Energy Sustainability in Morocco

October 17, 2015

Worcester Polytechnic Institute

Ribat Al Fath for Sustainable Development

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Letter of Transmittal

October 17, 2015

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Enclosed is our report entitled Energy Sustainability in Morocco. It was written at the headquarters of Ribat Al Fath in Rabat, Morocco during the period from August 31 through October 17, 2015. Preliminary work was completed in Worcester, Massachusetts, prior to our arrival in Rabat. Copies of this report are simultaneously being submitted to Professors Stephen McCauley and Aaron Sakulich for evaluation. Upon faculty review, the original copy of this report will be catalogued electronically in the Gordon Library at Worcester Polytechnic Institute. We appreciate the time that you, Kawtar Abendag, and the rest of Ribat Al Fath have devoted to us.

Sincerely,

Sydney Gustafson, William Hartman, Bryan Sellers, Jules Voltaire

Abstract

Morocco imports 96% of its energy, threatening its energy security. To combat this, 2,000 MW each of solar, wind, and hydroelectric power are planned. Energy conservation efforts have been initiated with mixed success. This report outlines Morocco's energy strategy, evaluating its successes and failures. Recommendations were made to reduce energy use, implement local-scale projects, pursue global collaboration, and promote research and development in renewable technology. This report will guide Ribat Al Fath in influencing Moroccan energy policy.

Acknowledgements

We would like to thank the several people for assistance in the completion in this project.

- Ribat Al Fath for Sustainable Development and the Environmental Club
- Bennani Abdelkrim, Ribat Al Fath President
- Mr. Abdelhadi Bennis
- Kawtar Abendag
- Sarah Lechfaq and Hajar Sallahi
- Our advisors Dr. Stephen McCauley and Dr. Aaron Sakulich
- Our program coordinator and project liaison, Anas Edik
- Those that we interviewed
    - Ministry of Energy
    - MASEN
    - ONHYM
    - ONEE
    - Ministry of Water
    - ABH Sebou
    - HCEFLCD
    - Ministry of the Environment
    - Moh Rejdali, Mayor of Temara
    - Ministry of Agriculture
    - Residents of Had Berachoua
    - ORMVAG
    - University Ibn Tofail
    - International University of Rabat
    - SPANA
    - AMCDD
    - Moroccan Association for Regional Science

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1. Introduction

As energy prices soar and global warming issues become more pressing, energy security and management rise in importance. Worldwide, solutions to these problems are being sought after, and alternative energy sources and improved technical solutions are frequently recognized as important tools for solving these issues. Energy security is essential for developing nations to modernize successfully.

Environmental and energy issues have been a topic of growing concern in Morocco. As an energy poor nation with around 96% of energy imported from foreign nations (Morocco Economy, 2009), Morocco has taken strides in the past several years to increase energy security. With a rapidly growing population and an increasing quality of life, energy consumption is expected to escalate significantly. In order for continued development and modernization, it is essential for Morocco to obtain energy security and independence.

To combat this vulnerability, the Moroccan government created a national goal to harness 42% of its energy from renewable resources by 2020 (U.S. EIA, 2013). This goal is ambitious, and especially challenging for a developing nation. For context, worldwide, only 10% of energy comes from modern renewable sources (IEA, 2014). This goal is indicative of the emphasis that Morocco puts on increasing energy independence. Morocco is currently working on several large-scale projects to harness sustainable energy, focusing on the goal of producing 2,000 megawatts (MW) each of solar, wind, and hydroelectric power by 2020. These programs are supplemented by smaller-scale initiatives aimed at residents and industries. Energy conservation and efficiency are additional tools used to reduce energy consumption, and reliance on renewable energy production, assisting the achievement of energy goals. Even though these programs have had many initial successes, they fail to fully resolve the energy problem and leave many areas in Morocco's energy policy unimproved.

In the collaboration with Ribat Al Fath for Sustainable Development, our team assessed the energy situation in Morocco regarding energy production, consumption, efficiency, and conservation methods. Present initiatives to increase energy supply security and energy

consumption awareness were evaluated. Professionals, including engineers, scientists, non-governmental organizations (NGOs), and governmental agencies were interviewed to further understand Morocco's energy situation. The data retrieved from interviews, current renewable energy projects, energy policies, and conservation measures enabled comprehensive analysis of Morocco's energy state and the formulation of recommendations centralized around sustainable energy development.

2. Background

2.1 Ribat Al Fath for Sustainable Development

Ribat Al Fath for Sustainable Development is an NGO that was created in 1986 to promote solutions to social, economic, and cultural issues. This NGO receives minor funding from membership fees, but is primarily funded from partnering organizations. Ribat Al Fath engages the local population to understand their pertinent issues and to give them the opportunity to be involved. The NGO lobbies government agencies to implement solutions to these problems. Ribat Al Fath often partners with governmental organizations and other NGOs to solve larger-scale obstacles (Abdelkrim, personal communication, September 2, 2015).

Ribat Al Fath is responsible for the success of several programs established to support sustainable development. Ribat Al Fath was a leader in the national illiteracy program. The initiatives of this program increased the literacy rate in Morocco from 30% to 70%, proving to be very rewarding for the less fortunate part of the population. Ribat Al Fath also helped persuade the European Union to give Morocco preferred status. These accomplishments illustrate Ribat Al Fath's influence in Morocco's mission for sustainable development (Abdelkrim, personal communication, September 2, 2015).

2.2 The Status of Global Energy

In 2012, the total amount of energy produced worldwide was approximately 104.4 billion megawatt hours (MWh) (IEA, 2014). This total includes final energy consumption in all forms, whether it is used as gasoline, electricity, or biomass. The rate of global energy consumption is growing quickly having nearly doubled since 1973 (IEA, 2014). The global average for energy use per capita per year is 22.1 MWh, but this varies significantly depending on wealth, energy availability, and environmental factors, ranging from 206.32 MWh per capita per year in Iceland to 1.51 MWh per capita per year in Eritrea (IEA, 2014).

Globally, fossil fuels are the most common source of energy. Renewable sources accounted for 19% of international energy use in 2013. Of this, however, only 10% came from modern renewable energy technologies (such as solar, wind, or hydroelectric power), with the rest coming from traditional biomass such as burning wood for heating or cooking (IEA, 2014). Renewable energy use is increasing worldwide. This increased level of interest can be explained by the concern for reducing greenhouse gas (GHG) emissions, securing energy supply necessary for economic development, and reducing dependence on energy imports.

2.3 Moroccan Energy Scope

Morocco currently relies on fossil fuels for its energy. Since there are nearly no domestic oil reserves, Morocco is forced to import 96% of its energy. The vast majority of Morocco's electricity is currently generated at domestic power plants with imported fossil fuels. Morocco's dependence on imported fuel poses many potential problems due to growing energy demand. With a growing population, growing wealth, and improving quality of life, Morocco's energy use is expected to quadruple by 2030 (Norton Rose Fulbright, 2012). Considering the growing demand for energy and external dependencies for fuel, energy security is becoming a major concern for Morocco. To combat this growing concern, Morocco has committed to generating 42% of the energy it uses internally, from renewable resources.

In 2009, Morocco launched the National Energy Strategy which covered five specific areas. In this strategy, it outlined goals to optimize the fuel mix in the electricity sector, develop renewable energies, consider energy efficiency a national priority, encourage foreign investment, and increase regional integration of the grid (International Energy Agency, 2014).

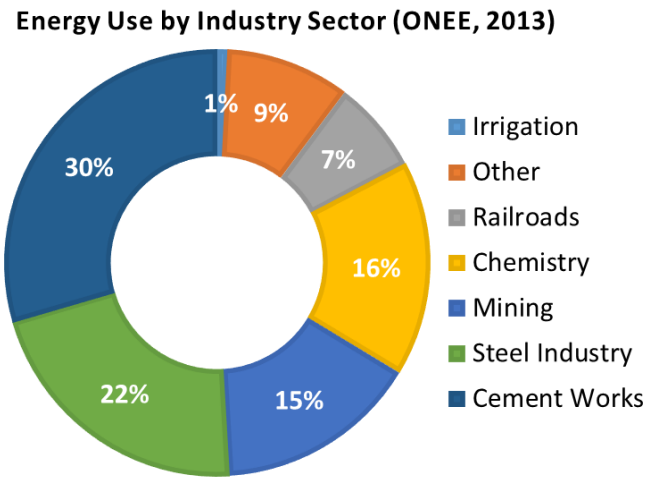

Figure 1: The amount of energy used by each industrial sector

The majority of Moroccan energy use comes from industry, followed by residences, commerce, agriculture, and transport (see figure 1). In industry, energy use is dominated by two sectors: cement factories and steel plants (see figure 2). Energy use in these industries is difficult to reduce significantly, as it is required in the necessary chemical processes. In other sectors, like irrigation, relatively small changes can lead to noticeable energy savings. Residential energy use is significantly higher for those in urban areas, as rural residence have less consistent access to electricity. Considering urbanization, the

growing population, and growing wealth, residential energy use is expected to increase more rapidly than other sectors (European Investment Bank, 2013).

Morocco has made strides to increase environmental education. In June 2013, the World Environmental Education Congress was hosted in Marrakech. The theme for the event was “Environmental Education in Cities and Rural Areas: Seeking greater Harmony”. King Mohammed VI sent a speech through his sister, the President of the Mohammed VI Foundation for Environmental Protection, to read at the event. In this speech, King Mohammed VI indicated that it is necessary to adopt policies that will protect the environment and that efforts towards sustainable development must be made. He also calls for increased commitment from public authorities and specialized agencies and sponsors (Speech by King Mohammed VI). This indicates the importance that Morocco has put on environmental matters in recent years.

2.4 Social Implications

When considering environmental policy and programs, social aspects and impacts must be considered as well. Policy changes inevitably cause lifestyle and behavioral changes. While changes may cause consistent and significant improvements in a nation's environmental impact, it is imperative to ensure that the social implications of these changes are morally sound.

One common tactic used to cause a reduction of environmentally damaging behavior is to increase the costs of these behaviors. This may be a reduction of tax breaks or subsidies (as in Morocco's reduction of oil subsidies) or direct increases in price. These tactics are largely successful, but have significant effects on the lives of low income people. These people may be forced to change their behavior too drastically, possibly significantly altering their livelihood.

Most other strategies aimed at decreasing electricity use or increasing the use of renewable energy sources requires some level of governmental involvement or commitment. This commitment may be through programs that distribute goods such as small solar panels or energy efficient light bulbs, or may be through direct investment into power plants and the grid. While these government investments certainly benefit residents of Morocco, they may cause higher taxes or a reduction in other government programs. The removal of fossil fuel subsidies lead to a financial burden for many Moroccans was at least partially motivated by budgetary concerns (IMF 2014). If other large investments by the Moroccan government were reduced, this financial hardship may have been avoidable.

However, it is also true that successful environmental reforms also carry a significant positive social impact in and of themselves. The preservation of the environment positively affects almost all stakeholders. When issues like global climate change and diminishing oil reserves are present, a move towards environmentally friendliness benefits the world at large, as well as future generations.

Successful environmental reform is somewhat of a balancing act; lifestyle change is necessary, but this change should not be so drastic as to damage lives and livelihoods (Walker,

1998). To avoid these issues, proper stakeholder analysis is important. By considering each stakeholder and their needs, the effects of environmental reforms can be balanced properly, so they can cause a large positive effect without negatively impacting too many lives.

2.5 Renewable Energy Technology

Solar Energy

In Morocco, there are two primary methods used to produce electricity with solar energy. The first, and more traditional method, is using the solar photovoltaic (PV) process, and the second is using concentrated solar power (CSP).

Solar photovoltaic production is the process where solar panels are used to produce electricity by collecting solar radiation in solar cells which are made from semiconductive materials such as silicon. These are often used in rural regions because they can be put on a rooftop and space is not a large concern (Union of Concerned Scientists, 2015).

Concentrated solar power (CSP) uses mirrors to concentrate the energy from the sun onto receivers, powering a steam-turbine generator. Some CSP systems are able to use chemical solutions to store energy for up to seven hours, which is extremely beneficial for combating sunlight and consumer variability. CSP plants are also more efficient than PV plants when there is not any cloud cover, which is generally consistent with Moroccan solar plant locations (SEIA, 2014). Unlike PV solar generation, CSP requires expansive land. This makes it inappropriate for home use, but very useful for large-scale solar production.

Wind Energy

Wind power is a sustainable method for generating electricity without releasing CO_2 or other pollutants. Wind power is generated using turbines that harness the energy potential of wind to spin a generator, producing electricity (SEI, n.d.). The wind conditions play a major role in the electricity production capabilities of wind power.

Conditions in Morocco are adequate for wind farming. Morocco receives wind speeds of greater than 4 m/s along the Casablanca-Agadir coast, greater than 6 m/s along the Atlantic coastal area between Laayoune and Dakhla, and between 5 m/s and 10 m/s between the Atlas and Rif mountains. There are 17 regions of Morocco that have been marked as suitable for wind

generation based on observed wind speeds, however, there are many regions that have not been studied. Wind speed is the most important element to consider in determining the feasibility of wind farms. Proximity to cities and major buildings are also taken into consideration (Nfaoi *et al.*, 1998). Wind power plants cannot be excessively remote because energy storage and usage become inefficient. However, close proximity to buildings can affect wind activity and efficiency (Union of Concerned Scientists, n.d.).

Another technique to utilize wind energy is to install wind turbines in the ocean. Offshore wind sources are generally more abundant, powerful, and consistent than onshore sources, increasing the energy production capacity exponentially (Bureau of Ocean Energy Management, n.d.). Additionally, offshore wind power is believed to be unobtrusive on nearby sea organisms because the wind turbines' undersea structure often creates an artificial reef that can be used as a habitat for marine life (Casey, 2012). Finally, offshore wind power is less bothersome to local populations due to the remoteness of the wind farms, generally avoiding noise and visual concerns. However, due to their location off the coast, there are potential drawbacks including turbine damage from sea corrosion, and power grid access difficulties. Fortunately, technology is being developed to combat these concerns, increasing the desirability of this new innovation (Office of Energy Efficiency and Renewable Energy, n.d.).

Hydroelectric Energy

Hydroelectric energy is generated by the conversion of kinetic energy from water in a turbine into mechanical energy which is converted into electricity. Hydroelectric energy generation is viable and active in Morocco supplying 1700 MW of power to the grid (Ministry of Water, personal communication, September 11, 2015). There is research involving the use of hydroelectric technology to store excess energy generated from wind turbines, which would help remedy some of wind power's shortcomings with intermittency. This is useful when energy demands are low, such as at night, or when wind speeds are too low for effective power generation.

Tidal and Wave Energy

There are several types of tidal energy generators in the research and development phase. In Morocco, the most promising generator type is tidal stream generators. Tidal stream generators use underwater currents to generate electricity using a windmill-like turbine. Other tidal generator varieties include tidal dams and generators that float on waves, but the return on investment of these options is low. Tidal stream generators are also expected to have the lowest potential environmental impact (Elgalhi *et al.*, 2007; Boehlert *et al.*, 2010).

When tidal power is more mature, there is significant interest in the installation of a tidal stream generator in the Strait of Gibraltar (Charlier, 2003). Since currents at this point are exceptionally consistent and strong, the potential for electric generation is considerable. At the present time though, this project is entirely hypothetical and no planning has begun. At some point however, the Strait of Gibraltar may be a significant asset in Morocco's renewable energy efforts.

3. Findings and Analysis

3.1 Status of Large and Local-Scale Energy Projects

Large-Scale Energy Projects

The Moroccan Agency for Solar Energy (MASEN) was launched in 2010 with the passing of law 57-09. Its purpose is to assist in the goal of producing 2,000 MW of energy from solar power by 2020. MASEN is responsible for many of the large-scale solar power plant projects in Morocco. These include the solar projects at Ouarzazate, Ain Beni Mathar, Foum Al Ouad, Boujdour, and Sebkha Tah. Currently, the most prominent of these plants is the Ouarzazate power plant which consists of four phases: Noor I, Noor II, Noor III, and Noor IV. Noor I will be completed and operational by the end of 2015 (Cole, 2015). Upon the completion of the power plant in 2019, it will be about the size of Rabat and will provide about 500 MW of energy, representing 25% of Morocco's solar energy goal (MASEN, personal communication, September 7, 2015). Noor I-III will consist of concentrated solar power that will be used throughout the country. Noor IV will be a smaller 50 MW photovoltaic plant which will cover the energy needs of residents in the Ouarzazate area.

Wind speed and frequency are location dependent. There are 17 regions of Morocco that have been marked as suitable for wind generation based on observed wind speeds. There are 17 regions of Morocco that have been marked as suitable for wind generation based on observed wind speeds, however, there are many regions that have not been studied.(Enzeli, 1998). Several large wind farms are under construction or being planned under the ten year Integrated Wind Energy Project. This project aims for growth from 280 MW of wind energy in 2010 to 2,000 MW in 2020. In 2010 there were five wind power plants under development at the locations Tarfaya, Akhfenir, Bab El Oed-Laayoune, Haoma, and Jbel Khaladi. These developments will generate 720 MW of wind energy upon completion. In particular, the wind power plant in Tarfaya was completed in 2013. This plant serves 1.5 million households and is the largest wind power plant in Africa with a capacity of 300 MW. An additional 1,000 MW will

be developed before 2020 through the completion of five additional wind farms (Moroccan Investment Development Agency, n.d.).

Large-scale projects are typically funded via public-private partnerships. This allows for one primary business to facilitate these major projects. This facilitating agency opens the market to private manufacturers to bid for different components of the project, allowing competition and specialization. This method of competitive bidding increases the quality and price of the product, and drives innovation.

These large-scale and cutting-edge power plants have helped to make significant progress towards reaching Morocco's 42% goal. Currently, reaching this goal is feasible, however it is not guaranteed. Success is contingent on continuing to field foreign investment and continued economic stability in Morocco.

While large investments have been invaluable for Morocco's green energy sector growth, they do pose some problems. If Morocco stays dependent on foreign investments and foreign corporations for meeting its energy needs, its energy security situation is only marginally better than its current dependence on imported fossil fuels. Using foreign nations for their renewable energy experience and funding abilities is a valid strategy to start focusing on decreasing energy dependence, but homegrown local industry is a far superior endpoint.

Previously in the competitive bidding process, many contracts have gone to international corporations rather than local ones. According to analyses done at MASEN, about 30-40% of competitive bidding jobs are suitable for Moroccan companies (Amrane, personal communication, September 7th 2015). While this is largely a practical issue, since few companies worldwide can function at the scale needed, it is a missed opportunity to stimulate Morocco's green energy sector. Local businesses have been used for some portions of the project however, which has contributed to Morocco's economy and energy sector experience.

Local-Scale Energy Projects

Morocco has supported its larger-scale efforts with smaller-scale projects. These projects typically affect smaller groups of stakeholders, rather than reaching the entire country. While large-scale projects are crucial for meeting large-scale goals, smaller-scale projects have allowed more citizens to see specific benefits to their lives.

In 1995, the Moroccan government introduced the Rural Electrification program. This program aims to provide electricity to the rural people of Morocco. Over the past two decades, this program developed the grid, increasing electricity access nationwide from 18% to 98% (International Energy Agency, 2014). The program also supplied photovoltaic units to areas where grid connection would be uneconomical, which accounted for approximately 10% of homes in rural Morocco (George, 2002). The rural electrification program has likely contributed to the consistent annual economic growth rate of 4-5%.

In 2009, Morocco launched the Renewable Energy Law (law 13-09). This law promotes renewable energy production by private entities (Norton Rose Fulbright, 2012). Previous to law 13-09, the Office National d'Electricité et de l'Eau Potable (ONEE) had a monopoly over energy production in Morocco. With the implementation of this law, private entities can produce electricity using renewable sources and sell this electricity back into the grid. Private producers with a capacity of under 20 KW do not need permission or contracts with ONEE (Norton Rose Fulbright, 2012).

Other local-scale renewable energy projects include programs for solar water heaters, off-grid self-contained pumps, and off-grid water purification. The Shemsi program for solar heaters aims to install 1.35 million m^2 of these heaters as an energy conservation method. This is part of a larger national strategy that aims to install 1.7 million m^2 of solar water heating by 2020 (ADEREE). These projects are also useful in rural areas where they can offer an improved quality

Figure 2: A solar powered, coin-operated water pump that pumps water from a well to provide drinking water for community members

of life without requiring increased energy use or access to the grid.

In the rural community of Sidi Taibi, a rural town with limited access to water and electricity, there is a water purification center that provides water for a high school. The fountain serves as a water hub for the entire community. Water purification is energy intensive, so this project required a large solar panel, wind turbine, and a series of batteries to operate. Renewable energy made the water purification possible in this rural area without relying on grid availability.

More local-scale projects that specifically target groups of stakeholders are invaluable in ensuring that energy improvements reach all citizens, including those in low-income and rural populations. These smaller-scale projects tend to carry a smaller cost yet still have the potential for significant energy efficiency and availability improvements. Due to this cost/benefit relationship, small scale projects are generally worth pursuing, perhaps to a similar degree as large-scale power plants. What small projects lack in prestige and immediate appeal is easily made up for with direct and positive impacts.

3.2 Energy Conservation and Efficiency Projects

Large-scale energy production, as opposed to local-scale production, energy efficiency, or conservation, is the main focus that many agencies, including ONEE, are taking with regard to Morocco's energy plan. These large-scale energy production projects have considerably more momentum than the energy conservation and efficiency projects. Although the Ministry of Energy has involvement with energy conservation and efficiency projects, local-scale projects are given less attention than energy production projects. This suggests that a stable energy economy and citizen energy rights are a larger priority in Morocco than conserving the environment or reducing the carbon footprint.

While renewable energy projects are important for Morocco's long-term energy sustainability, they offer fewer benefits in the short term. Practically speaking, it is unrealistic to assume that Morocco could operate without using fossil fuels for the foreseeable future (ONHYM, personal communication, September 28th 2015). When considering this, it is apparent that Morocco will always have some level of dependence on imported fuel. To further reduce this dependence, energy conservation must be considered.

The act of energy conservation can lead to increased energy productivity and savings worldwide. The cost of conserved energy (CCE) of conservation can be measured by identifying the initial capital costs, the capital recovery factor (dependent on interest rate and lifetime of the loan), the annual operation and maintenance costs, and the annual energy savings. If the CCE is less that the energy price, it is a worthwhile investment and will be profitable over time (Worrell *et al.,* 2003).

The methods used for increasing energy efficiency in Morocco are generally large-scale and sweeping. In 2009, the National Energy Efficiency Program, a national energy efficiency strategy aimed at reducing electricity use 12% by 2020 and 15% by 2030, was launched. The program aims to lower energy usage by focusing on the construction, transportation, and industrial sectors. The largest single step towards reducing energy use was likely the massive reduction in fuel subsidies. Gasoline and diesel subsidies were effectively ended from pressure

from the World Bank and International Monetary Fund, leaving only subsidies for butane cooking gas (El Yaakoubi, 2014) (International Energy Agency, 2014). While reduction of these subsidies was unpopular, there have been no concrete signs of public anger (El Yaakoubi, 2014). Fears of subsidy cuts for butane, which is essential for cooking and heating in the lives of many, are common. Were these cuts to occur, it is easily possible that they could cause widespread social unrest and economic damage (Thakore, 2014). Protests concerning the subsidy cuts were encouraged by the PJD political party, but none of consequence ever occurred. The PJD party holds a majority, indicating that the general public is opposed to this type of subsidy cut, and that cuts of these types likely will not continue. The reduction of the subsidies, however, did have major fiscal benefits, as subsidies for fossil fuels took up 17% of Morocco's total budget (World Bank, 2012).

Some policies put into place have focused on reducing residential energy usage. Law 47-09 set minimum energy efficiency requirements that must be met by all appliances and electrical equipment sold. This ensures that all equipment and appliances sold after 2011 are energy efficient and technologically up to date (United Nations, 2012). A rebate program that has shown success is the "20-20" initiative. The initiative gives a 20% rebate on any energy bill that conserves 20% of energy when compared with that same month in the previous year. This initiative has been popular with Moroccan residents (ONHYM, personal communication, September 29, 2015). Finally, the implementation of daylight savings time in the summer (moving to GMT+1) also has helped to conserve energy, saving as much as 80 megawatts (MEM 2013).

There is a large potential for increasing energy efficiency in the industrial sector. Promoting energy efficiency in buildings is a high potential method for reducing overall energy use. In addition, energy efficient buildings in general have fewer environmental health risks than traditional buildings do due to better climate control and less window, wall, and ceiling draught (International Energy Agency, 2008).

Energy management in offices has the potential for significant energy savings. During off hours, offices use 30-50% of the energy that they use during active working hours. Much of this

is due to heating and cooling costs, ventilation systems, copier machines, computers, lighting, and small appliances. Energy usage in office spaces could be reduced by 60% during off hours which would cause an electricity savings of 20-30%. Simple measures such as using motion sensing lighting can make a large difference in industrial lighting (Blok, 2015).

3.3 Status of Youth and Higher Education

Youth Education

In Morocco, public knowledge of energy issues is limited. When this issue of public awareness of energy issues was discussed with Moh Rejdali, the mayor of the city of Témara, he confirmed that there is a lack of energy awareness in citizens in the region, especially with regard to demand side management and the use of proper lamps. Rejdali also indicated the difficulty of implementing certain laws, such as a law passed by parliament that enforced strategic placement of windows to reduce energy use. Furthermore, when asked what campaign issues are important for voters, Rejdali indicated that services were the most crucial. This opinion indicates that environmental measures that cause behavioral changes may be met with resistance (personal communication, September 22, 2015).

Currently and in the past, there have been educational programs which promote energy conservation. These educational programs inform the importance of energy as a resource. Educating the youth generation is of interest, as increased energy availability gives them the potential to use more energy than previous generations. Between the growing populations, the expansion of the grid, and the increasing quality of life, energy demand is expected to rise dramatically. This rise in demand makes resource management and energy education increasingly important. Adult education programs are less present than youth programs, but as current usage patterns are not unreasonable, this is not a critical issue. Morocco is currently a low contributor to the emission of GHGs, however, as the nation develops it is important to maintain a low energy use per capita. Energy efficient behaviors allow for lower per capita consumption without the added challenge of encouraging lifestyle changes.

In recent years there has been an overall increased interest in environmental matters and environmental education. There have been efforts made by various groups, such as the Ministry of the Environment, to add environmental issues into public school curriculums. The Ministry of the Environment built a learning room for children. Due to limited resources, however, public schools seldom own any form of transportation, making field trips unlikely. The Society for the Protection of Animals and Nature (SPANA) created a highly successful education

program at Sidi Baba. The representative from SPANA in Morocco indicated that a large part of their success came from providing transportation for students to their facilities (SPANA, personal communication, September 16, 2015). In addition, there are several programs that are supported by the Mohammed VI foundation that encourage environmental education for youth. These programs include Young Reporters for Environment, Eco Schools, an Educational Circuit, and communication workshops. The Eco Schools program was designed by the Foundation for Environmental Education (FEE) and was brought to Morocco in 2006 by the Mohammed VI Foundation. This program encourages eco-friendly behavior and presently enrolls 1,127 schools (Mohammed VI Foundation for Environmental Protection, n.d.).

Additionally, advertisement campaigns are an effective way to educate people about energy efficiency and conservation techniques. In 2006, the International Finance Corporation (IFC) helped launch a large-scale advertising campaign called “Save Energy!” in Russia. The campaign used the press, newspapers, magazines, bus stops and subway posters, billboards, television programming, and internet content, to increase awareness among the population. The success of the campaign resulted in a massive increase in CFL adoption, which lead to 838 Gigawatt hours of annual energy savings. Advertisement platforms are an interesting method to increase awareness about a wide variety of issues (Enerdata, n.d.).

Higher Education

There are currently relationships between various organizations and universities that explore energy issues. Supported by Moroccan universities, renewable energy engineers, scientists, and researchers are beginning to become important for Morocco’s economic and environmental future. However, further expansion is possible. In order for Moroccan green energy to be revered on a global scale, international collaboration is crucial. Some universities, specifically Université Internationale de Rabat (International University of Rabat - UIR) are currently working to collaborate, but further commitment to collaboration is important. Wind and solar power are well suited for research in Morocco, as potentials are high and investment

is present. Proximity to Europe could be an excellent facilitator for collaboration with European universities and corporations.

Moroccan universities have some level of communication with the large-scale projects for renewable energy (MASEN, personal communication, September 7th 2015). This kind of connection between institutions is a valuable asset for the development of renewable energy education. By continuing to build connections between educational institutions and governmental groups, connections are more likely to persist when students become full-fledged members of the green energy industry. Linkages between the public sector, private sector, and academia are leading to a more effective industry that is able to develop more quickly, adapt more easily, and cooperate more efficiently.

There have been large successes in renewable energy technology that have stemmed from technologies implemented in Morocco. However, many of these accomplishments have made little impact on the global green energy community. This lack of impact is likely explained by the minimal presence of the projects in the academic community. Few articles are published by Moroccan energy researchers in international journals, and little data is available online.

Initial efforts on increasing international connections between universities are also valuable. An international perspective and the participation in the global scientific community is both important for the development of Moroccan universities, the Moroccan green energy industry, and green energy technology as a whole.

4. Recommendations

4.1 Implement and Increase Awareness about Energy Conservation and Efficiency

Morocco is increasing its energy consumption each year due to its rapid development. The effort to increase the nation's energy supply to meet this demand is heavily supported. However, the concept of decreasing the usage of the current supply of energy by utilizing conservation methods and increasing energy efficiency is underdeveloped. Conserving energy is cost-effective and generally requires small upfront investments that are made back relatively quickly. Reducing use while simultaneously increasing renewable production is an effective way of reducing fossil fuel consumption and eliminating wasted energy.

Residential Sector

Residences consume a significant portion of Morocco's electricity, at around 33% of total use (RCREEE, 2012). Residential energy demand continues to grow as the population grows, rural populations gain grid connections, and new technology develops. Due to these growth areas, efficiency improvements are essential for energy stability. There are many aspects of residences that can easily be improved upon that save unnecessarily wasted energy. These improvements are listed below:

- Efficient light bulb distribution
- Initialize Minimum Energy Performance Standards
- Establish Mandatory Product Labeling and Certification
- Perform Energy Audits

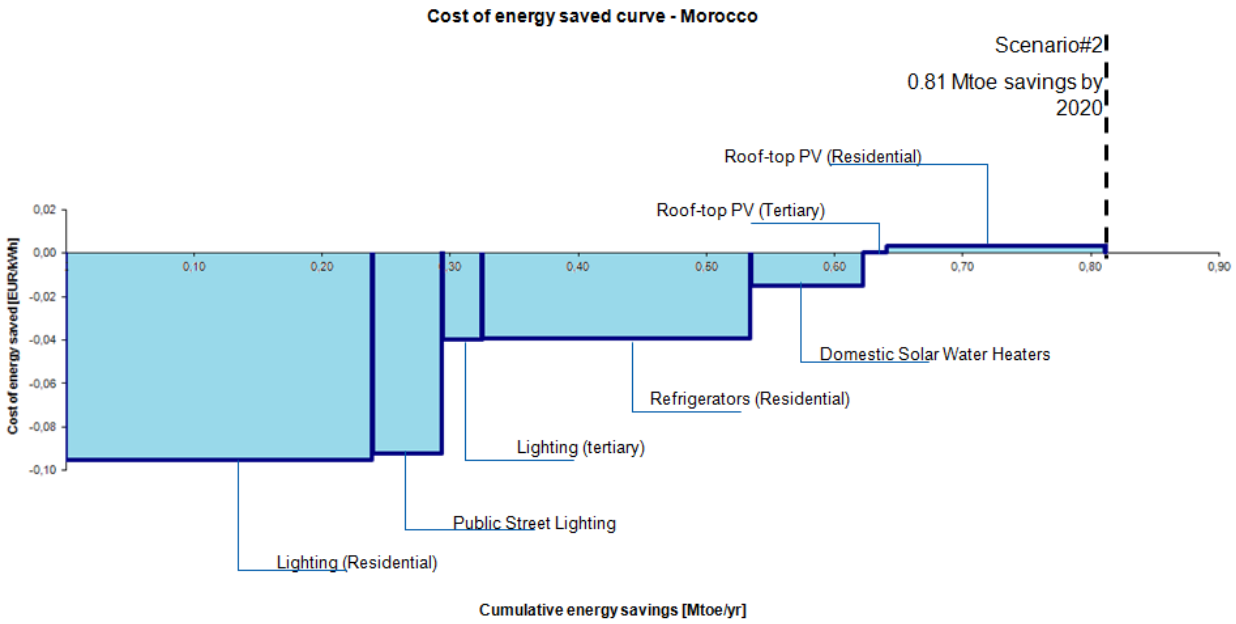

Figure 3: Graph depicting energy saving potential in Morocco

Lighting is a residential area that has already been focused on as a viable improvement for efficiency in Morocco. There is an energy efficient lightbulb distribution program that is run by the government, however it appears that advertisement of this program is low, and there is concern that citizens are not aware enough of this program for its full effects to shine through. This is indicated by a lack of online resources for this program. In order for a light bulb distribution program to reach a maximum number of people, the promotion of the program must be far-reaching and effective.

Continuing to install efficient light bulbs is an important measure for decreasing energy waste, however the current program needs to become more visible. In revamping this program, the government could give away a large quantity of CFLs or LEDs to the general population for residential usage. Another option would be to create subsidies making energy efficient light bulbs more cost-effective. This would encourage people to make this transition because the initial investment would be lower and the cost savings in the long-term would be especially worthwhile. Lighting is a major contributor to energy consumption, so increasing efficiency can make a significant impact.

Incandescent bulbs radiate heat as wasted energy, requiring extra effort from cooling units to compensate. Cooling units are one of the largest energy consumers, so reducing their energy demand is significant.

The widespread adaptation towards more efficient lighting is one of the most practical energy saving solutions for developing countries. The upfront investment is minimal per household, which allows developing nations to participate. The energy savings are both substantial and almost immediate, making a considerable impact in a short period of time.

There are two additional types of government regulations that could increase energy efficiency in Morocco if implemented. These are minimum energy performance standards (MEPS) for new installments and mandatory labeling for new installments. MEPSs are put in place to remove inefficient products from the market by setting efficiency baselines. This has the added benefit of assisting in the evolution of more energy efficient products. It is critical for these standards to be developed frequently because new technology is constantly being developed, causing prior products to become outdated (Blok, 2005). Often the process for establishing the standards for product labeling can be time intensive, and by the time the standards have been agreed upon, they are already almost obsolete. Therefore, it is essential to develop a process to streamline future creations of standards.

Mandatory labeling and certification provide consumers with information, comparing each product in terms of energy efficiency and cost-effectiveness. These comparisons are displayed at the point of sale, which draws extra attention to the instantaneous energy and subsequent cost saving opportunities. Labeling also allows manufacturers to illustrate their energy efficiency technologies which can lead to competition and drive technological innovation. Various developing countries have placed plans to ban the sale of incandescent bulbs to move towards more efficient lighting nationwide. A few South Asian countries, including Sri Lanka and Malaysia, have already put this ban into effect (Gelil, 2011).

Usually when appliance standards are considered, these are set for large appliances, such as refrigerators or washing machines. Labeling and energy efficiency standards are effective ways to reduce energy consumption. Similar methods, however, are not relevant

when it comes to small household appliances such as coffee makers, microwaves, and phone chargers. Small appliances use a small amount of electricity per unit. This means that financially incentivizing energy efficient small appliances will likely not be productive. An effective way of creating energy efficient small appliances is to set practical rules for manufacturing so that the manufacturer can only create a product that meets or exceeds the practical guidelines (Blok, 2015).

A useful technique to determine energy inefficiencies is to perform home energy audits. It is suggested for Morocco to incorporate energy audits into its conservation and efficiency programs. A home energy audit is the process of assessing how much energy a home is consuming, determining inefficient home energy practices, and implementing solutions to make the home more energy efficient (U.S. Department of Energy, n.d.). Homeowners can request to have a professional inspect their home for aspects that need improvement. Energy audits often result in saving energy by sealing air leaks, properly maintaining heating and cooling systems, exchanging inefficient light bulbs (such as incandescent) to more efficient ones (such as LEDs), and checking faucets and pipes for water leaks (U.S. Department of Energy, 2014). In the United States, companies such as National Grid provide free home assessments (U.S. Department of Energy, n.d.). These assessments are an effective tool for identifying energy inefficiencies in residences and providing cost saving and energy reducing solutions.

A method to increase awareness for locals about the ability to request energy audits would be the implementation of an online platform in Morocco. This platform would be able to instruct Moroccan home and business owners on how to perform energy audits and could inform them of national rebates, local rebates, and incentives that would allow them to potentially save money and protect the environment. Online resources are used by many developed countries to spread awareness and make information easily accessible. According to the United Nations, approximately 55% of Moroccans have access to the internet; however, in urban regions of Morocco, where most energy use and inefficiency occurs, 75% of the general population and 90% of the youth population regularly access the internet (Ericsson, 2014). Therefore, the most inefficient energy users are the most likely to be able to utilize this online resource and benefit from this program.

Industrial Sector

The industrial sector is a large energy consumer, using 37% of total worldwide energy (Abdelaziz, 2011). Energy savings potential in the industrial sector varies depending on the specific industry. However, there are some basic energy saving processes that can be used across several sectors to reduce overall energy consumption. As Morocco develops and increases its industrial presence, it is important that energy saving techniques are considered. These techniques often come in the form of increased energy management and government incentives, agreements, or taxation methods.

Energy management training programs could be implemented by the Ministry of Energy, another governmental organization, or an NGO. This type of workshop would convey energy management techniques to business owners who could then implement changes in their workplaces. This type of educational program could take place once or twice a month and would require little cost, but has the potential to educate a large group of people. This is desirable for both the energy sector and the private sector, as it encourages decreased energy use while providing an opportunity to save money for the business owner. In addition, free energy audits could be offered to businesses so that professionals can insert their opinion about energy savings on a case by case basis. This is mutually beneficial to the auditor, who can sell services, and the business owner, who can potentially lower his or her energy expenditure. Strong energy management is vital for energy efficiency in buildings. The goal of energy management is to reduce energy waste without affecting productivity. Energy audits are an energy management tool that searches for areas where energy is being wasted or misused and offers potential methods for changing usage patterns. Another energy management method is providing energy training programs for employees. These programs insert mindfulness into the workplace, encouraging changes in employee behavior such as shutting off computers at night. A third energy management technique is overall housekeeping of the work place. Housekeeping techniques include distributing light sources for optimal lighting and taking advantage of

natural light. Also, painting walls bright colors allows light to reflect and tends to reduce the need for artificial light which can, in turn, reduce energy use (Abdelaziz, 2011).

Additionally, energy efficiency measures can be implemented in the design of industrial buildings. Buildings are generally heavy energy consumers due to climate control, ventilation, lighting, and various appliances. An effective way to convince developers to implement energy efficiency is to offer the potential for money savings. Building owners invest in the cost of making a building energy efficient with the promise that they will make back the invested money in energy savings (International Energy Agency, 2008). Buildings can last many decades, so implementing updated energy efficiency technology in new buildings is crucial for sustainability in the future. It is important to incorporate energy efficiency early on in the design phase of new buildings to reduce the costs of implementing these technologies. There are design features that can cause increased energy efficiency while requiring little or no additional investment. For example, the orientation of buildings and windows and the materials used to construct and insulate a new building can greatly affect energy efficiency (International Energy Agency, 2008).

Minimum energy requirements can be implemented to create an energy efficiency baseline for new buildings. As Morocco continues to develop, infrastructure will expand steadily. It is crucial to increase efficiency as new buildings are constructed, capitalizing on energy savings whenever possible. Even slightly outdated technology can have a significant impact on long-term energy savings, demonstrating the importance of utilizing current efficiency methods.

Education

Habits generally develop most effectively during the early stages of people's lives when they are impressionable and learning at their peak level. This is the stage where education is essential, and when energy conserving behaviors should be encouraged. It is necessary that primary schools stress the importance of responsible energy use at home. There has been an

increased focus on environmental education in Morocco, which is made evident by the endeavors of the Mohammed VI foundation and by the hosting of the Environmental Education Congress in Marrakech. These programs should be pursued and promoted by the government and educators. In addition, there are simple teaching methods, like stressing the importance of turning off lights, which encourages conscientious behaviors. Ways to illustrate these ideas effectively can be to increase exposure in classrooms. Displaying posters that promote environmentalism and energy conservation can be a technique to encourage mindfulness in young students. If children are raised to value conservation, Morocco's per capita energy use can be kept low without requiring disruptive lifestyle changes for anyone.

Increasing advertising presence from NGO's and environmental organizations could additionally increase environmental and energy awareness in Morocco. Since around 90% of the urban youth population regularly have access to the internet, an online platform could reach and educate young people (Ericsson, 2014). NGO's could link up with the government and work to implement these advertisements on common websites such as media players and social media platforms. Advertisement platforms could also be run on more traditional platforms such as radio and TV, and children shows that enforce green behaviors could be run on public television. Educational content could also be displayed in the form of posters in public areas such as train stations.

4.2 Support Local-Scale Energy Projects

Morocco is enthusiastically and successfully pursuing large-scale renewable energy projects. It is relatively likely that the 42% goal will be reached, assuming that Morocco continues with its current momentum and continues pursuing investors. While large-scale renewable energy projects have been successful, small and medium scale projects are given far less attention by the Ministry of Energy, ONEE, and ONHYM.

Distributed generation is a type of local-scale energy project that has shown success in many parts of the world. Small power stations provide many benefits, such as reduced grid demand during peak loads, reduced chance of power loss, and energy generation beyond the reach of the grid (U.S. Department of Energy, 2007). Net metering and feed-in tariffs are distributed generation policy tools that have shown promise in various parts of the world. Law 13-09 allows for businesses to generate their own renewable energy and to profit from the excess electricity via feed-in tariffs. Businesses should continually be encouraged to use such methods to power their facilities, especially in the case of energy hungry industries such as the cement or steel industries, which are responsible for 28.6% and 20.7% of industrial energy use respectively. Similar methods could also be used in a residential setting where residents who have solar panels could sell excess power back into the grid. Renewable energy can similarly be used to power non-industrial endeavors such as water purification centers, desalinization plants, and irrigation systems. In order to implement local-scale projects, many stakeholders need to be involved. It important that projects are integrated both vertically and horizontally. Furthermore, it is important for local authorities to be aware of governmental programs and available opportunities, as well as educate community members on these programs. Residents of the affected community need to be involved in the process of bringing new technologies into their communities. Integrating NGO's into this process is a powerful way to bridge a community with the government. According to an analysis of community-NGO interactions, common pool resources are best managed by informal institutions. NGOs can be effective in assisting with the management of common pool resources for local people in rural areas. NGOs have proven a valuable resource for organizing citizen participation in community matters (Wright, 2012).

4.3 Enhance Morocco's Growing Reputation in the Renewable Energy Space

Morocco's position in the global green energy field is unique and powerful. Morocco has the commitment and successes of larger, wealthier nations, but few of the long-term established patterns of unsustainable energy usage that come with wealth. By leveraging this position and these accomplishments, Morocco could further increase its standings in the field. The recommended approach for increasing Morocco's position is twofold: focus on research and development projects, and promote projects and accomplishments more effectively on a global level. International collaboration is a powerful tool because it allows for increased connections and emphasized attention and prestige for academic research in Morocco.

With increased access to data, the energy community would be able to fully understand and evaluate any accomplishments. The increase in the level of published data needs to extend across all sectors. It is important, for the public sector, that government statistics, new and existing laws, and initiatives are frequently being published in a user-friendly manner, allowing citizens and corporation's up-to-date information. Websites with real-time data (see figure 4) could be valuable for researchers and citizens. Increased transparency allows citizens to view and to learn about the details of these projects. For many, increased interest can lead to increased involvement

Figure 4: An example of a website with real time data concerning energy use (California Independent System Operator, n.d.)

The impact of increased data availability would be multi-faceted. With additional access to data, Moroccans may become more interested in energy issues, possibly increasing their involvement in energy sustainability, or the green energy industry. This data access would also allow universities to learn and better collaborate with one another. This would also make communication across sectors more accessible. An online presence would not directly contribute to the Moroccan green energy infrastructure, but it would significantly contribute to its influence in the field and to its connection with the global renewable energy community.

4.4 Consider New Long-Term Renewable Energy Projects

Pursuing additional long-term energy projects would be beneficial in the future. Morocco's current energy projects are giving it a reputation in the green energy space. As demand grows and research progresses, pursuing new energy projects would be prudent. By being involved with and contributing to research in the green energy sector, Morocco can further prepare itself for more innovative energy projects in the future.

Tidal Power

Tidal power is a promising technology, but it is still undergoing active research and development (see appendix E). Tidal stream generators are early in their development, but some installations, such as SeaGen in Northern Ireland, have seen early success. The Moroccan Atlantic coastline has potential for tidal power generation. The real opportunity, however, lies in the strong and consistent currents of the Strait of Gibraltar. A seafloor mounted tidal stream generator in this location could likely generate a significant amount of electricity if installed (Charlier 2003). While the installation of the generators may difficult considering shipping traffic, the generators themselves would be deep enough to avoid any possible collisions. With careful planning of turbine placement, issues with scheduling installations with maintenance could likely be solved. A partnership between the Moroccan government and Spanish government would allow for an array of generators, spanning from the Moroccan seabed into the Spanish seabed, which would increase the potential of this project and bolster the grid interconnections between them.

Since this field is burgeoning, Morocco has the potential to enter into the research phase of this technology. By partnering with other researchers, Moroccan universities could play a major role in the research and development of tidal stream generators. Moroccan researchers and universities could attempt to collaborate with educational groups like IDCore (a multi-university collaboration that gives engineering doctorate program focusing on offshore energy research, including tidal) or research groups like the European Marine Energy Centre (a

major tidal energy research and testing group). If Moroccan universities and companies can cement their position as effective researchers and global collaborators, Morocco could gain a position as an international leader in tidal power while also growing the local green industry.

Nuclear Power

Morocco has made substantial strides over the past few years in expanding its energy capabilities to meet its development needs. This progress suggests the possibility of successfully installing nuclear power in the future. From an economic standpoint, Morocco may already have the resources needed for nuclear power. Gaining international support may be a lengthy process, but considering Morocco's stability, it certainly seems feasible.

Morocco could greatly benefit from nuclear power to meet its growing energy demands, decrease import dependency, increase diversity of energy sources, and mitigate local and global air pollution (Jewell, 2011). It is recommended to continue research and development for nuclear power, and consider the possibility of making the needed investments for a nuclear power plant in the future.

Offshore Wind Power

In Morocco, most energy is consumed in coastal areas (Bennis, 2015). This is a benefit of offshore wind power in Morocco, as energy is produced just off the coast, making it easy to import to nearby populations. Close proximity to a power generation area shortens power line distances, reducing the electricity lost during distribution, and increasing the reliability of service (NREL, 2006). The power transmission lines are buried deep below the seabed, which protects them and reduces risks of distribution failures.

Morocco has already constructed effective wind farms on land, but the variability of wind conditions has hampered the progress of these developments (MASEN, 2015). Offshore wind helps resolve this issue because of the increased consistency of wind patterns. It is

suggested for Morocco to pursue this emerging technology, and in the future, initiate its own offshore wind program to capitalize on the aforementioned benefits.

Algae Biofuel

Algae biofuels could offer Morocco an effective method to use renewable resources to power already existing machinery that relies on the fossil fuel infrastructure. This could help to improve energy security by reducing fossil fuel use in areas that would be difficult to reach in any other way.

Even with its rapid development of renewable power, Morocco will continue to use fossil fuels for the foreseeable future since, in many cases, replacing existing technology is not cost-effective (ONHYM, personal communication, September 28, 2015). Biofuels offer a stop gap solution, reducing use and emissions for older technology. Biodiesel can be used in unmodified diesel vehicles. Biofuel ethanol can be used as an additive in gasoline in unmodified cars, helping to reduce emissions and fossil fuel use. For a developing country like Morocco, it is unrealistic to assume that all legacy equipment, especially in the agricultural and transportation sectors, could be replaced with energy efficient alternatives. By adopting biofuels, renewably generated power could be used for older machinery and equipment without the need to invest in replacements.

Traditional biofuels, while potentially beneficial, are not especially practical. Most fuel crops require excessive land, are too costly, and offer little fuel as a yield. Considering Morocco's agricultural capacity, traditional biofuels would need to imported, and would offer few improvements over fossil fuels. The use of land and crops for biofuels can also increase food prices. Considering the many subsidies on food that are already in place, this could be disastrous for Morocco. This type of effort could have positive environmental impacts but would not help to increase Morocco's energy independence.

Recently, there has been growing research in the development in novel biofuels. This could be viable in Morocco. One area of research is in using algae to create to create fuels.

Algae fuel is perhaps the most promising approach for creating biofuels, including biodiesel or ethanol. This technology lacks many of the downsides of using traditional fuel crops but retains many of the benefits, like its sustainability, relatively low cost, and near carbon neutrality (Appendix G).

Algae biofuels are also complementary to the efforts to combat Morocco's water shortage. Part of the solution to this shortage is effective wastewater treatment and reuse. Algae is already commonly used in the wastewater treatment process. If one uses the correct species of algae and the correct process, algal biofuel can be collected as a byproduct of the wastewater treatment process (Appendix G).

Algal biofuel technology is currently functional but expensive, especially when the process is combined with waste water treatment. Before these technologies can be viable in Morocco, they must undergo additional research and development to become cost-effective. These technologies could offer significant benefits when they become cheaper in the near future. Moroccan universities and researchers also may be able to accelerate the growth of these technologies with research and industrial partnerships.

Conclusion

The energy situation in Morocco was assessed regarding energy production, consumption, efficiency, and conservation methods. Present initiatives to increase energy supply security and decrease energy consumption were evaluated. Professionals including engineers, scientists, NGOs, and governmental agencies were interviewed to further understand Morocco's energy situation. The data retrieved from interviews, current renewable energy projects, energy policies, and conservation measures enabled a comprehensive analysis of Morocco's energy status and the formulation of recommendations centralized around sustainable energy development.

Morocco's energy goals are ambitious but attainable. These goals are being pursued enthusiastically with some success but some areas of Morocco's energy policy are slightly lacking. Important conservation projects are underdeveloped, enforcement and implementation are frequently incomplete, and public awareness of environmental issues is low. While Morocco is well ahead of many of its peers when it comes to green energy development, there must be continued progress if it wishes to become a global leader. By addressing these issues and focusing on all facets of its energy issues, it is feasible for Morocco to become a model nation for sustainable development.

Appendix

Appendix A: Methodology

Introduction

Before arriving in Morocco, background information on Morocco's energy policy was obtained during a seven week preparation period. Then, after arriving in Rabat, loosely structured interviews with Moroccan stakeholders were conducted in order to perform more in-depth research on energy sustainability. These interviews aimed to uncover information regarding energy priorities, laws, and development in Morocco. After the data was collected, it was analyzed, and a report was made for Ribat Al Fath for Sustainable Development. This report included an analysis of the shortcomings of Moroccan energy policy, and offered recommendations to resolve these shortcomings.

Project Objectives

In completion of this IQP, we:

1. Collected background information and statistics on Morocco's energy profile.
2. Interviewed key stakeholders in order to gain insight from experts and stakeholders in NGOs, government offices, and industry.
3. Analyzed background information and stakeholder perspectives to understand strengths and weaknesses in Morocco's energy plans.
4. Produced a report which presents Morocco's energy state and offers recommendations based on analyses of current practices both in Morocco and internationally.

Conducting Interviews with Stakeholders

Loosely structured interviews were the primary means to extracting information from stakeholders. Before arrival to Morocco, interview strategies were submitted to and improved

by the Institutional Review Board (IRB) at Worcester Polytechnic Institute. This insured that all questions were regulated and ethical. In order to prepare for these interviews, the stakeholder was researched. Based on published work and background information on the stakeholder, open-ended questions were written to further extract information on matters that were unclear, under-published, or of high interest. Before the start of each interview, a request was made to record and use the contents of the interview. These requests were always granted without any difficulties. At most interviews, stakeholders gave a brief presentation. This presentation usually described the aim of the presenting group and offered enriching background information. Often new information was learned that was not found online previous to the interview. In these cases, questions were altered to better understand the new information. In other cases, discussions did not lead to certain questions, causing these questions to be omitted. Questions frequently changed during the interview and these changes were noted. When interviews were completed, contact information and a copy of the presentation slides were obtained if applicable.

Notes were taken at the interviews by all members of the team. Notes were combined and cross-referenced in order to make sure that all information was accurate and understood. Research was conducted post-interview on discussed topics and further findings were extracted. At the conclusion of the final interview, the notes from all of the interviews were analyzed. Questions were organized by topic with similar responses placed next to one another under the relevant question with the name of the stakeholder attached. This method allowed for comparison of responses to questions that were the same or similar, as well as for the perspectives of varied stakeholders to be compared.

Stakeholders Interviewed

While valuable information on energy use was acquired from published works and government statistics, more specific data was needed in order to make relevant suggestions. Various stakeholders were interviewed to gather this information. These interviews provided perspective about various energy concerns in the region regards to production, consumption,

conservation, efficiency, and education. Stakeholders were from various backgrounds and included scientists, engineers, professors, politicians, and rural farmers.

Stakeholders in the scientific and engineering fields included environmental scientists, engineers in the renewable energy industry, and research scientists. Interviewing scientists and engineers provided insight on Morocco's technical resources and whether or not these resources would be sufficient for renewable energy technology and maintenance.

Meetings were held at two universities, Université Ibn Tofail in Kenitra (Ibn Tofail University) and the Université Internationale de Rabat (International University of Rabat, UIR). University Ibn Tofail in Kenitra had science and engineering programs and are interested in integrating renewable energy into the university. The president of the university was consulted about the university's interest in sustainable energy usage in Morocco. The visit to the university included a campus tour which highlighted differences between Moroccan and American universities, contrasting different approaches towards accomplishing worthwhile solutions. The UIR's strong renewable energy science program was evaluated to identify and understand research being done to improve Morocco's energy status. The Vice President of the Renewable Energy School was met with in addition to several students in the school. This included the student President of the school's Energy Club. A tour highlighting the university's green energy projects was taken and information about these technologies was obtained.

Moroccan agencies were interviewed to collect information about the national energy status and current measures to improve this status. During the interview with the Moroccan Agency for Solar Energy (MASEN), questions were asked to address their role in solar energy production, the general energy profile for Morocco, and their strategy for meeting the goals set by the Moroccan Solar plan. The Office Nationale de Hydrocarbures et des Mines (National Office of Hydrocarbons and Mines, ONHYM) was visited and Amina Benkhadra, the general director, was interviewed. ONHYM's mission is to manage the mining and use of fossil fuels in Morocco. Strategies to diversify energy production, mobilize natural resources, increase energy efficiency, and integrate the region effectively were discussed in order to understand the

significance of non-renewable energy in Morocco. ONHYM's viewpoint on the utilization of shale resources was explained as well.

Representatives from several government ministries were also interviewed in order to provide data on energy policies, discuss the implementation of energy laws, and describe how these policies would affect constituents. These interviews also provided insight regarding the interest of Moroccan people in energy conservation and environmental issues. Individuals were interviewed at the Ministry of Energy which further strengthened our understanding regarding Morocco's current energy status. Morocco's main energy goals were outlined, and its priorities were ranked to identify the areas of primary concern for the ministry. The ministry representative discussed several issues concerning domestic energy. This included large-scale energy production, finances, and energy conservation and efficiency. Representatives at The Ministry of the Environment were also interviewed. Several ministry members from different departments were asked to discuss environmental issues in Morocco. The topics that were highlighted include climate change adaptation and prevention policies, environmental awareness strategies, and fossil fuel reduction initiatives.

A group of representatives from three local NGOs were interviewed as well. These organizations each sent a representative to discuss their primary initiatives. The first representative worked with the Society for the Protection of Animals and Nature (SPANA). This representative explained his objectives and experiences regarding animal protection, conservation of nature, and environmental education. The next interviewee represented the Alliance Marocaine pour le climat et le développement durable (AMCDD). He was asked about education, awareness, and communication between NGOs and the government. The final representative was member of Moroccan Association for Regional Science and a professor of forestry. He was asked to discuss the importance of adaptation to climate change and to speak on his experiences with the implementation of environmental policy

Contact/Representative	Agency	Date
Obaid Amrane	Moroccan Agency of Solar Energy (MASEN)	9/7/2015
H. El Bary	Universite Ibn Tofail	9/10/2015
H. El Bary	Lycée Al Annouar	9/10/2015
Secrétariat M. Geanah Fouad Douri	Ministère délégué pour l'Eau (MEMEE)	9/11/2015
Secrétariat B. Bouguenouch	Agence des Bassins Hydrauliques de Sebou (ABH Sebou)	9/11/2015
Secrétariat A. El Hafidi M. Adiel (member RAF) Zohra Ettaik	Ministère délégué pour l'Energie (MEMEE)	9/15/2015
Cabinet H. El Haite Cabinet Ministre: Mme Lahrissi	Ministère Délégué pour l'Environnement (MEMEE)	9/16/2015
Representative in Morocco	Society for the Protection of Animals and Nature (SPANA)	9/16/2015
M. Bouchafra	Alliance Marocaine pour le climat et le développement durable (AMCDD)	9/16/2015
Secrétariat A. Khattabi	Association Marocaine des Sciences Régionales (Moroccan Association for Regional Science)	9/16/2015
	Haut Commissariat Eau et Forêts et à la Lutte contre la Désertification (HCEFLCD)	9/21/2015
	Visit to Had Berachoua, a rural farming village	9/22/2015
Moh Rejdali	Mayor of Temara	9/22/2015
	Université Internationale de Rabat	9/28/2015
Amina Benkhadra, General Director	Office National des Hydrocarbures et des Mines (ONHYM)	9/28/2015
	Office Régional de Mise en Valeur Agricole du Gharb (ORMVAG)	9/29/2015
	Ministère de l'agriculture	9/29/2015

Appendix B: Ribat Al Fath Meeting Diary

Date	Activity	Notes
Thursday, 8/27/2015	**Initial meeting with Mr. Bennis at Al Fath**	Basic introduction, talked about what should be included in the final report,
Friday, 8/29/2015	**Team Meeting**	-Re-read Project Proposal -Analyzed Ribat Al Fath Documents for background -Prepared Questions for Meeting with the President
Saturday, 8/30/2015	**Meeting with Al Fath board and president**	Learned more about the organization, asked questions about the organization, took pictures
Monday, 8/31/2015	**Mr. Bennis Meeting**	- Assessed meeting with president (8/30/2015) - Discussed the upcoming elections - Tools for sustainable development - SWOT, DPSIR, and Logical Framework
Tuesday, 9/1/2015	**Team Meeting at Ribat Al Fath**	-SWOT for several Issues in Morocco (social, economic, environment, cultural, political, etc.) -SWOT for Energy
Wednesday, 9/2/2015	**Meeting with Bennis (State of Morocco)**	Discussed general information about the state of Morocco. We discussed the population, the income, geographic relevance, biodiversity, overexploitation of crops, rate of inflation, water problems, budget, illiteracy, political stability,
Thursday, 9/3/2015	**Team Meeting at Ribat Al Fath**	More research
Friday, 9/4/2015	**Meeting with Bennis (Energy)**	-Primary and final energy -energetic intensity -Renewable energy generation -MASEN -ONEE -Other energy organizations
Monday, 9/7/2015	**Moroccan Agency of Solar Energy (MASEN)**	- Discussed Moroccan energy profile - Ouarzazate solar plant - Discussed different solar technologies

Tuesday, 9/8/2015	**Meeting at Ribat Al Fath**	-Group Research on several topics -Concentrated Solar Power -Industrial Sector -Energy Consumption from Desalination -Interview Notes Integration -Background Research on University of Ibn Tofial in Kenitra (Translating information from their website)
Wednesday, 9/9/2015	**Meeting with Bennis (Water)**	-Water Shortage Issue in Morocco -Erosion and Waste water -Agriculture Impact -Influence of Pollution -Water Usage in Industry -Water Supply Awareness Issues -Formulated Questions for the University
Thursday, 9/10/2015	**University of Ibn Tofail in Kenitra** **Rural village tour of water facilities at high school**	- Tour of campus - Meeting with president - Water purification laboratory -Incorporation of Renewable Energy into the University
Friday, 9/11/2015	**Ministry of Water/ONEE** **Tour of a Dam**	Ministry of Water -Met with head of water resource division -Goal: meet national water strategy of Morocco -Mobilization of water resources -Drinking water -Sanitation -Irrigation -Climate Change Impacts -National Water Strategy of 2009 -Impacts of the Weather National Office for Electricity and Drinking Water (ONEE) -Biggest Water Treatment Plant in Africa -Desalination -Water Treatment and Sanitation -Water energy consumption
Monday, 9/14/2015	**Meeting with Bennis (Environmental State)**	-Waste in Morocco -Recycling Issue -Environmental Attention in the Media

		-Moroccan Methods for Environmental Sustainability -Discussed Questions for the Ministry of the Environment
Tuesday, 9/15/2015	**Ministry of Energy**	- Discussed current energy situation, renewable energy production, etc. - Asked question about energy efficiency and conservation laws - Energy economics and finance - Strategy challenges
Wednesday, 9/16/2015	**Ministry of the Environment** **- 3 NGO's (SPANA, AMCDD, Moroccan Agency for Regional Science)**	-Policies to combat climate change -Strategies to preserve biodiversity -Waste Management and Recycling -Fossil Fuel Emissions Protection Policies -Awareness Strategies for Environmental Issues
Monday, 9/21/2015	**- HCEFLCD (Center for Forestry Research)** **- analyzed meeting notes** **- Team Meeting**	HCEFLCD -Power Plant Impacts on Natural Habitats -Power Plant Site Determination Procedure -Policies to protect nature and wildlife Team Meeting -Combined meeting notes from all meetings -Made one concise document with the bulk of the information gathered from all organizations.
Tuesday, 9/22/2015	**- Tour of Had Berachoua** **- President of Temara** **-Team Meeting**	Had Berachoua - Met with the president on an NGO who work to provide training, water, and electricity to rural farmers - Took a tour of a farm, were told about biofarming, saw the well that powers the drip irrigation system at the farm. - Took a tour of a second farm, met some women and their children, saw a second well, saw a solar powered water pump Mayor of Temara - Talked about energy efficiency policy, lack of residential awareness, wastewater Meeting -Outlined and organized our findings and thoughts

		-Started with the method section -Made this diary
Wednesday, 9/23/2015	**Team Meeting**	
Monday, 9/28/2015	**UIR** **ONHYM**	UIR -Met with VP of energy program -Information on energy program and university partnerships -Toured energy infrastructure (solar farm, solar cube, solar water heaters ONHYM -Met with general director of ONHYM -Current status of various energy and energy efficiency projects -Information on traditional power plants under construction -Information on environmental impacts of power plants and mining
Tuesday, 9/29/2015	**Visit to large farm and Ministry of Agriculture** **Team Meeting**	Visit to farm (Jules Voltaire and Bryan Sellers) -Water Pumping/Filtration Plan -Power Grid Integration -Electricity Usage and heating/cooking fuel Team meeting (Sydney Gustafson and William Hartman) -Continued work on introduction and background (editing, polishing, reorganizing, adding new sections) -Started evolving outline of deliverable into a concise product
Wednesday, 9/30/2015	**Team Meeting**	Continued work on IQP report, project deliverable, and project presentation.
Thursday, 10/1/2015		

Appendix C: SWOT

SWOT is a technique designed to aid in the planning process by applying a rigid structure and aiding in comparison. In SWOT, the strengths, weaknesses, opportunities, and threats are outlined. Actions can then be planned to emphasize strengths, minimize weaknesses, utilize opportunities, and address threats. By using structured techniques such as SWOT, one is able to ensure that all facets of a situation are considered and evaluated. The SWOT technique was applied to over the course of this project.

SWOT for Energy in Morocco

Strengths	**Weaknesses**	**Opportunities**	**Threats**
Ambitious goals for renewable energy generation Strong wind and solar profiles Strong support from King Mohammed VI and other agencies	Imports 91% of their energy from foreign nations High energy costs and consumption Low energy access in rural areas Industry uses 38% of Moroccan energy Many areas not covered by grid Primary energy consumption is expected to triple between 2010 and 2030	Generate 48% of energy from renewable energy Reduce CO_2 emissions Reduce energy costs for residents through conservation Reduce pollution and increase air and water quality Encourage energy conservation Combine electrical grid with other Maghreb nations	Budgetary issues increasing costs of electricity Lack of public interest Issues with storing renewable energy generated but not used

Appendix D: Solar Power Technology

A solar panel is made up of small, solar cells also known as photovoltaic cells (PV cells). They are a very thin layer that is made from, most of the time, silicon and other conductive materials. Two types of silicon are used inside the solar cell: the n-type, which has spare electrons and the p-type, which has holes for missing electrons. The double silicon layer creates an electric field. When the light from the sun strikes the solar cell, photons radiated from the sunlight collide with loose electrons on the silicon and transfer their energy to these electrons. The electric field then drives the electrons in an orderly manner and creates electricity that can be used or stored (Union of Concerned Scientists, 2015).

Appendix E: Tidal and Wave Power

Tidal power is a hydroelectric power source with significant potential. It may offer significant returns with a reduced cost and fewer ecological impacts that traditional dam-based approached. While tidal power generation is promising, its real-world use is currently limited. Small installations have found success, but there are few large-scale installations in progress. While tidal energy have high potential for the coastal Morocco, investing in such an immature field may not be intelligent at this time.

Tidal energy generators come in several forms. The most promising of which are tidal stream generators. Tidal stream generators use underwater currents to generate electricity using a windmill-like turbine. Other generation sources include tidal dams and generators that float on waves, but the return on investment of these options is low. Tidal stream generators also have the lowest potential environmental impact (Elgalhi *et al.*, 2007; Boehlert *et al.*, 2010).

Figure 5: A map of the Strait of Gibraltar (Britannica Online for Kids. n.d.)

When tidal power is more mature, there is significant interest in the installation of a tidal stream generator in the Strait of Gibraltar (Charlier 2003). Since currents at this point are exceptionally consistent and strong, the potential for electricity generation is considerable. At the present time though, this project is entirely hypothetical and no planning has begun.

However, in the future, tidal generation in the Strait of Gibraltar may be a significant asset in Morocco's renewable energy efforts.

Appendix F: Nuclear Energy Technology

Nuclear technology uses the element Uranium as its fuel source. Uranium is naturally occurring in the earth's crust, which allows it to be extracted via mining. The mined Uranium (U_3O_8) is only mildly radioactive, which limits its energy capabilities. Accordingly, the Uranium is enriched by concentrating the material and converting it to a gas. After enrichment, the Uranium is compressed into fuel pellets and stored in rods for power plant usage (World Nuclear Association, 2015).

The fuel pellets are used to fuel the reactor by splitting the U-235 isotopes in a chain reaction, producing large quantities of heat. Water is boiled using the heat from the reactor core, which powers a steam-turbine generator. The water used is recycled by condensing the steam after it passes through the turbine. The fuel pellets are replaced occasionally for optimum heat output and energy generation (World Nuclear Association, 2015). This cycle is illustrated in the figure below:

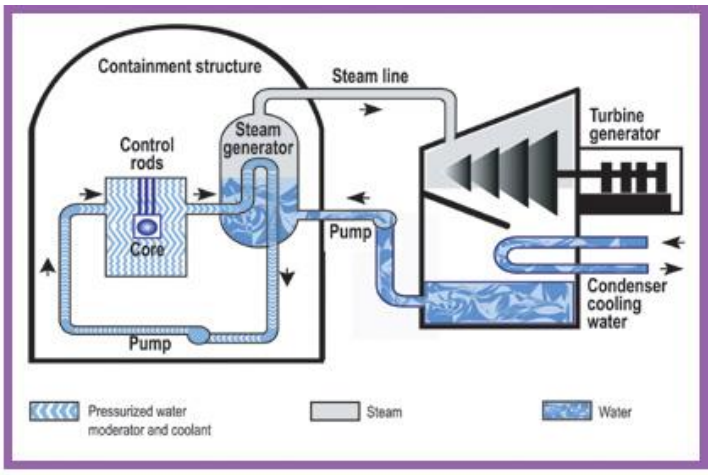

Figure 6: Power generation process for nuclear energy

High-level waste is created from the used fuel pellets and low-level waste is formed from tools and materials involved in the process. High-level waste makes up a small component of the total waste, but it is the most radioactive. The high-level waste from the reactor is cooled and stored in either pools of water (for up to 50 years) or underground storages. Low-level waste is disposed of more easily in less advanced underground depositories. Civil nuclear

wastes from power plants have never hurt the environment, animals or people. Over time, nuclear waste gradually loses its radioactivity making it even less dangerous to manage (World Nuclear Association, 2015).

Appendix G: Algae Biofuel Technology

Algae growth for biofuel production is a promising emerging technology for sustainably producing oil substitutes. Through industrial processes, algal biomass can be converted into methane, ethanol, butanol, and potentially hydrogen (Lundquist *et al.,* 2010). These fuels can burned for power, or used directly by existing diesel machinery. Since CO_2 released by the combustion of the resulting biofuel was consumed by the algae when they were growing, algae biofuels are carbon neutral and environmentally sustainable. Considering these factors, algal biofuels are a high potential method for continuing to use existing infrastructure and machinery without contributing to global climate change and reducing the emissions of other pollutants.

Many of these benefits are factors of biofuels in general rather than benefits of algae fuels specifically. Algae fuels however, are better positioned to provide both the benefits of biofuels and perform other useful services. The process for producing biofuels is relatively independent to the varieties and actions of the algae. While they are growing, these algae can perform useful functions, such as aiding in the treatment of wastewater, which is used as a growth medium due to its high nutrient content (Lundquist *et al.*, 2010). Algae also grows more effectively when CO_2 is bubbled through the growth medium. This CO_2, like the growth medium, can be reused, often using flue gas from the burning of fossil fuels. Furthermore, algae grows more quickly, more easily, and on a smaller land area than other biofuel sources (Chisti, 2008).

Some species of algae, such as Spirulina, can be grown in open, outdoor ponds. This approach is simpler and cheaper to reach high yields with, but contamination from other species of algae or microbes can be a significant risk. Some of this risk can be mitigated with a high bicarbonate growth medium and using an inoculum. For some species of algae however, the conditions needed to avoid contamination are unsuitable for the growth of the algae itself. These species need to be grown in closed bioreactors. For these species, it can be harder and more costly to reach high yields (Lundquist *et al*., 2010).

Algae is commonly used in the wastewater treatment process. If the right species and processes are used, biofuels can be generated with the resulting algal bloom. The process currently must take place in large ponds (usually 0.4 hectares per 100 to 200 people's worth of waste). The size of these ponds causes problems when collecting bacteria, as chemical products needed are cost prohibitive (Lundquist *et al.*, 2010).

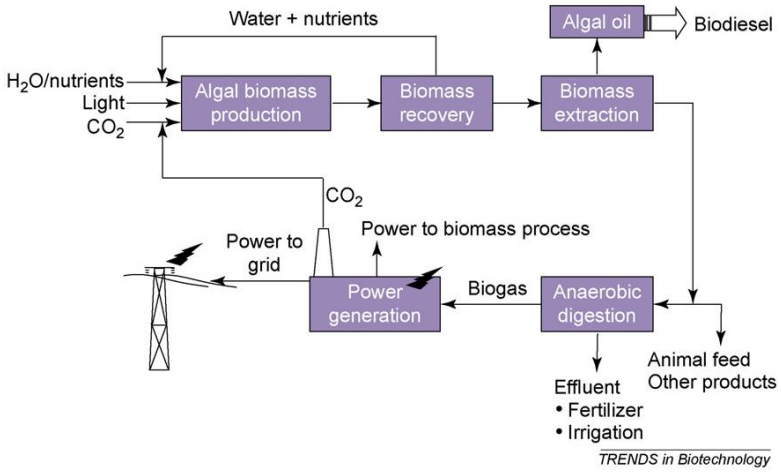

Figure 7: Process of creating biofuels from algae

Appendix H: Electricity Generation and Distribution

Energy production is only the start of the process of supplying power to the consumers. The power is generated at the source, which could range from anything from a massive coal-fired power plant to a solar panel on a resident's house. In a large power plant, the power is generated and immediately after generation, it passes through a step up transformer. This raises the voltage, so less power will be lost in the transmission lines. Next, the electricity runs through the transmission lines to a substation in a local consumption area. The electricity is converted to a lower voltage to be distributed through basic power lines to industries and residences safely.

The electricity produced from the source must be used immediately by consumers. If there is any excess electricity produced, it cannot be recycled or stored for later use. Highly efficient, capacitive and cost effective storage techniques have not been developed, making storage ineffective. The surplus of energy produced dissipates as wasted heat energy. This concept forces producers to constantly monitor how much energy is being consumed at one time in order to decide how much energy to produce at any given moment. Producers generally approximate the amount of power they will need to put out based on averages. These approximations vary by weather, time of day, and other factors that cause energy usage to fluctuate.

This standard process has a few flaws that make it less effective. The entire process causes a loss of up to 18% throughout the long distance traveled in the resistive transmission lines and the voltage conversions that take place (Morad, 2013). This is purely wasted energy that makes a significant impact in regarding energy conservation. The electricity in the grid runs in series, which means that if a wire along the way disconnects, the entire consumer population can lose power. Once the power is lost, the distribution companies have to locate the disconnection before they can fix the problem, which can take hours. Approximately 90% of power outages are from errors in the distribution system (Farhangi, 2010), so identifies a serious problem that needs viable solutions. These flaws can be improved upon by switching to a smart grid.

Appendix I: Interview Questions

High Commission for Water and Forests and Combating Desertification (HCEFLCD)

1. Do large-scale power plants have the potential to destroy habitats or forestry?
2. Is there an education campaign to encourage rural populations to plant more trees or to not cut down trees unnecessarily?
3. What process would one need to go through to receive seed subsidies?

International University of Rabat (UIR)

1. It has been stressed that the renewable energy school is a locomotive for local strategies. Can you describe any current or completed projects? How do you receive funding?
2. What do students at UIR do to protect the environment?

Moroccan Agency of Solar Energy (MASEN)

1. How will you affect the domestic economy? Do you use competitive bidding?
2. What types of professionals would be needed to upkeep new energy technology? Is that type of work force available in Morocco?
3. Can you describe the Moroccan grid capacity? Can it integrate new technologies? Is it possible for the grid to be connected to a broader grid system such as one in Europe?
4. Why do you focus on solar power over other sources of renewables considering the pricing, the environment, and other issues?
5. Can you describe collaboration that MASEN does with other organizations such as ONEE, the Ministry of Energy, or other NGO's?
6. Can you describe if your work will have an effect on impoverished people in Morocco? Will there be efforts to bring cheaper electricity to people living in slums? Will there be efforts to expand the grid to include more people in rural areas?

Mayor of Temara

1. What were some of the main points in your election campaign? What do the people care about? What do they look for in a politician?
2. Are there any local policies that the government of Temara uses to enforce energy efficiency or conservation?
3. Can you indicate the status of communication between yourself and various ministries and governmental groups such as the Ministry of the Environment and ONEE?
4. Can you discuss energy efficiency in building strategies?

Ministry of Energy

1. With the majority of focus on the development of new power plants, energy efficiency development seems to have stagnated somewhat. Why does the focus remain here?
2. Is this focus related at all to the global investments in renewable Moroccan energy? Do the interests of these investors align with Morocco's best interests?
3. Will producing many power plants affect Moroccan people?
4. Morocco has goals to generate 42% of its energy from renewable resources by 2020. If this goal is achieved, how much energy will remain in Morocco? How much will be exported?
5. Portions of Morocco's grid are reaching the age where they will need to be replaced. What is the current status of the grid's efficiency, and will it be improved in the upcoming years?
6. In the past, the Arab Maghreb Union aimed to increase the interconnection between electrical systems in North African countries. While this initial attempt seems to have failed, is an interconnected grid still considered a goal for Morocco?
7. Are there any expected changes in energy policy due to the recent elections? For example, the Islamist party showed interest in reducing energy subsidies.
8. What are you opinions in net metering and feed-in tariffs?
9. What is the status of hydroelectric power in Morocco?

Ministry of the Environment

1. What is the prediction of rainfall change due to climate change?

2. What policies are in place to protect the environment from pollution from fossil fuels, and how are these policies enforced?
3. How is the environment considered when selecting land for large-scale renewable energy plants (which are being built quite rapidly)?
4. Do you do work to increase awareness about environmental issues? How do you work to promote the culture of sustainable development?
    a. How is the average person educated?
    b. How do you reach the illiterate and poor?

NGO's

1. What are the projects carried out by your NGOs that you are most proud of?
2. What are the most effective ways that NGOs use to bring about change?
3. How do you communicate with other NGOs and government agencies?

National Office of Hydrocarbons and Mines (ONHYM)

1. What is the nature of your collaboration with other organizations such as ONEE, the Ministry of the Environment, the Ministry of Energy, and/or universities?
2. What controls are there currently in place for any wastewater produced during mining processes? Where are your largest mining facilities?
3. Have you considered nuclear power as an energy source?
4. How do you communicate with other organizations? Do you use internet based communication methods?
5. Can you elaborate on regional integration and Morocco's interest in exporting energy?
6. What is the likelihood of the extraction of shale oil and hydraulic fracturing "fracking"? What is your opinion on the potential environmental effects of this extraction?

University Ibn Tofail

1. Does the University implement project based learning?
2. What is the power source for the water purification station?

Village Had Berachoua

1. Could you describe electricity use of your (the average) family? What is your current level of access to electricity?
2. What is your current level of use of fossil fuels (gasoline, diesel, cooking gas, etc.)?
3. Do you ever burn wood or plants for cooking or heating?

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