Renewable Energy in East Africa: Solutions for Providing Electricity Using a Systems Approach

Abstract

Energy is an important factor in any country’s economic development. The lack of good energy policies and infrastructure has contributed in preventing countries in Africa from achieving economic growth. Developing nations in Africa face significant challenges due to poor or no energy infrastructures which continues to inhibit GDP growth. One way to do this is by modernizing and building their electricity capability. In addressing these energy problems, the region must include and develop sustainable energy systems. Providing electricity for the African continent must be performed in ways which are affordable, sustainable and flexible. Countries in the region must consider renewable energy solutions as they update and improve electricity capability. Systems engineering offers several great tools with which countries in the African region can assess the viability of renewable energy systems. In this paper, some of the tools highlighted include: Descriptive and Normative Scenarios, System Definition Matrix [Scope (Needs, Objectives, and Criteria) and Bound (Parameters, Variables, and Constraints)], and an example of how a Quality Function Deployment could be used. In systems engineering, significant effort is spent in assessing the problem, formulating requirements which are relatable to the customer objectives and analyzing the alternatives in meeting the set forth requirements. The problem of providing electricity for the African continent is a complex one with many factors and variables for consideration. Systems engineering offers a means to assess these problems and provide feasible solutions for implementation, meeting the customers’ requirements. This paper offers an overall look at the renewable energy problem, outlines the alternatives, and provides a general framework as to how a systems approach can be used.

Introduction

The purpose of this paper is to examine renewable energy as an option for solving Africa’s energy problems. Given the number of countries on the African continent, this paper will use as a case study, the East African region, specifically the three countries most recognized in that Sub-Saharan region (Kenya, Tanzania and Uganda). The region was identified because the African region was selected for evaluation given the authors familiarity with the region having grown up in Kenya and traveled to Tanzania. More significantly, the region offers very significant and complex challenges to which a systems approach to providing solutions may be well suited for.

Additionally, this region was chosen given the available amount of statistical information, and renewable energy research currently being undertaken.
The Current State of Energy in East Africa (EA)

Africa is the second largest continent in the world, both in terms of size and population, yet the continent continues to experience slower than desired economic growth and significantly high poverty levels. This paper focuses on Kenya, Tanzania and Uganda with approximately 40 million, 41 million and 33 million people respectively.

According to the U.S Energy Information Administration as shown in Figure 2, the most demand for energy from 2007 to 2035 will come from non-Organization for Economic Cooperation and Development (OECD). This will include countries in the East African region. This growth however is not keeping pace with some emerging countries such as China and India.
The high levels of unemployment which directly correlate to the high levels of poverty prevent the region from experiencing increased capacity in the rural areas. These three countries have measurably large unemployment levels with a large percentage of the population living in rural areas with no real access to electricity, as shown in figure three (3) below. The average urban electrification in the region is approximately 22% and 4% in the rural areas.
Figure 3: Urban and Rural Electrification in East Africa

Figure four (4), gives a comparison of the energy consumption per capita for the region compared with some notable countries.
When compared with the United States for example, it is clear a significant gap exists in the region in providing electricity across their populations.

The current state of energy in the region is characterized by a heavy dependence on biofuels in the rural areas. While biofuels is one of the alternatives for renewable clean energy, the current form of use in the region is in the “traditional” sense and has serious environmental and health disadvantages\(^3\),\(^4\). Research indicates that given the current wide scale electricity limitations, rural communities are forced to resort to using unvented biofuel cooking stoves which contribute to indoor air pollution. Additionally this is also adding to higher numbers of respiratory illnesses.

The electricity sector in East Africa is also affected by heavy system losses. This is due to a heavy reliance in hydropower in producing electricity. This reliance however, is affected by climate conditions in the region. Whenever severe drought is experienced, significant losses in electricity output are experienced. This leads to massive rationing of power which affects the productivity of the industrial base as well as the local populous way of life in the cities.

The region is also faced with a slow economic growth due to poor government policies. The governments in the region have not good executable frameworks and policies for electricity capacity expansion. This deficiency has made it very difficult for renewable energy implementation\(^8\).
Infrastructure Development

The EA region must bring its infrastructure into the 21st century. In order to compete with China, India as well as countries in South Africa, public transportation, roads, public health systems and the energy sector must be developed.

Electricity Capacity Development

The region currently has an old system with respect to electricity generation. As new systems are developed, it will be necessary to consider alternatives sources of fuel. This is necessary to ensure sustainability and security. The region has for a long time relied on the rest of the world to establish the trends with respect to energy policy. This must change as they seek to modernize and produce more electricity. They must consider renewable energy systems from the onset of development.

Renewable Energy

Renewable energy sources offer great potential to solving some of Africa’s energy problems. As shown in figure four (4), renewable energy use is projected to continue increasing however it does not keep pace with use from natural gas or coal. Therefore renewable energy solutions must be developed to reduce the dependency on coal for instance.

Africa has many avenues for renewable energy including:

- Solar power
- Geothermal energy
- Hydropower
- Biomass energy
- Wind energy
Solar Power

The African continent has large desert areas with a significant exposure to the sun. This could be exploited using solar technology to provide electricity. Solar technology can be used in two ways. The first involves using solar cells which convert energy from the sun’s rays into electricity. The second method involves using the heat from the sun’s rays to heat water in pipes or reservoirs. The super-heated steam could then be used to turn a turbine or generator which would in turn generate electricity.

Geothermal Energy

The region has tremendous geothermal potential due to the rift valley region which has volcanic activity underneath the earth’s crust as shown in figure five (5). Geothermal energy is natural heat from the earth’s core which has been stored in rocks and water. This source is made possible because there is a constant flow of heat from the earth’s core. The energy is extracted by drilling to tap the concentrations of steam at high pressures and depths low enough for economic viability. The steam is then used to power electricity generating turbines.
Hydropower

This source uses moving water to power generators and turbines. This method of electricity generation is currently being used in the region. It is encumbered by changes in the climate, i.e. drought which causes reductions in water levels leading to system losses which leads to power rationing. Figure six (6) shows a map of Kenya with the abundant distribution of rivers and lakes.
As hydropower is already used extensively in the region, it will not be discussed as one of the alternatives.

Biomass Energy

Traditional forms of biomass are used in the region to produce energy. This energy is used in small stoves and in personal lanterns. The current form of use however, has negative impacts to the environment as well as health consequences from indoor air pollution. Modern forms of biomass technology exist which if exploited by the region could generate clean electricity for the rural areas.

Wind Energy

The East African region is not the best suited region for wind energy according to various studies and reports. However, the potential exists for wind energy in pumping water from wells as well as the utilizing low speed wind vanes in the generation of electricity.

Problem Definition
Solving the EA region’s energy problem is complex. There are many variables which must be addressed in order to provide a solution which works. The first step to providing solutions is to adequately evaluate the problem. A systems approach offers a great way to examine the complexities, relationships between entities, and the system interfaces (boundaries) and so on. This paper does not provide a comprehensive analysis does identify some considerations for stakeholders and system designers.

In order to develop alternatives which may be able to solve the energy problem, it is important to ensure that the problem is well understood. Defining the problem is a vital step which must first be performed before requirements can be formulated. These requirements will then be used to analyze the alternatives hence validating that the solution put forth is suitable.

Problem Statement Formulation

There are numerous challenges with evaluating a problem statement with the renewable energy problem. A systems approach offers a methodical way of evaluating the problem. According to Sage and Armstrong, assessing the problem begins with a situation assessment.

Situation Assessment

A situation assessment is comprised of three steps:

Background Scenario

This identifies the past state of the renewable energy utilization in the region. In this case, renewable energy had not been utilized for electricity production in any significant capacity. The East African region like most of sub Saharan Africa had been slow to see technological improvements which have improved their infrastructure and economies.

Descriptive Scenario

This describes the current state of the system. The region has been dependent on conventional sources of electricity production with a heavy reliance on hydropower and traditional forms of biomass for localized energy production in the rural areas. Between the three countries, Kenya is the only country in the region which currently utilizes geothermal energy from three plants which produce approximately 70MW of power representing about 16% of electricity added to the national grid\textsuperscript{10}.

Normative Scenario

This describes the desired state of the system. This gives an idea of the objectives which this system should attempt to achieve. The overall objective of this system is to provide clean, reliable and affordable electricity for the EA region. The challenges to this objective include:

Lack of Good Policies
In the past, the governments have not had policies which have advocated or supported the renewable energy push in the electricity production discussion. Existing policies have not been well articulated and have failed to have a clear strategy for widespread development. This has led to local projects which have failed because of the lack of local governmental and community support especially in the rural areas.

Governments have failed to implement laws which support a clear energy strategy pushing for energy security. Energy security and independence has been discussed at the government level and renewable energy must be a part of this discussion as the African continent goes into the 21st century.

Lack of Technology

Each region faces different challenges with managing and developing plans for energy security. For example, while there might be some similarity, China does not face the same challenges as the United States. Similarly, the East African region has very different challenges from those countries. These technologies are being developed to solve problems for the regions which identified the need. Wind energy is a great source of electricity in the United States however it may not work as well in East Africa1. Alternatively, solar power would be well suited for the tropical region which gets great amounts of sunlight.

Technology maturity is another challenge. With increasing demand for oil from China, India, Brazil and other emerging nations, renewable energy has begun to receive significant attention and investment as countries look for energy independence and security. Previously, renewable energy technology for a long time did not keep pace with the changes in oil prices. It is much more cost effective to produce electricity using coal than it is to produce it from solar energy or wind energy. However, continued increases in oil prices due to the increased demand meant that renewable energy sources could become competitive hence companies became more willing to invest in their development. Africa can benefit from this as the region depends on the technology developed from western countries.

Another important point is the reliance of technology developed overseas but a lack of technical competence. The region relies of technology developed from the western world. Hence the technical skillsets are not available locally. For the rural areas, significant training must be performed at the local level for any systems being developed to ensure supportability and maintainability.

Financial Constraints

The region relies on donor support from the United States, Asian and European nations. 50% of the region lives below the poverty level and there is a heavy reliance on traditional subsistence farming. Any program would require substantial external support which would significantly limit the potential development.

Identification of Needs
The situation assessment gives a good indication of what the needs are, which is useful in identifying objectives. This is important in both understanding the problem and developing useful alternatives which could potentially solve the renewable energy problem.

The overall top level needs for this system can be identified as shown in Table 1 below:

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Need</th>
</tr>
</thead>
<tbody>
<tr>
<td>N1</td>
<td>Energy Security and Independence</td>
</tr>
<tr>
<td>N2</td>
<td>increased capacity for electricity production</td>
</tr>
<tr>
<td>N3</td>
<td>Poverty Reduction</td>
</tr>
<tr>
<td>N4</td>
<td>Environmentally clean systems</td>
</tr>
<tr>
<td>N5</td>
<td>Safety Protection</td>
</tr>
</tbody>
</table>

Using these top level needs, a system definition matrix can be developed which documents the scope and bounds of the problem.

System Definition Matrix (SDM)

As shown in Table 2, the SDM is useful in listing the needs, objectives, and criteria for the system. It also lists the possible parameters, variables, and constraints effectively defining the bounds for the system. With the SDM, a clear dialog can begin with stakeholders which will be useful in the development of requirements.

Using the SDM, a Cross Interaction Matrix (CIM) can be developed which evaluates how the objectives interact with each other. This is useful in identifying which objectives may enhance each other or where there might be conflict.

Table 3 shows a CIM for the renewable energy problem, where a “+” indicates a positive association, a “-” indicates a conflicting association, and “0” indicates that no apparent association between the objectives. From the CIM, it becomes apparent that the objective “to increase availability of affordable electricity” may conflict with the objective “to reduce harmful effects of pollution” and “to reduce harmful health effects from pollution.” This indicates that those requirements may hinder each other and will probably require tradeoffs with each other if the system is to become successful.

Objective Tree Hierarchies

The tree identifies the hierarchy of objectives. It is useful in identifying lower level objectives which are more measurable than top level objectives. At lower levels, activities and functions are defined which stakeholders are able to pursue. In accomplishing the low level objectives, the
higher level objectives are accomplished as well. For the renewable energy system, figure seven (7) shows how an objective tree can be used.

The objective tree answers the questions “how” and “why” a system should be developed. Going down the tree looking at any branch tells the “why” for any lower level objective while looking up the tree should identify “how” for the higher level objective.

System Strategy

Using the information above, a comprehensive strategy begins to appear which can be used to analyze the alternatives. Before alternatives can be considered, the objectives will help in understanding the overall system. From the top level needs, derived down to the system objectives, a picture of the system begins to develop as shown in figure eight (8).

It becomes clear that three (3) stages are required in order to develop an effective system:

Small Scale System Scenario

These alternatives must address the needs for rural areas. Considerations must be modular and adaptable to the harsh terrain witnessed in the African rural areas. These systems should be intended to serve local communities with no intention of being integrated into the national grid. The main purposes for these systems should be basic lighting, cooking and refrigeration.

Hybrid System Scenario

These systems are meshed between the small scale systems for rural areas and the large power systems necessary for urban cities. These systems are intended to provide power for larger populations such as community centers. These should be designed to provide power for hospitals, schools, police stations as well as individual homes. These systems can be integrated into the national grids and so should be flexible. The benefit of this type of system is it creates a network of hubs or nodes interspersed throughout the region. A scale free network would work well in this environment as grid integration may not be feasible. Considerations should be given for scale free development where each plant would serve as a hub or node for a segmented area. This would provide a means to ensure that the national grid system does not become overloaded. It would also mean however that if one of nodes or hubs went down, then power may or may not be able to rout from another source until power was restored depending on the number of nodes within the network.

<table>
<thead>
<tr>
<th>SCOPE</th>
<th>BOUND</th>
</tr>
</thead>
<tbody>
<tr>
<td>Needs</td>
<td>Objective</td>
</tr>
<tr>
<td>Energy Security and independence</td>
<td>To reduce the reliance on foreign oil for electricity generation</td>
</tr>
</tbody>
</table>
**Increased electricity capacity**
- To increase the availability of affordable electricity for urban and rural areas
- Increased electricity production and consumption per capita
- Number of available sources of electricity generation
- kWh per capita
- Cost, Land Availability, Technology

**Poverty Reduction**
- To create a technical workforce and improve way of life
- Creation of and increased employment in job sector
- Number of jobs created and or increased
- Labor force per sector (industry and services)
- Cost, Technical competence Technology availability

**Environmentally clean systems**
- To reduce the harmful effects of pollution on the environment
- Reduced deforestation
- Reduced emissions
- Available forest acreage
- Kg per household
- Emissions laws and standards

**Safety Protection**
- To reduce the harmful health effects from pollution
- Reduced lung and respiratory diseases
- Doctor visits
- Number of doctor visits
- Laws and Public Policy

<table>
<thead>
<tr>
<th>Objective</th>
<th>To reduce the reliance on foreign oil for electricity generation</th>
<th>To increase the availability of affordable electricity for urban and rural areas</th>
<th>To create a technical workforce and improve way of life</th>
<th>To reduce the harmful effects of pollution on the environment</th>
<th>To reduce the harmful health effects from pollution</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NA</td>
<td>+</td>
<td>+</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>+</td>
<td>NA</td>
<td>+</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>+</td>
<td>+</td>
<td>NA</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>-</td>
<td>+</td>
<td>NA</td>
<td>+</td>
</tr>
</tbody>
</table>

Table 3: Cross Interaction Matrix (CIM)
harmful effects of pollution on the environment

<table>
<thead>
<tr>
<th>To reduce the harmful health effects from pollution</th>
<th>0</th>
<th>-</th>
<th>+</th>
<th>+</th>
<th>NA</th>
</tr>
</thead>
</table>

Figure 7: Example of Objective Tree for Renewable Energy Problem
Large Scale Scenario

The large scale system would be intended for large metropolitan areas. It would function as the typical large cities with large urban populations, businesses and industrial complexes. This system would be the typical grid connected network. Renewable energy solutions such as biomass should be integrated into this system.

Requirements Formulation

Once a sense of the objectives is developed, the next step is developing requirements with which alternatives can be assessed. Formulating appropriate requirements is perhaps the most important step in systems engineering. Understanding the end users’ needs by translating them into requirements is important in ensuring the “best” system gets developed. Requirements act as the bridge between the user and the systems engineers developing the system.
Developing requirements is a labor intensive and requires significant involvement from all stakeholders in order to ensure that each requirement clearly and adequately captures the intent of the objective. Given the scope for this paper, the focus was more on a technique which could be used to begin the requirements formulation process.

One system engineering tool which relates the user objectives to design requirements is the Quality Functional Deployment (QFD) Matrix. QFD uses a set of matrices (House of Quality) to correlate the user needs (objectives in this case) to the products technical requirements. QFD keeps the focus during system development on customer requirements. QFD can be useful in identifying potential issues at an early stage of development. Figure nine (9) shows an example of a QFD model.

From the QFD model, determining the technical requirements becomes the first step before the QFD model can be effectively utilized. If the customer requirements or objectives in this case are the “whats,” the technical requirements answer the question “how.” The technical requirements must be related to each customer objective in more measurable or quantifiable means. For the renewable energy problem, this can be expressed as shown in table four (4).
Using the determined objectives and the derived requirements, a flowchart can be developed based on the following requirements as shown in figure ten (10).
Figure 10: Customer Requirements Flow
Table 4: Relating Objectives to a Measurable Technical Requirement

<table>
<thead>
<tr>
<th>Objective:</th>
<th>Criteria</th>
<th>Variables from SDM:</th>
<th>Technical Requirement:</th>
</tr>
</thead>
<tbody>
<tr>
<td>To reduce the reliance on foreign oil for electricity generation</td>
<td>Reduced Oil imports spent on electricity generation</td>
<td>Barrels per Day</td>
<td>Electricity Sources</td>
</tr>
<tr>
<td>To increase the availability of affordable electricity for urban and rural areas</td>
<td>Increased electricity production and consumption per capita</td>
<td>kWh per capita</td>
<td>Electricity Quantity</td>
</tr>
<tr>
<td>To create a technical workforce and improve way of life</td>
<td>Creation of and increased employment in job sector</td>
<td>Labor force per sector (industry and services)</td>
<td>Labor force Proficiency</td>
</tr>
<tr>
<td>To reduce the harmful effects of pollution on the environment</td>
<td>Reduced deforestation</td>
<td>Kg per household</td>
<td>Clean Electricity</td>
</tr>
<tr>
<td>To reduce the harmful health effects from pollution</td>
<td>Reduced lung and respiratory diseases</td>
<td>Number of doctor visits</td>
<td>Electricity Access</td>
</tr>
</tbody>
</table>

A QFD model can now be developed using the customer objectives and relating them to each of the requirements. This process helps to identify the most important priorities of the overall system which is useful in determining contractual requirements which must be fulfilled. The next series of figures identifies how QFD was used for the electricity problem.

The first stage is assigning “levels of importance” to each customer objective (customer expectation) in this example as shown in figure eleven (11). Those levels of importance are basically numerical “weights” which will be used to score down the house of quality.

From the customer top level needs, “increasing the availability of affordable electricity for urban and rural areas” was assigned the highest weight. This is because that objective can be linked to most of the other requirements.

Using the importance with each objective and derived technical requirement can then be assessed for each objective. Here a scale with weights as follows was used:

\[
LOW = 1 \\
MEDIUM = 3 \\
HIGH = 9
\]
The scale is used to score each technical requirement down the house of quality matrix with each objective getting an “L”, “M” or “H” for example:

Using the objective: “To reduce the reliance on foreign oil for electricity generation” has an assigned importance of 3

When this is compared to the derived technical requirement of “Alternative Electricity Sources,” a ”M” was assigned

So using: Importance ×weighted scale

For this example, $3 \times 3 = 9$

The total for the individual scored technical requirements are then summed up for each column as shown in figure twelve (12). This process continues for each requirement down to the key process variables which help drive each requirement. The next few pages show how the model translated down to the key process variables.

<table>
<thead>
<tr>
<th>Y’s (What’s)</th>
<th>Importance</th>
<th>Alternative Electricity Sources</th>
<th>Electricity Quantity</th>
<th>Labor force Proficiency</th>
<th>Clean Electricity</th>
<th>Electricity Access</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>To reduce the reliance on foreign oil for electricity generation</td>
<td>3</td>
<td>M</td>
<td>M</td>
<td>L</td>
<td></td>
<td></td>
<td>21</td>
</tr>
<tr>
<td>To increase the availability of affordable electricity for urban and rural areas</td>
<td>5</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td></td>
<td></td>
<td>135</td>
</tr>
<tr>
<td>To create a technical workforce and improve way of life</td>
<td>4</td>
<td></td>
<td>H</td>
<td>L</td>
<td></td>
<td></td>
<td>40</td>
</tr>
<tr>
<td>To reduce the harmful effects of pollution on the environment</td>
<td>3</td>
<td>H</td>
<td></td>
<td>H</td>
<td></td>
<td></td>
<td>54</td>
</tr>
<tr>
<td>To reduce the harmful health effects from pollution</td>
<td>4</td>
<td>H</td>
<td>L</td>
<td>H</td>
<td></td>
<td></td>
<td>76</td>
</tr>
<tr>
<td>Total</td>
<td>117</td>
<td>58</td>
<td>39</td>
<td>63</td>
<td>49</td>
<td></td>
<td>326</td>
</tr>
<tr>
<td>Relative Weight (Priority)</td>
<td>35.89%</td>
<td>17.79%</td>
<td>11.96%</td>
<td>19.33%</td>
<td>15.03%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 12: Customer Objectives related to Technical Requirements
### Figure 13: Technical Requirements related to Derived Functional Requirements

<table>
<thead>
<tr>
<th>Y's (What's)</th>
<th>Relative Weight</th>
<th>Create Renewable Energy Sources</th>
<th>Increase Electricity Capacity</th>
<th>Create Jobs and Training</th>
<th>Emissions Reduction</th>
<th>Build Local Infrastructure</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alternative Electricity Sources</td>
<td>36</td>
<td>H</td>
<td>H</td>
<td>L</td>
<td>H</td>
<td>H</td>
<td>1327.91</td>
</tr>
<tr>
<td>Electricity Quantity</td>
<td>18</td>
<td>M</td>
<td>H</td>
<td>L</td>
<td>L</td>
<td>M</td>
<td>302.45</td>
</tr>
<tr>
<td>Labor force Proficiency</td>
<td>12</td>
<td>M</td>
<td>L</td>
<td>H</td>
<td>H</td>
<td></td>
<td>263.19</td>
</tr>
<tr>
<td>Clean Electricity</td>
<td>19</td>
<td>H</td>
<td></td>
<td>H</td>
<td></td>
<td></td>
<td>367.18</td>
</tr>
<tr>
<td>Electricity Access</td>
<td>15</td>
<td>M</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td></td>
<td>450.92</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>631.288</td>
</tr>
<tr>
<td><strong>Relative Weight (Priority)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>23.28%</td>
</tr>
</tbody>
</table>

### Figure 14: Functional Requirements related to Design Requirements

<table>
<thead>
<tr>
<th>Y's (What's)</th>
<th>Relative Weight</th>
<th>Build plants (Geothermal, Solar, Biomass)</th>
<th>Upgrade existing plants</th>
<th>Create Technical and Trade schools</th>
<th>Establish new and upgrade current emission standards</th>
<th>Establish electricity connections</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Create Renewable Energy Sources</td>
<td>23.280543</td>
<td>H</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>325.9276</td>
</tr>
<tr>
<td>Increase Electricity Capacity</td>
<td>23.959276</td>
<td>H</td>
<td>H</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>790.6561</td>
</tr>
<tr>
<td>Create Jobs and Training</td>
<td>5.9502262</td>
<td>H</td>
<td>M</td>
<td>H</td>
<td>L</td>
<td>H</td>
<td>0</td>
</tr>
<tr>
<td>Emissions Reduction</td>
<td>23.970588</td>
<td>H</td>
<td>L</td>
<td>L</td>
<td>H</td>
<td>L</td>
<td>124.9548</td>
</tr>
<tr>
<td>Build Local Infrastructure</td>
<td>22.839367</td>
<td>H</td>
<td>M</td>
<td>H</td>
<td>L</td>
<td>H</td>
<td>1119.129</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>684.26</td>
<td>313.38</td>
<td>258.74</td>
<td>123.63</td>
<td>258.74</td>
<td>2360.67</td>
</tr>
<tr>
<td><strong>Relative Weight (Priority)</strong></td>
<td></td>
<td>29.0%</td>
<td>13.3%</td>
<td>11.0%</td>
<td>5.2%</td>
<td>11.0%</td>
<td></td>
</tr>
</tbody>
</table>
As previously mentioned, developing requirements is a critical step and there are many tools available to ensure the adequate requirements are captured. This paper just highlights one such tool which could be used in the beginning stages of the requirements formulation. What this model shows is that customer objectives can be traced down to a requirement and conversely that requirement back up to an objective. An observation from the model identifies the key design requirements as building new and updating existing plants. As these requirements get traced back through the house of quality, it becomes clear that in order to solve the problem hence meet the objectives, the alternatives will have to meet that requirement.

Analysis of Alternatives

Analysis of Alternatives (AoA) is an objective analysis effort that studies the costs, effectiveness, and risks for potential solutions to a stated requirement. AoA should inform decision makers well enough so they can wisely choose an alternative. Given the scope of this paper, a complete AoA cannot be performed. This paper will however highlight a useful tool which can be used in the AoA.

When it comes to comparing these alternatives, many analysis tools exist but this report will highlight the Technique for Order Preference by Similarity to Ideal Situation (TOPSIS) method. The main idea behind TOPSIS is that the chosen alternative should be as close to the ideal solution as possible and as far from the negative-ideal solution. TOPSIS is a useful tool in evaluating alternatives in multi-criteria decision making.
As previously mentioned in figure eight (8) the best approach is segmenting these technologies into three segments: Large, small and, a hybrid system which may constitute a cross between two or more of the other systems. For the purposes of this report, the analysis of alternatives (AoA) will be performed on the large and small scale items under consideration.

<table>
<thead>
<tr>
<th>Large Scale System</th>
<th>Small Scale System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geothermal</td>
<td>Wind</td>
</tr>
<tr>
<td>Solar</td>
<td>Microbial</td>
</tr>
<tr>
<td>Biomass</td>
<td>Biomass</td>
</tr>
</tbody>
</table>

As previously mentioned hydropower was not considered because it is currently the primary source of electricity generation in the region. The purpose of this paper is to identify additional sources which could bolster the current capacity.

The Large Scale Scenario

This section will focus on the large system approach but could be performed similarly for small scale systems. Providing electricity for the region poses some significant challenges. This next section looks at the available technologies and assesses their viability in meeting the set forth objectives.

Solar Energy

Solar power can be broken into two categories:

Solar Photovoltaic (PV) Technology

This technology directly converts the sun's energy into electrical energy and solar thermal energy. This system uses solar cells which convert energy from the sun into electricity. This electricity can then be used to power equipment.
Concentrated Solar Power (CSP)

CSP uses the heat from sunlight to generate electricity. This technology differs from solar PV in that CSP does not directly convert the sun's energy into electricity. There are three (3) main types of CSP systems:

Linear Concentrator Systems (LCS)

This technology uses long rectangular mirrors which are curved in the direction of the sun as shown in figure seventeen (17). Several kinds of LCS exist: parabolic trough systems which have receiver tubes running along the “focal” of each parabolic mirror and the linear Fresnel system which has receiver tubes positioned above several mirrors. These tubes carry superheated water which drives the turbine used in the generation of electricity.

Dish (Engine) Systems
In this system, the sunlight is reflected onto a thermal receiver using a large mirrored dish. This dish is mounted onto a base which is powered to track the dish with the sun’s movement. This receiver absorbs heat which is transferred to a generator\textsuperscript{16}.

**Power Tower Systems**

This system uses an array of flat mirrors (Heliostats) which concentrate the sunlight to the top of a tower. This tower has a thermal receiver which generates heat used to run a turbine\textsuperscript{16}.

![Diagram of Concentrated Solar Power System](image.png)

**Figure 17: How Concentrated Solar Power Works – Example shows a LCS\textsuperscript{19}**

Solar energy is advantageous in that the sun is a readily available resource and the region receives abundant sunshine\textsuperscript{6}. This technology has near zero emissions which make it great for sustainable development. Another important factor is that the technology is proven and reliable.

The challenges with solar energy are high setup costs which may be difficult to overcome considering the financial constraints on the region. Another challenge is that implementation requires a significant foot print which makes this not suited for small scale projects.

**Geothermal Energy**

Geothermal energy takes heat from within the earth’s crust which can be used to generate electricity. Geothermal plants use high temperature (300 degrees F to 700 degrees F) from either wet or dry wells which are drilled beneath the earth’s surface.
The benefits of geothermal energy are; it produces near zero emissions which is good for the environment. Another advantage is plants do not require a significant footprint when compared to solar energy plants.

The Challenges of implementing geothermal energy for electricity production are the high initial setup costs which are still lower than solar energy. Another significant challenge is the fact that the resource is limited. The heat in the earth’s core may decrease over time which affects the life cycle for these projects.

There are three types of geothermal plants:\textsuperscript{14}:

Dry Steam Plants

This system uses steam which is piped directly from a well which turns the generator turbines.

Flash Steam Plants

This system takes hot water at high pressure from deep inside the earth’s core and converts it to steam which in turn drives the generator turbines. As the steam cools and condenses into water it is recycled back into the ground and the process is repeated.

Binary Cycle Power Plants

This system transfers heat from geothermal hot water to another liquid (ex. oil). This liquid then turns to steam which is used to drive a generator turbine.
Biomass Technology

Electricity from biomass is best exemplified by cogeneration. Cogeneration utilizes a power station to both generate electricity and heat\(^3\). Conventional power plants radiate heat as a by-product of the electricity they produce. However in cogeneration also known as Combined Heat and Power (CHP), the by-product heat is captured from the basic industrial process and used in conjunction with a water (liquid) source to produce steam which turns a generator turbine. Biomass as a source of electricity generation is suited for the EA region which has a rich agricultural industrial base.

Biomass offers the advantages of being environmentally friendly, it is inexpensive to implement when compared to solar and geothermal. The technology is relatively easy and very efficient. Biomass is suited for both small scale and large scale integration and cogeneration is probably the best suited approach for the region. This is because electricity would essentially be a beneficial by product of a basic industry such as sugar cane or corn production.

There are several challenges with utilizing biomass; it does not generate enough capacity to be used as a sole source of electricity production. This limitation however makes biomass a good consideration for smaller scale electricity production where factories are located in rural farm areas with segregated populations. The electricity produced can by the factories and local communities and the surplus sold to the national grid if necessary.
Another challenge with biomass as a small scale option for electricity generation is the costs associated setup. While these costs have been identified as being less than the other options, rural areas where this technology is probably best suited is also where the poorest communities are often found. These communities may not have the resources to afford the equipment to setup a plant. This challenge can be overcome by local and foreign investment.

Figure 19: How Biomass Energy Works

The Small Scale Alternatives

Wind Energy

Wind energy is categorized with the small scale systems as the region is not ideally suited for developing large scale wind farms. This is due to the low wind speeds in the region which when compounded with the system development costs creates the infeasibility.
As shown in figure twenty (20), the region has wind speeds ranging approximately between 3.5 and 5.5 meters per second (7.8 and 12.3 miles per hour)\textsuperscript{22}.

Wind systems convert the kinetic energy produced by the wind which is converted into mechanical energy. The mechanical energy is used to drive a generator which produces electricity.

The advantages of wind technology are near zero emissions as expected. At the small scale level, it offers reliable energy and is affordable when compared to solar or geothermal energy. The challenges with wind energy are variability and cost if being implemented as a large scale system.
Microbial Technology

Microbial fuel cells (MFCs) obtain small current which exist naturally in dirt as it breaks down organic material. A chemical reaction occurs in which an anode and cathode are utilized to generate small amounts of electricity.
The advantage of microbial technology is “dirt” is readily available. The challenges with this technology are low power generation. Currently, only low power levels can be produced which can only power devices such as batteries or light emitting diodes (LED) lights. Another challenge is the lack of technology maturity.

Biomass Technology

The previous section discussed how biomass could be used for large scale electricity production. This section highlights how biomass (biogas) could be used for electricity generation but a much smaller scale. Biogas is derived from a mixture of methane and carbon dioxide produced during the decomposition of organic substances.\textsuperscript{25, 26}

Figure 22: How MFCs Work\textsuperscript{24}
Using biomass technology in this way would provide electricity for rural areas which are very remote making connection to the national electricity grid difficult.

A systems approach to evaluating Alternatives

Using a systems approach provides designers a great way to analyze and assess alternatives with complex considerations. One method is the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) model.

TOPSIS offers several advantages for analysis:
- It is simple to use
- It is difficult to dispute the resultant rankings obtained from the model

The Renewable Electricity Large System (RELS) Alternatives

For this analysis, the first step was to create a decision matrix by grouping the alternatives with objective/subjective criteria as shown in table six (6). Once the decision matrix is obtained, the model can be executed as shown table seven (7) through fifteen (15).
A qualitative scale is necessary for weighing the subjective criteria. The environmental and operating costs are shown as subjective criteria for this analysis.

Table 7: Qualitative Weight Scale

<table>
<thead>
<tr>
<th>Qualitative Scale:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Excellent</td>
<td>9</td>
</tr>
<tr>
<td>Above Average</td>
<td>7</td>
</tr>
<tr>
<td>Average</td>
<td>5</td>
</tr>
<tr>
<td>Below Average</td>
<td>3</td>
</tr>
<tr>
<td>Poor</td>
<td>1</td>
</tr>
</tbody>
</table>

The next step is to assign numerical values to all the subjective criteria as shown in table eight using the QWS in table seven (7) as shown in table eight (8):

Table 8: Updated Data Matrix

<table>
<thead>
<tr>
<th>Data Matrix:</th>
<th>Capital Cost ($M)</th>
<th>Environmental Impact</th>
<th>Technology Readiness Level (TRL)</th>
<th>Gross Output (MW/hr)</th>
<th>Pollution Control</th>
<th>Operating Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geothermal Energy</td>
<td>1,850</td>
<td>Excellent</td>
<td>9</td>
<td>300</td>
<td>Above Average</td>
<td>Excellent</td>
</tr>
<tr>
<td>Solar Photovoltaic Energy</td>
<td>1,190</td>
<td>Below Average</td>
<td>4</td>
<td>150</td>
<td>Above Average</td>
<td>Below Average</td>
</tr>
<tr>
<td>Concentrated Solar Energy</td>
<td>1,400</td>
<td>Average</td>
<td>6</td>
<td>100</td>
<td>Excellent</td>
<td>Below Average</td>
</tr>
<tr>
<td>Biomass</td>
<td>480</td>
<td>Average</td>
<td>7</td>
<td>90</td>
<td>Average</td>
<td>Above Average</td>
</tr>
</tbody>
</table>

Once numeral values as assigned to every value, the next step is to normalize the values. This was done by taking each attribute and dividing it by the sum of each value down the attribute in the column. The results are shown in table nine (9) below:
Table 9: Normalized Matrix

<table>
<thead>
<tr>
<th>Evaluation Criteria:</th>
<th>Capital Cost (SM)</th>
<th>Environmental Impact</th>
<th>Technology Readiness Level (TRL)</th>
<th>Gross Output (MW/hr)</th>
<th>Pollution Control</th>
<th>Operating Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geothermal Energy</td>
<td>0.6978</td>
<td>0.7606</td>
<td>0.6671</td>
<td>0.8301</td>
<td>0.4901</td>
<td>0.7398</td>
</tr>
<tr>
<td>Solar Photovoltaic Energy</td>
<td>0.4488</td>
<td>0.2535</td>
<td>0.2965</td>
<td>0.4151</td>
<td>0.4901</td>
<td>0.2466</td>
</tr>
<tr>
<td>Concentrated Solar Energy</td>
<td>0.5281</td>
<td>0.4226</td>
<td>0.4447</td>
<td>0.2767</td>
<td>0.6301</td>
<td>0.2466</td>
</tr>
<tr>
<td>Biomass</td>
<td>0.1810</td>
<td>0.4226</td>
<td>0.5189</td>
<td>0.2490</td>
<td>0.3501</td>
<td>0.5754</td>
</tr>
</tbody>
</table>

Once the normalized matrix is setup, the next step in analyzing the alternatives is establishing a relative importance by assigning weighted values. The weighted values are shown in table ten (10) below:

Table 10: Weight Scale

<table>
<thead>
<tr>
<th>Weight Scale</th>
<th>9</th>
<th>7</th>
<th>5</th>
<th>3</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Significantly More Important</td>
<td>9</td>
<td>7</td>
<td>5</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Slightly More Important</td>
<td>7</td>
<td>5</td>
<td>3</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Equal</td>
<td>5</td>
<td>3</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slightly Less Important</td>
<td>3</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Significantly Less Important</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Each alternative is assigned a weight which is then factored with each attribute value in table nine (9). The weights are assigned based on the importance as considered from the house of quality model in the requirements section. The results are shown in table eleven (11):

Table 11: Matrix with Weights Applied

<table>
<thead>
<tr>
<th>Weights Applied</th>
<th>Capital Cost (SM)</th>
<th>Environmental Impact</th>
<th>Technology Readiness Level (TRL)</th>
<th>Gross Output (MW/hr)</th>
<th>Pollution Control</th>
<th>Operating Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geothermal Energy</td>
<td>0.1249</td>
<td>0.1121</td>
<td>0.0913</td>
<td>0.1748</td>
<td>0.0877</td>
<td>0.1090</td>
</tr>
<tr>
<td>Solar Photovoltaic Energy</td>
<td>0.0803</td>
<td>0.0374</td>
<td>0.0406</td>
<td>0.0874</td>
<td>0.0877</td>
<td>0.0363</td>
</tr>
<tr>
<td>Concentrated Solar Energy</td>
<td>0.0945</td>
<td>0.0623</td>
<td>0.0609</td>
<td>0.0583</td>
<td>0.1128</td>
<td>0.0363</td>
</tr>
<tr>
<td>Biomass</td>
<td>0.0324</td>
<td>0.0623</td>
<td>0.0710</td>
<td>0.0524</td>
<td>0.0626</td>
<td>0.0848</td>
</tr>
</tbody>
</table>

Now the extreme positive and negative values for each attribute are identified:
# Table 12: Positive and Negative Ideal Solutions

<table>
<thead>
<tr>
<th>Ideal Solution</th>
<th>Capital Cost (SM)</th>
<th>Environmental Impact</th>
<th>Technology Readiness Level (TRL)</th>
<th>Gross Output (MW/hr)</th>
<th>Pollution Control</th>
<th>Operating Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive Ideal Solution</td>
<td>0.0324</td>
<td>0.0374</td>
<td>0.0913</td>
<td>0.1748</td>
<td>0.0626</td>
<td>0.1090</td>
</tr>
<tr>
<td>Negative Ideal Solution</td>
<td>0.1249</td>
<td>0.1121</td>
<td>0.0406</td>
<td>0.0524</td>
<td>0.1128</td>
<td>0.0363</td>
</tr>
</tbody>
</table>

# Table 13: Distribution from Positive Matrix

<table>
<thead>
<tr>
<th>Positive Matrix</th>
<th>Capital Cost (SM)</th>
<th>Environmental Impact</th>
<th>Technology Readiness Level (TRL)</th>
<th>Gross Output (MW/hr)</th>
<th>Pollution Control</th>
<th>Operating Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geothermal Energy</td>
<td>0.0086</td>
<td>0.0056</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0006</td>
<td>0.0000</td>
</tr>
<tr>
<td>Solar Photovoltaic Energy</td>
<td>0.0023</td>
<td>0.0000</td>
<td>0.0026</td>
<td>0.0076</td>
<td>0.0006</td>
<td>0.0053</td>
</tr>
<tr>
<td>Concentrated Solar Energy</td>
<td>0.0039</td>
<td>0.0006</td>
<td>0.0009</td>
<td>0.0136</td>
<td>0.0025</td>
<td>0.0053</td>
</tr>
<tr>
<td>Biomass</td>
<td>0.0000</td>
<td>0.0006</td>
<td>0.0004</td>
<td>0.0150</td>
<td>0.0000</td>
<td>0.0006</td>
</tr>
</tbody>
</table>

# Table 14: Distribution from Negative Matrix

<table>
<thead>
<tr>
<th>Negative Matrix</th>
<th>Capital Cost (SM)</th>
<th>Environmental Impact</th>
<th>Technology Readiness Level (TRL)</th>
<th>Gross Output (MW/hr)</th>
<th>Pollution Control</th>
<th>Operating Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geothermal Energy</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0026</td>
<td>0.0150</td>
<td>0.0006</td>
<td>0.0053</td>
</tr>
<tr>
<td>Solar Photovoltaic Energy</td>
<td>0.0020</td>
<td>0.0056</td>
<td>0.0000</td>
<td>0.0012</td>
<td>0.0006</td>
<td>0.0000</td>
</tr>
<tr>
<td>Concentrated Solar Energy</td>
<td>0.0009</td>
<td>0.0025</td>
<td>0.0004</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
</tr>
<tr>
<td>Biomass</td>
<td>0.0086</td>
<td>0.0025</td>
<td>0.0009</td>
<td>0.0000</td>
<td>0.0025</td>
<td>0.0023</td>
</tr>
</tbody>
</table>

# Table 15: Closeness to Ideal Solution

<table>
<thead>
<tr>
<th>Closeness to Ideal Solution</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Geothermal Energy</td>
<td>0.558</td>
</tr>
<tr>
<td>Solar Photovoltaic Energy</td>
<td>0.417</td>
</tr>
<tr>
<td>Concentrated Solar Energy</td>
<td>0.275</td>
</tr>
<tr>
<td>Biomass</td>
<td>0.502</td>
</tr>
</tbody>
</table>

Results of the TOPSIS Model
The results of the TOPSIS model, as shown in table fifteen (15) above reveal geothermal energy as the best alternative for providing electricity as a large system. Interestingly the model also revealed that the next option for consideration is the utilization of biomass. A similar analysis can be performed for the alternatives for small scale systems which would provide system designers with good indications of which alternatives are best suited given a similar set of attributes.

SUMMARY

This paper presented an overview of several techniques used by systems engineers in analyzing problems and validating solutions. Systems engineering offers many great tools which can be used for solving complex problems many of which exist in developing nations.

Providing electricity is one such challenge faced by developing nations. Regions like Africa continue to face slow or nonexistent economic growth due to the lack of energy infrastructures. The realization that having a good energy policies and infrastructures may have donned on developing nations, the challenge now becomes figuring out how to implement systems that work.

Renewable energy offers great potential for solving Africa’s energy crisis and should be considered as these countries build up their energy portfolios. The challenge then becomes how to implement renewable energy systems in these developing nations.

This paper looked at the East African region which comprises of:

- Kenya
- Uganda
- Tanzania

The region is characterized by high levels of unemployment, traditional forms of energy production and generation and large rural areas with no access to electricity having to depend of firewood for heating and lighting needs.

Renewable energy sources are a great way of meeting the growing demands for energy within the region as well as ensuring sustainable development. Currently renewable energy sources include:

- Solar Power
- Wind Energy
- Geothermal Energy
- Biomass

This problem however is a large problem and cannot be easily solved without some analysis which systems engineering tools afford. This paper looked at the following tools using the renewable energy scenario:

- Problem Formulation
One shortcoming of this paper was the lack of an economic feasibility assessment. This is an important part of any analysis and must be performed as cost is bound to be a significant variable.

Recommendations

A systems approach offers a great way of evaluating the complex energy issues faced by developing nations. As the countries and outside agencies such as the United Nations and the World Bank consider providing funding for such development projects, supporters must ensure that the programs being developed align with the best interests of the nation, offer measurable results and provide opportunities by which energy programs can be initiated, developed, maintained and sustained. This can only be facilitated by undertaking these projects utilizing an effective systems approach which encompasses the entire paradigm. One major consideration which must be considered by developing countries is renewable energy sources in building energy capacity. Developing countries stand to benefit if they implement these systems at the current basic level(s) as opposed to trying to integrate them later. As electricity systems in the region are being developed, renewable energy sources should be considered and built into the national grid and also at the rural areas where grid integration may not be necessary.

This paper recommends that renewable systems in the region should be implemented in three phases:

Small Scale

These systems should be flexible and modular with no intention for grid integration. The basic uses for these would be lighting, cooking and the ability to charge equipment. More analysis is necessary in developing useful alternatives for the small scale sector.

This segment offers local entrepreneurs the opportunity to develop technologies which can be used to support the initiative. This paper did not examine those technologies but offered the example of microbial which has great potential in electricity sources at a small scale level.

Large Scale

A lot of work is necessary if the EA region is to develop infrastructures comparable to the west. The goal here should not be to duplicate their systems but to emulate the best things about them and implement them in a way which is viable for the EA region. The region should invest in newer technologies with respect to hydropower, geothermal and biomass technologies.

The Way Ahead

Both the small and large scale considerations are going to require significant changes to the overall culture before successful systems can be implemented.
Some of these considerations include:

**Strategic Frameworks and Policies**

These systems are guaranteed to fail without good measurable frameworks and policies. Laws and policies must be established which emphasize and drive the industry toward sustainable development. The region depends on donor aid which is used for infrastructure development. Historically, this aid has not been utilized efficiently in executing the development plans. Without good frameworks and policies poor execution will continue to occur and the region will continue to lag behind the rest of the world in developing sustainable energy resources.

**Technology Development**

The region has to develop solutions which are indigenous. The paper mentioned several technologies which for which the sources are available locally but the technology is developed primarily in the west. African countries must begin to participate in the development of these technologies which will ensure the solutions presented meet their needs.

**Local Financial and Human Capital Investment**

The regions demands on foreign donors such as loans from the World Bank which often have to be repaid with high interest rates. This takes away from the GDP and prevents investment back into developing other areas of the economy. One way the region can alleviate this burden is shifting some of the revenues from taxes and revenue streams such as tourism into infrastructure development. If this is executed in conjunction with good frameworks and policies, it will greatly increase the chances for implementing successful systems.

Another important area is human capital investment. Workers must be trained to ensure technical competence and skill proficiencies which will drive job growth and promote economic growth. This can do done by establishing renewable energy schools which educate the local workforce on the technical aspects of building and maintaining renewable energy systems.

**Foreign Investment**

The current reality is that building energy systems which include renewable solutions is going to require foreign investment. However, due to the political climates in most of these countries, these investments are very limited as the investors are often concerned with the levels of risk. This means that the EA region will continue to rely on foreign donors in the foreseeable future. While this has some disadvantages, it does present some benefits like getting approval for large projects and help to implement them. These donors also provide great opportunities for long term financing which local options currently cannot provide.

Organizations such the United Nations and The World Bank have invested large amounts of money investigating the problems faced by developing nations and are often eager to help them develop and implement solutions which work. This proves beneficial for countries that can leverage those good strategies for significant investments for these organizations.
Renewable Energy Works

In conclusion, renewable energy solutions must be considered for any country considering energy infrastructure growth. The global environment faces significant challenges which are guaranteed to continue into the 21st century. Developing countries must institute “responsible” systems which ensure that the economies continue to grow and thrive.

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