The Environmental Impact of Electricity Production

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Abstract

In choosing a technology for electricity production today, governments must balance a variety of factors such as citizens' satisfaction, economic outcome and environmental impact. These key issues must be evaluated in the selection of appropriate energy generation technologies, and must all be weighed against the positives and negatives of each technology option based on the individual country goals and desires.

The objective of this research is to analyze the environmental impact of the three primary energy sources available – fossil fuels, nuclear power, and renewable energy sources (RES) - wind and solar. In addition to comparing these energy sources to determine which source may be better suited for a long-term commitment to sustainable environment protection, a comparison between the uses of these primary energy sources was also conducted in order to propose recommendations and conclusions for decision making.

The scope of this broad analysis is based primarily on developed nations. Two main results arise from this study. First, it was found that it is difficult to transfer the results from one country to another since most environmental impacts are site/community specific with the exception of climate change. Second, it was found that RES have less impact on the environment but are overall more costly and unreliable. The high cost and unreliability of RES may have broad implications for nations that invest billions of dollars in renewable energy infrastructure.

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1.0 Introduction and Background Information

In 1992 Fernand Braudel identified the structure and distribution of energy production, using Europe as the basis of his research. There he found that animal labor accounted for approximately half of all energy produced, followed by one quarter energy produced through wood-burning, and another one eighth of energy was produced by water-driven systems like dams and waterwheels. The remaining energy, he found, was divided between human muscle, wind, and sail (Braudel, 1981). The distribution of this energy balance main focus was on agricultural uses.

The most critical fact to note about the energy sources listed above is that they can all be considered renewable and have little environmental footprint, at the levels at which they were practiced (Keay, 2007). Deforestation did not become a serious issue until man's productive capacity had expanded far beyond the levels discussed above, and the remaining energy sources, such as animal consumption and water use. At that time, energy production did not require substantial amount of real estate to support itself. As a general rule, the energy requirement for each human required a plot of land approximately three times the size of the plot required to support human alone on subsistence farming (Warde & Lindmark, 2006). This placed a relatively low population ceiling, as settlements could only be condensed so far until the associated energy need to support a population became prohibitively high.

Some of the most critical driving factors for electricity production are the increase of population, change in overall human culture, transportation industry, buildings consumption and industrial and commercial needs. In 2009, fossil fuel accounted for 80 percent of electricity production in the world**.** Nuclear, coal and natural gas account for about 8%, 23% and 24% of the total energy consumed in the U.S., respectively (Atlantic Council of United States, 2010).

Coal is used primarily for producing approximately 50% of electricity and natural gas is used to produce approximately 18% of U.S. electricity (Energy Information Administration, 2007).

Power generation is the largest source of greenhouse gas (GHG) emissions. Rising levels of GHG have caused progressively more radiated energy from the sun to become trapped in the atmosphere and held by the planet, resulting in global trends towards a hotter earth. This trend is commonly referred to as global warming or climate change. Although some factions contend that GHG has nothing to do with climate change, there are obvious signs that something is wrong - warmer winters, cooler summers, floods, hurricanes, storms and droughts. Over the past 150 years carbon dioxide gas has risen form from 280 parts per million (ppm) to approximately 380 ppm. Compared to the early 1990s, in the early 2000s the construction of natural gas plants doubled due to demand resulting in higher fuel prices but minimal decrease in emissions (Department of Energy, 2003). Since the heavy public outreach campaign on the part of Al Gore, 45th Vice President of the United States and others in the late 2000s, global warming is generally recognized as a visible and serious issue by the international community.

2.0 Electricity Generation Technologies – Impacts

All energy sectors have reportedly strived to minimize the effects of environmental issues especially those accompanying energy production (Bharvirkar, et. el, 2003). For instance, the French nuclear energy has implemented policies to protect the health of its citizens against harmful effects from electricity production. Some of these policies include the Nuclear Security and Transparency Act, the Nuclear Safety Authority Strategic Plan and the Waste Act. As noted by Bird & Blair (2004), the impacts of electricity production related to environmental issues have generated considerable arguments that have taken various dimensions; some argue that it has resulted in increased degradation of the environment while others argue that it has contributed to stability of environmental conditions by using renewable energy sources. Very impressive efforts have been made by various industries to minimize the negative impacts on environment as a result of electricity production e.g. the effort made by electricity generating companies to reduce environmental degradation has been facilitated by the development of nuclear energy and RES. There have been numerous comparisons in the performance of various cycles of fuel by different electricity generating companies with the aim of evaluating their impacts on environmental conditions and how they may be able to contribute to the sustenance of the environment.

i. Fossil fuel

The most widely-used fossil fuel is petroleum oil, which accounts for 44% of the world's fossil fuel consumption, followed by coal at 28.1% and natural gas at 27.3% (Lincoln, 2005). Based on the 2008 data from Canada's National Inventory Report under the United Nations Framework Convention on Climate Change (UNFCCC), GHG emissions from the electricity generation sector contributed around 16% to Canada's inventory of emissions and the coal-fired electricity generation 78% of total electricity sector emissions. A report by the International Energy Agency (2004) estimated that 79.6% – nearly four fifths – of the world's energy supply comes from fossil fuels. The mining and use of fossil fuels damages the environment, our health and quality of life. The consumption of fossil fuels for the purpose of power generation releases carbon dioxide (CO_2), nitrogen oxide(NO_x), sulfur dioxide (SO_2) and methane (CH_4) which are potent GHGs that is estimated to have caused a rise in the average global temperature of approximately 0.6 degrees Celsius over the past century (Lincoln, 2005). Mercury (Hg) is found in coal and other fossil fuels and when the fuels are burned Hg is released into the environment and can results in trans-boundary pollution. Hg in the air settles in water bodies and affects water quality. Exposure to methylmercury (CH_3Hg) on wildlife can include mortality, reduced fertility, growth retardation and development and abnormal behavior that affect survival. The chemical reaction between air vapour, SO_2 and NO_x, produces acid rain primarily from the combustion of coal which destroys crops, forests, wildlife populations, and causing respiratory and other illnesses in humans. Table 1 shows fossil fuel emission levels.

Natural gas combustion is composed primarily of water vapor, CH_4 and CO_2 which according to the Environmental Protection Agency (EPA, 2007) have less impact on the environment compared to coal and oil. Coal and oil emit higher levels of CO_2, NO_x, and SO_2 and releases high levels of particulates (carbon monoxide, reactive carbon, ash, soot, metals) resulting in pollution –smog and poor air quality. Particulate matter affects the respiratory system of humans and can result in premature death. Emissions of particulates from natural gas combustion are 90 percent lower than from the combustion of oil, and 99 percent lower than burning coal.

Table 1 ***Fossil Fuel emissions level of CO_2, NOx, SO_2, particulates and Hg***

- Pounds per Billion Btu of Energy Input

Pollutant	Natural Gas	Oil	Coal
Carbon Dioxide	117,000	164,000	208,000
Carbon Monoxide	40	33	208
Nitrogen Oxides	92	448	457
Sulfur Dioxide	1	1,122	2,591
Particulates	7	84	2,744
Mercury	0.000	0.007	0.016

Source: *Natural Gas. org*

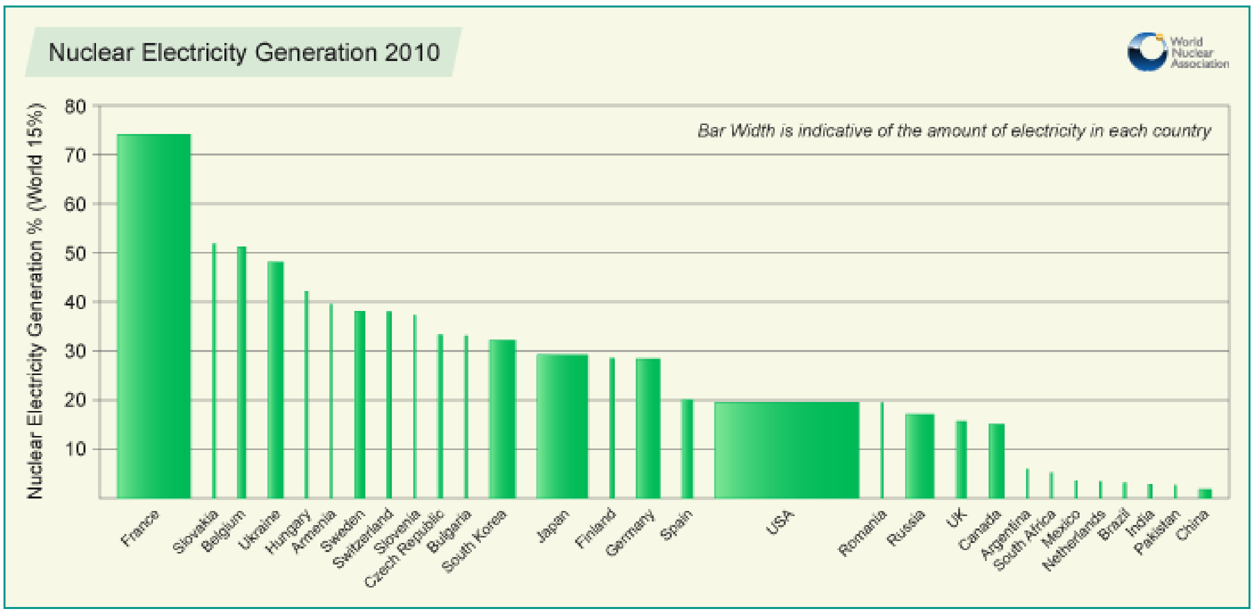
Fossil fuels are formed as a result of millennia-long process of decomposition from decomposition of animals and plants. While accessibility to this decomposed matter is limited, they are said to be in abundance, hence not predicted to run out any time soon. While current reserves of oil are estimated to last approximately 41 years at the rate of production of 2003, there are many more, less conventional sources of fossil fuels which can be tapped at that point. There are millions of tons of fossil fuel stored in so-called “heavy oil” and oil sands that are too expensive to extract at current oil prices. However, as prices rise, these sources will become profitable for extraction, and the supply of fossil fuels is guaranteed as long as demand is high enough to raise prices to an acceptable level to begin these extraction processes.

ii. Nuclear energy

Nuclear energy, also a non-renewable source represents a compromise between the “dirty” energy of fossil fuels and the “clean” energy of renewables. Nuclear energy harnesses the power of the atomic bomb in a slow, controlled and precise manner in order to gradually extract the wealth of energy available from splitting the atom. In a nuclear reactor, heavy water is super-heated by the energy released from a series of blocks of radioactive material. This super-heated water is used to heat a tank of water which is not under pressure, which boils and spins a turbine that results in the generation of energy. The steam is then re-condensed, filtered back to the heating element, and the process begins anew (Peterson & Hermes, 2010). It is important to note that this process, unlike the burning of fossil fuels which releases products of combustion directly into the atmosphere, is self-contained. Construction of a nuclear plant includes new roads, increasing traffic flow in the existing roads, excavations, cutting trees and other plants and impacts on ecology. Radioactive effluents released from nuclear power plants are, however, the main object of monitoring and control to minimize exposure of the public to ionizing radiation. Thermal discharge from nuclear and fossil fuel impacts biota survival, growth and reproduction. However, there are major concerns about the treatment and risks associated with the generation and storage of radioactive wastes and the possibility of a catastrophic release of radioactive material, as occurred at Chernobyl Ukraine in 1986, and most recently Japans Fukushima disaster in 2011. Also, the tailing dams from uranium mining are high in radioactive content, remaining as toxic ponds that leach into the environment, causing acid leaching into the soil, surface and groundwater. For nuclear plants, underground cable is not a feasible option for transmission of electricity therefore transmission lines must be located above ground.

According to World Nuclear Association (2011) there are over 430 commercial nuclear power reactors operating in 31 countries, with 372,000 MWe of total capacity and provides approximately 13.5% of the world's electricity. Figure 1 indicates that US uses approximately 20%, France approximately 75% of nuclear followed by European countries.

Figure 1 ***Nuclear Electricity Generation (2010)***



Source: World Nuclear Association

An increase in nuclear power production on the order of magnitude necessary to significantly reduce fossil fuel reliance would require a massive increase in the amount of fissile radioactive material produced. Feiveson (2001) estimates that the quantity of plutonium necessary to power such a large-scale product, would be enough to produce 70,000 nuclear warheads every year. Such a large quantity of nuclear material would be difficult to effectively control and monitor, representing another serious threat to human life and the environment in case of an error.

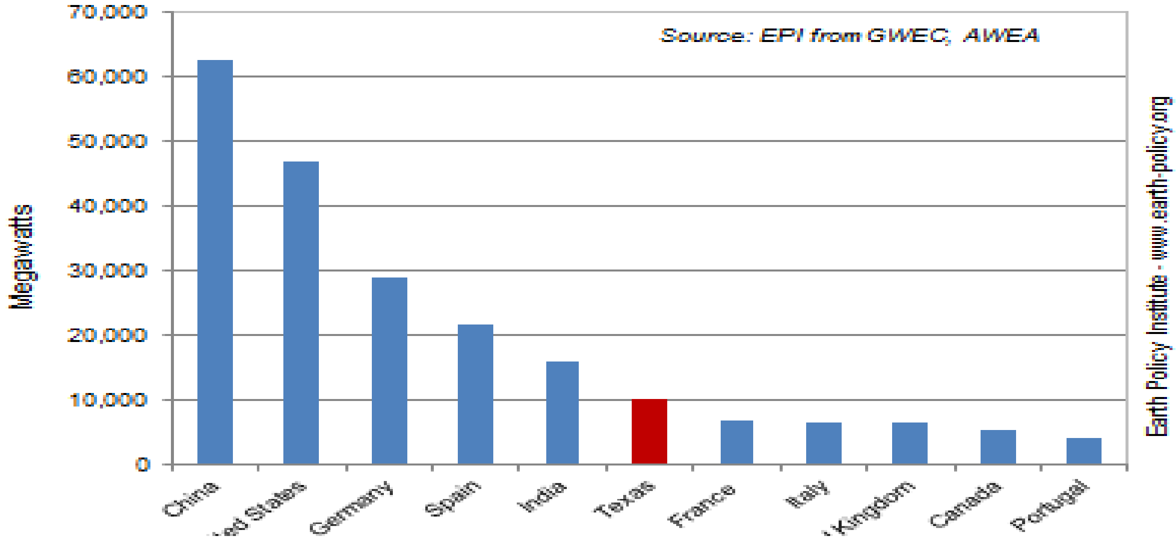
iii. Renewable Fuel

RES draws their power from natural processes replenished by the processes of the Earth. Unlike nuclear power and fossil fuels, renewables have no “expiration date” past which humanity will be forced to find a new solution. RES comes in a variety of forms, which include wind power, solar power, biomass, biofuels, geothermal, and hydroelectric (Amin, A. et al. (2011). This section will focus on the two most popular forms of renewal sources, wind power and solar power.

a. Wind

Four thousand years ago wind power was used by the Chinese to pump water for crop irrigation (Darvill, 2012). Wind is generated when warm air rises and other air blows in to replace them. The energy in the wind is used to blow large propellers of the turbine tower around which turns a generator and produces electricity. When multiple towers installed in the same location, usually referred to as wind farm, they increase electricity generation. The ideal location for wind farms are in places where the wind is strong, steady and reliable with an average speed of around 25 km/h (Darvill, 2012); coastal areas, at the tops of rounded hills, open plains and gaps in mountains . One of the biggest issues with wind farming is acceptance among citizens. Some feel that wind farming is unsightly, kills birds and affects radio and television reception (Darvill, 2012). Wind turbines produce no carbon dioxide, carbon monoxide, sulfur dioxide, nitrogen dioxide, mercury, radioactive waste, particulates, or any other type of air pollution during operation. Wind energy consumes materials such as steel and aluminum emits CO_2 during processing. CO_2 emissions of wind power come from the concrete manufacturing for the foundation of the turbines and range from 14 to 33 tonnes (15 to 36 short tons) per GWh of energy produced. Electric Reliability Council of Texas (ERCOT), 2011) shows that wind’s share of electricity in the ERCOT region jumped from 2.9 percent in 2007 to 8.5 Percent in 2011.

Figure 2 ***2011 Cumulative Installed Wind Power Capacity in Texas and Top 10 Countries***



Source: ERCOT

b. Solar

The sun's energy is used to generate electricity using three main methods: solar cells which convert light directly into electricity; solar water heating where heat from the sun is used to heat water panels on the roof and solar furnace which uses mirrors to concentrate the suns energy into a small space to produce high temperatures. Following the 1973 oil crisis, there has been a rapid rise in solar power production. The International Energy Agency (IEA) (2004) estimate solar electrical energy production by 2040 will be 9.2% of the global demand. One of the major environmental issues with this fuel cycle is the manufacture and disposal of solar cells and other equipment required to capture the radiation before it is transformed into electricity. PV cells are required for the panels and manufacturing involves the generation of some hazardous materials such as arsenic and cadmium. Leftover pollutants such as silicon tetrachloride during manufacturing of solar must be disposed of and pollute the environment if appropriate disposal measures are not implemented. Energy is also used during manufacturing, which pollutes the air, creates heavy metal emissions and greenhouse gases.

Since the Japan Fukushima disaster, countries such as Germany, UK and France have decided to reduce some of their nuclear power plants and focus more on RES. In fact, Germany has vowed to eliminate all of its nuclear plants by 2022. The tsunami tragedy set a trend especially among European countries to move from dependence of fossil and nuclear energies to safer alternatives like solar and wind power sources

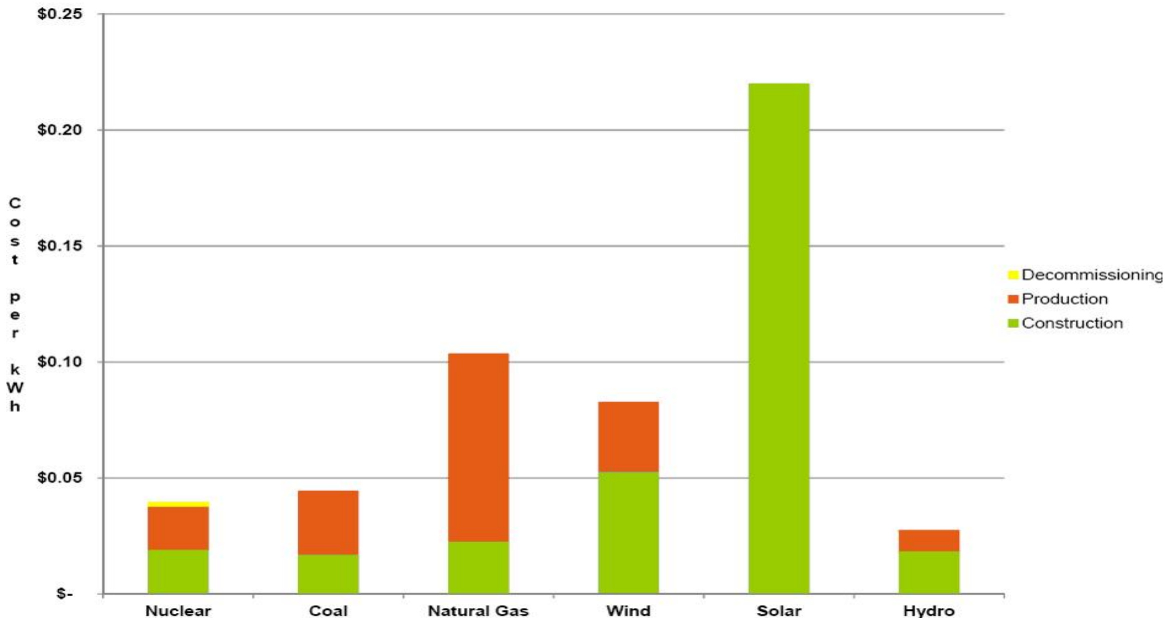
3.0 Sustainability Analysis

This section will focus on the, environmental, engineering and financial sustainability of the technologies over their life cycles based on existing literature. It is important to understand the life cycle impacts of different energy resources for electricity production to help better understand which resource may be best suited for the environmental protection. Implementation of the life cycle assessment (LCA) process is defined by ISO 14040 as a “cradle-to-grave” model to analyze processes through the entirety of their production through their consumption or a “cradle-to-cradle” model to describe a material or product that is recycled into a new product at the end of its defined life. This study will identify the corresponding power production process of fossil, nuclear and RES as the starting point, and the consumer as the end point. Consumers may be businesses, governments, or individuals, and power may be utilized in any way for the purposes of this study.

a. Cost

The average electricity price for all technologies is shown in Figure 3 in US dollars ($) per kilowatt hour (KWh), averaged over the life cycle of the technology.

Figure 3 ***Total Cost of Electricity Production per KWh***



Source: Morgan (2010), 'Comparing Energy Costs of Nuclear, Coal, Gas, Wind and Solar'

Based on Morgan's (2010) calculations, coal and nuclear are tied at $0.04 per kWh. Wind power is $0.08 per kWh and solar power was by far the most expensive at $0.22 per kWh. Solar is most costly of all at approximate six (6) times more than the average nuclear cost. Despite fluctuations in the cost of fossil fuel their price may be more stable compared to that of wind and solar. According to Morgan (2010), there is a high degree of uncertainty related to the cost of wind and solar energy because of poor and varying data regarding the useful life of the facilities and their capacity factors. The high cost for RES may be due to cost of land for wind turbines location, material processing and manufacturing for technology components, reliability and efficiency. According to World Coal Association (2012), coal prices have historically been lower and more stable than oil and gas prices and it is likely to remain the most affordable due to its abundance. 0.02% of the electricity produced worldwide comes from wind and solar power and in the U.S., less than 1% compared to approximately 78% of fossil around the world. These RES operate at best only one-third of the time and require fossil fuel backup. When there is no wind, there is no electricity. The sun shines on half of the world for half of a day; a decrease in sunshine correlates to a decrease in efficiency. A nuclear power can run non-stop for weeks and fossil fuel plant can be switched on and off and still be capable of generating efficient electricity. From the sources mentioned in this study only nuclear and fossil fuel electricity generation is reliable and steady enough to meet world demand growth for electricity. Will renewables ever be able to compete with non-renewables?

b. Raw Materials

Due to the rate of economic growth, and access to non-conventional sources (e.g. oil sands) it is expected that reserves of oil and gas will be depleted within the next 40 - 60 years (Green, 2006). Access to raw materials poses difficulties, hence extraction cost will continue to increase thus increasing life cycle of carbon emissions. With renewables there may be no substitution for some of the raw materials and metals needed for production, resulting in increase in demand. As discussed previously, the wind is free, uses no fuel hence produces no waste or greenhouse gasses during operation however, the extraction of raw materials and manufacturing of the wind turbines releases GHG. Unlike fossil where fuel is shipped to a processing plant, wind energy generates electricity at the source of fuel. Finally, like fossil fuels, nuclear materials are not-renewable. Optimistic predictions of the magnitude of uranium reserves predict that, at current rates of consumption, supplies will be depleted over the next two centuries (Green, 2006). A substantial increase in consumption rates would lower this number drastically, making nuclear power, as it currently exists, at best a stopgap measure until more cost-efficient renewables are developed.

c. Water Consumption

Electricity production requires water consumption especially during the cooling process. The results of the water consumptions study by Shpant (2010) indicates that nuclear requirement for water consumption is extremely high due to the need for cooling of reactors, the highest of all the technologies within this study (see Table 2).

Table 2 ***Water consumption and total withdrawal during electricity generation***

Energy Type	Water Withdrawal (Gal/MWh)	Water Consumption (Gal/MWh)
Nuclear (steam, once through cooling)	25,000 to 60,000	400
Nuclear (steam, pond cooling/cooling towers)	500 to 1100	400 to 720
Fossil/Biomass/Waste-fueled Steam (once through cooling)	20,000 to 50,000	300
Fossil/Biomass/Waste-fueled Steam (pond cooling/ cooling towers)	300 to 600	300 to 480
Natural Gas/Oil combined-cycle (once through cooling)	7500 to 20,000	100
Natural Gas/Oil combined-cycle (cooling towers)	230	180
Natural Gas/Oil combined-cycle (dry cooling)	0	0
Hydro	4,500	4,500
Solar thermal	1,040	1,040
Geothermal	1,800 to 4,000	1,800 to 4,000
Solar Photovoltaic	30	30
Wind	1	1

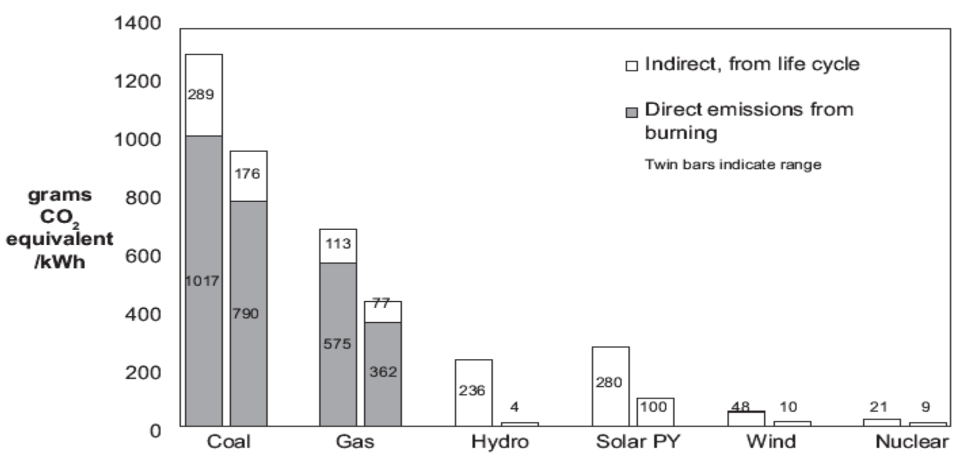
S*ource: Shapant, (2010). 'Energy, Technology and Policy'*

Shpant (2010) indicates that every day in the U.S, 2 to 2.5 gallons of water is used to produce a gallon of gasoline and with the aging of the wells water consumption will increase. Taking the highest range, nuclear withdraws 60,000 Gal/MWh more than wind. Fossil is second highest for withdrawal. There is a difference of 10,000 Gal/MWh between fossil and nuclear. At only 1g of water used per megawatt hour, wind has negligible water use. Photovoltaics also use very little water, approximately 30 gal/MWh. These low values for wind and photovoltaics indicate that they are more sustainable than nuclear and fossil fuel with respect to water consumption. The literatures reviewed had no mention of water being recycled during manufacturing and operation.

d. GHG Emissions

Globally, power generation emits nearly 10 billion tons of CO_2 per year. Since the Industrial Revolution the concentration of CO_2 in the atmosphere due to fossil fuel combustion has risen to approximately 40% (see Figure 4). CO_2 has been declared a health risk to humans and scientific research indicates that it is the leading cause of climate change and rising temperatures on the planet.

Figure 4 ***Greenhouse gas emissions from electricity generation***



Source: International Atomic Energy Agency (2010)

Nuclear has the lowest average and range of emissions; the emissions would be to enrichment of the ore uranium during mining but no emissions during operation. Second lowest is the emissions from wind which previously mentioned is generated during manufacturing and there are no emissions during operation. GHG emissions for the production of wind turbines and solar cells vary according to the country of production, primarily due to the differences in the electricity grid mix of the specific country. In comparison to fossil fuels, RES and nuclear generation have a low carbon footprint and most emissions are during construction and transportation. Renewable energy technologies are often viewed by many as the answer for mitigating global GHG. The wind and solar technologies for electricity generation is relatively new and with innovation and changes in processing and manufacturing may be able to generate less emission.

e. Land Use

For fossil fuel and nuclear, land use impact is mainly related to mining, extraction, supply, transport and waste disposal but for RES land use is only required during the operation. Land use does not measure the amount of land being used, how much damage is done by the technology or for how long the land is being used but measures the amount of land required by the installation and operation of the technology. Table 3 shows that nuclear followed by coal and gas has the lowest requirement for land use, not taking into consideration the damaging impact on the land used over the life cycle of the technology. The land use for wind power is high, this is based on the value for the entire wind farm. The amount of land that turbine occupies taking into consideration the entire wind farm, is only 1-10% of the area, while the remaining site can be used for grazing, agriculture or recreation (Fthenakis & Kim, 2007).

Table 3 ***Life cycle land occupation for electricity generation***

Technology	Gagnon m2/KWh	Fthenakis m2/kWh
Photovoltaic	0.045	0.0003
Wind	0.072	0.0015
Gas		0.0003
Coal	0.004	0.0004
Nuclear	0.005	0.00005

Source: Fthenakis and Kim (2007)

Nuclear and fossil in terms of land use is most sustainable at 0.005 and 0.004

respectively followed by photovoltaic at 0.045

While there is no upper limit on renewables in terms of their lifespan, there is a limit to the amount of energy that they can produce. Wind may be among one of the best methods to provide energy to remote locations and since the towers are built high above ground there is amble space below to accommodate farming. Wind does not need to be mined or transported therefore the cost is fixed when compared to nuclear and fossil fuels. Wind energy creates 30% more jobs than a coal plant and 66% more than a nuclear power plant per unit of energy generated (Windustry, 2012). There are also limitations to wind farming. With no wind there will be no energy and suitable locations with high wind e.g. along the coast, the land tend to be costly (Darvill, 2012). Solar energy is free, does not use fuel and produces no waste. However, it can be unreliable in the absence of the sun (night) plus large area of solar panels are required to get a decent amount of power. Wind and solar showed the lowest values for water consumption however they were the highest in terms of cost with high payback period. RES tend to have a near-zero carbon footprint, by virtue of the fact that they require no burning of fuel, and so are very attractive from an environmental point of view with that said, there are also concerns that the total amount of renewable energy available may be insufficient to meet the world's energy needs.

Today 78% of our electrical energy needs are met by fossil fuels and nuclear energy. Of all electricity generation sources fossil fuel appears to be the most reliable, less costly, most abundant, produces most of the world’s electricity yet it is responsible for most of the environmental and health impacts. With respect to nuclear there is the question on the availability of uranium, for how long can we continue to mine it and issues of disposal.

Nuclear energy suffers from severe limitations – most severely, the limited quantity of uranium available for mining and reclamation from the surface of the Earth – and appears to grant no quantifiable benefit to those who opt to use it. There have been developments to replace uranium. Fossil fuels, conversely, are supported by the numbers from a social and economic perspective. The overall downsides to solar is the need for consistent sun and wind is constant supply of wind however there are high cost associated with commissioning, operation and maintenance associated with both these RES. Once they have been properly implemented, they are self-sustaining. When analyzing technologies it is imperative to understand the life cycle of each individual technology. If considering GHG emissions only RES would be the best choice for the environment, however full implementation of RES has been delayed which appears to be based more on, reliability, economic and political reasons rather than technical.

4.0 Policy Implications

To assist in protecting the environment, policies must be implemented by governments to support the development of RES and to find ways in which the traditional methods (fossils and nuclear) can be processed without impacting the environment. Key components for implementing successful policies are enforcement, keeping complexity low, transparency and the rules being fair and applicable to everyone. Energy policies must focus on solving the present energy demand without increasing the impact to the environment and not hindering the economy therefore the framework must include environmental, social, economic and international goals. Policy design and implementation success would need smooth interaction between new and old or existing policies. Some of the policy implications are discussed in this section.

4.1 Sound Science on Emission Controls

Skeptics and advocates of climate change disagree on how to approach climate change; the best way to reduce GHG emissions, voluntary versus mandatory controls and whether the responsibility of addressing emissions is the same for both the undeveloped and developed nations (Council on Foreign Relations, 2010). Skeptics believe that caps on greenhouse gas emissions could cause more economic harm than good. With uncertainties in science, appropriate decision tools and management must be implemented to facilitate use of scientific information for the application of GHG control policies. Therefore, the need to have procedures and policies in place to facilitate adaptation to changes in scientific information is highly important. Governments need to allocate more money for research so that sound science can guide policy on greenhouse gas emissions. In the face of uncertainty, the precautionary principle should be used.

4.2 Limit Energy Intensive and High Water Consumption

The interdependence between water and energy must be clearly understood for the implementation of effective and beneficial policies for electricity. Metz et el (2005) indicate that implementation of ultra-supercritical coal and IGCC plants has the potential to increase energy efficiencies by 25–50% compared to the traditional pulverized coal plants. Therefore, for countries that intend in building new fossil fuel power plants public policies by the government should mandate that these plants consider ultra-supercritical coal and IGCC plants that have both higher water and energy efficiencies resulting in carbon capture and decrease in water consumption. The 2009 Toxic Reduction Act (Ontario Ministry of Environment, 2012) in support of a greener economy stipulates that information on substance reduction in the companies processing be made available to the public, therefore, energy supply companies should also publish the life cycle of their processing; amount of water consumption, percentage of GHG emissions, etc. Partnership agreements would be required between nations for deployment of new and advanced technologies. Hence public policies should be based on limiting energy intensive and high water consumption industries.

4.3 Energy Conservation and Efficiency

Although every country and community is different, energy conservation must be made a top priority on national, regional and international levels. Every nation should seek to adopt conservation resources on a national level to promote and strengthen energy saving, despite its state of economic development and energy abundance. This should be led by the International Energy Agency. Effective mechanisms to share insights and results both internationally and nationally on policies will lead to more improved policies. The Canadian industry program for energy conservation (CIPEC) is an integrated strategy based on voluntary, collective targets for industrial sectors. Under the CIPEC program between 1990 and 2003, companies were able to reduce their energy intensity by 8.7%. According to Price and Worrell (2000), the participating industries saved enough energy that would be required to heat 4.8 million Canadian households for one (1) year. UNESCAP (2007) recommends undertaking the following steps to implanting national level strategic planning and management of energy efficiency initiatives: Crafting an Inspiring National Energy Efficiency Vision, Translating the National Energy Efficiency Vision into Objectives and Targets, Building National Commitment for Energy Efficiency Action and Strategic Management of Energy Efficiency Programs. Continuous monitoring and elevation of these steps when implemented is necessary to determine success or failure for more sound future efficiency undertakings. Nations should individually and collectively come together in supporting each other to develop a framework and improve on efficiency management data sharing and sustainable energy by developing Universal Energy Efficiency Indicators.

Governments and institutions must foster scientific and technology progress and encourage the participation of citizens and industry. Measures implemented must be evaluated on a continuous basis to check performance and alternative methods of improvement. Governments must support and promote energy savings projects and industrial saving energy. High energy consumption products should be eliminated within a given phase out period and make energy saving products more affordable. Public programs should be developed to show the benefits accrued through conservation. Energy regulation is necessary to protect consumers of electricity in respect of the prices charged, the reliability of supply, consumer satisfaction and the quality of the electricity supply. Generation capacity with an adequate reserve is crucial to improving the availability and reliability of the electricity supply within a country (National Renewable Energy Laboratory, 2001).

4.4 Fossils as Clean Energy

For countries with abundant fossil fuels it may be best to invest in advancement in clean fossil technologies for electricity production than investing too heavily in RES. This should be part of the strategic plan for the governments. RES often relies on weather conditions which can be unpredictable and inconsistent. Therefore, RES is unable to generate the required amount of electricity compared to fossil and nuclear technologies. Countries with abundant fossil require implementation of rigorous regulations and producers would need to be held accountable to those standards so that fossil fuels can become part of the clean energy solution. Maybe countries with abundant fossil fuels should implement policies to encourage improvements in efficiency in energy from fossil fuels and decrease demand for electricity generation from RES. Countries which experience long cold winters may not fully benefit from wind and solar electricity as depicted during the winter period in the UK in 2010. It is imperative that decision makers and different stakeholder groups undertake scenario studies that are not based solely on emissions to help understand energy related risk and the present and future energy systems.

Studies should encompass security, availability, affordability, reliability and accessibility.

4.5 Development of RES

There is uncertainty in terms of reliability and security of RES; given this uncertainty how are policies and decisions to be made? How do we measure the short term benefits of RES with long-term cost? With the uncertainty surrounding fuel oil prices, countries that import fuel should focus on the development of RES and allocating funds to undertake pre-feasibility and feasibility studies to identify the most suitable renewable technologies for the country and set a time frame to have a complete renewable energy technology based on the country's needs. In order to sustain growth of renewable technologies within the market consumers must understand the benefits (environmental, risk reduction etc.) and the ultimate trade-off between costs and benefits. Education and awareness programs must be used for creating effective community participation. Nurturing students at an early age to understand the impacts of electricity production is a long-term investment to the solution. Academics, consultants and governments should put money into research into cheaper RES or less costly ways to utilize RES. Denmark and Germany are known to be leaders in renewable energy development and renewable energy has helped in industrial development and job creation, and CO_2 emission reductions. Other countries can learn from these leaders.

4.6 Backcasting

Robinson (1982) suggest, backcasting, 'working backwards' from a particular future end-point to the present to determine what policy measures would be required to determine energy supply and demands. Backcasting indicate the relative implications of different policy goals with respect to the relationship between analysis and policy. According to Robinson, energy backcasting appears to offer the chance to avoid a number of the problems associated with energy forecasting and provides a useful method of policy analysis. National energy authorities should use the backcasting technique as part of their planning tools.

4.7 Taxes

Taxes related to energy use or energy-related CO_2 emissions, according to economists are theoretically superior to other policy instruments because they internalize the environmental costs associated with energy consumption. These taxes reduce demand for the product taxed, raise revenues, and they reduce pollution and related detrimental health and labor productivity impacts (Royal Society, 2002). These taxes were first adopted in a number of northern European countries in the early 1990s. According to Scrimgeour et el (2005) carbon taxes show that they generally achieve their objective of reducing emissions.

Over the years, it is noted that governments from such countries like France, USA, Germany, Canada, Asian and other European countries, and other policymakers have relied on legislative and regulatory restriction on polluting activities to guarantee adequate protection of the environmental quality by the employment of voluntary agreements between the regulators and polluters. This is viewed as an alternative to compulsory approaches based on regulation or legislation. To some extent, these agreements encourage proactive cooperation approach from industry. This, as explained by Segerson & Miceli (1998) is viewed as an excellent way of reducing conflicts existing between the regulators and the polluting industries (Segerson & Miceli, 1998). Use of this approach also increases greater flexibility and freedom to find cost effective answers that are fashioned to address specific conditions. Another effective policy that can be utilized in ensuring that environmental impacts from the electricity productions are abated is the polluter pay principle. This policy calls for the total costs of pollution to be borne by those who caused the pollution. Utilization of this policy will promote justice, harmonization of international environmental policies; it also promotes efficiency, and defines how costs within a given state should be allocated (Lucia, 2008).

CO_2 taxes can be used to provide an incentive to industry to improve the energy management at their facilities through investments in energy-efficient technologies. The CO_2 tax programs can recycle the revenue back into the economy, use the revenue to provide tax incentives for energy-efficiency investments or to provide information and auditing programs, and provide tax reductions for industries that meet negotiated energy efficiency targets.

4.8 Smart Grid Systems

Smart grid integrates both renewable and non-renewable energy technology. Smart grid would help to alleviate the cost option and unreliability associated with RES. Privacy protection advocates are concerned that smart is not secure in terms of uses personal information and that energy companies can use consumers' personal information for other purposes. The need for less costly, reliable and efficient energy calls for better policy implementation of smart grid in particular consumer protection. The power authorities should implement smart grids as part of their strategic direction for energy conservation.

5.0 Conclusion

Most of the studies reviewed seem to focus mainly on the environmental implications of fuel cycles in terms of their contribution to global warming which can be misleading. For example toxics such as cadmium and saline are used in the photovoltaic power systems. What would be the environmental impact of recycling these materials plus in some cases materials has to be imported or exported. Consideration should also be given to the possibility of depletion of raw materials for renewable energy technology and nuclear. The life cycle of land does not take into consideration the impact on land caused by climate change etc. These are all important factors to be considered by policy makers.

Today one of the most crucial challenges we face is to reduce the environmental impacts of electricity production, specifically, GHG emissions and the answer to some appears to be RES. Research has shown that RES has far less environmental impacts than fossil and nuclear but can we cannot survive solely on RES. Research has also proven that RES is unreliable and most types of renewable energy production cannot exist without substantial government investments, incentives, loans and/or tax breaks. Renewable needs the support of non-renewable therefore we may have to rethink coupling of the energy systems to help reduce impacts and find ways to improve the extraction of fossils for electricity. The energy problem is a difficult one, one that needs to be solve and tackled from many angles. We must move beyond our current way of thinking and seek better ways to have innovative methods and procedures, not simply for being innovative but considers mitigating environmental, economic and social impacts in technology implementation.

6.0 Limitations/Recommendations for future research

While the results of this study are conclusive and its design is sound insomuch as the data allow, there is a need for additional research from a public policy standpoint and other renewable technologies. There is no way to examine an energy source as separate from the nation which chooses to implement it. One interesting experiment that warrants serious research is an examination of how the introduction of technologies such as renewables influence a country which is already established and how does implementing one technology impact other existing technologies.

7.0 References

(1) Agency, European Environmental. "Air pollution impacts from carbon capture and storage (CCS)." 17 November 2011. European Environmental Agency. 2 June 2012 http://www.eea.europa.eu/publication/carbon-capture-and-storage.

(2) Alkire, S. & Foster, J. (2010). *Designing the inequality-adjusted human development index (IHDI)*. United Nations Development Program Human Development Reports Research Paper. Retrieved from http://hdr.undp.org/en/reports/global/hdr2010/papers/HDRP_2010_28.pdf

(3) Amin, A. et al. (2011). *Renewables 2011 global status report*. Renewable Energy Policy Network for the 21st Century.

(4) Bharvirkar, R, Dallas, B, & Alan, K. (2003) "NO Emissions trading and episodic air quality violations In Maryland". *Final report prepared for Power Plant Research Program*

(5) Bird, L & Blair, S. (2004), "Green power marketing in the United States: A Status report", seventh edition. National renewable energy Lab.

(6) Braudel, F. (1981). *Civilization and Capitalism, 15th-18th century, vol 1: The structures of everyday life : the limits of the possible*. New York: Harper & Row.

(7) Central Intelligence Agency. (2012). The World Factbook page on France. Retrieved from https://www.cia.gov/library/publications/the-world-factbook/geos/fr.html

(8) Council on Foreign Relations, 2010. http://www.cfr.org/climate-change/alternative-views-climate-change/p14318

(9) Darvill. A. (2012), Energy Resources. http://www.darvill.clara.net/altenerg/index.htm

(10) DOE "Annual Energy Outlook," Energy Information Administration, 2007

(11) DOE "Electric Power Annual," Energy Information Administration, 2003.

(12) Feiveson, H. (September-October 2001). The search for proliferation-resistant nuclear power. *The Journal of the Federation of American Scientists, 54(5).* Retrieved from www.fas.org/faspir/2001/v54n5/nuclear.htm

(13) Fthenakis, V. M. and Kim, H. C. (2007). "Greenhouse-gas emissions from solar electric- and nuclear power: A life-cycle study." Energy Policy 35(4): 2549-2557.

(14) Green, J. (2006). *Nuclear power and climate change*. EnergyScience.org.au. Retrieved from tp://www.energyscience.org.au/FS03%20Nucl%20Power%20Clmt%20Chng.pd

(15) Halper, M. (2012) *Iceland attracts new business with clean energy*. RenewableEnergyWorld.com. Retrieved from http://www.renewableenergyworld.com/rea/news/article/2012/04/iceland-attracts-new-business-with-clean-energy

(16) "IPCC Fourth Assessment Report: Climate Change 2007." *AR4 SYR Synthesis Report Summary for Policymakers*. The Nobel Foundation, 2007. Web. 26 June 2012. <http://www.ipcc.ch/publications_and_data/ar4/syr/en/spms1.html>.

(17) International Energy Agency. 2004. *Key world energy statistics.* IEA, Paris. Retrieved from http:// www.iea.org/dbtw-wpd/bookshop/add.aspx?id=14

(18) http://www.iaea.org/Publications/Magazines/Bulletin/Bull422/article4.pdf, Spider J, Langlois L and Hamilton B (2000), "Greenhouse gas emissions of electricity generation chains-assessing the difference", IAEA Bulletin 42 2. Back

(19) ISO 14040. (1997). *Environmental management – life cycle assessment – principles and framework.* International Organization for Standardization.

(20) Keay, M. (October 2007). *Energy: The long view.* Oxford: Oxford Institute for Energy Studies.

(21) Lincoln, S. F., (2005). Fossil fuels in the 21st century. *Ambio, 34(8)*. Stockholm: Royal Swedish Academy of Sciences

(22) L. Gagnona, c. Belangerb & Uchiyamac, Y. "Life cycle assessment of electricity generation options: The status of research in year 2001." Energy Policy 35.1 (2002): 413-423.

(23) Lucia, Vito De. "Polluter pays principle." 22 August 2008. The Encyclopedia of Earth. 25 May 2012 http://www.eoearth.org/article/Polluter_pays_principle

(24) Metz, B., O. Davidson, H. de Coninck, M. Loos, and L. Meyer, editors. 2005. Carbon dioxide c The Royal Society.http://www.world-nuclear.org/policy/royalsociety-emissions.pdfapture and storage. Cambridge University Press, Cambridge, UK.

(25) Morgan, J. (2010). "Comparing Energy Costs of Nuclear, Coal, Gas, Wind and Solar." Nuclear Fissionary. www.nuclearfissionary.com Retrieved June, 2012

(26) NaturalGas.org, Natural Gas and the Environment; http://www.naturalgas.org/environment/naturalgas.asp

(27) NationMaster.com. (2008) *Electricity production by source > fossil fuel.* Retrieved from: http://www.nationmaster.com/graph/ene_ele_pro_by_sou_fos_fue-electricity-production-source-fossil-fuel

(28) Portney, P. (2000): "Environmental Problems and Policy:2000-2005." The journal of Economic Perspectives 14.1 199-206.

(29) Peterson, L. & Hermes, M. (2010). *Nuclear Power 2010*. Kennesaw State University. Retrieved from http://www.chemcases.com/2003version/nuclear/nc-10.htm

(30) Pepermansa G., Driesenb, J., Haeseldonchxc D. Belmansc R. & D'haeseleerc, W. "Distributed generation: (2005): defination, benefits and issues." Energy Policy 33.6 787-798.

(31) Price L, Worrell E. International industrial sector energy efficiency policies, 2000

(32) Roberta Capello, Peter Nijkamp & Gerand, Pepping.(1999). Sustainable Cities and Energy Policies. New York, NY: Springer

(33) Robinson, J. (1982) Energy Backcasting. 'A proposed method of policy analysis'.

(34) Rogers, S. & Evans, L. (2011) *World carbon dioxide emissions data by country: China speeds ahead of the rest*. The Guardian. Available from http://www.guardian.co.uk/news/datablog/2011/jan/31/world-carbon-dioxide-emissions-country-data-co2#data

(35) Rose., K. "The state of retail electricity markets in the U.S." The electricity journal 17.1 (2004):

(36) IPPC, Special Report on Renewable Energy Sources and Climate Change Mitigation (SRREN), 2011, Special Report on Renewable Energy Sources and Climate Change Mitigation — SRREN

(37)Segerson K. & Miceli, T. "Voluntary Environmental Agreements: Good or Bad News for Environmental Protection?" Journal of Environmental Economics and Management 36.2 (1998): 289-296.

(37) Schneider, M. et al. (November-December 2009). 2009 world nuclear status report. *Bulletin of the Atomic Scientists, 65(6)*

(38) Smith, H. L. (March-April 1991). The environment since the Industrial Revolution. *Cato Policy Report*. Washington, D. C.: Cato Institute

(39) Shpant (2010). "measuring the water footprint of energy consume", Energy, Technology and Policy. http://webberenergyblog.wordpress.com/2010/02/21/measuring-the-water-footprint-of-the-energy-we-consume/ retrieved June 2012.

(40) "Sustainable Energy." August 2011. World Nuclear Association. 25 May 2012

http://www.world-nuclear.org/info/inf09.html
(41) Tsoutsosa T., Frantzeskakib, N. & Gekasb, V. "Environmental impacts from the solar energy technologies." Energy Policy 33.3 (2005): 289-296.
(42) UNESCAP, 2007. Guidelines for strengthening energy efficiency planning and management in Asia and the Pacific. www.unescap.org/esd/Energy-Security-and-Water-Resources/energy/publications/ee-guidelines/EE-Guideline-Final.pdf
(43) Windustry. “Why Wind Energy” www.windustry.org
(44) Warde, P. and Lindmark, M. (2006). Energy and growth in the long run. In Proceedings of XIV International Economic Congress, Helsinki, August 2006.