Inquiry into Issues Affecting The Planning, Design and Development of a Renewable Energy Network for Electricity Production:

The Feasibility of DESERTEC

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“We need several great world engineering projects which will help save us incredible sums of money spent on national duplications, increase productivity of the world economy and help us save the environment... The world energy grid should receive top attention and be supported.”

Robert Muller, Former UN Assistant Secretary General, Chancellor of the University for Peace

Idea 943: February 8, 1997 from the “2000 Dreams and Ideas for the Year 2000” by Robert Muller
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Abstract

The global energy demand is expected to grow by 50% over the next 20 years. With the current fluctuating prices of oil, its limited supply and the harmful emissions caused by fossil fuel use in energy production, the need for cleaner energy from renewable sources will be the cornerstone of sustainable human development. The DESERTEC concept for a network of power plants with renewable energy sources across various European, Middle Eastern and North African (MENA) countries is a promising step in the right direction. This Inquiry assesses the feasibility of energy cooperation among states, from the environmental, social, political and economic dimensions. Cooperation in clean energy production will be the way out of the era of global climate change by alleviating poverty, reducing greenhouse gas emissions and sustaining current and future global energy needs.
Section I: Introduction

1.1 Purpose of the Inquiry

The intent of this paper is to examine and assess the feasibility of global energy cooperation in order to produce electricity to meet the global demand. By doing so, the paper will uncover the sustainability of a global energy network among states, chiefly, among the European Union (EU) and the Middle East and North African (MENA) region. The paper will do so by delving into the following questions:

WHAT ARE THE PROSPECTS OF A RENEWABLE ENERGY NETWORK BETWEEN EUROPE AND THE MIDDLE EAST/NORTH AFRICA REGION?

What are the economic, environmental and social benefits and challenges in the way of achieving such a network? What political impact will this have globally and on the regional level? How can we ensure the sustainability of a global energy network based on renewable energy sources with an intermittent nature?

1.2 Paper Overview

With the continual rise in the global mean temperature (Hansen et al 2006), and with the observed increase and fluctuation in fossil fuel, oil and food prices, the rational move forward would be towards more renewable energy sources to avoid more unnecessary harm to the planet. If we are to curb the harm we cause the climate and the ecosystems around us, we need to invest in energy efficient processes; ones that do not harm the environment or the society living within the environment where they are
created, and ones whose economic costs are not a huge deterrent given their great benefits.

However, unsustainable development and unrealistic economic growth should not guide our future decisions. Humanity ought to focus on the great benefits that renewable sources can provide (Twidell and Weir 2006; Mitchell and Connor 2004; Kaygusuz and Kaygusuz 2002; Krewitt and Nitsch 2003; Dincer and Rosen 1999; Byrne, Shen and Wallace 1998). Renewable energy can be defined as “energy obtained from the continuous or repetitive currents of energy recurring in the natural environment” (Twidell and Weir 1986). We can also think of renewable energy as “energy flows which are replenished at the same rate they are used” (Sorenson 2000). And with approximately 1.6 billion people still living without electricity (UNDP 2007) and lacking access to the basic modern energy services, it is clear that the path we have taken so far is unsustainable, inequitable and unproductive. Such deficits in energy provisions cost the world’s poorest unnecessary health risks and a poorer quality of life, they cost women unnecessary drudgery and lack of income generating employment, and they cost the environment tonnes of CO$_2$ and other Greenhouse Gas (GHG) emissions (UNDP 2007).

Hence, the need for cleaner and more sustainable electricity generating networks that can be accessed by poorer nations, or that can generate water and income for them, is great. But it is important to account for the costs of establishing such a network and then comparing these costs with the possible benefits to decide its feasibility. This paper will assess the viability of a global energy network to produce electricity and
illustrate whether or not it is a sustainable option. The paper will do so by examining the associated policies and issues in the following manner:

The second section of this document will outline the current technologies and policies in place that relate to renewable sources of energy used in generating electricity. This section will also illustrate the needed capital, the achievable service levels and the quality of service, and finally the needed resources and skills in planning, designing and developing renewable electricity plans. The section will also introduce the DESERTEC concept as a suitable model for global energy cooperation. Then, section three of the document will explore the barriers and challenges to global energy cooperation. It will demonstrate the support for and against a global renewable electricity grid and describe the associated challenges. This section will also analyze DESERTEC’s vision and policies and whether it can lead by example. Furthermore, an integral part of dealing with such challenges is developing policies and future policy frameworks. The fourth section of this report will deal with suggested policies that can be used to encourage global energy cooperation while curbing most, if not all, the associated challenges. This will include frameworks for governments, International Organizations (IOs), Nongovernmental Organizations (NGOs), industry and civil society to follow in order to make them all aware of the achievable positive outcomes from a global energy network, as well as to demonstrate the need for energy conservation in order to achieve such benefits. The fifth and last section of the paper presents conclusions and future research directions that can be adopted to help us rethink the way we think about energy and make this vision a reality.
Section II: Renewable Energy for Electricity Production

2.1 Overview of Employed Technologies

Since the outset of the Industrial Revolution, the global energy needs have increased tremendously in a race for economic development. This in turn resulted in an exponential growth in fossil fuel usage causing major global environmental harm; human-induced climate change due to the large quantities of greenhouse gas (GHG) emissions, such as Carbon Dioxide (CO₂), Methane (CH₄), Nitrogen Oxides (NOₓ), Sulfur Dioxide (SO₂) and others, that are released into the atmosphere by fossil fuel combustion in the production of energy (Lloyd and Subbarao 2009). However, such unsustainable extraction and use of finite resources needs to be addressed, especially when it comes to generating electricity.

Over the past few years, and in order to curb such toxic emissions and combat the global warming phenomenon, interest in renewable energy has been rising particularly in the electric power sector (Chedid et al. 1999). Chedid et al. (1999) also note that it is possible for renewable energy systems to be integrated into existing power systems in order to reduce fuel costs for fuel importing countries, and in order to limit toxic emissions from the energy sector. It is estimated that the installed electrical capacity from renewable energy sources globally is around 160 Giga Watts (GW) or 4% of the total electrical capacity (Abengoa Solar 2008). Currently, there are a few demonstrated technologies related to renewable electricity production that are in use globally.
2.1.1 Concentrating Solar Power (CSP) Plants & Photovoltaics (PV)

Solar radiation is estimated to be around 5.4 million exajoules (EJ) per year, with 30% of it reflecting back into space (Boyle 2004). Hence, the remaining 3.8 million EJ, which is more than 10,000 times more than the rate of consumption of fossil and nuclear fuels in 2002 (Boyle 2004), can be used directly or indirectly converted to obtain useful energy to fuel our ever-growing energy needs. The benefits of solar power are compelling: the fuel is free, abundant and inexhaustible. Since “more energy from the sun hits the Earth in one hour than all the energy consumed by humans in an entire year” (Lewis 2007), it is quite apparent that the need to invest in solar technology and the need for innovation in this field is now. Currently, there are many available technologies that make direct use of solar energy to produce solar thermal energy for power generation.

Solar thermal engines follow a relatively simple procedure to generate electricity. The sun’s rays can be concentrated using mirrors to obtain high temperatures capable of boiling water to drive steam turbines or Sterling engines (Fink and Beaty 1999). These engines, in turn, can be used for producing mechanical work (pumping water), or even for generating electricity by driving electric generators. This process of concentrating and collecting the direct solar radiation is what Concentrating Solar Power (CSP) technologies are based on. The “solar heat collected during the day can also be stored in liquid or solid media like molten salts…concrete, or, in the future, phase-changing salt mixtures” (Greenpeace 2005, p.4). Then at night, or on overcast days, the stored heat is extracted from the storage medium and can continue turbine operation (Mancini and Geyer 2006).
However, and since these solar thermal power plants use direct sunlight, they need to be placed in areas with abundant direct solar radiation with Direct Normal Irradiance (DNI) > 1,800 kWh/m$^2$yr (Abengoa Solar 2008). Some of the ideal locations are South-Western United States, Central and South America, Northern and Southern Africa, the Mediterranean countries of Europe, the Middle East, Iran, and the desert plains of India, Pakistan, the former Soviet Union, China and Australia (Aringhoff et al. 2005).

CSP technologies have four main elements: the concentrator, the receiver, the transport and/or storage element and the power converter (Sedghisigarchi and Davari 2008). A variety of mirror configurations is used in the operations of the concentrator and receiver elements, while the transport and storage elements relate to the ability of the plants to produce electricity at night or with overcast skies (Greenpeace 2005). In fact, the main reason why innovations in the field of thermal energy storage for these plants are being developed is to extend these plants’ production time (Siemens AG 2008). Finally, in the power conversion element, one can combine the operation of the CSP plant with other renewable or non-renewable technologies, called hybrids, if a reliable peak-load supply is not able to be met due to low radiation intensity (Ibid.). There are four main CSP systems being used today (Greenpeace 2005):

1. Central receiver or solar tower systems, like the

![Figure 1: The PS10 & PS20 projects in Seville, Spain. (Credit: Abengoa Solar 2008)](image-url)
ones illustrated in Figure 1.

(2) Parabolic trough systems, such as the one in Figure 2.

![Figure 2: A Parabolic Trough System (Credit: Warren Gretz, NREL 2004)](image)

(3) Parabolic dish systems, such as the ones illustrated in Figure 3.

![Figure 3: Parabolic Dishes in Windorah, Australia. (Credit: AAP: Solar Systems 2007)](image)

The differences between these systems are illustrated in Table 1 which was obtained from a report on concentrated solar thermal power done by Greenpeace (2005, p. 13) on September, 2005.
Furthermore, the importance of reliable energy storage in solar thermal power plants cannot be overstated. An efficient medium of heat absorption, storage and transfer is essential to ensure solar-only and even hybrid power plants become as efficient as possible - as well as economically attractive - by enabling solar energy collected during the day to be stored then transmitted when demand is required. Currently, the most widely used technology operates on the basis of two molten salt tanks for energy storage; one hot salt tanks and one cold salt tank, that exchange the heat transfer fluid (HTF) as it is heated by solar radiation, and when it is needed to
generate electricity (Abengoa Solar 2008). Investment costs in such thermal energy storage (TES) systems range between $10/kWh and $20/kWh (Tamme 2006).

Photovoltaic cells directly convert the ultraviolet sunlight rays into electricity using the semiconductor materials present on their surfaces (Markvart 2000). Once these semiconductors are exposed to solar rays, they excite the electrons generating direct electric current (Mao and Chen 2007). Typical photovoltaic power plants are comprised of the following components: an optical component, a photovoltaic cell, an inverter and a solar tracker (Lenardic 2007). The optical component uses various configurations of mirrors and lenses to focus the sun’s rays onto the photovoltaic cell; it is the element where the photovoltaic effect takes place, producing direct current (Abengoa Solar 2008). Then this current passes through an inverter which transforms the incoming current from the cell into an alternating current which can be then sold to the grid and used (Geyer and Quaschning 2000). In order to maximize system efficiency, a solar tracker is needed to constantly orientate the photovoltaic module towards the sun (Walker 2008).

As for the capital and operating costs of solar power plants, the Global Market Initiative of June, 2004 stated that:

“For the current state of parabolic trough CSP technology, and at very good sites, a solar kWh can be generated for about 15-17 US cents/kWh. This generation cost will be reduced when more projects are implemented. CSP industry anticipates reducing solar power generation costs by 20-25%, once 1,000 MW of new solar capacity has been implemented. Upon reaching 5,000 MW of new solar capacity, solar electricity generation cost will be fully competitive with fossil-based grid-connected mid-load power generation” (Greenpeace 2005, p. 15).

In 2006, the American National Renewable Energy Lab (NREL) estimated that the present value (in 2005 US dollars) of the total cost of building and operating a generating solar power plant, in California, over its economic life was around
“$148/MWh for the first CSP plants installed in 2009” and that it was higher than the $104/MWh cost of the natural gas combined. The NREL (2006) went on to say that with advances in the field and improvements in CSP construction and efficiency, and if the projected fuel and gas prices continue upward along their 2015 projections, CSP systems become competitive with combined cycle power generation, reaching about $115/MWh versus $119/MWh for the non-renewable generation. Not only that, but CSP systems also have a reliable source of energy, and therefore, the electricity generated is a “fixed cost generation resource - that is the cost of generating each MWh of electricity is primarily dependent on the capital cost of the facility, rather than on fuel costs” (NREL 2006, p. ES-3). As such, they “offer a physical hedge against the fluctuating cost of electricity produced” with other resources (NREL 2006, p. ES-5).

In addition, if we were to consider the environmental impacts of CSP plants as part of their total cost as well, we can compare them to non-renewable energy generation plants. If we assume solar-only operation of these CSP plants, the environmental impact would be at least threefold: (1) The amount of land that needs to be set aside for such projects, (2) the effects such projects have on biodiversity and the ecosystem, and (3) constructing a reliable transmission system from such remote locations that are optimal for CSP plants. This would imply more energy intensive procedures and greenhouse gas emissions. However, for the issues of land, a fossil fuel plant would actually require more land than a CSP plant if we account for the land needed for exploration, mining and road-building for transportation and transmission purposes. For example, in many regions of the world, one square kilometer of land is enough to generate as much as 100 -120 gigawatt hours (GWh) of electricity per year.
using solar thermal technology. This is equivalent to the annual production of a 50 MW conventional coal or gas-fired mid-load power plant (Greenpeace, 2005). Furthermore, CSP plants have the environmental benefit of no greenhouse gas emissions from the power generation mechanism, which then makes them even more attractive. However, they do displace native species which may affect the whole food chain or at least cause an imbalance. As for transmission losses, and since the need for electricity is not always concentrated in locations where harnessing renewable resources and the energy they produce is economically attractive, any sustainable energy network will need to account for connections to any existing grid with high voltage transmission or incorporate building a new transmission grid into the economics of the project (Solar Southwest Initiative 2008). High voltage transmission lines can be used either for alternating current (HVAC) transmission in densely populated areas and over short distances, typically in the form of overhead transmission lines, or for direct current (HVDC) transmission over longer distances (over 500 km), typically either underground or underwater (Wolff 2008). It is estimated that HVDC underground power cables cost anywhere between 10% to 20% more than overhead HVAC power lines, however, HVDC lines have narrower transmission corridors and can transmit enough power for millions of people (Solar Southwest Initiative 2008). An example of an HVDC line is the Pacific Intertie that extends “from the Pacific Northwest to the Los Angeles area” and has a line capacity of 3,100 MW with a 50 foot wide right of way and serving about three million households (Bernstein and Covarrubias 2006). In addition, an advantage of long-distance high voltage transmission is that little power is lost over the several thousand kilometres of transmission, where “transmission and distribution losses in the US grid...
are currently around 7% of total system power” (Solar Southwest Initiative 2008). The Solar Southwest Initiative (2008) also estimates that in case “desert power plants were connected with load centers on the East Coast by high-voltage DC lines, just 15% of the power would be lost in transmission from end to end”; which is supported by another study done by the European Solar Thermal Electricity Association in May of 2008 (ESTELA 2008). A breakthrough in HVDC transmission losses was recently achieved when two transmission system operators in the Netherlands (TenneT) and Norway (Statnett) established the NorNed-underwater-cable between the two nations. The cable is 580 km long and is buried at a maximum depth of 410 m under sea with transmission losses of about 4% for full utilization at 700 MW (Nortrade 2008). Furthermore, and according to the laws of physics, HVDC networks would not emit any electromagnetic radiation. In accounting for power losses on transmission corridors for CSP plants, we need to account for transmission congestion power loss with other power plants, as well as the fact that oil will have to travel through very narrow straits, when shipped to China, for instance, which is even more CO₂ intensive (Lyons 2008).

Finally, if we consider the transmission lines needed and the long distances they have to travel, plus all the operations that are needed to build such transmission grids, one could argue that they might not be as polluting as feared; since these would be negligible compared to the amounts of greenhouse gases that are saved from the power generating process. It is suggested that CSP plants can reduce annual carbon emissions by almost 800 to 1,570 megatons, by using the Vattenfall CO₂ abatement chart. Lastly, CSP plants create more jobs and enhanced welfare. They create more
job opportunities in the planning, design, construction, operation and maintenance of the plants and higher economic returns as compared to gas plants, for instance.

“Each dollar spent on CSP contributes approximately $1.40 to California’s Gross State Product; each dollar spent on natural gas plants contributes about $0.90 -$1.00…” and “…with the move toward bigger CSP plants, California will be able to create 3,000 permanent jobs from the ongoing operation of the plants” (NREL 2006, p. ES-2).

2.1.2 Biomass

The 5.4 million exajoules (EJ) of incoming solar radiation per year are either reflected back into space (30%) or used on Earth. The remaining 70% of the incoming solar radiation energy, or the 3.8 million EJ, is broken down as follows: (1) 2.55 million EJ are directly converted into heat in the air, earth and oceans; (2) 1.26 million EJ are manifested in the hydrological cycle; (3) less than 1% (or around 11,700 EJ are manifested as wind, waves, convections and currents; (4) 1,260 EJ are converted by photosynthesis into biomass, or organic matter, with the remaining EJ manifesting as convections in volcanoes and hot springs, conduction in rocks, and ocean tides (Boyle 2004, p. 12). The 1,260 EJ/year that is converted to biomass accounts for around 0.03% of the incoming solar energy, and part of such organic matter has already been buried hundreds of millions of years ago by sediments and earthquakes or transformed by bacterial action into coal, oil and gas which constitute, representing the nonrenewable fossil fuels we know of today (Goldemberg 2004, p. 2).

The process of photosynthesis in plants converts atmospheric CO\textsubscript{2} and water, with the help of solar radiation, into carbohydrates (Boyle 2004, p. 13). In developing nations, biomass, in the form of firewood, rice husks and other plant or animal residues is burned in order to produce heat. These sources are known as “traditional biomass”, and they account for a large part of energy consumption (Boyle 2004; Victor and Victor
2002), around 9.3% in 2001 (WEA 2004), and 10.6% in 2004 (IEA 2006). For instance, in the year 2002, the world primary energy consumption was 451 EJ at an average consumption rate of about 14.3 TW, of which traditional biomass accounted for almost 10.6% of it (UNDP 2000, Chapter 5). Recently, however, there has been a shift towards the use of “new” biomass (Boyle 2004, p. 106) which is mostly processed on a commercial scale in more industrialized nations; the inputs being purposely-grown energy crops, such as sugar cane, bagasse, sorghum, and miscanthus, or organic wastes (Londo, Deurwaarder and Lensink 2007). The output from such processes is in the form of useful heat, or solid, liquid and gaseous fuels to replace fossil fuels (Boyle 2004), via processes such as gasification, pyrolysis, anaerobic digestion and fermentation, which are outside the scope of this paper. New biomass inputs account for almost 2% of the world primary energy (UNDP 2000).

However, biofuels are only considered a renewable source of energy “if the rate at which they are consumed is no greater than the rate at which new plants are re-grown – which, unfortunately, is often not the case” (Boyle 2004, p. 13; Reijnders 2006). A paper done by Chen, Corlett and Hill (1998) supports that idea since they arrive at the conclusion that a “half-yearly harvest reduced the percentage cover of the vegetation from 96% to 83% over 2 years” in China. Although critics tend to think that the combustion of biofuels generates large quantities of atmospheric CO₂ emissions, these tend to be offset by the all the CO₂ that has already been absorbed by the plants when they were growing, however, they would still constitute a significant source of other greenhouse gas emissions, if they are burned inefficiently (Boyle 2004). An important and powerful greenhouse gas that is emitted from anaerobic digestion of biomass is
methane. One molecule of methane is almost 30 times as powerful “in trapping the radiated heat from the Earth as a molecule of CO$_2$” (Boyle 2004, p. 139; Reijnders and Huijbregts 2008), and depending on the process of anaerobic digestion, for instance energy from incinerating municipal solid waste or landfill, the amount of CO$_2$ equivalent emissions could increase by 100-200 g/kWh of energy produced (Boyle 2004). However, methane can be captured and used for electricity generation and heating (Zafar, 2008).

Furthermore, biomass is a land-intensive energy source, with some scholars suggesting that using the land for other forms of renewable energy would be more successful in limiting GHG emissions (Smith et al. 2000). Boyle (2004, p. 139) gives a good comparison between the land needed by PV modules, wind farms and energy crops to attain an electrical output of 1.5MW. The results suggest that PV modules would need an area of 0.4 km$^2$, while wind farms would need an area of 1 km$^2$ to produce the same output. As for biomass, Boyle suggests that with reasonable yields and conversion efficiencies, energy crops would need anywhere between 3 to 10 km$^2$ of area in order to achieve that same output. Some scholars are more optimistic however claiming that a global increase of 50% of the area currently dedicated to sugarcane, which would be around 100,000 km$^2$ by 2022 “up from the 29,000 km$^2$ presently in use in Brazil would result in the production of 79.5 million m$^3$ of ethanol, which together with the United States production would more than suffice to meet projected needs” (Goldemberg and Guardabassi 2009, p. 12). Goldemberg and Guardabassi (2009, p. 12) claim that this will cut carbon emissions by about 57 million tons per year.

The capital costs of Bioenergy systems include the fuel costs needed by the energy crops in the form of fertilizers, pesticides, planting, harvest and transport.
However, some systems do generate negative fuel costs in the form of payment for disposal of wastes, like Energy from Waste (EfW) systems (Boyle 2004, p. 142). For electric power generation from landfill gas, and since the gas itself is the waste product that must be collected and flared off anyways, to protect the environment and prevent explosive hazards, additional costs, like piping the gas to the engine, are estimated to be quite minimal. The capital costs include the cost of the generator, engine and connection to the grid, in addition to modest operating and maintenance costs, depending on the plants output (Boyle 2004). For example, if we consider a landfill site that is able to accommodate 2 MW of generating capacity over a lifetime of 15 years, with an average capacity factor\(^{(1)}\) of 88%, the plant cost will be around $1,150 US per kW and operating and maintenance costs will be around 1 c/kWh (ETSU 1999), and the electricity unit cost would be around 3 c/kWh\(^{(2)}\).

\(^{(1)}\): Capacity Factor is defined as actual annual output of plant divided by maximum possible annual output (i.e. if the plant runs constantly for one year (8760 hours) at its rated capacity.

\(^{(2)}\): Calculation based on a discount rate of 8% can be found in Appendix I.

### 2.1.3 Hydroelectricity

Hydropower is another form of indirect sunlight which can be considered a renewable energy source. The solar radiation results in the evaporation of water from the oceans, which in turn precipitates again on Earth, in the form of rain, creating rivers. Hydroelectric plants require reservoirs of water to guarantee a steady supply of water in order to generate electricity. These reservoirs are in the form of dams that are built on rivers with hydropower capacity. The main characteristics of a hydropower site are the height through which the water falls, called the effective head, and the volume of water that flows per second, called the flow rate (Boyle 2004, p.150; Dragu, Sels and Belmans
Large dams are those with effective heads over 100 meters from the foundation, like the Hoover Dam on the Colorado River, which has a total height of 220 metres and a water reservoir, Lake Mead, of 35 billion m$^3$ of water (Boyle 2004, p. 162). Medium dams are those with effective heads greater than 15 metres, and small dams have effective heads of less than 10 metres and usually do not have a storage reservoir (Goldemberg 2004, p. 2).

Hydropower is already a major contributor to world energy supplies, as it is a well-established and old technology, producing both reliable and competitive electricity for decades (Boyle 2004, p. 148; WEA 2004). It is estimated that hydropower provides around one-sixth of the world's annual electricity output and about 90% of electricity from renewables (IEA 2007). However, hydropower is no less controversial when it comes to its environmental effects than the other renewable energy sources. The benefits of hydroelectricity as compared to other types of power plants lie mainly in the fact that their operation is virtually GHG-emission free, with no CO$_2$ emissions, and virtually no Sulfur or Nitrogen oxide emissions (Boyle 2004, p. 177). It would be interesting to note, as a separate inquiry or research project, the quantities of GHG emissions resulting from constructing hydroelectric power plants as part of a Life Cycle Assessment (LCA) on them, and then comparing them with other power plants after conducting separate LCA's on them as well. Fearnside (2004) casts the debate that hydroelectric dams are not as GHG-free as one would like to think. In fact, as water passes through the spillway or rises from the turbines, the change in pressure releases the dissolved methane and carbon dioxide gases instantaneously (Fearnside 2004). It is estimated that almost 4 million tons of CO$_2$ equivalent of methane gas are released.
In any case, the operation of hydroelectric plants produces no dioxins that are harmful to human health and no radioactivity. In addition, even though dams are subject to collapsing, they do not cause major hazards like explosions or fires that other power plants, such as nuclear power plants, can cause; as such, they are relatively risk-free. Moreover, other spillover benefits are achievable from hydropower, such as irrigation and flood control, and it may also provide a source of leisure for boating activities in the reservoirs (Boyle 2004; Bartle 2002). On the other hand, large hydropower plants that use up large areas of water may end up displacing people and have deleterious effects on hydrology, by causing changes in water flows and rearranging water sources and sinks, and society, through destroying or displacing communities and houses and disrupting ecosystems; in addition to the added harms caused by dam-failures causing thousands of deaths over the years (Boyle 2004, p. 177; Goldemberg 2004, p.2). It is estimated that some “20% of all freshwater fish species are now considered threatened or endangered” because of hydropower water dams (Truffer et al. 2001). It is interesting to note Bartle’s (2002) position on hydropower, where she states that despite the conflict over hydropower from large dams and reservoirs, “it is clear that hydro stations which are planned, constructed and operated with full account being take of environmental and social aspects have a major role to play in future world energy supply” (Bartle 2002, p. 1238), and that we need to also account for the fact that only about 20% of the “world’s approximately 45,000 large dams are actually built specifically for hydropower generation…the vast majority are primarily (or exclusively) for irrigation water, thus contributing to world food supply” (Ibid).
The costs associated with hydroelectric power plants are difficult to assess because they depend on many variables. Though much is known about the water-control systems, turbo-generators, and output controls (few hundred watts to hundreds of megawatts) (Boyle 2004, p.186) and about the expected lifetime of the machinery, (25-50 years) (Ibid.), as well as the lifetime of the external structure, (50-100 years) (Boyle 2004), the construction costs vary by site. Hence the initial capital costs of such projects are extremely variable depending on the different sites. Hall et al. (2003) performed a study on hydro potential in the United States. They assessed the total development costs, which include both initial capital and running costs, of over 2000 sites with capacities ranging from 1 to 1300 MW. Almost 50% of these sites had a total potential of 17 GW and have no existing dams and hydropower plants established on them – or what they call “green-fields”. They estimated the development costs for these sites to be in the range of $2,000 to $4,000 per kW, with the initial capital costs in the form of civil engineering costs accounting for 65% to 75% of total development costs. In addition, they estimate an extra 15% to 20% is needed in civil engineering, i.e. site specific initial capital costs, to meet the environmental criteria necessary for licensing. Furthermore, there are no associated fuel costs, and the net present value of the operating and maintenance costs typically do not account for more than a 2% addition to the capital costs. In a similar 1999 UK-based study conducted by, then, Energy Technology Support Unit (ETSU), the results were confirmed and it was concluded that the largest plants and those with the highest effective heads tend to have the lowest unit costs. Boyle (2004, p. 187) gives a good example to illustrate why such renewable sources are neglected in the decision making process: A 5MW plant with relatively low
effective head, just 25 m, would need an up-front total of $20 million (Boyle 2004, p. 187). However, this same amount would buy about 50MW of combined-cycle gas turbine plant, and as such, if decision makers neglect the fuel costs, they would be tempted by the second option\(^{(3)}\) (Ibid.). Smaller hydro plants will mitigate most of these impacts, ensuring sustainability (Frey and Linke 2002).

\(^{(3)}\): See Appendix II for a table summarizing the arguments for and against China’s Three Gorges’ dam project on the Yangzi River.

### 2.1.4 Geothermal Energy

Moving along with solutions to the energy problem that do not contribute to further global climate change and that are cost effective, the next technology this paper will discuss relates to geothermal energy. Geothermal energy is independent of solar radiation and its ultimate source is the earth itself. Geothermal is not an optimal solution everywhere; but in certain locations where the earth’s heat flow is concentrated enough to generate steam and hot water at degrees between 180° and 250° Celsius, it may be feasible. Such resources would be available in shallow rocks capable of generating electricity and are called “high-enthalpy” resources (Boyle 2004, p. 342). Enthalpy is defined as the heat content of a substance per unit mass, and it is a function of pressure, volume and temperature. The techniques for mining these resources involve drilling boreholes into the reservoir, pumping the hot fluids to the surface, or allowing them to flow naturally, and then using conventional steam turbines or heating equipment to generate electricity or heat (Ibid.). Boyle (2004, p.342) estimates that in 2000, the global electrical power generating capacity from geothermal sources had reached approximately 8 GW electrical, while estimating that it would reach almost 11 GW
electrical by 2005 (Huttrer 2000). An additional 16 GW thermal is being used in space heating, agriculture and industrial processes (Boyle 2004, p. 342).

The environmental issues raised with geothermal technologies are usually all in the planning and development phases, and they tend to dissipate in the operational phases. These include: (1) noise pollution from drilling, well testing and site preparation; (2) disposal of drilling fluids in large-sediment lagoons; (3) ground subsidence and induced seismicity; (4) gaseous pollution mainly in the form of CO$_2$, and less so as SO$_2$, hydrogen sulfide, methane, hydrogen and nitrogen gases (Boyle 2004, p. 373). According to the International Geothermal Association (IGA 2002), the weighed average of CO$_2$ emissions is around 122 g/kWh, while typical CO$_2$ emissions from fossil-fuel fired power stations range between 460 g/kWh to 960 g/kWh. As for the costs of geothermal technologies, and since they offer predictable power 24 hours a day, they did drop significantly from older figures. For example, Boyle (2004, p. 376) estimated that from 1981 to 1991 the capital cost per kW of capacity dropped by almost 13% from $3000/kW, and that similarly, operational and maintenance costs have dropped by 45% from 4 $/kWh to around 2.2 $/kWh, and as such the overall energy production cost has dropped by 33% from 8.5 $/kWh to almost 5.7 $/kWh.

### 2.1.5 Wind Power

The last renewable resource that this paper will discuss before moving on to the concept of energy cooperation is wind. Electricity is generated by means of converting the kinetic energy in the wind, as wind passes through a wind turbine. The concept of energy conversion may seem to be straight forward, but wind power gets complicated when it comes to turbine design. While there are numerous designs of wind turbines
available, the ones most commonly used and commercially available are turbines that employ a horizontal-axis configuration. These tend to have two or three blades attached to their rotors, and have an aerodynamic design similar to that of aircraft propellers (Boyle 2004, p. 253). In addition to the rotor, the wind turbine has a “drivetrain including a gearbox and generator, and a tower to support the rotor” (Bull 2001, p. 1218). Wind turbines vary in size from anywhere between 200 and 750 kW (Ibid.) with the largest turbine currently in operation being the Enercon E126, with a rotor diameter of 126 metres and a power capacity of 6 MW (GWEC 2008, p.11). However, the produced electricity is directly dependent on wind speeds.

Wind turbine technology has been rapidly progressing and is becoming more and more competitive with other sources of conventional power (Quarton 1998). Bull (2001, p. 1218) estimates that the capital costs of wind power technologies have dropped by about 54% from almost “$2.2/W in the early 1980s to less than $1/W today”. Bull (2001, p. 1218) also estimates that in regions with wind speeds of over 7 metres/second (±15%), which are considered to have good wind resources, the energy costs have also decreased from by about 85% (±5%) from almost $0.40/kWh to as low as $0.04 to $0.06/kWh recently. With further advancements on the way, it is estimated that this cost will drop to almost $0.02/kWh. With wind resources being quite abundant throughout the globe, many countries are increasing their installed capacities of wind turbines, both on and off-shore. In Europe, Germany and Denmark’s wind turbine installations have exceeded ones in the United States, and the figures are still on the rise. By 2000, the United States has installed about 30 MW (Ibid.), and it estimated that the average capacity of turbines installed around the world in 2007 alone was around 1.5MW
According to the American Wind Energy Association, as much as 13,500 additional megawatts of wind capacity may be installed worldwide in the next decade.

To successfully integrate wind power into the electrical grid, a number of issues need to be considered, including the intermittent nature of wind and available storage options, the design and operation of the power system, and grid-connection of wind power and the grid’s infrastructure (GWEC 2008, p. 25). These issues will be discussed further in Section Three as they not only pertain to wind power, but most of the renewable sources. As for the environmental impacts of wind turbines, they can be classified as follows: (1) noise and electromagnetic interference; (2) aesthetics; and (3) danger to birds. When it comes to noise levels, wind turbine noise levels as compared to other activities turn out to be not that noisy. For instance, a wind farm located 350 metres away will generate a noise level between 40 and 50 “acoustically weighted decibels or dB(A)” (Figure 4) versus a busy office which has a noise level of 75 dB(A) or a car going at 64 km/h which has a noise level of 55 dB(A), or a quite bedroom which has a noise level of around 35 dB(A) (Boyle 2004, p. 271).

![Figure 4: Decibel Chart (Credit: AWEA 2008)](image)
Hence, wind turbines are not as noisy as their opponents predict them to be. In fact, the mechanical noise of the wind turbines is the cause of most of the nuisance and it can be controlled by using quieter gears and using acoustical enclosures for the gearbox (Boyle 2004). However, wind turbines, and depending on the materials that their blades are made of, do cause some electromagnetic scattering causing interference with communication and military systems in worst case scenarios (Ibid.). As for the visual impact of wind turbines, this is a very subjective matter and relates back to a person’s own perception of beauty. And finally, the issue with wind turbines being a danger for birds and bird migration, is exacerbated by the fear that these turbines will create hazards to birds causing fatal collisions as birds may fly into the blades (Ibid.). However, this issue can be prevented by developing more off-shore wind turbines, as they can be shorter than on-shore turbines and still produce the same electricity output (Ibid.). In fact, the Global Wind Energy Council (GWEC 2008) estimates that less than 1 in 10,000 bird fatalities are caused by wind turbines, as compared to 850 in 10,000 bird fatalities caused by vehicles, 1,060 in 10,000 caused by cats and over 5,800 in 10,000 bird fatalities caused by buildings or birds crashing into windows (GWEC 2008, p. 32). Therefore, the impact wind turbines, as long as they are dispersed in a properly managed way and not sporadically placed, are almost negligible. In 2006, the World Wind Energy Association (WWEA) released the chart shown in Figure 5, showing the world wide installed wind capacity and the predicted increase in installed capacity up to the year 2010. The results of the WWEA’s 2007/2008 Wind Energy International Report supports the predictions of about 90,000 MW installed capacity in 2007, where the number is actually around 93.800 MW, of which 19,700 MW where added in 2007 alone.
The WWEA released new predictions for 2008 to 2010, shown in Figure 6, where they once again raised the predicted installed wind capacity, thereby showing that the world seems to be favouring this renewable resource even more.

**Figure 5:** Worldwide Installed Wind Capacity (Credit: WWEA 2006)

**Figure 6:** New Worldwide Installed Wind Capacity Predictions (Credit: WWEA 2008)
2.2 DESERTEC: The Concept

When a nuclear reactor or any large power station goes offline by accident or as a result of a planned shutdown, it does so instantly, resulting in an immediate “loss of many hundreds of megawatts” (GWEC 2008, p. 25). So too is the case on a more global scale. Electricity supply needs to be available at cheap economic costs as well as environmental and social costs, all the while being available all the time, to anyone, anywhere. Hence, the electrical grid should be made immune to a sudden trip off, and instead it should be backed up through variable energy supplies from variable sources across different localities. This will ensure that the variations be smoother since there will now be dispersed and numerous units rather than a few large power stations in each country, which are independent of each other and cannot come to each other’s aid, as it were. This will make system operation much easier since it will be able to predict and manage changes in supply (Pepermans et al. 2005). In a large, interconnected grid, the overall impact if wind stops blowing in one particular place, is very minimal to that place and to other locations. From here comes the importance of energy cooperation and forming an interconnected energy network across countries’ boundaries sustainably to ensure reliable, cheap, socially conscious and environmentally friendly electricity delivery to everyone, everywhere at all times (Al Khal et al. 2006). The DESERTEC Concept - a renewable energy project that is currently underway - does just that.
In 2003, the Trans-Mediterranean Renewable Energy Corporation (TREC) was founded. On its website, TREC states that it is “an international network of scientists, politicians and experts in the fields of renewable energy forms and their development,” with nearly 50 members from the EU, the Middle East and North Africa (EU-MENA). TREC’s chief purpose is to create a totally renewable system (DESERTEC) capable of supplying the EU-MENA region with energy from renewable sources through multiple projects in the area (Figure 7). This “Euro-supergrid”, with its decentralized fashion and interconnections throughout the EU-MENA regions, TREC claims, would help put the EU back on its Kyoto targets of cutting down their CO$_2$ emissions, and ensuring the security of their energy supply. In addition, it believes that such a grid would also create
jobs, increased earnings and even much needed drinking water in the MENA areas. Waste heat from the power generation plants can be used as input streams of heat into desalination plants and for thermal cooling. TREC hopes that such a project would help alleviate the fresh water shortages in the MENA region and encourage sustainable power generation through global participation (TREC 2008). Since the most accessible source of energy on the planet is abundant in the deserts around the equatorial regions of the earth, the DESERTEC Concept is designed to link these deserts into service with existing technologies in order to improve global security of energy, water and the climate. TREC has, thus, proposed that “Europe, the Middle East and North Africa (EU-MENA) begin to cooperate in the production of electricity and desalinated water using concentrating solar thermal power and wind turbines in the MENA deserts...[F]rom a political point of view, implementing DESERTEC in countries like Australia, China, India and the USA, should be even easier” (DESERTEC 2008). The urgency in the implementation of such a concept stems from the developments in both energy provisions and climate change.

The main issues with the project are that it needs the political will necessary to achieve such a global and historic cooperation between nations, as well as the right policies and framework of incentives. In addition, transmission issues and interconnectivity to the grid and to other parts of the system need to be addressed. Furthermore, concerns over the amount of land required for such a project would be raised. However, the German aerospace centre (DLR) estimates that almost less than 0.3% of the entire desert areas can be used to generate enough electricity to meet current EU-MENA demand. In the long-term, though, such a demand would increase,
especially if the system proves reliable. This would in turn necessitate building even larger areas for CSP plants and other renewable energy plants.

Section III: Challenges of Global Energy Cooperation

3.1 Central Question and Anticipated Findings

In examining the challenges posed by global energy cooperation on the scale of something like DESERTEC, this paper will focus on the feasibility of establishing a renewable global energy network in order to produce electricity to meet the global demand. It will do so by focusing primarily on WHAT ARE THE PROSPECTS OF A RENWABLE ENERGY NETWORK BETWEEN EUROPE AND THE MIDDLE EAST/NORTH AFRICA REGION?

Firstly, and most importantly, we need to be able to ensure that such energy cooperation and interdependence does not lead to energy autonomy, but rather energy security. This means that establishing such a network will not put the “right-to-electricity” in any one nation’s hands, or allow any one side to take advantage of the other. Instead it will be about the sides working together to achieve an overarching goal: clean and sustainable electricity. Hence, the answer to the central question will be obtained by way of answering the following questions regarding some of the challenges of establish such a network:

(1) Would it be beneficial for the EU to support renewable energy development in the MENA region? And would imported clean energy be able to compete with local energy supply and production in a healthy manner? Or would the financials of such a project be a deterrent from its realization?
(2) Would political insecurity lead to the detriment of any such project? As such, what
depolitical impact will this have globally and on the regional level?

(3) What stands in the way of implementing this project today: economically,
environmentally and socially? For instance, would transmission losses lead to the failure
of the DESERTEC and similar initiatives? And is it at all possible to ensure the
sustainability of a global energy network based on renewable energy sources with an
intermittent nature?

Five anticipated findings for these questions will help shed better light on the
answer to the ultimate central question. Anticipated findings #1, #2 and #5 will answer
the first group of questions, while finding #3 will help answer the second group of
questions, leading to the third group of questions whose anticipated answers will be in
findings #1 and #4.

3.1.1 Anticipated Finding #1: Environmentally Friendly, but Cost Prohibitive

The most accurate answer to whether or not a renewable energy network is truly
environmentally friendly needs an LCA on the system as a whole and then comparing
that with having centralized fossil-fuel burning power plants’ LCA results. However, for
the purposes of this inquiry, I assume that the operation of technologies based on
renewable sources to produce electricity is more environmentally friendly than it is
deleterious. Section 2 made that fact quite clear by pointing out the environmental
impacts of each of these technologies and how they were more reasons for inaction
than actual negative environmental effects. However, renewable power plants are not
the full story. There is still the matter of the actual grid and the accompanying physical
infrastructure. This goes back to Integrated Resource Planning (IRP) and Community
Energy Management policies (Jaccard et al. 1997) as well as Least-Cost Planning (Lovins and Lovins 1991). Urban planning in an energy-conscious way will necessitate a prioritization of urban infrastructure, like Jaccard et al. (1997) point to, by planning for the infrastructure with the longest lifetime and most constraints first and then moving in the direction of planning infrastructure with shorter lifetimes at the product level. Hence, a renewable energy network is only as environmentally friendly as the cities and areas to which it is expanded. Steinberger, Niel and Bourg (2009, p. 363) note the fact that “the average North American consumes more than twice as much energy as the average European can be directly linked to differences in past infrastructure choices: low habitation density, high modal share of private vehicles.” They conclude that in order for a system to truly be low on the energy intensity scale, one need plan for a low-consumption infrastructure from today in order to avoid any unnecessary energy expenses in the far future. In addition, and as has been noted earlier, the issues of the amount of land needed for CSP plants, wind farms and hydroelectric plants should be taken into consideration, while accounting for the scale of the projects. The network being decentralized will thus require much smaller power plants dispersed all over. As such, there will be no huge land-stressed areas in any one country or location, at the same time producing more electricity than if there were. Table 2 provides a comparison of renewable energy delivery per unit of land area.

<table>
<thead>
<tr>
<th>Energy Source</th>
<th>Annual Delivered Energy (in kWh/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind Energy</td>
<td>11 (at average wind speeds) – 19 (at high wind speeds)</td>
</tr>
<tr>
<td>Biomass</td>
<td>15 (low efficiency) – 45 (high efficiency)</td>
</tr>
<tr>
<td>Photovoltaics</td>
<td>50-100</td>
</tr>
<tr>
<td>Geothermal</td>
<td>160-200</td>
</tr>
</tbody>
</table>

*Table 2: Renewable Energy Delivery per unit land area (Adapted from Bull 2001)*
The matter of cost comes down to the amount of capital needed to invest in such a network, and the money needed to ensure its operation and maintenance throughout its lifetime. However, with renewables, even though initial capital costs may be quite high, as was seen in Section 2, compared to fossil fuel power plants, they do not require fuel costs to operate or run, creating great savings. In the short-term, a minimum base load capacity will be needed to be able to support the network and that will have to be based on fossil-fuel power plants or nuclear plants, since they are more readily available and currently more predictable than renewable power plants. But the need for a base load cannot be taken as extra incurred cost, since it would already have been a cost in the status quo scenario, with added fuel costs to meet the rest of the demand for electricity. Knies (2008, p.6) estimates that by 2050 the EU’s electricity mix would include “65% of European renewable energies, 17% solar electricity imports from MENA deserts, and 18% fossil-fueled backup and peak load power plants, with these becoming phased out completely from the mix soon after.” Furthermore, establishing the network requires a number of HVDC systems of high capacity in order to transfer the electricity generated from the deserts of MENA to the EU. Currently there are HVDC connections in place, but a larger network would require even more HVDC capacity. As such the costs, as estimated by Knies (2008, p.3), would be “5 million euros, or around $6.9 million USD, by the year 2020 to install 2 HVDC systems of 5 GW capacity, resulting in a net electricity cost (including the price from the renewable source) of 0.064 €/kWh or around 9 ¢/kWh, leading down to about 7 ¢/kWh by 2050”. Finally, Al Khal et al. (2006) note that estimated cost savings of 13% in installed generation capacities over a 15-year planning horizon is obtainable for a “northern Middle East region
consisting of Egypt, Iraq, Jordan, Lebanon and Syria,” enabling these countries to get up to 50% of their peak demand met by the other countries in the region. Table 3 below compares the economic potential of renewable energy sources in the United States based on 2001 figures. Though Bull (2001) does not make it entirely clear whether or not these prices are strictly operating and maintenance costs, they seem to also account for capital cost, which is the reason why photovoltaics are the priciest.

<table>
<thead>
<tr>
<th>Energy Source</th>
<th>Technology</th>
<th>Current Cost (€/kWh)</th>
<th>Estimated Future Cost (€/kWh)</th>
<th>Grid-connected Generating Capacity (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Photovoltaics</td>
<td>All Types</td>
<td>20-30</td>
<td>&lt;= 15</td>
<td>10</td>
</tr>
<tr>
<td>Concentrating Solar Power</td>
<td>Dish-Sterling</td>
<td>10-15</td>
<td>4-6</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Trough</td>
<td>10-12</td>
<td>7-9</td>
<td>354</td>
</tr>
<tr>
<td></td>
<td>Power Tower</td>
<td>6-9</td>
<td>3-5</td>
<td>0</td>
</tr>
<tr>
<td>Bioenergy</td>
<td>Direct Combustion</td>
<td>7-15</td>
<td>4-6</td>
<td>7,500</td>
</tr>
<tr>
<td></td>
<td>Co-firing</td>
<td>2-3</td>
<td>2-3</td>
<td>500</td>
</tr>
<tr>
<td></td>
<td>Gasification</td>
<td>8-10</td>
<td>4-5</td>
<td>0</td>
</tr>
<tr>
<td>Wind</td>
<td>All Types</td>
<td>4-6</td>
<td>2-4</td>
<td>2,500</td>
</tr>
<tr>
<td>Geothermal</td>
<td>Steam &amp; Hot Water</td>
<td>5-8</td>
<td>3-5</td>
<td>3,000</td>
</tr>
<tr>
<td>Oil*</td>
<td>-</td>
<td>7</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Nuclear*</td>
<td>-</td>
<td>3.73</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 3: Economic Potential of Renewable Electric Systems in U.S. (Adapted from Bull 2001; * Oil and Nuclear figures obtained from Singh 2004)

Hence, policymakers should reconsider the economical viability of any options based on both its use value and exchange value. This renewable energy network will be selling a service rather than a product and as such it will help reduce the material throughput of the economy, since it leads to decoupling final energy consumption from energy needs ensuring a sustainable network Steinberger, Niel and Bourg (2009, p. 368).

3.1.2 Anticipated Finding #2: Encourages Sustainable Development

With the DESERTEC concept, it seems hard to argue against sustainable development effects. The network promises to deliver water, through desalination by cogeneration solar power plants, to the water-stressed MENA region. Knies (2006)
notes that only about 35% of the incident solar energy is actually converted to electricity in solar thermal power plants, like the ones that will be established in the MENA region, and that about 50% of it is released as cooling heat. Knies (2006) adds that if “combined with sea water” this 50% or so of lost energy can be reclaimed and used as thermal desalination, resulting in 40 million m³ of water for every TWh of incident power. In Africa, access to this water will help ensure that the citizens become more productive, disease free and that they would be able to sustain themselves by reducing drudgery to women and young girls, who are no longer forced to travel distances to bring clean water to their families. This new source of water can also be used to improve the sustainability and environmental impacts of the agriculture businesses more so than unsustainable agriculture practices, and, it can thus help to alleviate poverty. These socioeconomic effects will help ensure sustainable development to the region, and eventually to the world, if done sustainably. Hence, not only will the EU be able to curb its greenhouse gas emissions, but it will also be able to jumpstart sustainable development by granting access to local water in poorer nations. In addition, the MENA countries will be earning income through electricity exports, and jobs will be created locally, especially during the construction phases, enabling less qualified professionals to immigrate. In fact, Hillebrand et al. (2006) estimate increasing Germany’s share of renewables by 10% by 2010 will yield almost 33,000 new jobs. If this is the case in a developed country with so many jobs in this field already in place, then the results in a more developing nation will be even better. Table 4 on the following page compares the number of direct jobs created in energy production based on the sector.
Renewable Energy Network for Electricity Production

<table>
<thead>
<tr>
<th>Energy Sector</th>
<th>Jobs yr/TWh of fuel production and power generation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Petroleum</td>
<td>260</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>250</td>
</tr>
<tr>
<td>Coal</td>
<td>370</td>
</tr>
<tr>
<td>Nuclear</td>
<td>75</td>
</tr>
<tr>
<td>Hydro (Mini-hydro)</td>
<td>250 (120)</td>
</tr>
<tr>
<td>Wind</td>
<td>918 – 2,400</td>
</tr>
<tr>
<td>Photovoltaics</td>
<td>29,580 – 107,000</td>
</tr>
<tr>
<td>Bioenergy from sugar cane</td>
<td>3,711 – 5,392</td>
</tr>
</tbody>
</table>

Table 4: Direct Jobs in Energy Production (Data obtained from Goldemberg 2004)

3.1.3 Anticipated Finding #3: Political Stability and Political Will are Lacking

Inherent in establishing a network of any kind is that political stability will allow for it. The MENA region being not entirely politically stable – take for example the situation in Iraq, or the American Embassy bombings in Sudan (1998) and Yemen (2008), added to the religious extremist networks present in the area that deter any possibility of development. However, Knies (2008, p. 6) writes that even if all 20 HVDC lines from the MENA get destroyed or become under attack, the energy balance will not be disrupted in the EU and can be “compensated for until they have been repaired or until a political solution has been found.” Since the grid will be decentralized, there will not be one enormous solar power plant or wind farm that could be destroyed at once. Instead, there will be hundreds of modular units and plants spread over several continents (Ibid.). In addition, and since solar energy is plentiful, unlike other sources of energy like oil and uranium, chances of conflict over the resource are quite minimal. And since the consequences are not that severe, then the risk is almost negligible, risk being the product of the probability of an attack and the consequences of such an attack. Furthermore, Knies (2008, p. 6) notes that while oil, gas or uranium can be sold at higher costs after any interruption in exports, if renewable exports are interrupted, there will be
no additional costs incurred, only lost revenue. Hence, peace and cohesion can be ensured in an interdependent network like DESERTEC.

As for the political will to act on such a project, it seems that it is still lacking. The EU, however, is already setting proposals for trade in the form of guarantees of origin (GOs) (Ragwitz et al. 2009, p. 300). GOs are currently implemented in member states as a fulfillment of the Renewable Electricity Directive requirement that “each country have a system that allows the tracing of the source of each kWh of renewable electricity and informs on this source” (European Parliament and Council 2001). These GOs can receive support by EU member states in the form of “feed-in-tariff payments, premium payments, tax reductions or payments resulting from calls for tenders” (Article 8(1)(a) of the Renewable Electricity Directive). But the political will of governments is not always in their own hands, in addition to possibilities of corruption. With globalization in full force, the decisions of governments are influenced by industry and large investors, whether the private sector or foreign governments, and as such are subject to coercion into inaction (Howitt and Wintrobe 1995). In addition, sometimes the citizens themselves see no pressing concern to support such political causes and they influence their presence on the policy agenda (Hajer 2003; Hilgartner and Bosk 1988). However, it is imperative that both the public and private sectors as well as small and large investors start investing in renewable power plants and transmission lines, since time is running out, since “implementing renewable energy projects will become more difficult as we move past peak oil. This urgency is currently being amply illustrated by the current (2008) food crisis in many of the developing countries” (Lloyd and Subbarao 2009, p. 244). And although climate change issues may not be sufficiently pressing to capture the attention
of developing countries, as some of them have either more basic needs that are still lacking, as with most Sub-Saharan African nations, or are more concerned with economic progress, as seems to be the case with India, there is no need for them to develop on an unsustainable path similar to the one taken by developing countries, when a sustainable path is being presented. However, currently more pressing issues such as access to clean water, food security, poverty alleviation and equitable energy access take centre stage. But with a renewable energy network, this can be achieved and should be communicated to these countries and their citizens and governments. However, it seems that renewable energy alternatives are getting their fair share of focus due to the global environmental and energy security challenges and concerns plaguing the world (Lloyd and Subbarao 2009, p. 244). As such, developing countries should be able to reap the benefits of the renewable agenda.

3.1.4 Anticipated Finding #4: Technical Challenges Might Deter Realization

Some technical challenges to renewables have been discussed in Section 2 of this paper. However, to help illustrate the challenges, the paper shall present a few examples of some of the technical difficulties faced by the renewable energies today, which include their intermittent nature (specifically solar and wind power) and the efficiency of the transmission network over long distances. For example, wind energy is not entirely intermittent in nature; rather, just as a power system is inherently variable, so too is the output of the aggregated wind capacity (GWEC 2008). Meteorological changes can greatly affect the output from wind power and as such a comprehensive understanding and possibly even a prediction-model should be in place to track such variations to ensure efficient integration of wind power to the power system.
Furthermore, on both the supply and demand side, the electricity flows are inherently variable, since they are influenced by a number of factors, both planned and unpredicted. Hence, when designing these systems, they need to be able to effectively cope with such variations through their configuration, control systems and interconnection. Furthermore, a decentralized approach to the electrical network will ensure smooth variations and as such reliability and predictability of service.

As for transmission costs, we need to account for both repairable and aging failures of HVDC components (Li 2006, p. 525). Li (2006) does that by introducing a probability distribution of HVDC capacity that incorporates these maintenance costs. Based on this model, we can then “quantify and prioritize importance of component maintenance” (Li 2006, p. 525). In Figure 8 below, we can see that an “HVDC transmission line has lower losses than AC lines for the same power capacity” (ABB 2007).

![Figure 8: HVDC and HVAC Transmission Losses (Credit: ABB 2007)](image)
3.1.5 Anticipated Finding #5: Rebound Effects Might Counterbalance Benefits

When assessing the feasibility of an environmental solution, it seems necessary to account for the rebound effect in the economy that may counteract any environmental benefits achieved. The idea of the rebound effect as defined by Barker et al. (2007, p. 4935) is when “some or all of the expected reductions in energy consumption as a result of energy efficiency improvements are offset by an increasing demand for energy services, arising from reductions in the effective price of energy services resulting from those improvements.” Hence, the effectiveness of energy policies are greatly affected by the magnitude of any rebound effect and as such these policies should take that into account. Greening et al. (2000) distinguish between three types of rebound effect:

- **Direct rebound effects**: Improved energy efficiency for a particular energy service will decrease the effective price of that service and should therefore lead to an increase in consumption of that service. This will tend to offset the expected reduction in energy consumption provided by the efficiency improvement.

- **Indirect rebound effects**: For consumers, the lower effective price of the energy service will lead to changes in the demand for other goods and services. To the extent that these require energy for their provision, there will be indirect effects on aggregate energy consumption.

- **Economy-wide rebound effects**: A fall in the real price of energy services will reduce the price of intermediate and final goods throughout the economy, leading to a series of price and quantity adjustments, with energy-intensive goods and sectors gaining at the expense of less energy intensive ones. Energy efficiency...
improvements may also increase economic growth, which should itself increase energy consumption.”

It is clear then, that as this renewable energy network becomes more and more reliable and competitive with non-renewable energies, the demand for more and more energy production will increase, leading to either economic growth in the form of increased savings of income, which can be spent on environmentally unsustainable activities, like air travel, or to more power plants being constructed on a wider scale with even more increased capacities, consuming more amounts of land, requiring more water resources and biomass and becoming less and less sustainable. However, I believe that as the economy becomes more dependent on renewable and clean energy sources, and as people become more aware of such resources, they will make more energy efficient choices; a future research direction may, thus, be to see if this actually materializes.

Section IV: Meeting the Challenges

4.1 Policy Frameworks and Proposals

In order to effectively realize economic, environmental and social benefits from renewable energy resources, the need for global cooperation on issues of energy is crucial. From developing the technologies to decommissioning global electric energy grids, policies on renewable energies are an essential element in achieving sustainable development. The United Nations World Summit on Sustainable Development (WSSD) in 2002 agreed on a comprehensive agenda in this regard, guided by principles of sustainable development and poverty alleviation. The WSSD governments agreed to improve access to “reliable, affordable, economically viable, socially acceptable and
environmentally sound energy services and resources”, and “to increase the use of renewable energies, to enhance energy efficiency, and to provide cleaner liquid and gaseous fuels.” This can be achieved to a great degree by the introduction of a renewable energy network for the production of electricity on regional and more global scales. Although the benefits from renewable energies do vary from one country to another based on local situations, these benefits can be shared globally in an effort to protect the global environment in which we live.

4.2 Policy Recommendations

4.2.1 Establishing Global Energy Trading Schemes

In order to effectively manage the trading of electricity and energy across country borders, there needs to be global energy trading schemes, ones that specifically deal with electricity trading, set in place to ensure that imported electricity does not compete with locally produced electricity, but rather complements it. This would entail setting up a new global institution that will actively set trade prices at equitable levels worldwide. This organization would be accountable to the UN, which would monitor and oversee its activities. In addition, strong local public institutions need to be established at the national levels that will communicate and report to the global entity. These institutions will set priorities and future plans, as well as encourages renewable energy markets through their policy agendas. This will require the cooperation of the ministries energy, rural development, health, education, water, environment, and others in order to create incentives for renewables. The International Conference for Renewable Energies (ICRE 2004) also suggests that “national agencies, including centres of excellence and research institutions, are needed to carry out country-specific research, data collection
and analysis (including gender disaggregation), training, education, and to provide technical support to respective ministries” to complement the work of these organizations.

4.2.2 Subsidizing Energy from Renewables

ICRE (2004) estimates that global subsidies for conventional energies will exceed $200 billion annually, which would create yet another bottleneck for the competitiveness of renewables. In addition, externalities such as human health, safety and security, and environmental degradation costs are typically unaccounted for when comparing conventional energies to renewables. Without ecological and full cost accounting, it will be very hard to establish incentives for renewables to be able to compete in the energy market. Furthermore, energy policies and market conditions do not always reflect all the benefits that renewables generate such as increased employment, reduced foreign oil imports and dependence, and reduced burdens on foreign exchange. Hence, “leveling the playing field” is a good place to start. Governments should continuously monitor and report on energy subsidies, keeping market conditions transparent in order to attract investments. They can also set policies like “tax credits, grants or rebates, and long-term low-interest loans, combined with renewable electricity pricing or quota systems” (ICRE 2004). However, it is crucial to note that performance-based subsidies rather than investment-based ones should be the way of the future, even if the latter create temporary incentives. This is the case since performance-based subsidies tend to “reward the desired outcome—production of energy from renewables to enhance sustainable development” (ICRE 2004).
International Organizations (IOs) can also play an important role here in that they can provide funds dedicated completely for increasing renewable energy investments.

4.2.3 Regulating Industry’s Energy Consumption

The above policy leads directly to this one, in that it will encourage industry to curb the energy consumption by investing in more energy efficient options and pursuing renewable sources of energy. Cooperation between different businesses and the private sector will help in this domain, by ensuring that renewable investments are either risk-free or protected against risk, through banks, and that industry pursues “green” engineering technology such as renewables through communicating the business case to industry and the range of possible economic benefits that are achievable from investing in such technologies, which would outweigh the conventional route (Willard 2005).

4.2.4 Educating Consumers on Electricity and Energy Conservation

In order to ensure that rebound effects are minimal enough to be negligible, consumers need to be educated on the importance and benefits of a sustainable lifestyle. The ability to create equal access to electricity worldwide will create a perfect opportunity to communicate the benefits and need for electricity and energy conservation. When electricity become affordable enough for everyone all over the world to use, this should not in turn create huge and unexpected demands on the electrical grid, but rather, consumers need to be aware of living within their own means. Consuming more than they need and wasting energy and electricity is just as dangerous as over-consuming water. Public campaigning needs to ensure that the public is aware of healthy and sustainable lifestyle options, within their own means. In
addition, sustainability should be incorporated into the education programs worldwide to pitch the case for renewable energies and their benefits. Evidence for this is in the existence of programs like Engineering and Public Policy on the graduate level at McMaster University, or Engineering Society at the undergraduate level.

4.2.5 Encouraging Smart-growth and Green Urban Planning of New Cities

Another policy recommendation when it comes to energy cooperation is collaborating with urban planners and architects as well as NGOs and IOs that plan and develop cities around the world. The need to think of building and planning greener cities, like Masdar city in Abu Dhabi and the new green Chinese city in Liuzhou by William McDonough, is imperative. Since it is in the planning of these cities that one is able to truly gauge and control the energy and electricity needs, green engineering technologies will be extremely helpful in limiting energy consumption. In planning these cities to be totally sustainable, produce zero waste and zero Carbon emissions, the need to connect them to a renewable energy grid is important. In addition, when doing full-cost accounting of options, policymakers should start to include Life Cycle Assessments (LCA’s) in the choices they make, while these LCA’s should start accounting for economic rebound effects. This will guarantee making the right choice when it comes to energy and electricity projects to determine their “green-ness”.
Section V: Conclusion and Future Research Direction

In today’s globalized world, the need for cooperation on issues of energy and electricity production is important. With projects such as DESERTEC, energy cooperation in electricity production can ensure the reliability and quality of the electricity supply, reduce the GHG emissions responsible for climate change, stimulate economic growth, poverty alleviation and job creation in areas where they are most needed, guarantee improved social equity and gender equality; in sum, a renewable energy network will guarantee sustainable development. Even with the associated costs of some of the renewable technologies being employed, it seems that they are still a more feasible option that continuing with the status quo. However, more research in the form of complete Life Cycle Assessments that account for macroeconomic rebound effects need to be pursued in order to make the choice even clearer. In addition, engineers at the policy level should begin to evaluate priorities and decisions based on systems engineering processes such as Analytic Hierarchy Process, or modeling a Decision Support System and soft systems to include social, environmental and economic aspects of the project. Member states of the United Nations agreed at the WSSD in 2002 that: “With a sense of urgency, substantially (to) increase the global share of renewable energy sources with the objective of increasing its contribution to total energy supply”.

The opportunity to invest in renewable energies and in renewable energy networks is now. Developing countries are working on expanding and modernizing their energy systems, while industrialized ones are working on replacing their ageing systems to meet rising demands (ICRE 2004).
References


MEPP Inquiry:
Renewable Energy Network for Electricity Production


Appendix I: Cost Calculation Estimation for Landfill Gas

The landfill site is able to accommodate 2 MW of generating capacity over a lifetime of 15 years, with an average capacity factor of 88%. The plant cost is around $1,150 US per kW and operating and maintenance costs are about 1¢/kWh. A discount rate of 8% is assumed. Then, since there are 8760 hours in a year, an 88% load factor for a 2MW capacity would yield: $2,000 kW x 8760 hours x 0.88 = 15.42 million kWh per year.

The total cost of the plant is: $1,150/kW x 2,000 kW = $2.3 million and at a discount rate of 8% over 15 years this will amount to about $275,000 per year, which is the equivalent of 1.8¢/kWh. If we add the O&M costs, we'll obtain a cost of 2.8¢/kWh.
**Appendix II: Summary of Arguments in Favour of and Against China’s Three Gorges’ Dam on the Yangzi River (ChinaOnLine 2000)**

<table>
<thead>
<tr>
<th>Major Issue</th>
<th>The Criticism</th>
<th>The Defense</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost</td>
<td>Dam will far exceed official cost estimate; investment would be unrecoverable since cheaper power sources will lure away ratepayers</td>
<td>Dam is within budget; updating transmission grid will increase demand for its electricity; allows dam to pay for itself</td>
</tr>
<tr>
<td>Resettlement</td>
<td>Relocated people are worse off than before; human rights violations</td>
<td>15 million people downstream will be better off due to electricity and flood control</td>
</tr>
<tr>
<td>Environment</td>
<td>Increase in water pollution and deforestation; erosion of coastline; ecosystems affected endangering many species</td>
<td>Hydroelectric power is cleaner than coal burning; safer than nuclear; steps will be taken to protect environment</td>
</tr>
<tr>
<td>Local Culture &amp; Natural Beauty</td>
<td>Reservoir will flood many historical sites; legendary scenery of the gorges will be ruined; local tourism industry affected</td>
<td>Many historical relics are being moved; scenery will not change that much</td>
</tr>
<tr>
<td>Navigation</td>
<td>Heavy siltation will clog ports within few years; negates improvements to navigation</td>
<td>Shipping will become faster, cheaper and safer; rapid waters will be tamed and ship locks installed</td>
</tr>
<tr>
<td>Power Generation</td>
<td>Technological advancements made hydro dams obsolete; decentralized energy market allows ratepayers to switch to cheaper, cleaner power supplies</td>
<td>Alternatives are not yet viable; huge potential demand for relatively cheap hydroelectricity</td>
</tr>
<tr>
<td>Flood Control</td>
<td>Siltation will decrease flood storage capacity; damn will not prevent floods on tributaries; more effective flood control measures available</td>
<td>Huge flood storage capacity will lessen frequency of major floods; risk that dam will increase flooding is remote</td>
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