# Energy Sustainability in Morocco

Interactive Qualifying Project Report completed in partial fulfillment

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# 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.

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# Executive Summary

## Background

Morocco is largely dependent on foreign nations to meet its energy needs, with 96% of energy being sourced externally. Furthermore, with a rapidly growing population and an increasing quality of life, Morocco's energy use is expected to quadruple by 2030 (Norton Rose Fulbright, 2012). Between this dependency and expected growth, Morocco's energy security is in jeopardy. To combat this growing concern, Morocco has turned towards meeting energy needs internally.

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

## Methods

The overall goal of this project was to suggest possible improvements to Morocco's energy policy by identifying gaps and evaluating social, political, economic, and technical factors. This team interviewed scientists, engineers, non-governmental organizations, and governmental groups on what they believe are major challenges and opportunities in Morocco reaching its sustainability goals. Interview questions were written on a case by case basis depending on the mission of the group being interviewed. Interview responses were then analyzed and an official report was created in order to make suggestions on how Morocco can better achieve its goals.

## Findings/data

Morocco is heavily pursuing renewable energy by implementing large-scale power projects. The Ouarzazate solar plant's first phase, Noor I, is ready to be activated. The other three phases, Noor II-IV, are under development. Upon completion, this plant will produce 500 MW of solar energy and will meet 25% of Morocco's solar energy goal (MASEN, personal communication, September 7, 2015).

In addition, Morocco has suitable conditions for wind power plants, with 17 regions that have been marked as suitable for wind power development (Enzeli, 1998). There are currently several large wind farms progressing under the ten year Moroccan Integrated Wind Energy Project, which aims to expand the wind energy capacity from 280 MW in 2010 to 2,000 MW in 2020 (Moroccan Investment Development Agency, n.d.).

These large-scale projects are supported by more local-scale projects. These include hydroelectric power development, rural electrification, net metering and feed-in tariffs, and the implementation of solar water heaters and solar powered water pumps.

Increasing energy efficiency is an effective way to help ensure the security of energy supply in the long-term (International Energy Agency, 2008). In 2009, Morocco launched the National Energy Efficiency Program which aims to save 12% of electricity by 2020 and 15% by 2030. Several policies have been implemented to increase energy efficiency and encourage energy conservation. These include minimum efficiency standards, rebates on energy bills, and the implementation of daylight savings time.

## Analysis

Currently, reaching the national goal of producing 42% of energy from renewable resources is feasible, however it is not guaranteed. The level of success is contingent on attracting foreign investment and the continued stability of the Moroccan economy. Large-scale power projects are Morocco's main focus regarding energy policy. Energy efficiency and conservation projects are being given less attention than large-scale projects, even though they offer promising results if properly implemented and enforced.

Young people in Morocco are expected to have higher expectations from technology due to Morocco's rapid development and technological advancements. Accordingly, education programs regarding energy issues are important. It is important that children are educated about energy conservation and issues from a young age so that they can be mindful adults.

There are currently relationships between various organizations and universities that explore energy issues. Moroccan universities have the potential to build relationships with the renewable energy sector in Morocco. 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.

## Recommendations

Focusing on energy conservation and efficiency is important for Morocco's sustainable energy future. Energy conservation is cost-effective and generally requires minimal upfront investments that typically pay back quickly from energy savings. There is a large potential for energy savings in the residential sector, which uses around 33% of total energy in Morocco.

Encouraging residents to switch their lightbulbs from incandescent bulbs to CFLs or LEDs would induce large energy savings. Minimum Energy Performance Standards, mandatory labeling, and home energy audits are also popular methods for determining where energy conservation and efficiency techniques can be applied inside of the home. Many of these techniques would be simple to implement within Morocco.

Similarly, there is a large amount of energy wasted in the industrial sector. Energy use can be reduced in this area by implementing energy efficiency techniques in the designs for new buildings. Such techniques include strategic positioning of the building and windows and using materials that encourage climate control. Encouraging proper energy management and introducing energy efficiency policies are additional methods that can be used to encourage energy efficiency in an industrial setting.

Morocco would also benefit from increasing focus on local-scale energy conservation projects, as these projects are currently underdeveloped. Large-scale projects can have a large impact on many people but often overlook certain stakeholders. In order to provide targeted coverage for issues in these areas, it is recommended that NGOs be integrated into the process to improve the level of government/citizen communication.

Collaboration and partnerships in the international green energy research community could help to improve Morocco’s energy status. By collaborating, Morocco could improve its reputation in the academic and technological world while ensuring the continuous development of energy technology.

Finally, Morocco should consider investing in and contributing to research in developing renewable energy technologies. The discussed technologies include tidal stream generators, nuclear power, offshore wind power, and algae biofuel. By being involved with these technologies early on, Morocco could help to secure the development of its renewable energy goals beyond the ones that are currently planned.

Through continued commitment to new renewable energy projects and the expansion of its energy efficiency and conservation initiatives, Morocco has the potential to not only solve its energy security problems, but also become a global leader in the green energy community.

# 1. Introduction

As energy prices soar and climate change 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 96% of energy imported from foreign nations, Morocco has taken strides in the past several years to increase energy security (Morocco Economy, 2009). With a rapidly growing population and an increasing quality of life, energy consumption is expected to surge. In order for continued development and modernization, it is essential for Morocco to obtain energy supply security and independence. In accomplishing these goals, Morocco has an opportunity to grow into a leader in the green energy field.

To combat this vulnerability, the Moroccan government created a national goal to produce 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. In creating these massive renewable energy projects, Morocco hopes to build a domestic green energy industry, stimulating growth in the high-tech sectors of its economy. 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 assist 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. Through continued effort, commitment, and additional policies it is possible for Morocco to meet its goals and achieve energy independence.

# 2. Background

## 2.1 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 burned for heating. 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.

GHGs are gases that trap heat in the atmosphere, contributing to global climate change (EPA, 2015). Climate change is shown to cause many costly environmental effects by increasing the maximum and decreasing the minimum temperatures worldwide. Were climate change to worsen, these effects would be intensified. Coastal areas would be impacted by a rise in sea level, an increase in storm surge, precipitation intensity and variability, and a rise in coastal water temperature. Ecosystems would be harshly affected by seasonal life-cycle changes, and an escalation in extinction risks for various species (EPA, 2015). Climate change can also affect the global peak energy demand. Heating and cooling systems would be more active, new infrastructure would need to be built to meet the new energy demand, and energy production efficiency would decrease due to temperature increase (EPA, 2015). Lastly, the social impacts of climate change are significant. Impacts from heat waves, extreme weather events, reduced air quality, climate sensitive diseases, and agricultural yield decline would play a significant role in human well-being (EPA, 2015). These potential repercussions from fossil fuel combustion justify the importance of working towards energy sustainability advancement on a global level.

Despite the growing pressures from climate change, the implementation of renewable energy faces significant barriers, primarily the need for large initial investments. With the presence of this kind of barrier, renewable energy implementation slows and, the majority of energy still comes from nonrenewable resources. Due to the inevitability of running out of nonrenewable energy resources, fossil fuel production must eventually decline. It is important for alternative energy technology to be developed and viable in order to satisfy energy needs after this decline begins. There are varied estimates of when this “peak oil” point will occur, but experts generally agree that it is a matter of immediate concern. Some estimates state that the point of peak oil has already been reached (Bielle, 2012), while others suggest that it will be reached between 2020 and 2030 (Miller *et al.*, 2013). In order to avoid potential energy availability issues, many nations are prioritizing the development of renewable resources and energy efficiency.

## 2.2 The State of Morocco's Energy System and Potential for Renewable Energy Generation

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 (ONHYM, personal communication, September 28, 2015). The vast majority of Morocco's electricity is currently generated with imported fossil fuels. Morocco's dependence on imported fuel poses many potential problems due to an increasing energy demand. With a growing population, increasing wealth, and improving quality of life, Morocco's energy use is expected to quadruple by 2030 (Norton Rose Fulbright, 2012). Considering this growing demand for energy and external dependencies for fuel, energy security is becoming a major concern for Morocco. To combat this concern, Morocco has committed generating 42% of the energy it uses internally from renewable resources.

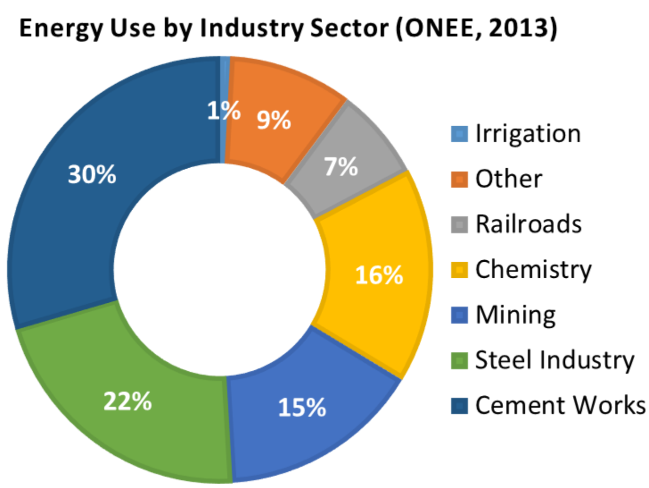


*Figure 1: The amount of energy used by each industrial sector (ONEE, 2013)*

In 2009, Morocco launched a National Energy Strategy which covered five specific areas. In this strategy, the government 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). The majority of Moroccan energy use comes from industry, followed by residences, commerce, agriculture, and transport. In industry, energy use is dominated by two sectors, cement factories and steel plants (see figure 1). Energy use in these industries is difficult to reduce significantly, as the necessary chemical processes use large amounts of energy. In other sectors, such as irrigation for agriculture, 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. Due to urbanization, population growth, and increased wealth, energy use in the residential sector is expected to increase more rapidly than in other sectors (European Investment Bank, 2013).

The electricity transmission grid in Morocco has undergone significant work in the recent past in order to expand the level of access in rural communities. At the time of writing, the grid reached 98% of Morocco's population (Ministry of Energy, personal communication, September 15, 2015). The efficiency of the grid is approximately 82%, falling into an area that is generally comparable to the efficiency of European electric grids (Morad, 2013). Most of the electricity lost is at the low voltage level, meaning that most inefficiencies would need to be corrected at the local level (Ministry of Energy, personal communication, September 15, 2015).

While there are few fossil fuel reserves available in the country, Morocco's geographic location and climate offer high potential for renewable energy production, particularly for solar and wind power. Morocco receives stable solar radiation, especially in regions in the Southeast that approach the Sahara Desert (MASEN, 2015). The exceptionally high intensity of the solar radiation allows Morocco to produce more electricity from solar power than would be possible in areas with less radiation available, with photovoltaic panels having a capacity of 5

$kWh/m^2/day$ in the Sahara (World Energy Council, 2010). Also, much of Morocco (notably the Southern and Eastern regions) has little cloud cover which allows solar power plants to operate at maximum efficiency for the majority of the daytime (MASEN, personal communication, September 7, 2015). Morocco's location in the trade winds offers promising capabilities for wind energy production. There is a strong wind profile in various regions, particularly in the north and in the Atlantic coastal area between Laayoune and Dakhla (Enzeli, 2010). To generate sufficient electricity from wind turbines, wind speeds need to be above 6.7 to 7.4 meters per second (m/s). In Morocco, wind speeds are suitable and consistent both in the north (between 8 and 11 m/s) and along the Atlantic coast in the south (between 7 and 8.5 m/s). Morocco's total wind power potential is approximately 6,000 MW (World Energy Council, 2010).

## 2.3 Renewable Energy Technologies with Viability in Morocco

There are various technologies that can be used to generate renewable energy, with the most popular and well developed being wind, solar, and hydroelectric power. These technologies offer an electricity generation method while avoiding the burning of fossil fuels and the emission of $CO_2$ waste. It is important that when installing renewable energy technologies, energy storage and intermittency are considered. Storage technology is low, and typically, energy produced must be used within a few hours of generation. Also, solar power plants are only operational during the day and wind power plants are only operational when the wind is blowing. This leave gaps when energy is not generated which can be problematic if demand is high during these times. For this reason, it is important that more than one type of technology is used to generate power. This allows generation gaps in one technology be made up by the other.

### Solar Energy

There are two primary methods through which electricity is produced using solar energy. The first, and more traditional method, is the photovoltaic (PV) process. The second method is concentrated solar power (CSP).

In solar photovoltaic production, solar radiation is collected in solar cells made from semiconductive materials such as silicon. An electric field is created between the materials in the solar cell which drives electrons and produces electricity (See Appendix A). These are often used in rural regions because they can be put on rooftops and do not require any infrastructure for their use (Union of Concerned Scientists, 2015).

Concentrated solar power (CSP) uses mirrors to concentrate solar radiation onto receivers. There are three main types of CSP mechanisms: linear/parabolic concentrator systems, dish/engine systems, and power tower systems. The linear/parabolic concentrator system collects the sun's rays with long U-shaped mirrors. The reflected sunlight then heats up a fluid in a tube, which boils water and powers a steam-turbine generator (NREL, 2014). The dish/engine system collects the sun's rays with a mirrored dish, concentrating the light on a thermal receiver. The receiver absorbs the heat energy from the sun and transfers the heat to an engine generator. The engine commonly uses a heated fluid from the receiver to move its pistons and, as a result, generates electrical power (NREL, 2014).

The power tower system consists of a large field of flat, sun-tracking mirrors called heliostats. The heliostats concentrate sunlight onto a receiver, which is located at the top of a centralized tower. The receiver heats up a fluid, powering a steam-turbine generator, in a way similar to the Linear/Parabolic Concentrator System (NREL, 2014).

These CSP systems often use salt as the fluid in the receiver. This is advantageous because molten salt stores heat for up to seven hours, which allows for steam generation when desired. This is an efficient method of energy storage, and is extremely beneficial for combating inconsistent sunlight and consumer variability. CSP plants are also more efficient than PV plants when there is no cloud cover, which is generally descriptive of Moroccan solar plant locations (SEIA, 2014). Unlike PV solar generation, CSP requires expansive land area. This makes it inappropriate for home use, but very well suited for large-scale solar energy production.

Wind Energy

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

Wind speed and frequency are location dependent. Therefore, wind farms are only sustainable in certain regions of the world. Wind speeds need to be above 6.7 - 7.4 m/s for wind turbines to generate sufficient power. Additionally, if wind speeds are too fast, turbines will implement a braking system and will not move in order to protect the turbine from damage (Union of Concerned Scientists, n.d.). The height of wind turbines and the size of their rotors also affect power generation, as wind speeds increase at higher altitudes. Wind turbine energy production can be estimated by the wind speed in m/s cubed, meaning that power generation grows exponentially with wind speed (Nfaoi *et al.*, 1998). Unfortunately, wind patterns are often intermittent, making turbine productivity somewhat unpredictable. Also, in many cases areas with high wind power potential are far away from the areas where electricity is actually used, which can cause loss in power lines.

A technique to utilize wind energy while avoiding some of the downsides is to install wind turbines in the ocean. Offshore wind sources are generally more abundant, powerful, and consistent with airflow than those of onshore wind, increasing the energy production capacity exponentially (Bureau of Ocean Energy Management, n.d.). Additionally, offshore wind power is believed to be unobtrusive on aquatic ecosystems, because the wind turbines' undersea structure often creates an artificial reef that can be used as a habitat for marine life (Casey, 2012). Offshore wind power tends to be less bothersome to residents due to the remoteness of the wind farm, avoiding noise and visual concerns. However, due to their remote location off the coast, there are potential drawbacks including turbine damage from sea corrosion and power grid access difficulties. There is ongoing development of technology which will help to combat these concerns and make offshore wind more feasible in the future (Office of Energy Efficiency and Renewable Energy, n.d.).

Offshore wind technology has been expanding worldwide, notably in the UK, the Netherlands, and Denmark. Denmark has the capacity to produce 1271 MW of offshore wind from its 13 established wind farms nationwide (Danish Energy Agency, n.d.). Denmark is also planning to expand its program by constructing nine more offshore wind sites. The United States has formulated plans to develop several large-scale projects off various coasts to harness this vast untapped resource as well (Office of Energy Efficiency and Renewable Energy, n.d.). This growing interest demonstrates the technological potential of offshore wind power generation.

## Hydroelectric Energy

Hydroelectric energy is derived from moving water sources and can often be generated in rivers. Small-scale hydroelectric generation can be implemented on rivers, streams, canals, and other areas with moving water. For consistent and reliable hydroelectric power generation, a dam is traditionally required (USBR, 2005). A dam is used to store water for later use, holding potential energy that will later be turned into electrical power. When energy generation is desired, the dam releases water, moving a turbine which moves a rotor that converts the mechanical energy of the turbine into electricity.

There is research involving the use of hydroelectric technology to store excess energy generated from wind turbines, helping to remedy some of wind power's shortcomings (Kapsali *et al.*, 2010). This is useful for when energy demands are low, such as at night, or when wind speeds are too low for effective power generation. In this process, excess wind energy is used to pump water uphill, storing the potential energy from the wind power. When energy demand is once again high, the water is released and used to generate hydroelectric power for use in the electric grid.

## Tidal and Wave Energy

Tidal power is a hydro-electric power source with significant potential. It may offer significant returns with a reduced cost and fewer ecological impacts than the traditional hydroelectric dam. While tidal power has potential to generate large amounts of energy, its real-world use is presently limited. Small installations have found success, but there are currently few large-scale installations.

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

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 consistent and strong, the potential for electric generation is considerable. At the present time though, this project entirely hypothetical and no planning has begun. At some point however, the Strait of Gibraltar may become a significant asset in Morocco's renewable energy efforts.

## Nuclear Energy

Nuclear power is a powerful low-carbon energy technology that has recently resurfaced globally as a valuable energy source. Nuclear power generates electricity by splitting a uranium ion to create heat and spin a steam-turbine generator (See Appendix C). It has the potential to produce a significant amount of electricity without emitting any GHGs, but it has been avoided by many due to its use of radioactive materials. High radiation exposure from serious accidents can lead to human health risks and environmental contamination (Union of Concerned Scientists, n.d.). Radioactive materials are safe when the right precautions are strictly followed and they are securely contained, but if they are used improperly, there is a risk for disaster.

Producing electricity in 31 countries, nuclear power plants generate over 375,000 MW and are responsible for over 11% of the world's electricity. Nuclear power typically generates about 97-98% more power than the process consumes. There are over 60 new reactors that are currently being constructed, 160 that are planned, and more that are proposed, as the demand for low-carbon electricity increases. Nuclear plants are also being retrofitted to increase efficiency and output capacity. The lifetime of nuclear power plants have been increasing, with new plants expected to last 60 years, making the initial investment more worthwhile (World Nuclear Association, 2015).

The energy potential for nuclear power is significant, but so is the initial cost of investment. The infrastructure for a nuclear power plant is expensive, which often requires funding from investors or banks. The advanced technology required for power generation is also very costly, which can pose as a problem for underdeveloped nations. Fortunately, the cost barriers for nuclear power are primarily in the initial development phase, and the reasonable energy production costs can make it worthwhile.

Fuel costs for nuclear energy are relatively small compared to fossil fuels due to the shipping costs of the latter. Nuclear fuel is much more dense and long-lasting, so shipments are less frequent and more cost-effective. Fuel storage is easier for nuclear power, because uranium is four times less massive than coal for equivalent energy. Uranium also does not degrade in storage, which eliminates wasted energy potential. Finally, the cost of uranium is 10 times cheaper than coal to produce the same amount of energy. These fuel cost factors decrease the long-term costs for nuclear power, permitting the production of substantial and reliable low-cost energy (Adamantiades *et al.*, 2009).

Morocco has expressed interest in the possibility of exploring nuclear energy and building its first nuclear power plant (Jewell, 2011). Morocco currently has a small research reactor and has begun the process of laying out a nuclear safety policy infrastructure, but has no concrete plans for a nuclear power plant (El Mediouri, 2011). Limiting factors including large investment costs, international support, private investment, and grid discontinuities all hinder initial research and development.

## 2.4 Non-Renewable Energy

Morocco’s energy status is relatively unique for a North African nation. Oil reserves are present, but remain relatively unexploited. Due to this lack of fossil fuel resources, Morocco is forced to source 96% of its energy externally. This includes crude oil, refined oil, and coal, with Saudi Arabia supplying 48% of Morocco’s energy requirements (IEA, 2014; Norton Rose Fulbright, 2012). Morocco’s reliance on imported energy significantly reduces Morocco’s energy security which, in turn, reduces Morocco’s national security. Currently, the majority of Moroccan electricity is generated within the country at state owned power stations.

Morocco, however, has large untapped reserves of shale. Shale is a common kind of sedimentary rock that can have a surplus of oil and natural gas trapped within its layers. A process called hydraulic fracturing or “fracking” is used to capture these fuels to be used for energy production. The technology to harness these resources was formerly too expensive to be efficient, but the new method of hydrofracking has increased effectivity (Davenport, 2010). There are several concerns involved with this method however. The environment can be negatively impacted by fracking because water polluted from the process may contaminate the water table. Water pollution can also cause increased risks of health problems for nearby residents. There is also a risk of an increase in earthquake activity from shifting faults during the fracking process. A way to combat this potential environmental risk is to have strict regulatory policies to keep hydrofracking as safe as possible (Davenport, 2010). Morocco also currently does not possess the technology needed to efficiently extract shale fuels.

Morocco's plans for the future of its energy profile certainly prioritize renewable energy. Large investments, firm goals, and powerful policy tools have all been implemented to accelerate the green energy sector. The extraction of fossil fuel resources is present, but is progressing at a relatively slow pace (ONHYM, personal communication, September 28, 2015).

Increased drilling off Morocco's coastline could lead to increased income and energy independence, but could reduce the sustainability and environmental friendliness of Morocco's energy production by promoting greater greenhouse gas emissions and introducing pollutants into the environment. Offshore oil drilling platforms can also cause significant ecological damage to surrounding waters, reducing overall biodiversity and biological productivity. The future of offshore drilling policy hinges on whether Morocco prioritizes future development or reducing negative environmental impacts.

Recently, the shale industry has been rapidly growing worldwide. Several foreign companies, including Cairn Energy, Genel Energy, BP, and Maersk, have expressed interest in pursuing the development of Moroccan shale deposits (Mainwaring, 2014). Research from these companies have led them to believe that there could be over half a billion barrels of shale oil in each of the two blocks offshore of Morocco (Alan, 2012). In fact, Morocco may have some of the largest reserves of oil shale in the world, which demonstrates the large potential for exploitation and expansion of this area.

The Tindouf Basin is an intriguing target for exploration and development in Morocco because of its vast amounts of shale (Boyer *et al*., 2011). San Leon Energy is very interested in the pursuit of shale gas, and is currently working towards shale oil opportunities. The success of the ongoing shale projects could lead to a shift in Morocco's future in energy sustainability.

In 2000, after King Mohammed VI, ascended to the throne, foreign countries showed greater interest in Morocco's natural resources. Mohammed VI changed the Hydrocarbon Code, which allowed further development of Morocco's fossil fuels. Shell, Lone Star Energy, and Skidmore Energy Inc. each signed several licenses, granting them access to explore various vast reserves Morocco had to offer. The majority of the Moroccan population have strong beliefs that the oil found in their region should benefit them, rather than solely the foreign investor (Maxted, 2006).

## 2.5 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 affecting 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 investments. The removal of fossil fuel subsidies that 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.

# 3. Methodology

## 3.1 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.

## 3.2 Project Objectives

In completion of this Interactive Qualifying Project, 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.

## 3.3 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.

## 3.4 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.

*Table 1: Stakeholders that were interviewed*

| 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<br>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<br>M. Adiel (member RAF)<br>Zohra Ettaik | Ministère délégué pour l'Energie (MEMEE) | 9/15/2015 |
| Cabinet H. El Haite<br>Cabinet Ministre:<br>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 |
| Cabinet Dr. A. Lhafi | 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 |

# 4. Findings and Analysis

## 4.1 Status of Large and Local-Scale Energy Projects

### Large-Scale Energy Projects

Morocco is aggressively pursuing its goal to produce 42% of energy from renewable sources by implementing new, large-scale renewable power projects, mainly in the form of wind and solar energy. These projects are largely supported by foreign investments. Utilizing state of the art technology, these projects can act as a model for the implementation of renewable energy elsewhere in Africa and the developing world.

The Moroccan Agency for Solar Energy (MASEN) was launched in 2010 with the passing of law 57-09. MASEN's 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 that will consist 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 all phases of the power plant in 2019, the plant will be about the size of Rabat and will provide about 500 MW of energy, representing 25% of Morocco's solar goals (MASEN, personal communication, September 7, 2015). Noor I-III will consist of concentrated solar power that will generate energy to be distributed throughout the country. Noor IV will be a smaller 50 MW photovoltaic plant which will satisfy the energy needs of residents in the Ouarzazate area.

Conditions in Morocco are adequate for wind power generation. 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, 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.).

Hydroelectric power has been present in Morocco since the early 20$^{th}$ century. Currently, hydroelectric accounts for about 1,700 MW of energy production. This is approaching the goal of producing 2,000 MW of energy from hydroelectric sources. Small projects are underway to reach this production goal by adding an additional 300 MW of hydropower (Ministry of Water, personal communication, September 11, 2015). Much of this additional capacity will be generated from micro hydroelectric generators.

There is interest in using nuclear power in Morocco, but there are no current plans for its implementation. Significant barriers exist for a potential nuclear power plant project, such as large initial costs, grid capacity concerns, and lack of international support. Despite these problems, nuclear power is considered to be a potential option for meeting Morocco energy demands in the long-term (ONHYM, personal communication, September 28, 2015).

The primary method for funding large-scale energy projects is the implementation of public-private partnerships. This structure allows for one primary business to facilitate these major projects. This facilitating agency opens the market to competitive bidding, in which private manufacturers bid to gain contracts for different components of the project, allowing competition and specialization. Decree 1-06-15 obliges public entities to use competitive bidding in the creation of renewable power plants projects (Norton Rose Fulbright, 2012). This encourages competition among green energy companies and leads to lower costs on power plant production (Federal Ministry for Economic Cooperation and Development, 2012). 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 (MASEN, personal communication, September 7, 2015). While this reliance on foreign companies is largely a practical issue, since few companies worldwide have the manufacturing technology and facilities that operate at the massive 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.

These large-scale and cutting edge power plants have helped to make significant progress towards reaching Morocco's 42% goal. Currently, reaching the goal of producing 42% of energy from renewable resources is feasible, however it is not guaranteed. Reaching this goal is likely due to strong projects and initiatives, but is contingent on fielding foreign investment and continued economic stability in Morocco.

While large foreign investments have been invaluable for Morocco's green energy sector growth, they do pose some potential threats. If Morocco stays dependent on foreign investments and corporations for meeting its power 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 when beginning to focus on decreasing energy dependence, but homegrown local industry is a far superior endpoint.

## 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 small-scale renewable energy projects include programs for solar water heaters, off-grid self-contained pumps (figure 2), 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 of life without requiring increased energy use or access to the grid.

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

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 served 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.

Smaller-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.

## 4.2 Energy Conservation and Efficiency Projects

Large-scale energy production, as opposed to local-scale production or energy efficiency, is the clear focus of the majority of Morocco's energy projects. These large-scale energy production projects have considerably more momentum than energy conservation or efficiency projects. Although the Ministry of Energy has involvement with energy conservation and efficiency projects, small-scale projects are given less attention than energy production projects. This suggests that a stable energy supply, a growth of a green energy economy, and citizen energy rights are a higher priority in Morocco than environmental degradation or reducing the carbon footprint.

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

Improved energy conservation can lead to increased energy productivity and decreased energy use. The cost of conserved energy (CCE) 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. In 2009, the National Energy Efficiency Program was launched. This plan aspires to reduce electricity use 12% by 2020 and 15% by 2030. 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. Due to pressure from the World Bank and International Monetary Fund to reduce spending, gasoline and diesel subsidies were effectively ended, 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). 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).

Morocco’s grid efficiency is good at its high voltage level, but the efficiency drops noticeably at the low voltage level (Ministry of Energy, personal communication, September 15, 2015). Another issues with the national grid is the possibility of large power outages. If above ground power lines fail to endure harsh conditions, there can be issues with electricity availability spanning long distances.

Some policies 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). Another 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 MW (MEM 2013).

There is a large potential for increasing energy efficiency in the industrial sector. Promoting energy efficiency in buildings is a promising method for reducing overall energy use. In addition, energy efficient buildings generally have fewer environmental health risks than traditional buildings 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. With proper management of these devices, energy usage in office spaces could be reduced by 60% during off hours, causing an electricity savings of 20-30%. Simple measures such as using motion sensing lighting can make a large difference in industrial lighting (Blok, 2015).

## 4.3 Status of Youth and Higher Education

### Youth Education

In Morocco, public knowledge of energy issues is limited. Moh Rejdali, the mayor of the city of Temara, 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 light bulbs. 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 (personal communication, September 22, 2015).

Education programs that promote energy conservation awareness are beginning to be implemented. These educational programs inform the importance of energy as a resource. Educating the youth generation is crucial, as increased energy availability gives the youth 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 in the coming years. 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.

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 called 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.

In recent years, there has been an increased level of interest in environmental matters and environmental education. There have been efforts made by various groups, such as the Ministry of the Environment, to encourage the addition of environmental issues into public school curriculums. The Ministry of the Environment built a learning room for children. Unfortunately, due to limited resources, 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 its success came from providing transportation for students to their facilities (SPANA, personal communication, September, 16 2015). In addition, there are several programs 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 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.

Renewable energy is an interdisciplinary field which incorporates engineers and scientists from various areas, such as electrical engineering, materials science, mechanical engineering, and economics. University programs for renewable energy must be equally diverse, providing students with a background in all of these areas in order for there to be qualified workers for renewable energy projects.

Moroccan universities have some level of communication with groups pursuing large-scale projects for renewable energy (MASEN, personal communication, September 7, 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 has been valuable research from Moroccan universities. 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 to the global community online.

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

# 5. Recommendations

## 5.1 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 (see figure 3). These improvements are listed below:

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

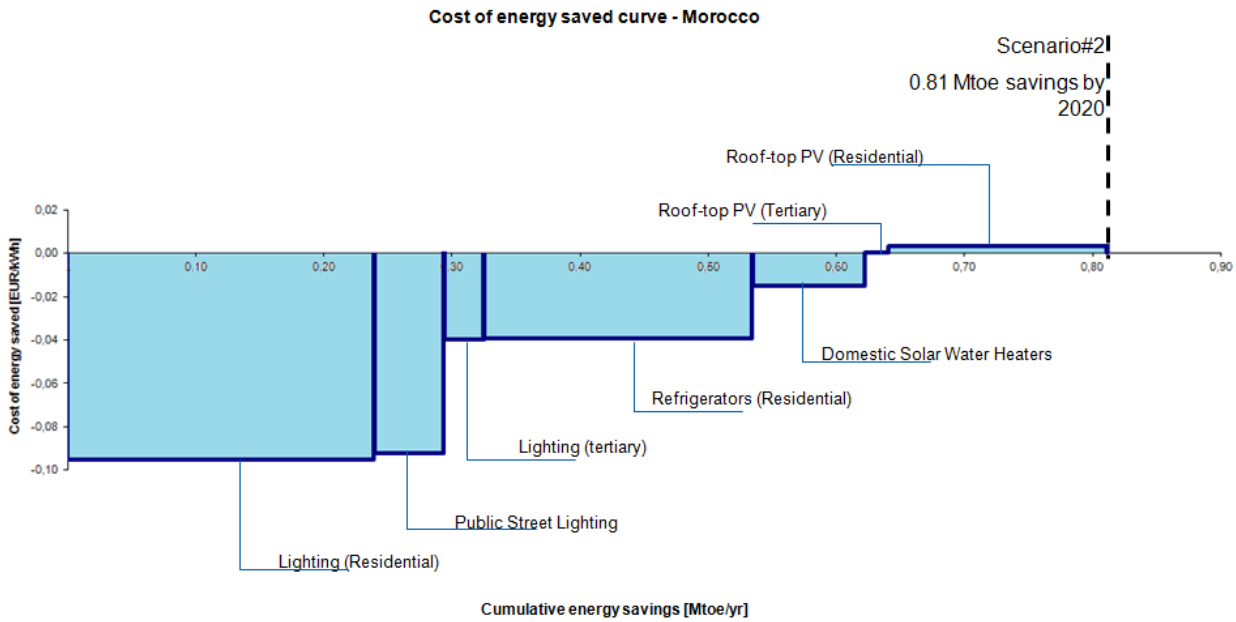


*Figure 3: Energy saving potential in Morocco (European Investment Bank, 2013).*

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.

## 5.2 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).

## 5.3 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.


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

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

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.

## 5.4 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 B). 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 D).

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 D).

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.

# 6. Conclusion

Through the completion of this Interactive Qualifying Project, 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. A report was composed incorporating these findings, evaluations, and suggestions as a resource for the Ribat Al Fath Environmental Club.

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.

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# Appendix

## Appendix A: 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 B: 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 (see figure 5) (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 C: 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:

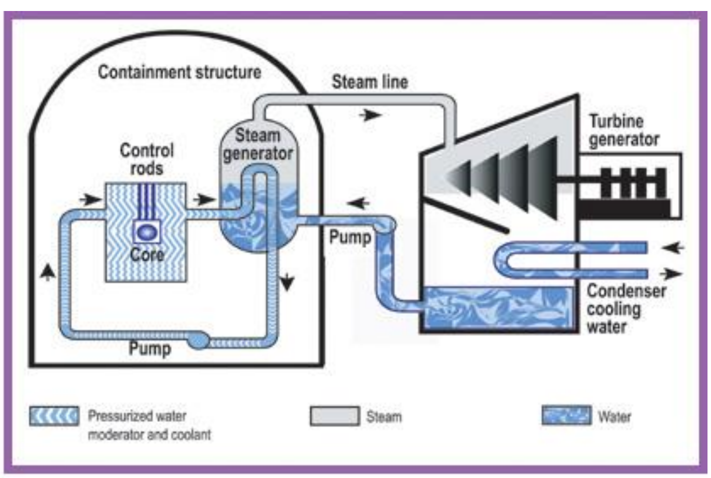


*Figure 6: Power generation process for nuclear energy*

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 D: 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).

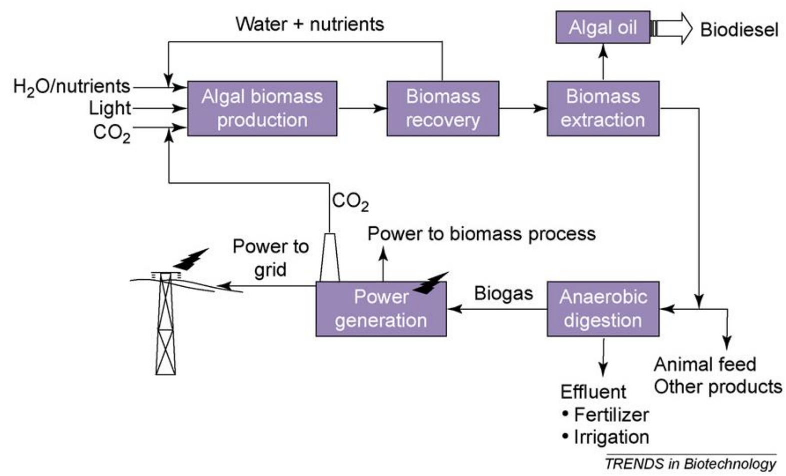


*Figure 7: Process of creating biofuels from algae*

# Appendix E: 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 F: 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?