The University of Arizona Electronic Theses and Dissertations Reproduction and Distribution Rights Form

Name (Last, First, Middle) Wills David Aaron	
Degree title (eg BA, BS, BSE, BSB, BFA): BA	
Honors area (eg Molecular and Cellular Biology, English, Studio Art): International Studies	
Date thesis submitted to Honors College:	
Title of Honors thesis: SOLAR ENERGY IN MENA: AN INTERNATIONAL PERSPECTIVE	
:The University of Arizona Library Release	I hereby grant to the University of Arizona Library the nonexclusive worldwide right to reproduce and distribute my dissertation or thesis and abstract (herein, the "licensed materials"), in whole or in part, in any and all media of distribution and in any format in existence now or developed in the future. I represent and warrant to the University of Arizona that the licensed materials are my original work, that I am the sole owner of all rights in and to the licensed materials, and that none of the licensed materials infringe or violate the rights of others. I further represent that I have obtained all necessary rights to permit the University of Arizona Library to reproduce and distribute any nonpublic third party software necessary to access, display, run or print my dissertation or thesis. I acknowledge that University of Arizona Library may elect not to distribute my dissertation or thesis in digital format if, in its reasonable judgment, it believes all such rights have not been secured. Signed: David Wills Date: 4/25/2012

Last updated: Nov 15, 2009

SOLAR ENERGY IN MENA:

AN INTERNATIONAL PERSPECTIVE

By

DAVID AARON WILLS

A Thesis Submitted to The Honors College

In Partial Fulfillment of the Bachelors Degree With Honors in

International Studies

THE UNIVERSITY OF ARIZONA

MAY 2011

Approved by:

David F. Dunford

Mr. David Dunford
Adjunct Instructor, Center for Middle Eastern Studies
Adjunct Instructor, Political Science

STATEMENT BY AUTHOR

This thesis has been submitted in partial fulfillment of requirements for a degree at The University of Arizona and is deposited in the University Library to be made available to borrowers under rules of the Library.

Signed: David Wills

Abstract

The purpose of this thesis is to examine and optimize desirable possibilities for the utilization of solar energy in the MENA region. Solar is growing in both installed watt capacity and international importance. MENA, the Middle East and North Africa region, has multiple qualities that make it an ideal location to produce solar energy. The potential for development of solar energy producing facilities in MENA is great, and the international impact its success could have would be even more significant. This examination considers; the solar technologies available, geography of the region, geopolitics, global economics, and practical application. The research materials include; scholarly journals and academic books, magazines, PDF documents and websites. The scholarly journals and books are the most reliable sources of information, but they are often incomplete and not up to date. This thesis includes noteworthy technologies and strategies not included in the scholarly works. The evidence examined suggests Solar will be an area of growth in MENA. There are many solar production strategies, which are economically profitable already, and more strategies that will be, as the price continues to drop. This thesis will help inform the reader of the international intricacies of producing solar energy in MENA.

Introduction

The Sahara Desert receives enough solar energy to power the entire world several times over using current solar technology. The advancement of solar technology makes this task cheaper at an accelerating rate. The cost of Solar Energy "is today equivalent to about 50 US$ per barrel of fuel oil… and coming down by 10-15 % each time the world wide installed capacity doubles… in the long-term, it will become one of the cheapest sources of energy" (Trieb, 1). There are numerous benefits, even beyond the long-term profit motive, for MENA countries and other actors to invest in solar energy in the MENA region. Harnessing the energy of the sun will have a considerable impact on major international issues and has the potential to change not only the face of the MENA region, but also Europe, Africa, and the world.

The versatility of different solar technologies can be utilized to maximize the gain for resources in demand and minimize the cost of resources that are scarce. Water is one such scarce resource in the MENA region. Concentrated Solar Power, CSP, is often criticized for the fresh water that it uses, but current technology allows for a paradigm shift. These power plants can use saline water or seawater without straining the fresh water resources at all. Waste heat from the solar thermal process can be harnessed for desalinization, thereby increasing the fresh water supply while simultaneously producing renewable electricity. PV, Photovoltaic panels, on the other hand, also have great potential. Cost, amount of space required, type of space required, efficiency, watt capacity, life expectancy, regional fresh water demand, industrial heat demand, and saltwater or waste water availability, all play into the decision of which technology to use in which location. Whereas politics and geography decide which locations should be considered. With different strengths and weaknesses, it seems more than one technology will have a share in the future of solar energy production in the MENA region.

Solar energy has more to offer the MENA region than any other region in the world. "Because of the region's aridity, only about 7% of the area is cultivated" (Richards, 45). The region has lots of arid land and also receives an extremely high quantity of solar radiation. Geographically, the region has plentiful access to seawater and is close enough to Europe to export the energy that it produces to a key market. Under developed areas in MENA and Africa could finally get access to a reliable source of electricity and heating or cooling through solar power. The region's desperate need for fresh water and independence from oil revenues also drives the demand for solar energy. Solar provides MENA countries with a bright opportunity to attract foreign investment and generate both skilled and unskilled jobs.

Many aspects of solar energy in MENA are often overlooked. CSP can not only utilize its waste heat to desalinate water, it can even do this in locations remote from the sea coast, if it is connected to underground saline aquifers, or by utilizing waste water from a nearby city. The Suntrof and Zenith Solar technologies are also often overlooked despite their low cost and high performance. There is surprisingly little literature about utilizing solar heated steam for the extraction of oil, which could play a very large role in the Gulf States, helping both the solar and the oil industry. Utilizing both on the grid and off the grid electric power is beginning to gain attention as well as combining solar plants with increased energy storage and fossil fuel plants to ensure a constant supply of energy on demand. An international overview that includes all of these topics as well as the more exposed topics is needed.

The utilization of solar energy is likely to continue expanding in MENA because the geography of MENA maximizes all of the potential benefits of solar energy and MENA also has much to gain by its development. Maathai recommended in her book, The Challenge for Africa that a "super grid in the Sahara could provide Europe with up to one hundred gigawats of clean electricity by 2050, while also supplying electricity for local consumption" (Maathai, 256). This is one of the types of MENA solar development that this paper comes to examine. Desertec is a consortium of companies and entities "developed by a network of politicians, scientists and economists from around the Mediterranean" that are working together to make this goal a reality (Desertec Concept). Their combined expertise and resources constitute a major factor to push solar development forward in the region. There are many issues in MENA and the rest of the world that solar energy can address, including; carbon emissions, water scarcity, energy price volatility, energy poverty, petro dictators, Dutch disease, large public sectors, unemployment, underdevelopment and security. The realization of this future requires an international perspective on solar energy in the MENA region that takes into account the technology available, the geography of the region, politics, economics, and the issues of practical application.

Solar Technologies

The first step to an international perspective on solar energy in the MENA region is to take a good look at the solar technologies that are currently available. "Several technologies are now used to harness the sun's energy, including both solar thermal collectors and photovoltaic cells" (Brown, 246). Current solar technology falls into one of these categories, or is a hybrid of the two methods. PV solar panels convert solar energy directly into electricity. CSP on the other hand uses solar energy to super heat a liquid. CSP therefore can have an efficiency advantage in hot water heating, space heating, desalinization, and other heat intensive industrial processes. "Due to its intrinsic properties… CSP will provide the core energy for large scale seawater desalination for the growing urban centers and mega-cities in the MENA region" (Trieb, 23). CSP can at times even be able to produce electricity cheaper than PV. Solar thermal also allows for the storage of energy in the form of a super heated liquid. This is a more efficient way of storing energy than by storing it as electricity. By storing energy as a super heated liquid, the stored energy can be used to generate new electricity on demand, even when the sun is no longer shining.

This thermal energy storage is more efficient than storing electricity in a battery and gives CSP another potential edge over PV. The plant could even be built as a hybrid plant that can switch to using natural gas for power during nights and cloudy days, or to run a base load of power from natural gas and use solar energy to add the peak load of power right at its peak demand. Energy storage and hybrid capability take away the risk of volatility due to fluctuation in solar radiation. Solar thermal plants with thermal energy storage can produce electricity "up to 15 hours in absence of sunlight, guaranteeing the supply of electricity, which can be adapted to user consumption demand." (Torresol Energy, 18). To truly see which technology is preferable in which situations, the predominate CSP, PV, and hybrid technologies must be individually examined.

Flat solar thermal water heaters that go on rooftops are a widely used means of harnessing solar energy. "In China, some 160 million people now get their hot water from rooftop solar water heaters" (Brown, 237). These are not used to generate electricity; rather they heat water for direct use or for space heating. The sun's rays heat the water in a flat panel and the hot water is stored in a tank until needed by the homeowner or institution. The design is simple but cheap and effective.

The low costs of solar water heaters and their operability in remote locations have made them an attractive solution in both developed and developing regions. Even in places with no electricity, "for as little as $200, villagers can have a rooftop solar collector installed" (Brown, 246). These solar thermal panels provide cheap energy off of the electric grid anywhere the sun shines. The implications for development are vast and will be discussed later on.

These devices are cheap and reliable but do not generate temperatures high enough for electricity production, desalinization, or other industrial uses. These aspects that the design is lacking are essential to optimal usage of solar power in MENA.

"Cost reduction of CSP will mainly be driven by market expansion within the electricity sector of countries with high solar irradiance" (Trieb, 28). Flat solar water heaters will doubtless be utilized in the region's future as a major part of the solution, but it is incapable of solving many problems that other solar technologies will address.

The most tested and trusted of all CSP technologies that produce electricity is the parabolic trough design. This design uses long mirrors in the shape of a parabola to concentrate the Sun's rays onto a receiver tube that runs along the focal point of the parabola. These parabolic troughs turn on one axis to track the sun across the sky in order to capture maximum solar radiation. They only need to move along one axis, because as the sun moves in the direction parallel to the trough, the same amount of sunlight is captured, it is simply reflected by the mirror slightly further down on the receiver tube. "The present parabolic trough plant design uses a synthetic oil to transfer energy to the steam generator of the power plant cycle" (Trieb, 30) .The petroleum product transfers that heat to another fluid, ideally salt water, which boils. The steam turns a steam turbine, which generates electricity.

Some of the advantages of this design include that it only needs to rotate along one axis and it has been extensively tested and shown to be effective. The synthetic petroleum product gets to a temperature that "reaches up to 400 degrees Celsius" (Schüssler, 222). Such high temperatures translate to high efficiency. It also has a much smaller land requirement than PV. All of this has helped to make the parabolic trough a favored design for CSP. It is the only CSP design that has had extensive long-term testing, and it has shown to be effective.

There are also drawbacks to the parabolic trough design. The Aqua CSP report shows in a table that its drawbacks include the cost of solar field, demanding construction requirements, difficult integration into the environment, and high land requirement (Trieb, 38). It is very expensive compared to the technology of fresnel reflectors which will be explained later on. The most efficient plant size is a 200 MW capacity plant. Smaller plants lose the advantage of economy of scale yet larger plants also lose efficiency. If no salt water is available, it will require lots of fresh water, which is already extremely scarce. This design also requires large plots of flat land. It cannot use "spoiled" land such as agricultural land or rooftops, and although its land requirement is low relative to PV, the land requirement for fresnel reflectors is significantly less. Although the efficiency of the super heated petroleum liquid is pretty high, it is not as high as the efficiency reached by the molten salt in the power tower design, which reaches even higher temperatures.

There is a cutting edge improvement on the parabolic trough design, which makes it much cheaper, easier to install and integrate into a landscape, and is able to even increase the design's efficiency in doing so. This improvement, the Suntrof design by Sol Terrah, has a stationary receiver tube and uses an overhead tracking system to rotate a rigid, light weight mirror around the receiver tube to track the sun. These systems do not require the heavy foundational infrastructure to support the parabolic trough that the traditional design requires, and the whole system is much lighter weight. Installing the plant is therefore fast and relatively easy and cheap. The overhead tracking system uses high leverage, reducing the energy needed to move the mirrors and eliminating the need for hydraulic motors. The stationary receiver tube does not require the expensive swivel joints. The Suntrof design is not only significantly cheaper to build, but also requires less maintenance. A deeper aperture allows it to produce even more energy at this reduced cost. As the Sol Terrah website puts it, “Same power for 40-50% less cost” (Sol Terrah). Although this improvement is new and untested, it uses the same mode of energy production as the well-tested traditional parabolic trough, making it a reliable option. Prior to writing this thesis, I briefly worked as an associate to a venture-marketing partner of Sol Terrah in marketing the Suntrof product.

The power tower CSP design reaches higher energy efficiency due to the higher temperatures it can reach. This design uses many individual mirrors to all reflect the sun’s light to a single focal point at the top of a tower. “Sunlight is focused on relatively small receiving spots on a tower. A heat exchanging system feeds a steam generator, a storage system and a power generator to provide electricity” (Schüssler, 222). The mirrors are each flat and on their own individual dual axis hydraulic motor to track the sun. This concentrated sunlight heats up molten salt. This molten salt gets to very high temperatures and heats a liquid that turns a steam turbine and generates electricity. The waste heat can further be utilized for other means, even as the plant produces electricity at full capacity. Alternatively, all of the energy could be used directly as heat energy.

The largest advantage to this design is the higher temperature and energy storage. In the Gemasolar power tower in Spain “salts circulate from the cold tank at

290^{o}C, through their pumping system, to the receiver on top of the tower. There, they are heated up to 565^{o}C" (Torresol Energy, 25). The ability to store solar energy for production later while simultaneously producing energy at full capacity is another major advantage. This increased storage capability allows the Gemasolar plant to "continue producing electricity up to 15 hours in absence of sunlight, guaranteeing the supply of electricity" (Torresol Energy, 118). The land used does not need to be flat, like it must for some other solar technologies, removing a key limitation. With this design, "plant sizes of 5 to 150 MW are feasible" (Trieb, 32) which allows for a lot of flexibility.

The biggest disadvantage of this technology is its complexity and lack of testing. Each individual mirror needs its own dual axis hydraulic motor. This drives up not only the cost of installation, but also the cost of maintenance. This technology is only able to heat the molten salt enough to produce new energy if cloud cover does not block the solar radiation. However, due to the storage system, stored heat energy can still be used to produce electricity during cloud cover. Regardless, "At the moment, there is still no reliable performance data available for these systems" (Trieb, 33). The lack of extensive testing for the technology presents an additional challenge, but as time goes by, more test data will be available from pilot plants currently in planning or in use.

The Solar dish technology is advancing rapidly and has been the choice for some recent solar power installations. "Parabolic dish systems are comparatively smaller units consisting of a dish-shaped concentrator that reflects solar radiation onto a receiver mounted at the focal point which heats thermal fluid for power generation"

(Salazar, 4). Each of these dishes rests on a dual axis hydraulic motor used to track the sun. One single dish could be used, or there could be an entire solar field filled with these dishes. There are different means of solar collectors used at the focal point of each dish that transfer the suns energy into electricity in different ways, such as through a stirling engine or through a steam cycle like the one used by the parabolic trough. Most cases where this design is chosen for electricity production will prefer the stirling engine design which does not require water, but uses air as the heat transfer fluid. A simplified explanation of the stirling engine is that it, uses heat to causes gas to expand and push a piston. This converts heat energy into mechanical energy, which is than used to generate electric energy.

This design has some distinct advantages. It has "the advantage of functioning as stand-alone systems and can provide decentralized power" (Salazar, 4). This means it can reach maximum economic performance without requiring an exorbitantly large initial investment. It also means that these dishes can be mobile and relocated to provide energy at remote locations, when in need, and later relocated again. Such flexibility is applicable with the stirling engine but not with a steam cycle. This technology does not require flat land, and can even use spoiled land, land used for something else. If mounted in urban centers, the dish's proximity to its users means that less energy is lost in transfer. The stirling engine is currently more cost effective than the steam cycle and it does not require any water, which is important in locations with lots of sun but little access to water or only access to fresh water. The flexibility and versatility of this design largely accounts for the technologies success, but the design can also be utilized in large solar fields.

There are of course also some limitations to this design. Each unit is relatively small, and a heavy structure on a dual axis hydraulic motor leads to expensive parts and high maintenance. The costs for this technology vary drastically and like the other solar technologies are rapidly changing. It can reach high efficiency but is still very expensive. "They only operate in the kilowatt range. However, they could be applied for decentralized, remote desalination" (Trieb, 37). The limited energy production is a major detractor. If this technology is to be used to create an entire solar field, it will require more space per MW, because each dish must be spaced away from all other dishes in all directions. If spoiled land is used, than the utilization of spoiled land will be more of an advantage, than the spacing of dishes would be a disadvantage, to land use.

The fourth type of CSP technology is known as the Fresnel Reflector. This technology uses long, flat, rectangular, mirrors. The design uses less land than the parabolic trough because, "the distances between mirrors are much smaller" (Trieb, 31). Above these mirrors are receiver tubes, similar to the parabolic trough design, but many mirrors share the same receiver tube, which is fixed in place. A single axis hydraulic motor must rotate each long row of mirrors to reflect the sun's light onto the receiver tube. Allowing a single mirror to focus its light onto one receiver for part of the day and another receiver for the rest of the day, allows the mirrors to be spaced closer together. A synthesized petroleum product flows through the receiver tube and heats the liquid that is used to turn the steam turbine.

This design is favored because of how cheap it is. Having a stationary receiver tube as opposed to a moving one reduces cost and maintenance. It also makes the moving part much lighter, causing this technology to require a less expensive foundation than the traditional parabolic trough. Since some of the mirrors do not need to be curved, cheaper flat mirrors can be used. Compared to the parabolic trough and parabolic dish, this design uses "less land use for the same energy output" (Schüssler, 223). Like the other CSP systems, thermal energy storage can be employed, a salt or wastewater source will negate its need to use fresh water, and the excess thermal energy can be utilized.

Unfortunately, this design does not reach high efficiency. "The simple optical design of the Fresnel system leads to a lower optical efficiency of the collector field, requiring about 33% more mirror aperture area for the same solar energy yield compared to the parabolic trough" (Trieb, 31). This design has also not been tested extensively. The Suntrof, improvement to the parabolic trough brought down the price of the parabolic trough to a level competitive with Fresnel reflectors. Suntrof did so while increasing efficiency, not decreasing it, and relying on tested models as opposed to untested models. The trade off of a lower priced plant that uses less land and integrates into the environment more easily, but gets lower efficiency and is untested, is a workable model. Fresnel reflectors will play a part in utilizing MENA's solar energy if the long-term data from its pilot plants reflect success.

PV or photovoltaic solar power is another approach to solar energy. PV technology is typically, "solid-state junction devices, usually made of silicon, crystalline or amorphous… (or) Thin film photovoltaic cells made of CuInSe or CdTe … (or) multi-junction devices" (Grätzel, 993). These cells use semi-conductors to transfer solar radiation directly into electricity. The multi-junction devices uses high concentration solar energy, which means the sun's light must be concentrated with a lens or with a mirror. Sometimes they operate on reflective dishes that need dual axis hydraulic motors to track the sun in the same way the solar thermal solar dish does. Crystalline and thin film solar PV typically are stationary and are not required to track the sun. There are few practical differences to choose one stationary PV technology over another except for cost, efficiency, durability and space available all of which vary from one model to the next. The multi junction devices tend to have higher cost and shorter life spans, but they are the most efficient and are improving at the fastest rate. Their higher cost is tied to the need for them to track the sun, which Crystalline and thin film do not require.

The amount of photovoltaic cells installed is "growing by over 40 percent annually, doubling every two years" (Brown, 248). As its installed watt capacity is increasing, its cost per installed watt capacity is also decreasing at an astonishing rate. Many argue that the cost of PV is dropping, and will continue to drop, at a faster rate than solar thermal. Current technology puts the price of PV at approximately $3.50 per installed watt capacity. The Copper Mountain Solar 1 PV plant "48-megawatt project cost $141 million" (Goldberg, 1). This is not yet as cheap as the most economical CSP design that we have examined, but it is simple and reliable.

There is one more mode of harnessing solar energy, and that is by combining both PV and CSP technology. With this technology, "The receiver consists of a multi junction PV coupled to heat exchanger that converts concentrated solar flux into electrical power (A) and thermal power (B)" (Zenith Solar, 1). Zenith Solar claims to get 72-75% solar efficiency of combined heat and power. This is exceptional when compared to most other current solar technologies that get about 20-30% solar efficiency. They do this by using parabolic dish shaped mirrors to focus sunlight onto a HCPV (high concentration photovoltaic) cell, and use a heat transfer device to transfer excess heat to a fluid, water or petroleum product. Channeling this excess heat away keeps the PV cell cool, thus heightening its efficiency and elongating its operational life expectancy while simultaneously increasing efficiency further by utilizing the excess heat.

This process heats the water up to 104 decrees Celsius, which is more than enough for desalinization, cooling or hot water use. HCPV is often criticized for its short life expectancy, yet Zenith Solar's product claims its product is "Designed for 20 year service, constructed from highly durable materials" (Zenith Solar). Furthermore, the multi junction PV cell is easily replaceable, and is the fastest growing type of PV cell. Therefore, by the time it will be necessary to replace it, the cost will not be just maintenance but it will upgrade the whole system, making it more efficient with the latest technology. Due to the trend of dropping prices for PV, this upgrade will also likely be significantly cheaper than the original HCPV panel.

MENA Geography

Now that the different forms of solar technology have been examined, the next place to turn is to the geography of the region. The region is mostly desert, but that does not mean that it is homogenous. There will be cases where variation in geography will determine which technology is best suited. More importantly the geography needs to be examined to determine what exactly harnessing solar energy can do to provide solutions to threatening problems that will be discussed further on. Geography is the reason why MENA, specifically, is the ideal place for solar energy. The abundance of sun, arid land, salt water, human capital and oil coupled with a shortage of fresh water, and access to the European energy market combine to make the region an ideal location for production of solar energy, and a region that could benefit tremendously from it.

Solar radiation is the first geographical feature to examine. The entire MENA region receives very high solar radiation compared to the rest of the world. "Algeria possesses 169.44 TWh/year of solar thermal energy, the highest quantity of sunlight in this region, according to the German Space Agency. Morocco also offers great potential for CSP implementation as approximately 30% of the country's surface area receives around 2000 kWh of sunlight per m^2" (Salazar, 30). Every country in the region has varying amounts of land with the required features and the solar irradiance to be used for solar power generation.

Other regions like Europe have been developing their solar energy resources even though they are so much less than those in the MENA region. There are many problems with this since they do not have a comparative advantage in producing this energy. Europe has begun to realize this and is now cooperating to develop MENA's solar potential as an energy resource that they can import. There is a large conglomeration of institutions known as Desertec, which receives global funding to develop the EU and MENA regions renewable energy resources and connect their power grids. This global funding is essential to large-scale implementation, at least at this point in solar development. The solar energy of the Sahara Desert is a cornerstone in this plan.

Solar radiation may be the first quality to examine, but the land itself must be examined as well. "The region has abundant solar radiation, cheap land and high electricity demand" (Salazar, 3). Most solar technologies require vast swaths of land. MENA matches this requirement well since it is almost entirely arid land. "Algeria has land area of 2,381.741 sq. km. It has been estimated that 82% of the total land is available for installation of CSP plants" (Salazar, 37). The population in North Africa is concentrated on the coast with only sparse population inland. The Middle East desert countries such as those on the Gulf follow a similar pattern. Building large solar plants on desert land would be harmful to nomadic travel, desert plant growth, and some wild life, but not much else. The land could likewise be purchased at a very low rate since there is very little it may have been used for otherwise.

The parabolic trough and fresnel reflectors require the land to be flat. In addition, it is essential that seawater, saline aquifer water or wastewater be available to any CSP plant that is expected to not draw from the fresh water supply and if it is expected to desalinate. If the CSP plant is to provide hot water for direct use by the end user than there must be access to a fresh water source. Fortunately, there is still abundant space that meets all of these specifications. The power tower design does not require flat land, and neither do PV or solar dishes, which can even use spoiled land. The land requirement counts as a major setback in other parts of the world, but in the MENA region it is only a minor issue.

Accessing salt water is essential to utilizing CSP to its fullest potential. All of the MENA countries that are largely desert and receive large amounts of solar radiation have at least minimal access to seawater. Even Jordan has a port on the Red Sea. As transporting seawater inland would not be economically feasible, facilities that utilize seawater will be limited to coastline locations. Seawater is the simplest option; unfortunately, the coastline is also where the heavily populated areas are, limiting the space available and driving up the cost of land. This paper will not discuss utilizing fresh water because of its unsustainable nature.

Fortunately, there are plenty of seaside locations that are available for CSP plants geared for electricity production as well as desalinization or other industrial uses. In a map that determines areas suitable for CSP in North Africa by considering solar radiation and "urban or industrial use, protected areas, topography, land cover or geomorphology" (Schüssler, 223), large areas along the cost in North East Libya and

North West Egypt met these specifications as well as other areas in North Africa. Certainly there are suitable coastal areas in the Middle East as well.

Another saline water source that could be used is underground saline water reservoirs. These have no other practical use and greatly broaden the area suitable for CSP desalination. Fresh water reservoirs are increasingly being infiltrated with salinity. According to the WHYMAP published in 2009 and the Aqua CSP study, a large salt water aquifer covers approximately the northern third of Egypt and the North East quarter of Libya and another large saline reservoir covers Oman, UAE, Qatar, and the South East part of Saudi Arabia. There are even two more saline aquifers on the border of Algeria and Tunis. All of these could be utilized to supply salt water for desalinization to inland CSP plants. Even if not used for desalinization, they could provide salt water for a CSP plant that makes steam to help with the oil recovery from near by oil fields. Such saline groundwater use would require geological surveys and drilling, increasing the cost, thus making seawater a more preferable method. For oil fields, that could benefit from solar thermal aided extraction, where saline groundwater is available, but seawater is not, this becomes an attractive option.

Utilizing wastewater from cities for power production is a novel idea, but not beyond reach. The Palo Verde Nuclear Power Plant operated by Arizona Public Service is the first nuclear power plant that is not built by a water source, because it uses wastewater from the city for its cooling towers. CSP could follow this model and build power plants near desert cities far from the coast, without using fresh water. Using waste heat to desalinate wastewater allows both products to be utilized rather than wasted. This concept is yet to be utilized with CSP, but if it can be done for nuclear power than it can be done for CSP as well. The problem with such an approach is that most MENA cities lack the infrastructure and public service necessary to collect the cities' wastewater and harness it. Developed cities such as those in the rich Gulf States are more likely to have such an infrastructure than cities in the Sahara.

Apart from the physical geography, the geography of MENA includes abundant human capital. MENA has experienced tremendous population growth, which "will continue to expand, both because fertility remains well above replacement levels in many countries and because past population growth ensures that there are many women who will soon enter their childbearing years" (Richards, 71). A very high birth rate has led to not only a quickly growing population, but also a very young population. This young and growing population will need jobs to work and water to drink, in addition to electric power.

The population in MENA is not only growing and young, but it is also largely educated yet unemployed. "The regions labor force is growing at the most rapid rate in the world. Unfortunately, the demand for labor has not been keeping up" (Richards, 133). This over abundance of labor drives down wages for laborers. The cheapening of labor means that developing solar power plants in the region will also be cheaper, giving the region an additional comparative advantage in solar energy that other regions do not have.

The high unemployment is documented as contributing to political instability. "Unemployment affects primarily young, semi-educated people, whose anger fuels political unrest" (Richards, 134). Such a sizable portion of the population that becomes easily aggravated against their government due to unemployment incentivizes government policy that will lead to the creation of green jobs. "A 100 MW solar power plant with 9 hour storage means… 1000 jobs during construction and 100 jobs during the 25 years of operation" (Salazar, 60). Policy aimed at creating these jobs, will make solar energy profitable now, even on the electric grid and allow it to continue its growth beyond needing government incentives.

The labor market of MENA also suffers from a burdensome oversized public sector. The structural adjustment reform recommended by the World Bank and the IMF is to "create a stable macroeconomic environment, to liberalize trade, and to privatize state-owned enterprises" (Oatley, 145). Solar industry is one means to expand the private sector and diminish the relative weight of the public sector on MENA economies. It is also an opportunity to attract foreign capital and the transfer of technology and experience.

The MENA region is well known for its energy exports, and will continue its energy exports of oil, but can also increase energy exports of clean energy. The North African Sahara Desert has not only the ideal geography for the production of solar energy, but also the ideal location for the export of solar energy. Europe, a fundamental market for clean energy is just across the Mediterranean. High voltage direct current transmissions lines used in the Desertec project make this more efficient than ever before. "HVDC can carry electricity generated from renewables over long distances with losses of just 3 percent per 1,000 kilometers" (Dasertec Concept, 1). This further extends MENA's competitive advantage at providing clean energy to Europe.

Of course, Europe is not the only potential market. Africa is in a state of energy poverty and is a tremendous potential market for solar energy. How solar energy ties into global development is an important international issue. Thomas Friedman asks "how… will the tides of poverty, HIV/AIDS, unsafe drinking water, and malaria be turned back in Africa for good without enough energy to turn on the lights?" (Friedman, 154). The location of the MENA region puts it in an excellent geographic position to power all of Africa with solar power as the region develops. This will be discussed in more depth later on.

The MENA region itself is an energy market. Solar power can already produce energy cheaper than oil or certain other means of energy production making it a viable energy source in the region. Saudi Arabia and other gulf countries have cut into their oil wealth unnecessarily by using oil for desalinization. As the cost for solar energy continues to fall, it will become not only viable, but the most profitable means of providing energy. Although the market for energy in MENA itself is relatively modest, a sizable portion of the population is not connected to the electric grid. Remote solar production via PV panels, solar dishes, and rooftop flat solar thermal water heaters, allows a means to provide those locations with power. If they become connected to the grid, they can be additionally powered by large-scale solar power plants. Competing for a share of the energy market on the grid is not simple, but will be discussed in depth later on.

The dominant cause for the influx of foreign capital into MENA is currently oil revenues. At first glance the abundance of oil may seem like a deterrent to develop alternative renewable energy such as solar, but this is not entirely true. First, the supply of oil is not endless and for many places will run out soon. Secondly, solar power will not make oil worthless; it will merely supplement the oil industry in earning revenue from energy exports. Oil dependence also causes many problems, which will be discussed in depth later. MENA has issues of water scarcity and unemployment that the solar industry can address far better than oil. Solar power can even already produce energy cheaper than oil. On top of all those reasons, CSP plants can actually directly help the oil industry. CSP technology is being utilized "in the world's largest enhanced oil recovery (EOR) project" (Brightsource, 1) where it heats steam that makes recovery of oil cheaper. The idea that oil-producing countries have no need for solar energy and will lose more than they will gain from it, is tragically misguided. Furthermore, solar energy is developing regardless, and it is better to be involved than left behind.

Countries with oil wealth should not be afraid of solar energy, but should embrace it. Sometimes the cheapest way to extract oil from the ground is by pumping hot steam into the oil well. BrightSource Energy built a 29MW CSP plant using the tower design to make oil extraction cheaper in Chevron's Coalinga oil field in California. "The steam is pumped deep into the sub-surface oil reservoir in order to heat the area, increasing the pressure of the reservoir and reducing the viscosity of the oil, making it easier to bring to the surface. To conserve water use, the steam is then cooled and recirculated in a closed loop system." (BrightSource Energy, 1) This is an example of how solar thermal energy is already being used to increase oil wealth. MENA, both in the Gulf and in North Africa could benefit tremendously from this method. Many of the oil producing MENA countries have not only plenty of seawater access but also saline ground water and sometimes also wastewater at their disposal.

Shale oil, which is much more expensive to extract than traditional oil wells, can utilize in situ shale oil recovery to extract the shale oil and spare tremendous damage to the landscape from pit mining. CSP can also potentially be applied to this practice. In this process, "the oil shale is first heated to a temperature from about 360C to 475C… the resulting liquids and gasses are collected and the residue is extracted" (Oil Shale recovery, 1). In MENA, this is especially applicable to Israel who is estimated to have as much oil in shale oil as Saudi Arabia's proven oil reserves. Israel avoids this method of oil recovery in order to protect its underground fresh water reservoirs. The US also has tremendous shale oil reserves.

The region's lack of fresh water is the final geographical reality of MENA that makes solar so attractive and appropriate for the region. Using fresh water at a rate far greater than the renewable water sources can regenerate is a fresh water deficit, which leads to the depletion of fresh water resources. Many MENA countries are running fresh water deficits. "Only four countries – Iraq, Iran, Syria and Lebanon – can be considered well above the water poverty limit of 1000 m3/cap/y, while all other countries in MENA must be considered as water poor" (Aqua CSP, 55). The Nile River provides the majority of Egypt's fresh water as dose the Tigris and Euphrates for Iraq and Syria. Other places must rely more on rainfall, lakes, rivers and aquifers. Rainfall is unpredictable, and all together rare in the region. Even lakes, rivers, and aquifers are subject to natural and man-made changes.

Lakes and aquifers are running dry from overuse, and are being spoiled by infiltrating salinity and impurities. Some human practices accelerate this infiltration, thereby reducing the supply of fresh water and increasing the value of solar desalinization plants. The production of the same fossil fuels that solar energy has to compete against are notable causes for this problem which in turn increases the demand for solar desalinization. Even solar in situ shale oil recovery threatens fresh water aquifers. Solar energy's ability to alleviate water scarcity through desalinization tremendously increases its value, especially in MENA.

Water scarcity is even more of a problem when it coincides with increasing fresh water demand. The increasing water demand is "driven by growing population and by economic development of the region" (Trieb, 71). These are two trends that will continue well into the future. Agriculture uses account for the vast majority of water demand, but industrial and municipal uses also contribute. The population growth will be concentrated in the cities, driving up both agricultural and municipal water demand. Even increases in efficiency and increased agricultural imports, though important, are unlikely to be enough to reverse the deficit. Fossil fuel powered desalinization is also unsustainable, expensive, and getting even more expensive as fuel costs are rising. A fresh water deficit and increasing fresh water demands, means that there is a market for desalinated water in MENA.

A higher demand for fresh water increases the value of solar desalinization facilities. Many gulf countries are already using large-scale desalinization to offset their deficit. But many of them are using oil to power this process. It has already been noted that, the cost of solar energy "is today equivalent to about 50 US$ per barrel of fuel oil… and coming down" (Trieb, 1). It is evident that using solar energy for desalinization is not only a more sustainable practice, but also a much cheaper one as oil now costs well over $100 a barrel.

Recent literature on desalinization concludes that mechanical Reverse Osmosis, RO, desalinization is more economical than thermal Multi Effect Desalinization, MED. RO is not thermal and therefore cannot benefit from solar thermal energy any more than it can benefit from electricity produced by other means. Those studies, however, do not take into account the additional efficiencies from using the waste heat of solar thermal to power the MED plant. When the additional efficiencies were calculated, "these effects lead to a slightly better technical performance of CSP/MED compared to CSP/RO" (Trieb, 43). The advantage is even greater in areas of high salinity like the Red Sea and the Arabian Gulf. Solar energy is the most logical and economical approach to increasing desalinization in MENA, which will be necessary to keep up with the demand and avoid a fresh water crisis. This could change if significant improvements in RO desalinization or in forms of electric energy production other than solar power were to lower the cost of RO below that of CSP/MED. However, solar energy itself is improving at such a rate that it seems unlikely that RO desalinization will surpass it.

Geopolitics

Geopolitics influence an international perspective on solar energy in MENA primarily through oil, international politics, and state politics. Oil is a fundamental component of the modern Middle East and North Africa that dominates the economies in the countries that possess it as a plentiful resource. Not all countries in MENA have plentiful oil supplies. Some, like Egypt, have only a little bit of oil, and others, like Israel and Jordan, do have oil, but it is locked in shale rock where it is relatively difficult and expensive to extract. It is necessary to analyze both the producers and consumers of oil, as well as how solar energy can affect the oil industry.

For large producers of oil such as the Gulf States, oil is their main source of revenue. In Saudi Arabia for example, "The petroleum sector accounts for roughly 80% of budget revenues" (CIA World Factbook). But the oil industry can also be a long-term economic drain on an economy and on the region as a whole. The damage caused by Dutch disease, price volatility, and reliance on a limited resource is harmful to the long-term economy of MENA.

The first phenomenon at hand is commonly known as Dutch disease. Dutch disease is when "the resource exports cause the country's currency to rise in value against other currencies. This makes the country's other export activities uncompetitive" (Collier, 39). Even in a system where the value of the currency is fixed to the value of another currency or to a commodity such as gold, the country must have a balance of payments between their current account and their capital account. "In a fixed exchange-rate system, balance of payments adjustment occurs through changes in domestic prices" (Oatley, 208). Domestic prices rise and foreign imports become cheaper, hurting domestic production. Dutch disease is harmful because it deters growth in other industries. Other industries, where innovation drives growth and development, are neglected, impeding development across the region. The economic damage from this seems minimal compared to oil revenues, but over time, the losses accumulate. The economic damage caused to MENA from Dutch disease cannot be calculated, but is certainly large enough that it requires attention. For countries dependent on oil that will soon run out, it requires immediate attention and action.

A high price for oil means that major oil exporting countries will have a budget surplus. This budget surplus leads to lots of spending. The excessive spending is a problem because the price for oil is volatile. When a country's budget is based around a price volatile natural resource such as oil, it is common that "employment in the diplomatic service goes up during the boom, whereas basic investment gets cut during the crash" (Collier, 40). Even countries without oil exports, such as Jordan are affected by the boom bust cycle because they rely on remittances from laborers in oil rich countries. Borrowing money is cheaper when there are lots of petro dollars being earned, but when the price for oil drops, there is a debt to be paid. Many people, institutions and countries are left in deep debt. In all of these ways, the price volatility of oil has slowed economic growth in MENA.

A cause of real concern in oil exporting countries is the physical limitations of their oil reserves. As discovery of oil continues, new technology brings down the price of recovering oil that was previously uneconomical to recover, and increasing oil prices also expand the amount of oil that is economically recoverable, oil reserves will continue to expand. Yet there is a finite amount of oil available and it will one day begin to decrease in production as supplies run out. There are widely varying opinions on when this may take place but there are accepted measurements for proven reserves. This data can be used to estimate when the proven reserves will run out based on current rates of production. It is the pace and scope of discovering new oil that is disagreed about. According to the Richards and Waterbury, Oman Syria and Algeria have less than 20 years left of oil production, Qatar has 50 years remaining and even Saudi Arabia only has 75 years remaining (Richards, 50) based on their proven reserves and rate of production. For all countries, it is not a question of if their proven reserves will ever run out, but a question of when they will run out.

Diversification is the key to countering Dutch disease, price volatility, and limited resources. Major oil producing countries are avidly seeking diversification so to one day be able to maintain high living standards independent of oil revenue. Solar technology innovation would certainly serve to help diversify the economy of other MENA countries as it has already done for Israel. Israel’s high-technology solar industrial policy has been successful at ”Boosting the international competitiveness of such industries” so they can compete internationally (Oatley, 99). Conversely, if a country is able to be the location where solar technology is built, the energy it produced can also serve to diversify the economy. The latter may be a more realistic strategy for most MENA countries to push their comparative advantage.

Damage from oil to its producers is not just economical but also political. Huge oil revenues has reduced scarcity in oil rich states and allowed unfit rulers to buy continuing support. The residents in these countries have a high standard of living and therefore have more to lose from challenging their government than they have to gain from it. This creates a sort of holiday from politics. This holiday will not last forever. When their natural resource base runs dry, all of the political problems, which were marginalized during the times of wealth, will come to a head. Anticipation of the turmoil that will result from such an upheaval causes much uncertainty and discourages investment in the region that is necessary for growth and development.

Thomas Friedman observed "a correlation… between the price of oil, and the pace, scope, and sustainability of political freedoms and economic reforms in certain countries" (Freidman, 94). The more oil riches a government has at its disposal, the more it will oppress its people. This can be observed across the globe from Russia to South America and certainly to MENA. States like Syria without oil yet with high levels of oppression, demonstrate that there are other factors at work, but the trend is widespread.

Consumers of oil are an equally important part of the equation as the producers of oil. Price is determined by supply and demand, making the consumer an essential mechanism to determining the price of oil. Solar energy and oil have as much an effect on the consumers as on the producers, as these are truly international issues. Consumers of oil fall into one of three general categories: Industrial oil use, transportation fleets, or individual auto use. It is important to examine how these consumers are affected by unwanted effects of oil consumption, and how solar might mitigate these issues.

The history of oil price volatility indicates the precarious nature of future oil prices. The price of oil is measured per barrel in US Dollars. After the October War of 1973, an oil embargo sent prices up sharply. During the shock, Iranian oil sold for "between US$9.00 and US$17.34 per barrel… while in Rotterdam spot price hit US$26.00 (Richards, 53). The price then went down again, but later it "leapt first to US$17.26 in 1979 and then to US$28.67 in 1980"(54). Another shock happened when, "Prices collapsed, falling to under US$10 in late summer of 1986" (56). The price has continued to fluctuate greatly and is currently at a price of well over 100 dollars. If Iran were to close the shipping of oil from the gulf, prices would shoot up dangerously. The unpredictability of price, for a resource that is essential to all major economies, causes many great losses all over the world. Energy diversity provides a cushion against the damage of price shocks.

Global warming is potentially an additional unwanted consequence of oil consumption. Burning fossil fuels such as oil release CO2 into the atmosphere. The atmospheric levels of CO2 have gone up dramatically since the industrial revolution. This is worrisome because "in 670,000 straight years, whenever CO2 has gone up, temperatures have gone up, and whenever CO2 in the atmosphere has gone down, temperatures have gone down" (Friedman, 119-120). It is however true that, although a minority, there are also scientists "who have looked at the data and concluded for different reasons that the rapid and extensive increase in greenhouse gas emissions since the Industrial Revolution is not a major threat to the planet's livability" (Freidman, 114-115). If one subscribes to the majority opinion among the experts, then there is sufficient reason to severely decrease the consumption of oil and other fossil fuels.

An additional unwanted effect to oil consumers is the conflicts that arise with powers that are funded by petro dollars. America and the West have a ravenous appetite for oil and have transferred vast sums of wealth in purchasing it. "Through our energy purchases we are helping to strengthen the most intolerant, antimodern, anti-Western, anti-women's rights, and antipluralistic strain of Islam" (Friedman, 79). The enemies of America and the West have no doubt been enriched by this wealth transfer and have used these resources against the West. This will be discussed more in the section that deals with international politics.

The easy transport and storage of oil is the reason that it is easily shipped all across the world and used to provide energy for automobiles. Other hydrocarbons such as coal and natural gas are not so easily transported, or conveniently used and can therefore not be used to replace all of oil's uses. They do however produce heat and can produce electricity that can at times replace the energy produced by oil. Most energy produced is utilized in the form of electricity, and coal can produce this electricity at the lowest price. There is price fluctuation for electricity as well, but it is not nearly as unpredictable and damaging as the price volatility of oil. Solar power is also able to produce energy as both heat and as electricity and can therefore contribute to protecting against price shocks.

All of this evidence to reduce oil consumption, or at least reduce dependence on oil consumption, is only relevant to the discussion on solar energy, in so far as solar energy is able to replace oil. In the current state of being however, solar energy is not capable of replacing oil in many of its uses. As mentioned before, oil is used by industrials; transportation fleets, and individually owned automobiles. It is the power source of choice for those markets because it is light, cheap, easily stored and transported. There are however ways that solar energy can serve to replace oil in those key energy markets, thereby diminishing dependence on oil for consumers and expanding the market for solar energy.

Oil use in industrials has already begun to diminish, as better alternatives are being discovered and implemented. This has already been demonstrated for the industry of desalinization, which once required oil for thermal desalinization, then Reverse Osmosis powered by the grid became more economical, and now research shows CSP desalinization utilizing waste heat is indeed even more efficient. It has been shown that solar power can produce energy cheaper than oil, since its cost "is today equivalent to about 50 US$ per barrel of fuel oil" and oil on the open market is now over $100 per barrel (Trieb, 1). Other industrials, especially those located in the appropriate geography, that utilize the heat from oil, could perhaps utilize solar heat more economically than oil. "There is potentially an enormous range of Solar Thermal applications within this (industrial) sector which can supply a large portion of our total energy demand"(European Solar Thermal Industry Federation, 2). Food and textiles are among the most suitable industries to utilize CSP, but the industrial market for CSP goes well beyond that.

Since solar energy can produce not just heat energy but electricity as well, the industrial electric demand could also be met by solar power. Solar equipment on the site of an industrial facility produces onsite renewable energy during peak demand. This reduces the losses and therefore also the cost of buying energy from the grid. For industrial sites not connected to the grid, solar energy could power the entire operation and save on expensive infrastructure investment. The Zenith Solar hybrid heat and electricity design is a good match for many industrial processes.

Replacing oil as a power source for transportation fleets is a more difficult question. The only reasonable way for these fleets to store solar energy using current technology is by storing it as electricity in the battery of an electric vehicle, or EV. This poses many problems: the energy must be electricity, so there is no utilization of CSP waste heat, the solar energy will have to directly compete with electricity produced at lower costs by fossil fuels, and current batteries have short battery life, long charge time, and a short life span before the battery must be replaced. There are, however, factors that make EVs more reasonable, such as: cheaper energy that is less volatile than oil, simpler cheaper cars, and less maintenance expenses on those cars. These factors alone are not enough to induce a significant proliferation of EVs with today's technology and at today's oil prices.

Israel is implementing a system to use EVs that circumvents many of the shortcomings of battery technology. "Better Place provides this solution via a network of battery switch stations that use an ingenious robotic system to switch new batteries for depleted ones" (Betterplace). In this system, developed by the company Better Place, EVs run on batteries that can be charged while at home, or at work, or at various other charging station parking lots. But unlike previous EV models, Better Place owns the battery instead of the vehicle owner. If the battery runs low while the driver needs to continue driving, he can simply pull into a battery changing station and change it out for less money and time than it would take to refill the gas tank of a regular vehicle. This frees the EV from the limitations of the battery, as long as it is in range of a battery switch station. As battery technology improves to batteries that charge faster, hold more charge, and have longer life spans, the new technology can be seamlessly integrated into the same battery shells of current technology.

This concept is a landmark achievement in the development of EVs for transportation fleets. Transportation fleets often operate with many vehicles within limited area. By installing battery-changing stations at strategic locations, entire fleets of vehicles can switch to Better Place when they need to be replaced and then operate along their transportation routes on electric battery without fear of their battery running out. Cheaper cars and cheaper energy make this much more economical for the transportation companies than gas powered cars. With enough users, it is profitable for Better Place to make the necessary initial investment of building the battery changing stations. In places that enough transportation fleets have committed to purchasing these vehicles, the infrastructure is already being laid. In Israel, the first of these Better Place cars are already on the road.

The market for individually owned EVs could piggyback off of transportation fleets. Once the battery changing stations have been installed for use by transportation fleets, they will be available to the public as well. Individuals can buy their Better Place car for less money than a regular car and save time and money every time they recharge or swap batteries. Even without a Better Place system, faster charging and increased energy storage in batteries as well as hybrid integration with gas engines is constantly pushing EVs forward. Fast charge stations that are being installed in such places as Walgreen's parking lots use chargers which "can provide a full charge in as little as 15 minutes" (Mead). The Nissan Leaf, the Chevrolet Volt, and the Tesla Roadster are plug in electric cars that have found a limited market without the better place model. To truly compete against gas cars without the Better Place models at today's gas prices requires more technological development. In places with Better Place infrastructure like Israel and soon other places, EVs will be more competitive.

Due to development spurred by high prices and the other problems associated with oil, large portions of the market for oil will likely be siphoned away. The solar industry plays a key role in providing this energy. Some of it, as in the case of the EV will be in the form of electricity. Other alternatives to oil, especially when it comes to industrial heating and desalinization, will be in the form of solar thermal energy. It would be misguided for those who benefit from oil to blame solar energy for taking away key markets. The development of the EV was not accelerated by solar energy, because the concept is just as effective if it uses electricity produced by coal-fired power plants, as it would be with solar energy. In the industrials sector, there may be some markets that will be directly captured from oil by solar power, but the positive benefits solar energy offers the region out weigh these losses. Like the EV, many of these too were inevitably going to switch away from oil independent of the advent of solar energy.

The market for oil is in no imminent danger and is currently even expanding. "For good or for ill… oil from the Middle East will continue to be central to the world's energy economy for several decades to come" (Richards, 50). The people in developing areas, such as that in Asia, are acquiring wealth and purchasing automobiles, there by increasing demand for oil. Additionally more and more of the world is industrializing, further expanding oil's current market. When the market for oil decreases because it is getting chipped away by alternatives, supply and demand dictates that oil prices will drop, which means many markets that sought alternatives when the oil price was high will revert back to oil. Saudi Arabia even intentionally dropped the price of oil to drive alternative energy out of business. This means that even as alternative energies surpass oil, the price of oil may not decline for a long time, oil will certainly not become obsolete any time soon. By developing their solar sector, oil producing MENA countries can secure revenue, jobs and development, even in the face of the perhaps inevitable decline in the oil market.

Although a major part of geopolitics in the world and especially in MENA, oil is not the only geopolitical concern when it comes to an international perspective of developing solar energy in MENA. International politics also plays a central role. Solar energy in MENA is tied to international security, international hydropolitics, and international environmental politics as well as international economics.

The international security issues related to solar energy are closely tied to the international security issues that revolve around oil. The security dilemma is when a country fears for its security because of militarized neighbors, so it commits resources to militarizing. When other countries see this, they in turn feel insecure and militarize more so, leaving the originally insecure country less secure than at the start. This cycle consumes vast resources and does not result in more security. "Heavy outlays on defense and warfare divert scarce resources away from directly productive investment and human-capital formation" (Richards, 349). MENA is a highly militarized region. The frequency of military confrontations in the region and the threat of future confrontations, both internal and external, lead states in the region to fall into the security dilemma. Oil provides much of the wealth for this wasteful and dangerous cycle. Solar could help to divert more of these resources to development and thereby benefit the region.

Oil wealth can even go so far as to cause a war. When Iraq invaded Kuwait, the motivations included punishing them for over producing oil and horizontally drilling Iraqi oil, as well as to acquire Kuwaiti oil wealth. There are many who believe the reason the US invaded Iraq after 9/11 had more to do with oil than security. The smaller Gulf States have expressed concern that that Saudi Arabia will attempt to swallow them up because of their oil wealth. Furthermore, "Saudi Arabia and Libya… were the source of about 60 percent of the foreign fighters who came to Iraq in the past year to serve as suicide bombers or to facilitate other attacks" (Friedman, 90). Although oil wealth is a great source of revenue, it causes many security problems. By replacing oil, solar energy may cheapen, or at least lessen price increases, in the natural resources of many MENA countries. However, this will happen slowly, and the result will be heightened security, and hopefully a lasting peace.

Oil not only causes unwanted conflicts, but it can also deter necessary confrontations. The genocide in Darfur region of Sudan was not quickly and effectively stopped partially because China protected the government in order to keep Sudan as an oil provider. Iran is currently stating its intent to destroy Israel at the same time it has already been revealed that their aggressive nuclear development is for nuclear weapons. The world has been handicapped in stopping them because they can dramatically reduce the flow of world oil.

If this were to happen, the price for oil would skyrocket. According to The Economist, "if the Strait of Hormuz is threatened, the resulting surge in oil prices will spell the end of the global (economic) recovery" (The Economist). World leaders would have more freedom to stop Iran's nuclear weapon development, if it were not for the importance of oil. Many states will not consider military action an option, because the disruption it could cause to the worlds oil market would be costly. Solar development and other alternatives to oil such as the EV would allow more freedom to the world to take the necessary action to stop Iranian nuclear weapon capability. Conversely, if Iran did stop oil shipping through the straight, It would likely result in war with the US which would devastate Iran and reopen the straight to shipping in a relatively short period of time. The resulting high price of oil and the acknowledgement of oil's vulnerability would boost the development of solar energy and other alternatives. Although the global economic collapse would be a major setback, such a scenario would increase investment in solar after the recovery.

Hydro-politics is an increasingly important international political issue that the proliferation of solar energy can certainly affect in MENA. In the region, "Eleven countries' (plus Gaza) water use already exceeds 100% of renewable water supplies; water quality problems plague another ten" (Richards, 144). The section above that dealt with MENA geography discussed the threat of the water deficit and how solar energy can off set it, but did not address the international political issues connected to water supply.

Water scarcity is such a great international issue, it can even be the cause for war and peace. Many countries in the region are forced to share their natural fresh water sources with neighboring countries and, "In the volatile political environment of MENA, the sharing of water resources holds the potential for international conflict" (Richards, 174). Israel's relations with its neighbors exemplify this point quite clearly. Contention over fresh water sources from Syria to Israel served to escalate preexisting tensions and led to the outbreak of the 1967 war between Israel and its neighbors. There is controversy between Israel and Lebanon over the Litani River in Southern Lebanon, which Israel occupied. Rights to fresh water aquifers in the West Bank are a point of contention between Israel and the Palestinian Authority; so much so that negotiating these water rights is considered one of the five unresolved final status issues that stand in the way of peace.

Syria demands the Golan Heights from Israel as a precondition to peace but Israel will not risk losing such a strategic place with so much of Israel's fresh water supply. Israel was willing to give away fresh water resources as part of its peace agreement with Jordan, showing that water is truly an essential resource when it comes to both starting wars and making peace. Israel is the most easily observed case of hydro-politics, but the entire region is involved in the same struggle. Solar thermal desalinization can ease water scarcity. Solar energy can therefore open up more room for peace negotiations and save the region from conflicts over water.

International environmental politics are closely tied to solar energy. It is these environmental policies that give a market to renewable energy before it is able to openly compete against hydrocarbons on the electric grid. There are many international agreements dealing with energy policy. The Kyoto protocol personifies this in that it bound many nations in the international community to limit their green house gas emissions. "The European Union has committed to achieve an overall reduction of greenhouse emissions by 8% by increasing the proportion of renewable energy in overall energy from 6% in 2005 to 12% by 2010. This will further boost the adoption of renewable sources of energy such as solar, wind, geothermal and tidal" (Salazar, 5). Supplying the demanded energy with out exceeding these levels has caused a shift towards alternative energy such as solar power.

These policies are largely motivated by the claim that green house gases released into the atmosphere are causing a very dangerous trend of global warming, which can be averted by reducing these green house gas emissions. From an international, long-term perspective, policy that incentivizes solar energy is beneficial to the world, even if there is no threat from green house gases. This will be increasingly true economically and politically into the future. The trend of decreasing prices for solar energy and increasing prices for fossil fuels make solar energy a more preferable long-term choice.

State politics is perhaps as important to solar as international politics, and the two are certainly closely related. When one state incentivizes solar energy, the effects will be felt on international issues as well. States' energy policies include both subsidies and mandates. Additionally, state policy on land use may disqualify some solar energy possibilities that would have otherwise been preferred. State policy must be assessed in any potential location selected for solar power.

Fortunately for the solar industry, many MENA countries are recognizing the potential benefits of solar energy and are attempting to shape their policy in a way favorable to attracting the investment from solar Multi National Corporations, MNCs. In addition to the many national and international problems that the solar industry can specifically address, western companies that develop solar power in MENA are MNCs. MNCs bring Foreign Direct Investment, FDI, into the region, which "allows a society to draw on the savings of the rest of the world. By doing so, the country can enjoy faster growth than would be possible if it were forced to rely solely on its domestic savings"

(Oatley, 173). Of course, the transfer of technology and managerial experience are also important reasons why many MENA countries are seeking to be attractive options for solar MNCs.

Land policy in MENA varies from country to country. The specific policies of various MENA countries are beyond the scope of this report. Land policy will affect the solar technologies that utilize large power plants that require sizeable land allotments. The technologies with smaller land requirement will be less restrained by theses policies, and designs that can use spoiled land will be even more impervious. It is worth noting that the policies in the region are likely to be less restricting than land policies in Europe and other parts of the world, contributing to MENA's comparative advantage in solar energy production.

Subsidies are typically in the form of tax breaks or grants to institutions that develop solar energy. An example of this is how the "EU has already contributed with approximately € 25 million for research projects aimed at developing CSP technologies, under the Fifth and Sixth Framework Programmes for Research. The 7th Framework Programme (FP7) running from 2007 to 2013 is anticipated to invest approximately € 50 billion in solar research" (Salazar, 23). This method of stimulating growth is at times criticized for picking winners and losers and using taxpayer money inefficiently. When one solar company gets a large grant from the government and another company does not, then the grant recipient is more likely to survive. Other companies that have better products or systems may not survive. This is not only unfair, but also counterproductive to developing the next generation of solar energy, which is the goal of the subsidies. Perhaps even more disturbing is when the recipient of a major subsidy fails even despite the help of taxpayer money. This was the case for Solyndra in the US. All of the money that the already highly indebted US Government invested in Solyndra was lost when the company failed. Fear of such wastefulness is a major inhibitor of policies to subsidize solar energy.

There are however notable cases in the solar industry where such subsidies have yielded positive results. "Governments of several countries, including… Algeria and Morocco in North Africa, and Israel in the Middle East, have granted incentives in the form of tax relief, capital cost grants, favorable electricity export rates for power generation through CSP" (Salazar, 7). All of these countries hope to gain a competitive edge in the growing industry of solar energy. Israel has developed a growing industry of solar technological development, pushed by government subsidies. With this additional motivation, Israelis have been able to make many of the major developments in the field of solar energy technology, and the use of this technology across the world has benefited Israel. China was also able to use subsidies to make China the foremost manufacturer of solar panels.

Mandates guarantee a market for renewable energy by requiring utility companies to purchase a certain amount of energy from renewable sources. Offering a feed-in-tariff that subsidizes energy produced by approved methods is one way to guarantee a market to approved renewable energy producers. "Except for Algeria, no country (in North Africa) offers a feed-in-tariff system for CSP… Thus there is very low support from the government in terms of subsidies and tariffs in North African countries" (Salazar, 34). The drawbacks of such a "feed-in-tariff" or mandate policy is that it drives up the cost of energy for energy consumers. Higher energy prices means more cost for domestic production. This could cause domestic production to lose a competitive edge to foreign producers. Therefore domestic producers may be pushed out of business and many jobs could be lost. One benefit of mandates is that they allows for competition between renewable energy producers. This too can be undermined if the mandate is so large that even relatively inefficient technologies can be guaranteed a market. When this happens they lose any economic incentive to improve in any way other than by expanding their capacity.

A policy of renewable energy mandates is, however, essential to achieving the multiple benefits of solar power. There are staunch adherents to the theory of climate change who claim that, "massive change is inevitable". They claim that this change could come as a result of green technology that moves the world forward, or "because we fail to act and civilization begins to unravel" (Brown, 265). This approach calls for large subsidies and mandates in order to develop capable renewable energy and decrease carbon emissions in time to prevent catastrophes. Regardless of the accuracy of those predictions, it is clear that solar energy is advancing at such a pace that it is already cheaper than some fossil fuels, such as oil, and it will soon be cheaper than other fossil fuels.

Subsidies and mandates are only a temporary tool to bring the industry to a point where its can compete on its own, and the solar industry is rapidly approaching that point. Even before that tipping point is obtained, the other benefits of solar are already at the world's disposal. The subsidies and mandates play into the broader topic of international economics with regards to solar energy.

Global Economics

The capitalist economy is based on of the profit motive, which assumes each player will seek to maximize profit and minimize loss. In international trade, even countries that have a disadvantage in absolute terms may have a comparative advantage that allows them to compete in international markets and accumulate wealth. The evidence examined shows that MENA has a comparative advantage when it comes to producing solar energy. In a global economy, the preferred method may be to innovate the technology in Israel, manufacture it in China, build it in MENA and export the energy to Europe. The economic potential of solar energy in MENA depends on global economic growth, defeating fossil fuels on the grid, and solar energies' ability to provide energy off the grid.

The expansion or contraction of the global economy has a profound impact on how solar energy will develop in MENA. The Desertec concept consists of a consortium of institutions from across the world. "With around 20 staff members and regional Network-Coordinators, and a large global community of supporters, the DESERTEC Foundation is now active around the world" (Desertec Concept). The International Monetary Fund, IMF, and World Bank have even been instrumental in assisting this project. This type of global funding removes barriers that would otherwise cause a long time gap between investment and return on investment. Global funding is important to solar energies' success in the region. If, however, the funding were to be cut due to a faltering global economy, solar development in MENA could suffer a devastating blow. This very phenomenon has considerably damaged the solar industry in America. The two possibilities, of global economic growth and global economic contraction, must each be examined to determine how they affect solar energy in MENA.

In the optimistic approach to the future of the global economy, the developed world will undergo economic growth, and the developing world will become increasingly developed. This growth will contribute to solar development in MENA which will further the economic growth resulting in a positive feedback cycle. This cycle will benefit Europe and MENA as well as the rest of the world. The first step of this positive feedback cycle would be for completed solar projects to be considered a success by policymakers and investors. This would indicate that the policies that enabled the success were valuable, and should be increased. As this happens, investment in the renewable industry will increase because of the evidence of success and the increased incentives to further invest.

This increased investment will mean a significant drop in the price of solar energy as economies of scale and technological advancements bring the cost down and the efficiency up. Ultimately, these advances will be so great that solar energy will become more economical than its' fossil fuel counterparts. When this happens the subsidies and mandates can be repealed and market will dramatically expand anyway. All of these steps are happening already, slowly and simultaneously, except solar energy has not yet reached the tipping point of being cheaper than coal.

The developed world would be powered by cheaper, less volatile, renewable energy as a result of this positive feedback loop; and the developing world would perhaps benefit even more. In the host country, the original building of the plants will immediately attract foreign investment, and create jobs, and develop technical and managerial skills among employees. When the solar energy produced in MENA is cheaper than traditional fossil fuels and is available to the local inhabitants, price elasticity of demand suggests that the demand for electricity will increase. A growing MENA economy will also increase electricity demand.

The increased demand will make it profitable to extend the electric grid to populations that are currently unconnected. "According to a survey by ESTIA, for Solar Thermo-Electric Power Plants, every 100 MW installed will provide… 600 contracting and installation jobs and 30 annual jobs in O&M (operation and management)" (Salazar, 36). These new jobs will also help drive the economy. Solar power will also be increasingly able to provide energy to populations in remote locations, without connecting them to the grid. All of this will help to energize the MENA economy and bring revenue to MENA. Development of solar energy, on and off the grid, could ultimately bring Sub-Saharan Africa out of energy poverty.

Alternatively there is also the pessimistic approach to the future of the global economy. If the solar industry is viewed as failing, the policies that are currently making solar development economical will be considered unsuccessful and will be repealed. If the global economy contracts enough, politicians may forsake solar friendly policy, even in the face of success. Strangely, there are often large subsidies to fossil fuels that have not come under scrutiny during tough financial times. The result would be a tapering off of further investment in solar energy. If the investment in solar energy dries up, technological development will also be cut short. This will cause many previous investments in solar development to be wasted, without deriving many of its benefits or solving many of the problems that solar was to alleviate. Elements of this pessimistic scenario are also already a reality.

In the case that renewable policy is abandoned before its self-sufficient potential becomes realized, the problems that solar energy sought to address will continue to get worse. According to Collier, "investors are wary of falling for a policy that looks attractive but is not maintained" showing the importance of commitment to the appropriate policy (Collier, 153). Missing out on the benefits of solar energy, in a region with so many states so close to state failure, could be tragic. In a situation of state failure, the economic environment becomes so unstable that investment, even in conventional industries, ceases to flow into the country. Those unfortunate enough to be caught in such a trap, are likely to remain poor and in energy poverty. Climate change is expected to damage poor countries the most, who are ironically, the ones who contributed least to the problem.

The reality of the future will likely include aspects of both the optimistic and pessimistic approach. The question is which will be more prevalent. Some countries at times may resemble more the optimistic approach and other countries at times may more closely resemble the pessimistic approach. Not all MENA countries are poised for success with the solar industry and investment should be done in the region but with the proper caution. Policy makers must make sure that they are committed to the policies they make, which must be effective at bringing solar energy closer to its goal. Solar self-sufficiency is within reach and worth working towards. Much of the world has already begun to do so.

Defeating fossil fuels on the grid would not be such a daunting task "if prices keep rising and external costs will be internalized" (Schüssler, 221). The rising price of fossil fuels is, like that of oil, a function of supply and demand. As the demand continues to expand and production becomes more costly, the prices of fossil fuels will go up. Solar on the other hand is becoming cheaper with time. "With 5000 MW of capacity scheduled to be installed world-wide by 2015, CSP technology is likely to become competitive by that time with world market prices of most fossil fuels, especially fuel oil, natural gas and liquid natural gas" (Trieb, 27). The battle, however, is not yet over. Natural gas has come down in price and coal is cheaper than the above fuels and is the dominant mode of electricity generation.

In the absence of favorable international and state policy, coal is the fuel that solar energy will ultimately have to defeat, in order to win a share in the market for grid energy. Coal prices are not as high or volatile as other fossil fuels but, "Coal prices doubled… starting with 30 $/ton in 2000 and ending up with an average cost of 60 $/ton in 2006" (Trieb, 129). There are also externalities to coal, such as CO_2 emissions, that if internalized would help solar energy to compete. Even still, the price of solar will have to come down a long way to compete against coal in a free and open market. Many believe this day will come soon, others are not so sure. Other renewable energy technologies are also competing to surpass coal too. The same company that developed the patent for the Suntrof technology also has a patent pending for a hydro technology called Airwatt. The company claims that it will be able to produce renewable energy at a cost per generated kilowatt hour of 1.3 cents. This is considerably cheaper than coal. This technology is currently little more than a concept, and far from manufacturing and commercialization, but it shows how close renewable energies are to defeating coal.

Even before reaching the level of open market competition with coal, there are politically independent and economically profitable markets for solar energy already. “For the nearly 1.6 billion people living in communities not yet connected to an electrical grid, it is now often cheaper to install solar cells rooftop-by-rooftop than to build a central power plant and a grid to reach potential consumers” (Brown, 249). As discussed before, the industrial potential for PV, CSP, and roof top solar water heaters allow for a market not in competition with coal. Powering remote, nonindustrial, locations with PV and providing them with hot water from rooftop flat solar thermal panels also gives solar an off grid market. In this nonindustrial market that is not connected to an electric grid, solar energy will very soon be cheaper than other power sources, if not already. As mentioned before, this plays a key role in increasing development. It also allows for a market within which solar can grow and improve, free from dependence on politics.

Even many places with grid access may prefer solar water heaters over gas for economic reasons since “in industrial countries, these systems pay for themselves from electricity savings in fewer than 10 years” (Brown, 248). In this way, even in places as urban as New York, solar is expanding bit by bit with small investments and less political constraints than big power plants. Companies that install urban solar panels have already designed payment plans that alleviate the problem of the high initial cost. With such plans, the monthly payments can, with subsidies, be lower than the cost of monthly electricity from coal that they replace.

In all of these ways, the expansion of solar in MENA advances the region forward in global economics. The shortsighted perspective portrays solar as wasteful economically, but the big picture explained above dispels such pessimism about the long-term economic profitability and success of solar energy. There is no guarantee that solar energy will achieve large-scale profitability independent of politics within a reasonable time frame, but it is a reasonable goal that is worth working towards.

Practical Application

The practical application of solar technology to the MENA region requires further examination. The potential of solar production in MENA with exports to Europe and to local markets has shown to be desirable. Yet there are some practical issues with the realization of this plan that have not been addressed above. One must address cultural concerns, ways of attracting investors, and the risk of instability, before drawing up a strategy for expansion in the region.

Arabs are the majority demographic in MENA. An understanding of Arab culture is important to doing business in the region. The first point to acknowledge is that the inhabitants of MENA harbor a collective history of colonialism. This history predisposes many in the region to mistrust former colonial powers from Europe and their twentieth century heirs, the US and Israel. Individuals and institutions in MENA are likely to suspect Western people and institutions of being exploitative. “Because of that, large infrastructure projects like CSP have to prove their participatory character, while simultaneously they have to be economically successful and sustainable” (Schüssler, 226). Solar energy achieves this by creating jobs and transferring skills, technology, and capital to the region. It has also been discussed above how solar energy can promote development in the region and alleviate other problems.

MENA backlash against globalization is significant and may also be related to this colonial history. The anti-globalization movement is worldwide and is in “opposition to a global economy that they believe prioritizes corporate and commercial interests over other concerns" (Oatley, 346). It is hard to imagine this group of activists opposing solar energy, which provides jobs and fresh water and renewable energy free of CO2 emissions. Employment, sustainability, development and environmental issues are often the "other issues" that anti-globalization activists believe should be prioritized above corporate interests.

MENA is known for its informal policy making procedures, which is another cultural issue to address. This issue is in a way political. In rich Arab kingdoms, decisions are often made in congruence with the perceived will of the king. Formal decision-making institutions are frequently empty shells, and it is often not clear when or where a decision was made and who influenced it. Pushing an agenda can therefore be very difficult in the region.

Many Arabs do speak English, the current language of most international business, but not all. Even so, the Arabic language is very highly valued, but it also varies regionally. Increased knowledge of the language will enhance social interactions. These interactions are extremely important as friendship is held among the highest of values, just under honor and family ties. Friends in the Arab world expect that if they help you out, than you will help them out. "Good manners require that one never openly refuse a request from a friend" (Nydell,17). Undervaluing these personal relationships can be a costly mistake in the MENA region. Such cronyism fosters an environment of corruption. Gift giving and bribes are an essential part of doing business that one must be prepared for.

The importance of religion and the prevalence of Islam are pronounced in MENA. Arabs respect "anyone who sincerely practices his or her religion, no matter what that religion is" but do not respect atheists or agnostics (Nydell, 81). Familiarity with Islamic banking, which circumvents a direct interest charge, may be useful in business dealings in the region. Arabs like to discuss controversial topics like religion and politics. It is recommended, not to directly oppose or offend their perspective. "Arabs consciously reserve the right to look at the world in a subjective way… if Arabs feel that something threatens their personal dignity, they may be obligated to deny it, even in the face of facts to the contrary" (Nydell, 28-29). This can be frustrating for westerners who hold the value of truth above honoring others. All of these cultural considerations and more should guide successful business dealing in MENA.

Attracting investors is a difficult process that needs to be practically addressed. Investors are generally looking to get the earliest and largest return on their investment as possible. This is challenging because the solar industry seldom offers this. Furthermore, its most advanced technologies are not yet sufficiently tested. Investors don't want to make high-risk investments, nor do they want to invest heavily in an old technology when a new technology can already out perform it. The recent global economic decline has caused a general disappearance of venture capitalists altogether and has put capital in high demand. Large solar plants require such a large initial investment that it may be too much even for investors that are convinced of its success. Solar in MENA means not only potentially risky technology, but also a risky environment. Conflict and political instability threaten profitability. Also, if the market is artificially created by policy, investors fear the change of that policy, and the disappearance of that market.

Many of these challenges have been met with solutions. MENA countries are increasingly seeing the benefit of hosting solar energy production and making an effort to guarantee a desirable production site, while Europe is attempting to guarantee a long-term market. It is the potential for growth in the industry, that makes it currently undervalued, and therefore worth the extended wait for the return on investment. To get companies to commit to either tested or advanced renewable technologies, the EU has made mandates to guarantee a market to renewable energy. Global finance partnerships are rectifying the disappearance of investors and large initial investment problems. Small scale, roof top PV and solar thermal panels sidestep this issue. This is true when the installer offers payment plans to eliminate high initial costs, as many solar installers are now doing. There are so many ways for the international community to benefit from solar energy that it would be illogical for the international community to reverse its policy. This should be comforting to investors. Conflict and political instability are enduring issues, and risky areas should be avoided until they stabilize.

The Arab Spring shook the entire region, causing some governments to be overthrown and others to be destabilized. Developing solar energy in an unstable country would be quite difficult and risky. Such countries include Syria and Yemen, which are still very unstable. Iraq is also a dangerous place as conflict is still raging. Any place susceptible to such instability should be avoided until its' situation improves.

If the health of an aging monarch deteriorates, such as in Saudi Arabia, that could be a sign of instability in the near future and a reason to withhold investment from that country. Tunisia, Egypt, and Libya have already undergone governmental transitions or are in the process of doing so. Civil wars and coup d'états "are costly and can be repetitive" (Collier, 17). However, it seems these countries are regaining stability and may be considered proper host countries for solar development.

Morocco and Algeria are also relatively stable and attractive options for solar development. Indeed, the Desertec concept includes all of the North African countries that border the Mediterranean. Israel is in an excellent position to utilize its solar resources and it is a per-capita world leader in doing so. If Israel were to connect its grid to Europe, its solar prospects would grow considerably. Jordan also has ambitions to host a CSP facility on the Red Sea. Gulf countries that are stable such as the UAE, Qatar, and Oman present a ripe opportunity for solar investment, particularly in oil retrieval and desalinization.

Conclusion

Having addressed the technology, geography, politics, economics, and practical application of solar energy in MENA, in an international context, the industry appears to be a sector that will undergo growth in the future. Some of the points discussed herein are widely acknowledged, but others are less recognized. The MENA region in particular is going to be, quite literally, a hot spot for solar growth. This is due to its numerous factors that contribute to a significant comparative advantage that the region has in solar production, combined with its proximity to a reliable clean energy market. Utilizing the flexibility of different solar technologies allows for a general growth of the entire solar industry in the region and will allow maximum utilization of MENA's rich solar resource.

For all of those places, where there is no reliable policy to guarantee a market through the electric grid, solar energy can still develop profitably. This applies in industries such as oil, desalinization, food and more. In rural areas, PV and flat solar panels may also be reasonable and the most economical energy option. For places that do have access to a reliable market for electricity, such as the North African countries that will be connected to Europe, large scale CSP for energy production is very attractive. These plants can simultaneously produce electricity and utilizes their waste heat for desalinization or other industrial purposes. In short, even at this very moment in technological development, policy, and stability, there are plenty of opportunities for solar growth in the MENA region.

When the global economy and the stability in the region show sure signs of recovery, even more expansion will be likely. As mentioned before, solar development will help contribute to a positive feedback loop that will facilitate the world and region in development and economic growth. If solar technology develops to the point that it can surpass coal as the cheapest form of electric production, a tipping point will be reached that will accelerate the growth of solar energy. The growth will be particularly prevalent in the MENA region due to its comparative advantage. The ultimate potential of solar energy in MENA is to improve the lives of people around the world in an economical and politically independent way. Solar energy is on its way towards this goal at a rapid pace. Every additional solar innovation and instillation brings solar energy and the world a little closer to this goal.

Thesis Works Cited

Better Place, prod. "The Soloution." *Battery Switch Stations*. Better Place, 2012. Web. 9 Apr. 2012. <http://www.betterplace.com/the-solution-switch-stations>.

BrightSource. "BrightSource Energy Delivers World's Largest Solar-To-Steam Facility for Enhanced Oil Recovery To Chevron." *BrightSource Energy*. N.p., n.d. Web. 2 Apr. 2012. <http://www.brightsourceenergy.com/>.

Brown, Lester R. *Plan B 3.0*. New York, London: W.W.Norton & Company, 2008. Print.

CIA World Factbook. "Middle East: Saudi Arabia." *World Factbook*. Central Intelligence Agency, n.d. Web. 9 Apr. 2012. <https://www.cia.gov/library/publications/the-world-factbook/geos/sa.html>.

Collier, Paul. *The Bottom Billion*. Oxford: Oxford University Press , 2007. Print.

Desertec. "Desertec Foundation." *Desertec Concept*. N.p., n.d. Web. 2 Apr. 2012. <http://www.desertec.org/concept/>.

Desertec. "Desertec Foundation." *Network Coordinators*. N.p., n.d. Web. 9 Apr. 2012. <http://www.desertec.org/organization/network-coordinators/>.

The Economist. "Oil and the world Economy." *How to assess the risks of a 2012 oil shock*. N.p., n.d. Web. 10 Mar. 2012.

European Solar Thermal Industry Federation. "Solar Industrial Process Heat – State of the Art – ." N.p., 25 Aug. 2006. Web. 9 Apr. 2012. <http://www.estif.org/fileadmin/estif/content/policies/downloads/D23-solar-industrial-process-heat.pdf>.

Friedman, Thomas L. *Hot, Flat, and Crowded*. New York: Frrar, Straus and Giroux, 2008. Print.

Goldberg, Delen. "Questions emerge over tax breaks for solar project." *Las Vegas Sun* 3 Apr. 2011: n. pag. Web. 2 Apr. 2012. <http://www.lasvegassun.com/news/2011/apr/03/ solar-power-lukewarm-job-production/>.

Grätzel, Michael. "Photovoltaic and Photoelectrochemical Conversion of Solar

Energy." *Philosophical Transactions: Mathematical, Physical and Engineering Sciences* 365.1853 (2007): 993-1005. *JSTOR*. Web. 24 Jan. 2012. <http://www.jstor.org/stable/25190484 .>.

Maathai, Wangari Muta. *Challenge for Africa*. New York: Pantheon Books, 2009. Print.

Mead, Derek. "Top Five Electric Vehicle Initiatives of the Year." *Green Tech Media*. N.p., 8 Dec. 2011. Web. 9 Apr. 2012. <http://www.greentechmedia.com/articles/read/top-five-ev-initiatives-of-the-year/>.

Nydell, Margaret K. *Understanding Arabs*. 4th ed. Boston, London: Intercultural Press, 2006. Print.

Oatley, Thomas. *International Political Economy*. Ed. Vikram Mukhija. 5th ed. Boston: Longman, 2012. Print.

Richards, Alan, and John Waterbury. *A Political Economy of The Middle East*. 3rd ed. Boulder: Westview Press, 2008. Print.

Salazar, Carlos Márquez. "An Overview of CSP in Europe, North Africa and the

Middle East." *CSP Today*. N.p., Oct. 2008. Web. 2 Apr. 2012.

Schüssler, Frank. "Energy Partnership Africa — Europe Concentrated Solar Power between Technical Realization and Ethic Responsibility." *Erdkunde Archive for Scientific Geography* 62.3 (2008): 221-230. *JSTOR*. Web. 24 Jan. 2012. < http://www.jstor.org/stable/25648126 >.

Sol Terrah, prod. Home page. *Sol Terrah*. N.p., 2009. Web. 30 Mar. 2012. <http://www.solterrah.com/suntrof-clean-energy.php>.

Torresol Energy. "Gemasolar." *torresolenergy*. N.p., n.d. Web. 30 Mar. 2012. <http://www.torresolenergy.com/TORRESOL/home/en>.

Trieb, Franz. "Concentrating Solar Power for Seawater Desalination." Nov. 2007. Pdf file.

United Stares. United States Patent. *In Situ Shale-Oil Recovery Process*. By Jan Bock, et al. Ed. Stephen J Novosad, Bruce M Kisliuk, and Henry E Naylor. New Jersey, 1984. PDF file.

Zenith Solar. "Z20 product description." N.p., n.d. Web. 2 Apr. 2012. <http://www.zenithsolar.com/>.

David Wills