must be pointed into the wind. Small turbines are pointed by a simple wind vane, while large turbines generally use a wind sensor coupled with a servo motor. Most have a gearbox, which turns the slow rotation of the blades into a quicker rotation that is more suitable to drive a generator. Vertical-axis wind turbines (VAWT) have the rotor shaft arranged vertically. VAWTs are usually situated closer to the ground since they can utilize turbulent winds. Also, the air has a higher density at low altitude carrying more energy at a given wind speed.

Utility-scale turbines range in size from 100 kilowatts to as large as several megawatts. Larger turbines are grouped together into wind farms, which provide bulk power to the electrical grid. Single small turbines, below 100 kilowatts, are used for homes, telecommunications dishes, or water pumping. Small turbines are sometimes used in connection with diesel generators, batteries, and photovoltaic systems. These systems are called hybrid wind systems and are typically used in remote locations where a connection to the utility grid is not available.

4. Fuel Cells

Fuel cells are a developing technology that many believe could possibly be a realistic, quiet, clean, and efficient solution to many of the current energy production threats. Fuel Cell technology has been around since 1838, and has been used to generate energy since 1955. Currently fuel cells are used to power large objects in remote locations such as spacecraft and submarines. A fuel cell is an electrochemical energy conversion device that drastically differs from the fuel burning, or combustion, production methods in use today. The process is two to three times more efficient and has clean byproducts [5].

In principle, a fuel cell operates like a battery. Unlike a battery, a fuel cell does not run down or require recharging. It will produce energy in the form of electricity and heat as long as fuel is supplied. Fuel cells consume reactant, which must be replenished, while batteries store electrical energy chemically in a closed system. Additionally, while the electrodes within a battery react and change as a battery is charged or discharged, a fuel cell's electrodes are catalytic and relatively stable. As long as steady fuel levels are maintained, the fuel cell will continue to run without interruption. Fuel Cells' ability to run without interruption is a benefit that clean renewable energy sources such as wind and solar power cannot provide.

The most attractive incentive to adopt fuel cells as an energy solution lies in its ability to produce power that is virtually free from pollution and other contaminants. If hydrogen and other gases could be created using sources such as wind, solar, or hydroelectric power than the process would be completely green. A final benefit of fuel cells that should not be overlooked is that the power output of fuel cells is a high quality in that it is "clean" computer-grade power free from voltage disturbances such as sags, spikes, or transients that affect the performance of some other technologies [5].

Fuel Cells produce electricity from various external quantities of fuel (on the anode side) and oxidant (on the cathode side). These react in the presence of an electrolyte. Generally, the reactants flow in and reaction products flow out while the electrolyte remains in the cell. Many combinations of fuel and oxidant are possible. A hydrogen fuel cell uses hydrogen as fuel and oxygen as oxidant. This is one of the most popular forms of fuel cell because of its simplicity, efficiency, and cleanliness. Hydrogen and oxygen go into the system, and water comes out. Other fuels include hydrocarbons and alcohols. Other oxidants include air, chlorine and chlorine dioxide. The most common of these is the PEM Fuel Cell.

A single fuel cell produces less than 1.2 volts with a typical fuel cell producing between 0.6 and 0.7 volts of power. Because this cannot supply power to most electronics on its own, fuel cells must be clustered together in stacks. Stacks can consist of numerous fuel cells placed in series or parallel to vary the amount of power supplied. Natural gas is purchased from Central Hudson Gas & Electric Company under a contract rate schedule. Energy bill savings from the fuel cell were estimated at $30,000 per year.

5. Liquid Propane

Propane naturally occurs as a gas. However, at higher pressure or lower temperatures, it becomes a liquid. Because propane is 270 times more compact as a liquid than as a gas, it is transported and stored in its liquid state. Propane becomes a gas again when a valve is opened to release it from its pressurized container. When returned to normal pressure, propane becomes a gas so that we can use it [6].

The LP-gas industry got its start shortly before World War I when a problem in the natural gas distribution process popped up. A section of the pipeline in one natural gas field ran under a cold stream, and the coldness led to a lot of liquids building up in the pipeline, sometimes to the point of blocking the entire pipeline. Soon, engineers figured out a solution: facilities were built to cool and compress natural gas, and to separate the gases that could be turned into liquids (including propane and butane) [6].

Although propane accounts for about 2 percent of all energy used in the United States, it has some very important uses. Propane is the most common source of energy in rural areas that do not have natural gas service. It is used for heating homes, heating water, cooking and refrigerating food, drying clothes, and fueling gas fireplaces and barbecue grills, cars, etc. [6]. LP-gases were discovered in 1912 when an American scientist, Dr. Walter Snelling, who discovered that these gases could be changed into liquids and stored under moderate pressure [6]. Pipelines, processing facilities, refueling stations, distribution centers and storage facilities already exist across the country, making large capital investments in infrastructure unnecessary [6]. In the United States, more than 14 million households use propane for at least some of their energy needs. Approximately 8.1 million households heat with propane, and more than one million owners have already chosen propane as their energy source for their manufactured homes [6].

Propane is a non-renewable fossil fuel, like the natural gas and oil it is produced from. Like natural gas (methane), propane is colorless and odorless. Although propane is nontoxic and odorless, foul-smelling mercaptan is added to it to make gas leaks easy to detect. Propane is a clean burning fossil fuel, which is why it is often chosen to fuel indoor equipment such as fork lifts. Its clean burning properties and its portability also make it popular as an alternative transportation fuel. Propane-fueled engines produce much fewer emissions of carbon monoxide and hydrocarbons compared to gasoline engines. Like all fossil fuels, propane emits water vapor and carbon dioxide, a greenhouse gas [6]. Propane won't ignite when combined with air unless the source of ignition reaches 940° F. Propane gas is nontoxic and produces minimal emissions. Propane is not harmful to soil or water [6].

The cost of liquid propane is around $1.87 per gallon. Electricity is most often considered to be 100% efficient, because none of the energy is given off as exhaust. Propane gas and diesel are both assumed to be about 80% efficient at the consumer's level. However, when efficiencies are evaluated to account for production of the fuel, then electricity falls way below the other two, because so much energy is required to produce the electricity in the first place, and much is lost in transmission lines from electric plant to the consumer's meter. Propane gas is a very efficient fuel source.

6. Gasification

Gasification is a process by which any organic material can be turned into synthesis gas which can then be burned to create electricity. This "syngas" can be directly used as gasoline for internal combustion engines or be converted to synthetic fuel. This fuel burns much more efficiently with lower emissions than gasoline [7].

The process of gasification occurs at temperatures above 700°C. This process can convert any organic material into syngas. The steps in this procedure happens in different places in the gasifier but can be looked at as four different steps in order to explain the reaction. First the material is dried. This stage takes place at about 150 degrees Celsius. This stage simply removes all the moisture from the material and creates steam. The next stage is called Prolyisis. This stage is the decomposition of the material without the presence of oxygen. Prolysis occurs between 150 and 700 degrees Celsius and creates solids (char), liquid and gases. The gas created in this stage has a very low value as a gas. After Prolysis, Oxidation occurs. Oxygen and other elements are introduced into the reaction between 700 and 2000 degrees Celsius. Oxygen and the decomposed material react and create carbon monoxide. Hydrogen reacts with the oxygen and creates steam, which can be used to create power on its own. Reduction occurs next at temperatures between 800 and 1100 degrees Celsius. In this stage many reactions occur without the presence of oxygen creating syngas and CO. Some ash and char remain after the process.

As stated before, this gasification process can be used for any organic material. Currently the main use of gasification is for the gasification of coal. This system is much cleaner than burning coal directly and can be a closed system in an IGCC (Integrated Gasification Combined Cycle) system. This system takes the syngas from the process and burns it for power and then recycles the heat and other fumes for further power generation. There are only three IGCC plants in the US today, but there are about seven plants in planning. Even though coal is currently the main use of gasification, using other materials in this process is where gasification is most promising. Gasification can be used with biomass and waste. If used with these renewable resources there would be no release of greenhouse gases during the process. These plants are more expensive but have become extremely popular especially in India. Overall, gasification process is a process by which any organic material is processed into syngas, which burns the same as gasoline, but more environmentally friendly and also more efficient. Currently coal gasification is the most popular form in the US but biomass gasification is where the industry is headed.

7. Bituminous Coal

Bituminous Coal is the most abundant form of coal in the United States. It is dense, and usually colored black or dark brown. Bituminous coal, also known as soft coal, accounts for about half of U.S. coal production, and in the United States is about 100 to 300 million years old [8]. The total worldwide bituminous coal reserves are broken down as follows: South America – 1.5%, Africa – 6% with over 90% being in South Africa, Asia – 35%, North America – 13%, Europe – 7% with over 95% being in Germany, Poland, Russian Federation, and Ukraine. It contains relatively little moisture content typically less than 20%. It contains 69-86% carbon by weight. Bituminous coal has a very high heat content of about 10,500 to 15,500 Btu/lb. It is used primarily as fuel in steam-electric power generation, with additional applications in the manufacturing industry and steel production.

Bituminous Coal has a gross heating value of 30,600,000 Btu/ton [8]. With an efficiency rating of 85%, the net heating value becomes 26 Million Btu/ton. 1 ton of Bituminous Coal can produce 6022.69869056 kWh of energy [8]. In the year 2000 for underground mining, estimates put the median output per Bituminous Coal Miner at 20 tons per day [8]. In the year 2000 for strip mining, estimates put the median output per Bituminous Coal Miner at 51 tons per day [8]. When raw coal is mined, there can be a lot of material that needs to be removed before the coal can be used. These materials are usually rich in iron sulfides, and are removed through machines. In the past, bituminous coal was a major pollutant of the environment. Pollution would occur both from the mining of the coal and from the burning of the coal in usage. However, laws and the development of technology have helped reduce coal's impact on the environment. When bituminous coal is mined from the surface, the ground can be destroyed if no action is taken to repair the land. In recent years, efforts have been made to "reclaim" the land after coal is mined from the surface. Since the mid-1970s more than 2 million acres of land has been restored and protected after mining [8].

For bituminous coal surface mining in 2005, there were 2.5 nonfatal injuries per 100 full-time workers [8]. This figure is below the private industry average. Underground bituminous coal mining is especially dangerous to the workers. Frequently, fire and explosions cause deaths, as well as accidents with equipment causing many deaths. In 2006 alone, there were 33 deaths in underground mining of bituminous coal in the US. This accounts for 70% of all deaths in coal mining! In 2005, for underground bituminous coal mining, there were also 7.5 nonfatal injuries per 100 full-time workers. This figure is 63% higher than the average for all private industry [8]. When bituminous coal is burned, it emits into the environment carbon dioxide, sulfur, nitrous oxide and mercury, amongst other greenhouse gases and pollutants. These pollutants can make their way into both air and water, which is very dangerous both globally and locally. Actions have been taken to reduce these emissions and to make the use of coal safer for the environment. For instance, coal miners will look for low-sulfur coal to mine in the first place. Also, many plants use technologies that clean the sulfur and mercury from the coal before it is burned and the smoke leaves the smokestacks [8].

9. Hydrogen

Hydrogen is the most plentiful gas in the universe. It is the fuel of the sun (through Fusion), and since it is lighter than air Hydrogen gas (H_2) does not exist by itself on earth. Hydrogen has the highest energy content of any of the common fuel sources by weight but the lowest energy content by volume. Since the hydrogen molecule (H_2) cannot be found naturally on Earth it must be manufactured. Hydrogen can be manufactured through Electrolysis, which is a process that splits the hydrogen out of water (H_2O). This process is expensive; however there are no bad emissions from the production. Another process of manufacturing hydrogen is called steam reforming. This process involves splitting hydrogen atoms from carbon atoms in methane (CH_4) and results in greenhouse gasses. Steam reforming is the least expensive way of producing hydrogen and it is used for about 95% of the hydrogen production in the United States [9].

An extensive amount of electricity is required to conduct electrolysis. However the cost of that electricity can be eliminated by using solar power as a means of generating the required electricity. With the hydrogen stored in tanks, and vehicles retrofitted with electric motors and fuel cells, the problem of relying on foreign oil could be in the past. A fuel cell will use hydrogen as its fuel, and convert it to electrical energy. The benefit of this type of energy is that the emission is water. Hydrogen is a candidate for an alternative fuel because the earth has an almost endless supply (in water) [9].

10. Biomass

Biomass is organic matter that has gone through photosynthesis and as a result, has stored solar energy [10]. The most notable biomass source for use is woody biomass. Other typical sources include other vegetable, plant and animal matter. A simple use of biomass fuel is the combustion of wood for heat [10].

Biomass is one of the oldest energy sources. In fact, wood used to provide Americans with 90% of their energy until about the mid-1800s when it began to be replaced by coal, natural gas, and petroleum [10]. According to the Union of Concerned Scientists, the US currently uses about 60 billion kilowatt-hours of electricity from biomass, which turns out to be about 2% of the total electricity usage in the nation [10]. In many instances wood is in pellet or wood chip form depending on its necessary usage.

According to Växjö University, woody biomass seems the most sustainable for energy use. There are 5 kWh contained in 1 kg of dry wood. Comparatively, 1 kg of fossil diesel oil contains approximately 12 kWh and 1 m3 of fossil gas contains approximately 8 kWh [10]. The biggest threat that we face using biomass, and woody biomass in particular, is the risk of deforestation to extreme degrees if the industry is not governed properly. If the trees are planted to then eventually be used for biomass, this is a different situation. Simply cutting down forests for use as biomass will eventually lead to problems with the decimation of eco-systems and habitats of many animals, as well as the increase of carbon dioxide in the air as there will be less trees and plants to absorb the carbon dioxide that they normally do in their life processes.

There are also issues regarding smoke emissions due to incomplete combustion of the wood. This is especially an issue in places where people are living, such as the case where a woodburner is used in a house to make heat. In New Zealand, where woody biomass is becoming very popular as a fuel source, the government has introduced standards specific to woodburners in homes that ensure safe air quality. This standard states that properties less than 2 hectares must have a maximum discharge of 1.5 grams of particles for each kilogram of dry wood burnt, and a thermal efficiency of at least 65% [10]. Many people believe that the processes necessary for obtaining the biomass – handling, transport on tractors, etc. – use up more energy than the biomass is worth [10]. This argument is debatable as the equipment used in these processes plays a large role in the energy used.

11. Biofuels

While many researchers seem to be investing their efforts in developing more efficient solar cells for capturing sunlight, building wind farms, or trying to figure out useful ways to use biomass, a new area of research has popped up that involves engineering bacteria to produce a quantity and quality of biodiesel that could be a solution to many current problems with the way we currently supply energy. The cyanobacteria were the first photosynthetic organism to be genetically sequenced. The cutting edge research involves growing a new kind of cyanobacteria that is being engineered to allow it to be manufactured for use as more efficient fuel source [11].

One aspect of the cyanobacteria that is altered is its membrane structure. By engineering a bacterium with more membranes the fuel produced can be more productive as a biodiesel. This is because membranes consist primarily of lipids which store large amounts of energy. This genetically engineered form of biodiesel is a great alternative to traditional combustible fuels because it would require very little change in the current energy infrastructure. Biodiesel can be put directly into any existing diesel engine and it can be transported using the current infrastructure. While this new bacteria already seems like a viable candidate to begin generating energy there is more to it than biofuels. The cyanobacteria also produce large quantities of hydrogen gas. The hydrogen gas can provide a great source of fuel for burning or for use in a fuel cell. These bacteria can be seen as a renewable clean energy source because the process will continue if uninterrupted.

12. Batteries

In the realm of renewable energies batteries are king. They are the media which allows the solar and hydrogen fuel cell energy sources to be stored and used as convenient by the user. The benefit of a battery is just that, the efficient storage of energy. Batteries come in all shapes and sizes and all of which are Direct Current. They can be arranged in series and in parallel to make a higher system voltage or higher system current (batteries in series create a higher voltage; batteries in parallel create a higher current). Traditional batteries store chemical energy and make electrical energy available at the batteries terminals [12]. There is another type of battery called a Betavoltaic battery which is being developed by the air force. This type of battery has two advantages: (1) its continuous power lifetime is rated at about 30 years and (2) its environmental footprint consists of semiconductor waste (no toxicity). These batteries use the beta electron emissions that result when a proton decays into a neutron which causes a forward bias in the semiconductor. The betavoltaics generate their power when an electron bombards a certain interface between two layers of material [12]. A prediction for the time to market of this battery is about two to three more years.

13. Atypical Energy Sources

a. Resins and Oils

Researchers at the University of Georgia have discovered a way to extract oils from pine tree chips for use with biofuels. This type of biofuel cannot power an engine on its own but it can be mixed with biodiesel and petroleum diesel to power the engines. This could essentially help reduce the price of producing fuels from biomass. The process of extracting this oil begins with getting chips or pellets of wood and burning them in the absence of oxygen. The gas that is released can then be condensed into a bio-oil, where about 34% of that product can be used for powering engines. A great disadvantage to this source of energy is that amount of wood that must be burned to get a significant amount of the oil. Right now about 17% of the dry weight of the wood can be converted to oil. Although it seems that this process could be bad for the environment, the researchers claim the fuel is actually carbon neutral if new trees are planted to replace the ones cut down for processing. Another advantage is that the production cost of this fuel is also fairly inexpensive because of the availability of trees. This is by no means the answer to our world's energy problems because the time it takes for a pine tree to reach a mature height (120 ft) is about 55 years [13].

b. Plants

Several products of Mother Nature can aid in the transition from traditional energy sources through the extraction of bio-oils. These bio-oils are used in bio-diesel engines as an alternative to conventional diesel fuel. One such product is actually a weed, called Jatropha. This tree can grow in almost any climate and it is hearty enough to produce seeds during a dry season. This tree produces seeds that have a high percentage of bio-oil in them. The tree has several advantages compared to other sources of bio-oil. Despite the fact that the weed can grow in several types of environments, the Jatropha is inedible and it doesn't require much water to survive. The Jatropha uses sunlight and, through its seeds, converts the sunlight into bio-fuel. The main requirements of installing Jatropha as an energy alternative are land and fresh water, which could pose a problem. It is important to consider that bio-oil production is not as much an alternative energy source as it is a supplement to an existing way of producing energy [13].

c. Ori-Emulsion

Oil is the basis of the Venezuelan economy, generating 84% of the income from exports in the year 2000 [13]. The Orinoco oil wells, an example of a non-traditional petroleum source, provide the raw material for the preparation of ori-emulsion, an emulsion of bitumen and water mainly used as fuel for power plants [13]. Ori-emulsion is an extra heavy crude oil, which is as heavy as tar. The country of Venezuela produces 250 bilion barrels of Ori-emulsion.

d. Acetylene

Acetylene is the most common gas used for fueling cutting torches in both general industry and the mining industry. When mixed with pure oxygen in a cutting torch assembly, an acetylene flame can theoretically reach over 5700°F. An acetylene molecule is composed of two carbon atoms and two hydrogen atoms. The two carbon atoms are held together by what is known as a triple carbon bond. This bond is useful in that it stores substantial energy that can be released as heat during combustion. However, the triple carbon bond is unstable, making acetylene gas very sensitive to conditions such as excess pressure, excess temperature, static electricity, or mechanical shock. Acetylene must be stored under special conditions because of its unstable nature. This is accomplished by dissolving the acetylene in liquid acetone. Acetylene is a very easy gas to ignite. The static charge developed by walking across a carpet floor on a dry day can be 1700 times greater than that needed to ignite acetylene [13].

Conclusions

It is apparent that a major alternative energy source is required to sustain our society and our Earth. There are several types of energy sources that have free fuel: eolic (wind), geothermal, tidal and to some extent solar energy, and have a small environmental footprint. These energy sources could be used to provide power to homes, businesses, and industries. Other sources of energy can be used to power transportation which is an integral part of our society. Such sources include Batteries and Fuel Cells. The costs of some non-traditional energy sources are much lower than others, but usually these sources pollute much more than the others. This includes coal and some synthetic fuels. In the case of coal, retrieving the coal destroys the land, and when burned (or used in synthetic fuels) it releases more CO_2 than traditional gasoline. Coal is on the rise as an energy source due to its relatively cheap cost, and its abundance in the United States, but if it is going to be the energy source of the future it must find a way to also help in the global warming crisis by releasing less greenhouse gases.

While some want to dig up some of Earth's resources, many feel we can find our energy sources on the surface of the planet, either by growing it, or recycling waste products and turning them into fuel. This set of energy sources include biomass, biogas, making biofuels, as well as using used oil as a fuel. Biofuels will have stable resources due to the amount of agricultural waste that occurs during the farming and production of the food we eat. This could decrease the amount of waste we produce, but many feel if this were to become popular the world's food supply could be harmed. These types of technologies are developing credibility, and if they can find a way to balance the needs of both food and fuel, they may have enough potential to become a part of our everyday life.

As technology progresses innovations will increase efficiency and yield of the energy produced from non-traditional energy sources. As described in the paper, there are case studies providing information on implemented alternative energy systems. Though there are several options to pursue as a major alternative energy source, several are already being implemented and producing results. Table 1 shows a comparison of implementation cost, consumer cost, and required resources between all of the non-traditional energy sources discussed in this paper.

Table 1: Comparison of Non-Traditional Energy Sources

Energy Source	Implementation Cost	Consumer Cost	Required Resources
Solar	10 to 12 million $/MW	0.15 to 0.25 $/kWh	Solar Radiation
Geothermal	2.5 million $/MW	0.05 $/kWh	Geothermal Reservoir
Tidal	1 million $/MW	1 $/kWh	Tidal Movement
Eolic	1 to 2 million $/MW	0.04 to 0.06 $/kWh	Wind
Fuel Cells	1.5 million $/MW	N/A	Hydrogen
Liquid Propane	N/A	0.104 $/kWh	Oil Well
Gasification	3.8 million $/MW	0.67 $/kWh	Organic Materials
Bituminous Coal	42.40 $/Ton	0.07 $/kWh	Coal
Hydrogen	N/A	30 $/kWh	Water
Biomass	N/A	N/A	Organic Materials
Biofuel	N/A	0.035 $/kWh	Organic Materials
Batteries	N/A	N/A	Multiple

On the other hand, and for comparison, in Table 2 we summarize some of the general characteristics of the Non-Traditional Energy Sources discussed in this work. In today's energy addictive world the efficient use of energy, alternative and new fuels, has become a daily concern all over the planet. Every day our industrialized society requires more and more energy, bringing more environmental problems, with limited efforts to reduce them. This clearly calls for a new generation of energy sources, technology and well prepared engineers that can help our world to minimize these problems and their potential dramatic consequences through energy management, research, development, etc. The solution to the energy crisis requires global collaborative efforts.

Table 2: General Characteristics of Non-Traditional Energy Sources

	General Characteristics		**General Characteristics**
Solar	- Fuel is practically free - Silent, low maintenance - Long Lasting Life - No Pollution	Bituminous Coal	- It exists in great amounts - Low comparative cost - Acidic waters are generated
Geothermal	- Clean - Unlimited source - Water can be recycled - Can restore the reservoir - No fuel burning - Long term energy solution	Hydrogen	- Waste generated is Water - The waste of a Fuel cell can be used to create more fuel. - It has~ 4 more times the energy of conventional fuels. - Hydrogen can be made for free by using batteries charged by solar panels as a power source.
Tidal	- Fuel is free - Low Environmental impact - Very Aesthetic	Biomass	- If woodchips, needs to be dried - Social-ecological-environmental and economic benefits if wood. - As a fuel it is renewable. - Reduces energy costs
Eolic	- Short construction time - No waste generation - Fuel is free - Low environmental impact	Biofuels	- Cheap and renewable - Carbon dioxide neutral process - Releases as much CO2 as diesel - Takes CO2 from photosynthesis do not contribute to its rise in the atmosphere [62]. - Use new or waste oils - CO2 & sunlight into ethanol [65]
Fuel Cells	- Small relative size - Provide clean on-site Energy - Very reliable - Waste generated is Water - Can be used with Cogeneration - Can capture industrial gases	Batteries	- Very portable & efficient for energy storage. - Serve as conduit through which a renewable energy system can store its product.
Liquid Propane	- Has multiple uses: Industry, Hospitals, Transportation, etc. - Low cost - Replace gasoline in vehicles - Low pollution (gases) - Cuts emissions of toxins (less smog and carcinogenics)	Tires	- Tire fuel costs are lower than natural gas costs and the overall unit costs of tire fuel are even less expensive than coal. - Scrap tire fuel requires processing, but their costs still remain low. - Lower levels of NO_x emissions - Scrap tire is largest use of waste tires. - Prevents big stockpiles of waste tires.
Gasification	- Fuel is any Biomass or Waste - To burn coal in closed system - Heat and fumes can provide additional power - Forms Syngas; clean burn	Biogas	- Non toxic, odor reducer - Great potential stream of electricity, biomethane, and heat energy - Generates biogas (methane) and a fertilizer with high N, P, K contents.

References

[1] www1.eere.energy.gov/solar/photovoltaics.html; www1.eere.energy.gov/solar/solar_lighting.html; electronics.howstuffworks.com/fiber-optic4.htm; www.thesolarguide.com/solar-power-uses/cost-faq.aspx; www-formal.stanford.edu/jmc/progress/solar.html; ezinearticles.com/?Solar-Energy-Advantages-Disadvantages&id=50178; www.metaefficient.com/news/north-americas-largest-solar-electric-plant-in-switched-on.html; pesn.com/2008/02/21/9500472_Abengoa_worlds_largest_solar_plant/

[2] geothermal.marin.org/pwrheat.html#Q2; www1.eere.energy.gov/geothermal/faqs.html; www.reuk.co.uk/Larderello-Worlds-First-Geothermal-Power-Station.htm; www.geysers.com/

[3] en.wikipedia.org/wiki/Tidal_power; www.esru.strath.ac.uk/EandE/Web_sites/01-2/RE_info/Tidal Power.htm; esru.strath.ac.uk/EandE/Web_sites/01-02/RE_info/Tidal%20Power.htm ; www.eere.energy.gov/consumer/renewable_energy/ocean/index.cfm/mytopic=50008; www.cbsnews.com/stories/2006/11/04/business/main2153298.shtml

[4] www1.eere.energy.gov/windandhydro/wind_technologies.html; www.dpa.unina.it/adag/eng/renewable_energy.html; www.canren.gc.ca/tech_appl/index.asp?CaId=6&PgId=232; www.fplenergy.com/portfolio/wind/benefits.shtml ; www.awea.org/faq/wwt_environment.html#What are the environmental benefits wind power; www.portlandgeneral.com/community_and_env/environment/biglow/default.asp; www.oregonlive.com/newsflash/index.ssf?/base/business-1/1207241650175480.xml&storylist=orlocal ; capewind.whgrp.com/

[5] www.fuelcells.org; www.masstech.org/cleanenergy/fuelcell.htm; www.eere.energy.gov/hydrogenandfuelcells www.masstech.org/Project_Srch.cfm ; www.dodfuelcell.com/pafc/westover.php4 ; www.dodfuelcell.com/pafc

[6] www.eia.doe.gov/kids/energyfacts/sources/non-renewable/propane.html ; www.deltaliquidenergy.com/Pages/propane_vehicles.htm ; www.usepropane.com/why/ ; www.propanecouncil.org/trade/manufHousing/general_benefits/general_benefits.htm ; www.arrowheadlpgas.com/dept.asp?d_id=5926&l1=5925&l2=5926

[7] gristmill.grist.org/story/2006/4/12/173831/909 ; www.desipower.com/economics/cost_electricity.htm ; www.indiasolar.com/bio.htm ; www.dakotagas.com/Companyinfo/index.html ; gasifiers.bioenergylists.org/gasdoc/abe/IndiaBioSummary050721.pdf

[8] www1.eere.energy.gov/industry/mining/pdfs/coal.pdf ; www.fpl.fs.fed.us/documnts/techline/fuel-value-calculator.pdf ; www.shec-labs.com/calc/fuel_energy_equivalence.php ; Cohn, Elchanan (1975). *The Bituinous Coal Industry: A Forecast.* University Park, Penn State University. ; www.teachcoal.org/aboutcoal/articles/faqs.html#howmuch ; www.bls.gov/iif/oshwc/osh/os/osar0006.pdf ; www.eia.doe.gov/kids/energyfacts/sources/non-renewable/coal.html ; pa.water.usgs.gov/projects/amd/

[9] www.eia.doe.gov/kids/energyfacts/sources/IntermediateHydrogen.html ; www.techbriefs.com/content/view/1828/34/ ; www1.eere.energy.gov/vehiclesandfuels/about/partnerships/freedomcar/fc_goals.html

[10] www.vxu.se/td/english/bioenergy/blog/biomass_as_an_energy_sour/index.xml/ ; www.serconline.org/biomassdefinition/fact.html ; www.fs.fed.us/woodybiomass/aboutus.shtml ; lsa.colorado.edu/summarystreet/texts/biomass.htm ; www.earthpeace.co.uk/Biomass/index.html ;

www.bioenergy-gateway.org.nz/Portals/0/docs/Microsoft-Word-TDC%20Sawmills__070725_FINAL.pdf ; www.dec.ny.gov/environmentdec/38208.html ; en.wikipedia.org/wiki/Biomass

[11] researchmag.asu.edu/2007/03/bacteria_for_biofuel.html ; berc.berkeley.edu/symposium2007/presentations/6-%20Innovation%20Sessions%20 II/Alternative%20Fuels/Tasios%20Melis%20-%20BERC-21-Mar-07.pdf.pdf ; greenicebergs.wordpress.com/2008/02/20/bacterial-photosynthesis-used-to-produce-hydrogen-for-a-clean-biofuel; www.realitysandwich.com/cyanobacteria_rescue ; sustainabletransition.blogspot.com/2007/09/ethanol-and-plastic-made-from-co2.html ; www.reuters.com/article/environmentNews/idUSL2357789520070823

[12] en.wikipedia.org/wiki/Battery_(electricity) ; www.nextenergynews.com/news1/next-energy-news-betavoltaic-10.1.html

[13] www.tgdaily.com/content/view/32100/113/ ; freakonomics.blogs.nytimes.com/2007/08/24/will-this-weed-really-save-humanity/ ; www.venezuelaemb.or.kr/english/e_economy.htm ; www.democraticdialoguenetwork.org/network/cases/view.pl?cases_id=3;var_name=abstract ; www.msha.gov/alerts/hazardsofacetylene.htm ;

[14] Jonathan Earle and C. Cardenas-Lailhacar, *"The University of Florida as a Destination for Energy Management: A New Program for Latin America and the Caribbean*" *LACCEI 2007, Tampico, México ;*
2,250 kg/day

APPENDIX: Biogas Case Study [14]:

Consider for example, a farm with only 250 pigs would not generate enough biogas to power a steam driven turbine. The underlying formula is as follows:

$$E = \mu \times H \times f \times \upsilon$$

Where,

E	=	Energy output	υ	=	Biogas volume
μ	=	Efficiency	υ	=	$C \times m$
H	=	Heat of combustion for methane, 28 MJ/m^3	C	=	Biogas yield per Kg of solid excrement
f	=	Fraction of methane in biogas	m	=	Total mass of the solid excrement input

For example, power output in the stream case with 500 diary cows is as follows:

$$E = 70\% \times 28 \text{ MJ/m}^3 \times 60\% \times .3 \text{ m}^3\text{/kg} \times 500 \text{ cows} \times 4.5\text{kg/cow/day}$$

$$E = 7{,}938 \text{ MJ/day}$$

Note that,

$$m = 500 \text{ cows} \times 4.5\text{kg/cow/day} = 2{,}250 \text{ kg/day}$$

Converting to Thermal Power (TP),

$$TP = E / 3.6 \text{ MJ/kWh} = 2{,}205 \text{ kWh/day} = 91.88 \text{ kW (continuous)}$$

Multiplying by the generator efficiency, the Electrical Power (EP) is:

$$EP = 91.88\ \text{kW} \times 40\% = 36.75\ \text{kW}$$

The power output in the reciprocating generator case with 500 diary cows is as follows:

$$E = \mu \times H \times f \times \upsilon$$

$$E = 35\% \times 28\ \text{MJ/m}^3 \times 60\% \times .3\ \text{m}^3/\text{kg} \times 500\ \text{cows} \times 4.5\text{kg/cow/day}$$

$$= 3{,}969\ \text{MJ/day}$$

Note that,

$$m = 500\ \text{cows} \times 4.5\text{kg/cow/day} = 2{,}250\ \text{kg/day}$$

And

$$\mu = \text{Reciprocating generator efficiency}$$

Converting to Electrical Power (EP),

$$EP = E / 3.6\ \text{MJ/kWh}$$

$$= 1{,}102.5\ \text{kWh/day}$$

$$= 45.94\ \text{kW (continuous)}$$

Similar cases are shown elsewhere [14]. Figure 1 shows the different values of electrical power generated (kW) as a function of the number of animals:

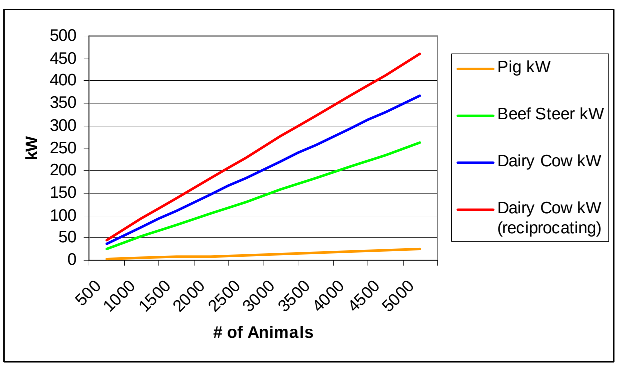

Figure 1: Power from different animals.