Sustainable Energy

by Victor Maertens

First man learned to harness the power of fire, millennia later in 1750 the industrial revolution began, introducing new technologies and energies which once again revolutionized the manner in which humankind lived. Once more, our species stands on the precipice of a new age, we stand on the precipice of the energy revolution, some would argue, it has already begun.

Energy Revolution

Since humankind gained the means to extract and use oil and natural gas they have been consumed on a large scale becoming vital to states, state interests and individuals. These finite resources have become a major driving force in the world. Yet fossil fuels such as "black gold" are not available to all. 1.6 billion people are deprived of electricity[1]. 3 billion people are in a state of energy poverty, deprived of modern energy sources and rely on wood, coal, charcoal and animal waste in order to cook and for heating[2]. Not only do these people suffer from energy poverty but due to their use of these fuels for vital human functions and fundamental human needs they suffer burns, or eye and lung disease from the dangerous fumes. These practices impact women and children most as they are inside when these compounds are burned[3]. Deaths attributed to the side-effects of these practices are responsible for 3.3% of all deaths annually, 2 million people[4]. The need to change these circumstances is paramount, not only due to the deaths they bring about but it is accepted that improvements in the energy sector are a prerequisite to achieving the United Nations Millennium Development Goals (MDGs)[5].

Climate Change

Reform in the energy sector is not only needed in order to save lives but to curb the pillaging and destruction of our only home. Humankind has assumed a mandate of superiority over the Earth and all of her resources, exploiting them for their own gain at times with blatant disregard for future generations and their fellow man. Fossil fuels are being over-consumed in order to feed the eternally famished machine with little foresight to recognize that the driving force of modern society is finite. Not only is the consumption of fossil fuels reducing the global supply but releasing greenhouse gasses (GHG), which are accelerating the natural phenomenon of global warming bringing about climate change. When discussing GHG there are numerous different compounds which contribute to the phenomenon. While CO_2 is the most abundant, other gasses also contribute and can hold considerably more heat than CO_2 such as methane and nitrous oxide, the production of which has also been bolstered by human activity.[6] Scientists estimate that if levels of CO_2 reach 450 ppm (parts per million) it will bring about major climate change[7]. The increasing carbon dioxide and other GHG emissions are thus a strong argument to prompt one to invest in and turn to renewable and green energy sources. From an economic standpoint, reforming the energy industry would also be a reliable argument. Fossil fuels are subject to volatile prices which compromise energy security and can impact political stability. Crude oil, one of the fossil fuels, reached a peak price in July 2008 of US$147[8] which had major impacts on the global economy, particularly the poor.

Renewable Energy

The most viable and promising alternative fuel sources are renewable energies. Renewable energies are forms of energy which replenish themselves over a short period of time and do not diminish in their stocks. Green energy is a sub-group within renewable energy and includes the energies which entail the highest environmental benefit.[9] The most widely accepted and most common forms of renewable energy are; solar, wind, hydro, tidal, biomass, geothermal and nuclear[10]. In the discussion of energy, the 1st law of thermodynamics is of paramount importance. Based on this law it is known that energy cannot be created or destroyed[11]. This implies that it can only transported and transformed. There are two categories of energy, primary and secondary. Primary energy is the energy type which derives its energy from utilizing present phenomena such as the renewable energies listed above, excluding nuclear and biomass. Secondary energy comes from the consumption of fuel, and from using the energy produced in the combustion process.[12] Once this energy has been harvested, the main challenges it faces are transportation and storage. Through the process of transportation, energy is "lost", and the further the distance the more energy is "lost".[13]

Sun

The most encompassing and abundant renewable energy source is solar. Our sun is a massive reactor constantly undergoing fusion[14]. Within 6 hours the deserts in the world receive enough solar energy to satisfy the entire annual global consumption[15]. Solar power can be employed in two different methods, passive and active. The former uses the natural properties of different construction materials in order to either heat or cool a space[16]. Two passive solar energy strategies: are using materials to capture heat during the day and release it at night, and building a house with south-facing windows (northern hemisphere) which allow in heat as well as passive lighting[17]. Active solar energy is once more divided into two sub-groups, photovoltaic and concentrated solar energy. The process of photovoltaic is when a solar panel is used to directly harness the energy of the photons from the sun's rays. In the process of concentrating solar energy, the sun's rays are concentrated by means of the solar collector. The heat is then captured and converted to mechanical and then electrical energy.[18] Both processes can be used either to generate electricity or to heat water. Photovoltaic cells have become popular and are the fastest growing type of renewable energy, available both for commercial and residential uses[19]. The efficiency of a solar cell differs, based on numerous factors, one of which is the elements used in the construction of the cell. The most common and efficient element in photovoltaic cells is silicon[20]. Furthermore, the sun's energy impacts numerous planetary systems which in turn create the forces which are needed to generate renewable energies which are based on different processes such as wind and water cycles[21]. Thus the sun is linked to multiple systems, helping to provide different sources through which to extract green energy.

Water

Another form of renewable energy which is large in both potential and usage is that of hydropower. Hydro-energy is linked to the sun on the basis that the water cycle is driven by the sun. Hydropower is generated by converting the kinetic energy of falling and flowing water into electricity. The water moves turbines which are responsible for the generation of electricity. This is a green energy as it does not produce CO_2 or other GHG in the process of electricity generation. Additionally, there are no ecological impacts when the electricity is generated. Yet the infrastructure needed in order to hold the water has the potential to indirectly impact the environment. Most hydropower generators require a dam to store water. In the process significant areas of land can be flooded which could submerge vegetation. This decaying vegetation may in turn release stored GHGs. Additionally, as the dams are built, they impact the flow of water lowering the water shed, primarily downstream. [22] The impact on water flow is significant as it can restrict water access, thus impacting irrigation and harming agriculture prospects. It can also have adverse impacts on agricultural production in the dam region as it floods potential farm land.[23] Not only is farm land flooded but residential areas may also be affected, forcing people to leave their homes and migrate[24]. Lastly, when employing hydropower, a community must make a decision as to where to allocate the scare resource. The communities must decide if they can afford to divert water from irrigation, especially in dry climates when the presence of a dam may leave the river empty or reduce the flow substantially during the dry seasons.[25] Despite these negative externalities it is a viable technology in certain regions. Although it contains a high upfront cost which is a major barrier when considering this technology, the facility has low operating and maintenance costs and the construction process provides temporary employment. Yet once such a plant is in place, it provides communities with a secure source of power which is not subject to volatile prices.[26] An additional aspect of this technology, particularly in Africa, is that the continent is endowed with an enormous potential for hydropower. Employing this technology would be valuable in the long run providing both energy security and energy access to the region.[27] While large regional or national projects are expensive and capital intensive, small scale hydropower also exists in the form of Small Hydropower (SHP) which has become increasingly popular in rural communities and can be used both on and off-grid[28]. Despite the potential for SHP there are still numerous barriers to overcome in order for the technology to become popular in Africa; lack of access to the technology, lack of infrastructure, lack of local capital, lack of information about the technology and a lack of private investors are but a few[29]. Thus while a viable technology, as with many other renewable energy sources, it too is plagued by the issue of price.

The technology to harness the power of the ocean and tides also exist. Tidal energy generally uses the changing of the tides and the height difference during these tides to generate energy. This energy is used mainly in Europe. Although much development must still take place in this sector, one approach involves trapping water behind a barrage during high tide and then letting the water out as the tide resides. Yet this form of renewable energy does have an effect on the environment as it impacts the natural process of tidal change. An additional method of extracting energy from the tides is by using turbines. Essentially an underwater windmill, the tidal forces spin the blades and generate energy. One of the appeals of tidal energy is the regular schedule of the tides, making it a secure and predictable energy source.[30]

Earth

Another natural phenomenon which is exploited in order to produce energy is geothermal energy. Vast reserves of heat energy exist under the Earth's crust which can be used for electricity generation or heat. Heat can be transported up through the crust by means of water conduction and convection. Similarly, the injection of lava into the crust also allows for this heat to be carried upward. This heat can then be used either as heat itself or be used to generate electricity. The technology to harness this energy exists and is used. In Iceland 25% of the country's electricity comes from geothermal origin and roughly 90% of the buildings and homes are heated by geothermal water. Although green and renewable, the rate at which this energy regenerates is not fast in terms of human time perception and the rate may also vary depending on the reservoir.[31]

Wind

A growing industry and historic energy source, wind energy is another renewable energy option. Once more, due to the wonders of technology the kinetic energy of the wind is converted into either electrical or mechanical energy[32]. Wind itself originates from a number of factors, the heating of the atmosphere by the sun, the rotation of the Earth and irregularities on the Earth's surface[33]. Thus wind energy exploits the natural phenomenon with which the energy sector does not have to compete for. This free energy is simply floating in the wind and by using it no natural functions are inhibited. Yet this does not mean that there are no impacts resulting from wind farms. The propellers can be noisy, considered ugly by some, and at times birds are killed by the blades. Yet many of these impacts can be reduced by further technological progress.[34] Another impact which wind farms have is one they share with all forms of energy generation or infrastructure; these facilities compete for land or water space.

Biomass

Potentially one of the oldest forms of renewable energy is that of biomass. Biomass is renewable energy which originates from biological sources such as crops, waste and wood. These materials can be used to produce heat, electricity and biofuels. While these might release CO_2 and other compounds, most of those have been absorbed during its lifetime, thus the net impact is significantly lower than consuming fossil fuels. The term biomass incorporates a vast number of different resources. The different materials have distinct properties providing the varying sources with unique energy properties. This source has potential, yet requires more research and development. Unfortunately this type of energy does have another externality; it competes with agriculture, natural environments and other land uses for space. Once again a decision must be made for what purpose land must be allocated and for what end the produce is used.[35] This becomes increasingly important when foods are used to generate energy which can then not be used for nutrition.

Nuclear

Another available alternative form of energy, although questions are raised as to whether it is green and renewable, is nuclear energy. Nuclear fuel can be used for multiple purposes and has benefits and pitfalls as almost everything does. Nuclear energy has been put under the microscope since the Fukushima incident in 2011, with certain countries actively closing and halting their nuclear energy programmes. Despite the backlash of Fukushima it is expected that the global amount of energy generated from nuclear sources will increase[36]. In Japan, before the devastating nuclear disaster, nuclear energy accounted for approximately 30% of Japans electricity with plans for nuclear energy to provide 50% of the electricity by 2050[37]. Nuclear energy is generated by the process of fission. In this process uranium atoms are split, and immense amounts of energy are released. A chain reaction is initiated so that more uranium atoms are split and more heat is produced, from which the energy is derived. During this process numerous by-products are made, including radioactive waste.[38] The process of generating nuclear energy is not universally the same. Several different

reactors and types of power plants exist. Two types of nuclear power plants are: boiling water reactors and pressurized water reactors. Water plays a major role in the fission process. In a boiling water reactor, the water around the fuel cells is heated and the steam is transported to the turbines by pipes. The steam produces the electricity. In a pressurized water reactor, the water is kept pressurized to prevent it from boiling when it is around the nuclear source. The heated water is transferred to a different water supply, where it does boil and the resulting steam generates energy by means of a turbine.[39] Differences also exist in the type of water; light versus hard water. Light water reactors require the uranium to be enriched before it can be used. Hard water contains sufficient deuterium to slow the neutrons so that the uranium does not need to be enriched before it is used. [40] Yet not all nuclear power plants are the same as they were in the 60s. New plant designs have been developed with better efficiencies and safety[41]. A vital aspect of uranium based nuclear energy is that the amount of uranium available is limited.

Application of alternative energy

With the abundance of alternative energies, viable solutions exist to replace our fossil fuel addiction and reduce the global carbon footprint. Hydropower has become increasingly popular and affordable. Nepal is among the poorest and least developed countries in the world[42]. A Nepalese government project REDP (Rural Energy Development Programme) supported by the UNDP, World Bank and other partners, has been working to install micro-hydropower systems. In the span of 10 years (1996-2006) they managed to provide over 130,000 people with electricity.[43] This off-grid project has reduced the GHG emissions of communities and reduced the pressure on the environment as the people were no longer as dependent on biomass[44]. Small hydropower is also a viable option in Africa, a continent with a large hydropower potential[45]. Africa currently (2011-2012) has 14% of the population but only 4% of the world's electricity[46]. The use of off-grid small hydropower would allow communities to use lights, phones and even small rural industry. Future expansion of the grid to include these communities would also allow for the small hydropower to feed into the grid.[47] Currently grid-expansion is an infeasible option as the World Bank provided an estimate in 2000 in which they stated that the average cost of expanding the grid was between US$8,000 - 10,000 per kilometre and up to US$22,000 in difficult terrain[48]. Globally, hydropower is the largest source of renewable energy, providing roughly 16% of the world's electricity (3,100 TWh in 2008)[49].

In Sub-Saharan Africa power outages are responsible for the loss of 1-4% GDP per year. It has the world's lowest electrification rate: 26%. While Africa needs an expansion of energy generation, many regions focus on maintaining current infrastructure.[50] The cheapest and most plausible option identified in order to increase access to electricity is a decentralized and off-grid approach[51]. These technologies would also reduce the regions dependence on fossil fuels which are expensive and subject to price swings[52]. Yet despite this realization, many regions lack the ability to purchase and operate these technologies thus require assistance in acquiring them[53].

While off-grid solutions are generally ideal for developing countries, national and regional programmes also exist which help increase the power supply in a country by means of green energy. The Middle East and North Africa (MENA) consumes 7% of the global energy. In an attempt to curb their GHG emissions, Morocco and Egypt have secured loans from the World Bank to develop concentrated solar power plants. Through this initiative they will also be creating new employment opportunities and lessening their dependence on oil. With their current capacity Morocco and Egypt are annually avoiding the emission of 20,000 and 40,000 tons of CO_2 respectively. Morocco has also announced its target of producing 2,000 MW of concentrated solar power in 2020.[54] A regional renewable energy project which demonstrates the feasibility of regional co-operation is that of the Brazilian-Paraguayan hydroelectric power plant Itaipu. Itaipu is the largest hydroelectric power plant in terms of power generation generating a record 94.6 GWh in 2008. Currently Itaipu provides 17% of Brazil's electricity and 73% of Paraguay's electricity.[55] Although a large venture taking 16 years to complete (1975-1991), this project demonstrates the plausibility for regional co-operation[56]. While this project was large scale and expensive, similar but less grand projects can also be implemented in other developing regions. Regional co-operation entails numerous advantageous which are forgone when acting unilaterally, such as accelerated finances, competitive contract terms, reduced transaction costs[57] and an expansion of the energy market[58], alongside the political gains of cooperation.

While scepticism remains, the age of nuclear power is far from over. A type of radioactive metal discovered in 1828 called Thorium which is considerably more common than uranium is making a comeback[59]. The concept of a liquid fuel reactor was pioneered by physicists at the Oakland Ridge National Lab in the 1960s but has since lost its popularity. China has taken up the mantel and is looking into the potential for this alternative nuclear fuel.[60] This form of radioactive material could be used in numerous different reactor types; unfortunately at the current level of technological progress most these reactors also require uranium as a fissile driver. The positive aspect of this requirement is under the correct circumstances Thorium; the alternative radioactive material, can act as a breeder.[61] The type of reactor advocated by Kirk Sorensen (former NASA engineer, chief nuclear technologist at Teledyne Brown Engineering and founder of Flibe) is the Molten Salt Reactor (MSR) which does not require high pressures or water cooling systems. Furthermore due to the inherent design of MSRs they have safety features which can shut down and safely store the coolant. Another property of Thorium which makes it more valuable than uranium is that much more energy can be extracted more efficiently. Less than 1% of the energy is extracted from uranium before it can no longer remain in the reactor. When using Thorium much more energy can be extracted.[62]

National policies can be a driving force in the development and the implementation of alternative and green energies. These policies will have varying success depending on the level of development of each country. One of the most successful renewable energy supporting policies is that of a Feed-in-Tariff (FiT). One of the great success stories of this policy is Germany. By means of this policy, the solar power industry was able to grow substantially and bring about technological development[63]. A FiT system forces electricity utility providers to purchase electricity from a renewable source from “producers” at a tariff rate determined by the authorities. This agreement is guaranteed for a number of years and the tariff level is influenced by the type of energy and the geographical circumstances.[64] These strategies help to make renewable energy more common and more competitive with subsidized conventional energies. FiT has also proven successful in the past, particularly with nuclear energy. Nuclear energy was facing several similar problems as those currently faced by renewables. Yet through consumer demand and political pressure, nuclear energies were also able to develop. The additional investment in the technology allowed it to grow and become more competitive with the conventional fuels as it also became more effective.[65] These policies in essence allow for smaller industries to develop in a safer environment[66]. Yet FiT and other incentive tariffs have made most of their success in Europe and on-grid systems. Developing countries have generally shied away from FiT because of the high costs involved.[67] Despite the lack of appeal for developing countries, an adjusted form of FiT has been proposed to be more appealing to those countries and to mini-grid systems. The policy of Renewable Energy Purchase Agreement Tariff (RPT) is meant to make renewable energies appealing to governments, consumers, communities and investors. The RPT system itself will also be adjusted depending on the socio-economic and technological barriers of the respective countries. One of the crucial elements of the RPT system is adjusting for the type of ownership of the renewable energy technologies.[68] RPT is not a one size fits all solution, it recognizes the unique character of each system and community. Through this recognition this tariff system provides numerous different potential puzzle pieces, depending on the nature of the community and energy situation such as ownership and legal frameworks, allowing governments to create the system most beneficial for them. Communal development is not a static and linear process; it is inherently unique and culturally dependent. This approach allows groups to adjust a policy to best fit a local scenario.

Kyoto Protocol

The development of renewable technologies not only serves local communities or nations but has intrinsic value to the global community. International treaties and conferences in regards to the environment and development have been gaining prominence on the world stage. One of such treaties is the Kyoto protocol. This agreement is intended to encourage its signatories to reduce GHG emissions. This document recognizes that the largest burden of GHG emission reduction should fall on the developed nations and that they are responsible for most of the GHGs in the atmosphere as part of their industrial revolution. In line with this recognition, the signatories established GHG emission targets for themselves. Understanding that achieving these targets was not easy, the Kyoto Protocol established a mechanism to help nations reach their targets, the Clean Development Mechanism (CDM).[69] By means of this tool, countries that exceed their CO_2 targets can invest and finance renewable energy programmes in developing countries to compensate for the additional CO_2 they emit, by providing them with Certified Emission Reduction (CER) credits[70]. While a valuable mechanism to promote renewable energy, CO_2 reduction and investment in developing countries the system has numerous shortcomings which prevent it from functioning as effectively as its creators

envisioned. The first problem is the lack of development in the area of CDM projects as the complicated and time-consuming administrative process to register CDM projects dissuades potential projects[71]. In line with the administrative process, the definition of CDM projects eliminates numerous projects which would be valuable. In order to qualify as a CDM project it must be an emission reduction project in a developing country and shall only be recognized if the project would not have occurred in a business as usual scenario[72]. From an economic perspective, the high upfront costs of these projects tied in with the administrative complications further discourage potential projects. As a result the CDM has not been as effective as its founders had hoped, being insufficient to provide a substantial push towards renewable energies.[73] Another limitation of CDM is that of the projects which did get approved, very few are small projects which are very effective and valuable in the developing countries[74]. Thus the initiative has fallen short of its vision and suffered from structural defects which prevented it from being the most effective for developing countries maintaining a mainly developed world perspective[75].

Dark Energy: a speculation

The Sun is a celestial body undergoing fusion. It is through this process that photons are produced which reach Earth. From these photons and other solar outputs our Earth's systems exist, and thrive, including almost all of our energy. All of the alternative energies listed above require the sun with the exception of nuclear energy. The fossil fuels themselves are the deterioration of biological matter, thus they too required the sun at some point in history. Imagine the world in the distant future when the sun has burned out and can no longer undergo fusion. Imagine that the expanding sun does not scorch and destroy our planet or that somehow humanity has managed to migrate to another terrestrial planet within our solar system which survives after the sun. How will anything survive in the dark abyss after the sun? How should this futuristic human society provide for their energy needs or the necessary energy to produce food? One potential answer to this question may also help modern society. The universe is a complex system which is not fully understood. It was generally accepted that although the universe has been expanding since the Big Bang and that the expansion has been slowing down. Yet in the 1990s two groups of scientists came to the stunning conclusion that the universe was in fact expanding at an increasingly faster pace. Out of this discovery a new theory of dark energy emerged.[76] More about dark energy is a mystery than what is actually known. Dark energy impacts the expansion of the universe and constitutes approximately 70% of the universe. In his theory of General Relativity, Einstein added a cosmological constant after being made aware that the universe was in fact not static. With this prediction, Einstein believed that this empty space possessed its own energy, but more significantly, this energy did not become diluted as space expanded but more of this energy would come into existence as space expanded. A second theory on dark energy is based on the quantum theory of matter. The "empty space" would then be filled with temporary particles which are constantly being formed and then disappear. During this process energy would also be present, but when physicians tried to calculate the amount of energy, they came up with an answer which provided a solution that was 10^{120} times too large.[77] Yet recent studies have indicated that this dark energy has density[78]. A vast amount of research is required on this subject as it mostly unknown but it entails great potential. A question which should be considered is: would it be possible to harness this vast amount of natural, non-solar force in the universe, once it is better understood, and can it then be used as energy by humankind?

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