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# Site Selection Evaluation utilizing HDM model & STEEP perspectives: Case Study - Pyramid Power

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Author(s):

Yaser Al-Nasri
Aruna Bhatia
Nirupama Mantha
Mark Ryan
Mike Smith
Komal Vinchhi



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**List of Figures and Tables**

# Abstract

This paper presents a limited framework using Hierarchical Decision Making model with STEEP perspectives to assist in site selection for an environmentally focused waste energy conversion project. The framework in limited in that the structure presented is a stem, the beginning, and should be expanded upon if used. Examples of expansion criteria are given in this document to be considered along with relevant criteria derived from specific company and project background.

When choosing where to implement an energy-sector green project on a global scale there are countless factors that can help a project succeed or fail. Literature research yielded consistent and historical vetted cases where STEEP (social, technical, environmental, economic, political - sometimes abbreviated to PEST or PESTEL) perspectives were proven effective. This paper presents a model where project locations can be plugged in and relative weights can easily be assigned to suggest and categorize locations. To prove the model, a sample case study was used against the limited model for the company Pyramid Power in an endeavor to select a location for industrial diesel generator heat capture tooling. This tooling improves energy output by as much as 30% without additional fuel. The scale and success of this initial project are crucial to the success of the company, thus site selection is a top priority.

# Background

Pyramid Power has developed an innovative product that utilizes heat energy for conversion to electricity. There are thousands of locations where the availability of a heat source is sufficient to power the Pyramid Power electricity equipment. The company has a desire to select the most desirable location for its initial installation.

Industrial excess heat is a large untapped resource, this opens up a new source of energy that can be beneficial both commercially and environmentally. Converting the excess heat into energy can reduce the cost of energy and reduce the amount of heat and gases like CO2 released into the environment [1]. Industries across the globe are focusing their efforts on improving energy efficiency, recovering waste heat losses is an attractive option as it’s emission free and a cheaper alternative. Numerous technologies and variations/combinations of technologies are commercially available for waste heat recovery [2]. Captured and reused waste heat is an emission free substitute for costly purchased fuels or electricity [2].

The important components (Figure A) that are required for waste heat recovery are accessible source of waste heat, a recovery technology, and a use for the recovered energy [2].

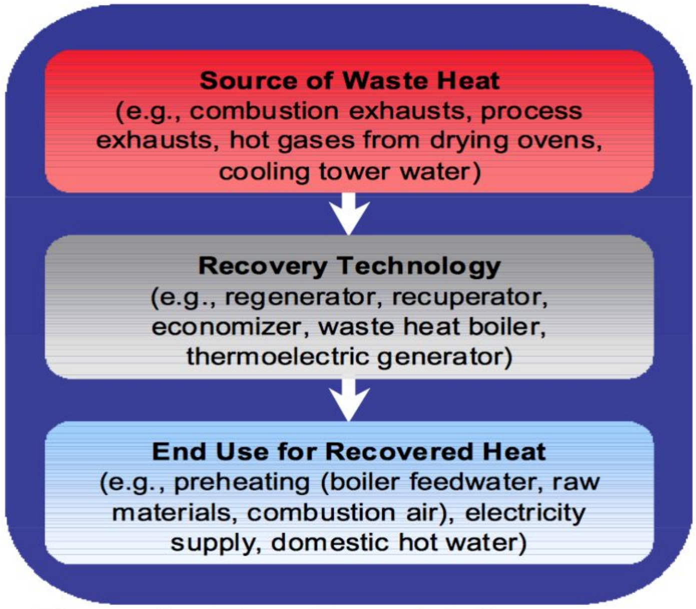


Figure A: Three Essential Components are required for Waste Heat Recovery [2].

*"Methods for waste heat recovery include transferring heat between gases and/or liquids (e.g., combustion air preheating and boiler feed-water preheating), transferring heat to the load entering furnaces (e.g., batch/cullet preheating in glass furnaces), generating mechanical and/or electrical power, or using waste heat with a heat pump for heating or cooling facilities"* [2]. Most unrecovered waste heat is at low temperatures. Study done by US Department of Energy showed that roughly 60% of unrecovered waste heat is low quality, ie below 450°F. Pyramid Power modules can operate at temperatures as low as 185°F [3].

The productivity of a facility is increased by using waste heat recovery technologies as it reduces their operating cost, because the electricity is being generated locally [2]. Several factors determine whether heat recovery is feasible in a given application. Small-scale operations are less likely to install heat recovery as they might not have the sufficient capital available. The heat source might only be available for a limited time every day or might not be easily accessible. These along with various other factors were discussed with the experts to determine the criteria for STEEP.

Industries these days are discharging large amounts of waste heat and it provides a greater opportunity to capture that heat and convert it into energy to reduce the environmental impact as well as gain huge energy savings.The industrial waste heat released from many manufacturing processes has a relatively high temperature enough to drive a power cycle and produce electricity for on-site use or sale [4].

As much as 20–50% of the energy used during the manufacturing processes is released to the atmosphere, and in some cases (e.g., industrial furnaces), the energy efficiency can be improved by 10% to as much as 50% by recapturing the waste heat. It was estimated that waste heat recovery in a midsize cement plant contributes to a potential enhancement in energy efficiency up to 20% and a reduction in the $CO_2$ emissions up to 10,000 ton/year [4].

There can be many benefits of waste heat power generation as its on-site and does not require a grid connection or firming generation like wind. It has a high potential utilization factor in comparison to solar or wind energy. It does not depend on the development of land or extraction of resources as in the case of wind or hydro energy.This can be privately owned, operated and maintained.

The major barrier to development of industrial waste heat for power generation is in-experience with design and operation of plants in various industries with potential resources and the identification of optimum opportunities to pursue.

# Literature Review

"Decision making is the process of making choices by identifying a decision, gathering information, and assessing alternative resolutions. Using a step-by-step decision-making process can help you make more deliberate, thoughtful decisions by organizing relevant information and defining alternatives. This approach increases the chances that you will choose the most satisfying alternative possible" [5]. Decision making is a mathematical science today [6]. It is evident that when a decision is to be made by a group, an organised method is required to make decisions based on the relevant information. Individuals of the group decide with respect to their understanding and knowledge.

Methods adopted for decision making range from the most casual ones like flipping coins to the more structured decision making tools like Analytic Hierarchy Process (AHP). AHP is developed by Thomas Saaty. AHP assesses, prioritizes, ranks and evaluates decision choices [6].

The use of multi criteria decision making has gained immense significance in the decision making process of energy management and planning problems over the years due to the growing complexity of these problems. Early on, single criteria decision making was used which focused on maximizing the profit and minimizing the cost. With time, cost- profit were not the only criteria considered for making decision but the growing awareness about the environment, social implication and impacts, rapidly growing technologies, etc started influencing these decisions. The advent and advocacy of renewable energy sources worldwide changed the way people used to make decisions related to energy planning. Multi criteria decision making methods were introduced as tool to deal with the complexity of these problems which has multiple objectives. Multi criteria decision making was found efficient in assessing the changed socio- economic scenario. These methods gained popularity in renewable energy management and planning as it could account for the multiple- conflicting criteria and derive better solution to these multi faceted complex problems [7][8].

The nature of the energy planning and energy management problems makes it extremely important to evaluate and assess any such projects taking into consideration the economic, technical, environmental and social attributes of the project. This unique aspect of these problems can be addressed by using multi criteria approaches. Multi criteria decision making is a decision making approach that can address intricate problems which can comprise of high uncertainty, conflicting objectives and goals, multiple interests and varied perspectives. Multi criteria decision making takes all human vagueness into account and give it a rational, quantifiable meaning. Since, the problem here is both difficult and sensitive which contains both the tangible and intangible aspects, multi criteria decision making methods will be put best in use in energy related projects [9].

These methods are a general class of Operational Research models which helps you make decisions when you have multiple objectives to fulfill. Here, the alternatives are predetermined and they are evaluated based on a set of criteria. The best alternative is then selected after comparing each alternative to each criterion. These methods have been very successfully used in Renewable energy projects in the past [10][11].

Hierarchical decision model (HDM) is a variant of AHP methodology. The general form of HDM was developed by Dr. Cleland and Dr. Kocaoglu in 1981 [12]. HDM basically breaks the complex problems in smaller subproblems which are easier to understand and assess. It uses different pairwise comparison scale and judgmental quantification technique. It consists of five hierarchical levels as Mission, Objectives, Goals, Strategies and Actions (MOGSA). The number of hierarchal levels depend on the complexity of the decision problem. Input to the method are judgements of the experts. Mathematical routines are applied to those inputs and the best alternative to the decision problem is presented as output [12].

The first step consists of breaking down the decision problem into levels consisting of objectives and their associated criteria. The second step involves input from the experts through pairwise comparisons. The third step is to process expert's input and calculate the priorities of the objectives. To avoid any random or illogical comparisons, it is very important to check consistency of each expert [12].

The decision of site selection has multi-dimensional impacts for the environment and socio-economic life, while it is affected by technical, economic, and political issues. However, considering only one or some of these aspects in evaluating the site is not adequate, particularly when environmental, safety, technical, and economic issues make an impact. The economic perspective on the site selection evaluation can be represented by the project cost, labor costs fuel, insurance, and similar costs. When environmental problems are talked about, an important aspect is the changing role of government. Climate change which is a worldwide concern today has interconnection to energy management as sharply increasing oil prices, concerns over the security of energy supply have been on the center stage. Therefore to make the best decision wherein the problem is of such a magnitude, it is best to consider all perspectives [13].

The site selection for energy project has all the inherent complexities of any energy planning problem. Because of the growing concerns around energy production, consumption, environmental and social impact and also the rapidly growing technology and all it brings with it, it becomes vehemently important for us to integrating all these critical factors into our research to addresses both the tangible and intangible aspects of the project. Thus, HDM was proposed and selected as our research tool to analyze all these critical factors, weigh in the preferences from various sources and generate the best solution. The perspective considered in the model is STEEP. The alternatives were chosen trying to represent the diversity of the locations, and the experts were students.

# HDM Model

Based on the literature review we chose the HDM model utilizing STEEP perspectives and criteria in order to assist with the decision process in site selection for renewable energy project locations.  Due to numerous success factors in each energy project, choosing where to invest an initial or pilot project can be crucial for the future success of a company.  For this purpose we created an initial model with the intention of expansion upon implementation.  This model can be seen below:

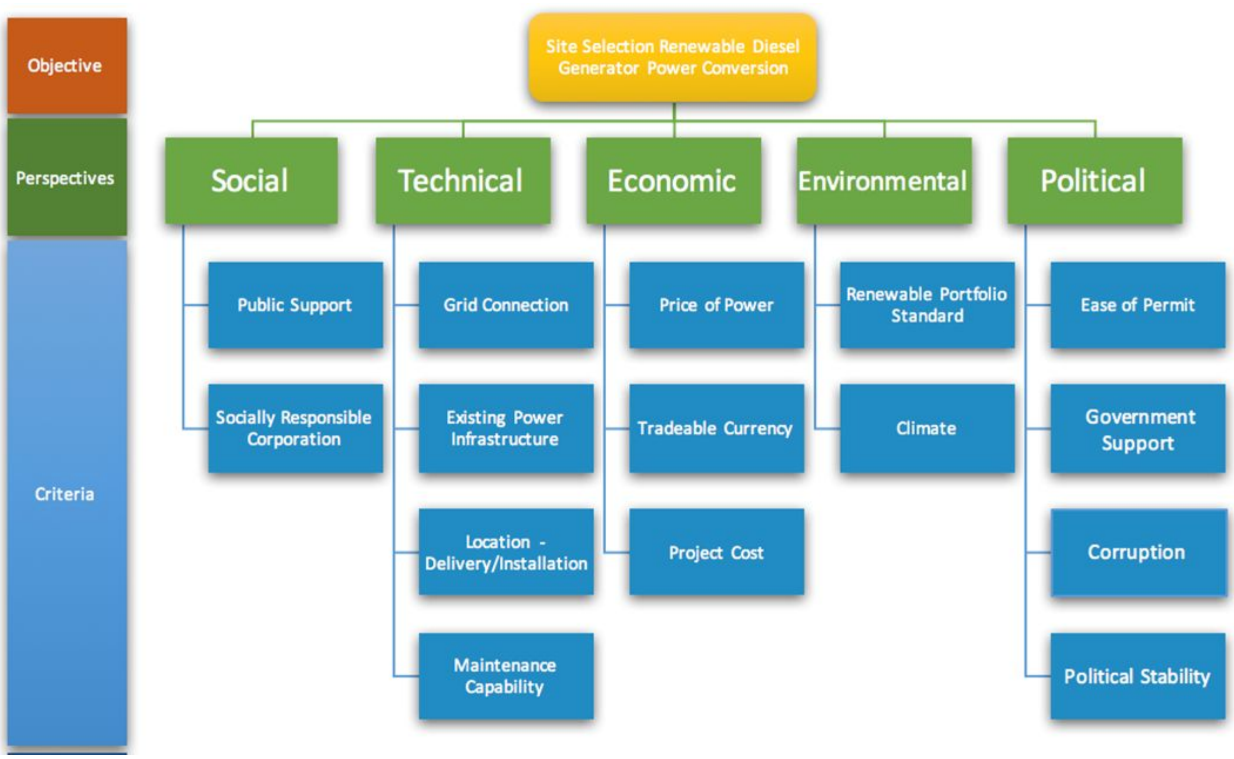


Figure B: HDM Model with Steep Perspectives and Criteria

## Social

Social perspective involves factors that may or may not directly relate to the consumer of the project. The general criteria under social will include those related to demographics, social and cultural values, education, culture, and health consciousness. The community where a project is implemented may or may not directly have access to the project's output or desire certain measures are taken to ensure they are in line with the community values for corporations operating there. An example of a company not living up to their Corporate Social Responsibility occurred in 2015 where Volkswagen admitted to modifying their cars to report false emissions, thus cheating to pass standards in various countries [14]. This caused various issues with not only vehicle sales that caused profits to drop, but money reserved for legal fees together caused a net profit drop of half in the second quarter of 2016 [15]. However reacting to the scandal appropriately has also lead the company to rebound, setting overall record sales numbers in 2016 [16].

Two factors were selected for our initial model: Public Support and Socially Responsible Corporation. These two factors represent both a public and community focus as well as a business focus. Examples of additional criteria considered and possible used in future models are: Health and Safety, Visual Impacts, Demographics, Ethnic Groups, Religious Groups.

## Technical

Technical perspective criteria may often seem redundant or focus on the tools or product, and not always include the technical implementation, maintenance, or long-term technical success. Technical design and implementation location decisions can have massive impacts on a company's success or failure. While not related solely to a single technical decision, the recent Fukushima nuclear disaster. The design and implementation of the reactor withstood the earthquake, but later proved vulnerable to the tsunami [17].

Four factors were selected were Grid Connection, Existing Power Infrastructure, Location (delivery/installation), and Maintenance Capability. The chosen criteria were selected with the idea that the initial focus would be on industrial diesel generators so grid connection and existing power may or may not exist, location for installation could make physical access difficult if remote, and location would tie to maintenance capabilities within the given location. Additional criteria considered were power production, longevity of installation, mobility, competitors.

## Economic

Economic perspectives control or influence every business decision. Standard criteria are centered on economic growth, interest rates, currency inflation, exchange rates, and overall market stability. When considering international locations economic stability and exchange rates can make or break a project. Economic impacts of project or strategic decisions cannot be ignored, and while often are heavily related to politics, they need to be considered separately. The automotive industry in America is a prime example, as General Motors dropped from #4 on the Fortune 500 in 2008 to #6 in 2009 to #15 in 2010. Comparing that to Ford Motor Company, who went from #7 to #7 to #8 in those same years [18][19][20]. The positioning Ford allowed them to sustain the downturn much more consistently than General Motors.

Three criteria selected were Price of Power, Tradable Currency, and Project Costs. These were chosen as the covered consideration of power generation versus purchasing (some locations have very high power costs), if there is a directly tradable currency as not all countries have this, and implementation costs. Additional considerations are evaluation costs, return on investment, taxation, financeability, interest rate, and exchange rate.

# Environmental

Environment criteria may seem the most important when considering a renewable energy project, but if that were the case the world would have been solar and wind powered only for the last 50 years. A balance is needed when making decisions, even if they are primarily in a specific perspective such as this project. That said, these criteria typically focus on regional climate, weather patterns and anomalies, and climate change. Fracking has been a recent source of natural gas with various effects on the community, the companies, and the environment. While innovative energy production can be a lucrative business, in this case slanted wells (typically used) result in up to 30% more blowouts of contaminated materials [21].

The two criteria selected were Renewable Energy Portfolio Standard and Climate. These represent both business and environment views - where organizations may be required to maintain a certain amount of environmentally-focused investments and if the existing climate for the install is compatible. Alternatives included installation impacts, operational impacts, and project reusability.

# Political

Politics are as different in every region as there are species in this world. Some political parties enable business that is innovative, while some require hefty bribes just to get by. Government intervention and mandates can play a large role in the project being successful in two different locations. These criteria focus around law (which can include taxes, environmental issues, labor laws), tariffs, permits (and/or bribery), and regional stability. Politics can range from national governing bodies all the way down to office or organizational levels, and while can sometimes lead companies to success, it often has unintended consequences. The space shuttle Challenger is a prime example of this as it exploded killing its entire crew in 1986. While Bob Ebeling, an engineer, tried to stop the launch as he knew certain seals would not operate in the lower than normal temps, management overrode him and ignored his data. Office politics, and perhaps national politics drove management to proceed with launch when data may have suggested halting [22].

The four criteria chosen for Political are Ease of Permit, Government Support, Corruption, and Political Stability. Considerations included regulatory bodies, political party variety, political term length, and regional conflict.

# Case Study – Pyramid Power

## Company Introduction

Waste heat from manufacturing processes worldwide that is currently going to atmosphere is several trillion BTU's of energy annually. There is more waste heat available from industry than from all renewable energy sources combined [23]. Facilities all over the world are looking at ways to increase their efficiency and decrease their carbon footprint.

Pyramid Power has introduced a new power production technology, which is significantly more efficient and is able to work at lower temperatures than existing heat to electricity technologies.

Pyramid Power's goal is to provide industry with engineered solutions to collect the thermal energy that is currently going to waste, put the waste energy into the Power Production System and create electrical power for use at the customer facility. Waste heat sources represent one of the world's largest untapped markets for the company's quick growth.

Every existing power plant, cement plant, steel plant, or other facility that has boilers or other forms of waste heat represent an opportunity for Pyramid Power to implement their Power Unit into the waste stream and generate essentially free power. The other major benefit of these projects is that they will not require any kind of environmental permits other than construction permits if there are any modifications needed for the site.

The benefits of working with waste heat sources are substantial. There is a potential to generate between 9% and 13% of the current fossil fueled electrical power by simply recycling waste energy streams. Such an estimate could reach as high as 30% of fossil-fueled electrical generation by tapping other waste sources not considered due to their lower temperatures that are within the range of the Pyramid Power. The clear benefit of recycled energy is that it is fuel-free and pollution-free, and displaces fossil generation, pollutants, and greenhouse gases. In this manner, recycled energy will reduce emissions of NOx, SOx, particulate matter, mercury and hazardous air products and will reduce greenhouse gases.

Recycling waste heat, like other decentralized energy sources, also provides an alternative to expensive and often controversial, transmission expansion. The need for such an alternative has become critically important over the past few years. A spate of recent power failures and electricity generation shortages has pointed to the need for both increased generation and transmission upgrades and expansions [24]. Pyramid Power technology and decentralized generation offers a less costly alternative. Decentralized generation needs no new transmission or distribution as it is produced on-site. And while 9% of centrally generated power is lost in transmission, decentralized generation - a less costly alternative, does not have transformer or line losses. Because the waste energy streams are produced on-site, the recycled electricity will be consumed locally, utilizing micro-grids, minimizing line losses and avoiding transmission and distribution system upgrades.

## Problem Statement

Pyramid Power has completed Design, Prototype and Packaging and is looking for an initial commercial project location to provide proof of concept in a production environment and profitability verification.

Because of the complexity and diversity of the decision elements in making the site selection decision, a Hierarchical Decision Model (HDM) was determined to be the most appropriate method.

After the model is completed and a site selection/market verified, the model will be used to evaluate other locations within a market(s) to provide ratings of projects for potential implementation.

## Site Locations

Five site locations were chosen as potential commercial installations. Each site is representative of a large potential market with variable and unique factors that will affect the desirability of the location or entire Market.

Market characteristics for each location were identified as:

1. Developed or Undeveloped. This characteristic is defined as the degree of development of the project location environment: Market, Infrastructure – grid, transportation, support, and social acceptance.
2. Location. Identification of region in the world and analysis of degree of remoteness as locations affect sales, installation, and maintenance.
3. Stability. Political stability, bribery, energy costs.
4. Energy Cost. Price of power, condition of power, availability of market for power.

Each potential site location (Figure C) was selected to represent a diverse set of characteristics in the global market:

- Los Angeles – Developed environment, Western hemisphere, Stable market, Moderate energy price.

- Maui – Developed environment, Island nation, Stable market, Moderate energy price.
- Frankfurt – Developed environment, Europe Union, 100% renewable, Moderate energy price.
- Fiji – Underdeveloped environment, Island nation, Slightly stable market, High energy cost.
- Congo – Micro-grid environment, Remote, Very unstable, Very high energy cost.


Figure C: Site Locations

## Expert Panel

The Expert Panel selected for this project consisted of the six members of Team 3.

Each member of the team conducted research about the characteristics of potential locations in preparation for determination of the model criteria and factors. A group consensus was made for factors that would be analyzed by the HDM decision model from the STEEP perspective. Based on the STEEP criteria perspective and factors that are associated with the criteria in the context of our Problem Statement, individuals of the expert panel conducted additional research about the factors for the five selected site locations.

Five diverse worldwide locations were identified and selected for evaluation in the HDM model to determine the optimal site location as defined by our problem statement.

The expert panel members individually identified and selected pairwise relationships between factors to complete the process of identification of the optimum site location for the first commercial installation for Pyramid Power.

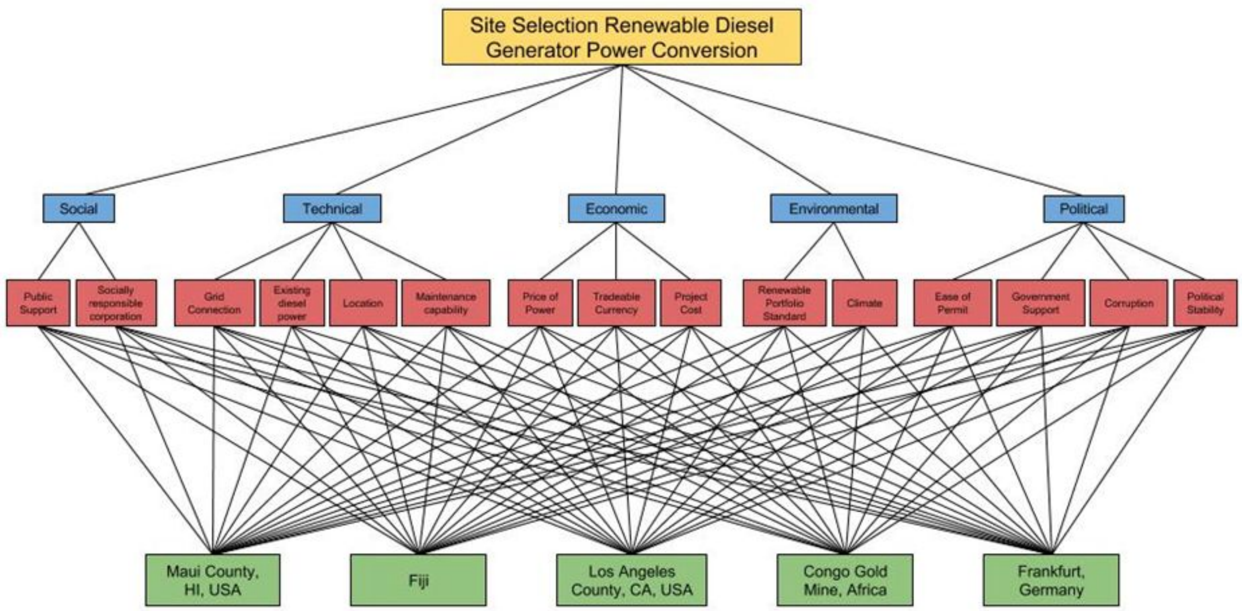


Figure D: HDM Model Relationships

# Result and Discussion

In this paper, Hierarchical Decision Model (HDM) is used to rank the site selection for renewable diesel generator power conversion. Six experts participated in this study and gave their judgment using pairwise comparison among the perspectives, criteria and alternatives. The HDM has four levels as shown in table 1 and figure E below:

Table 1 - HDM Levels

| | | |
|---|---|---|
| **Level 1** | **Objective** | Site Selection Renewable Diesel Generator Power Conversion |
| **Level 2** | **Perspectives** | Defined based on STEEP analysis (Social, Technical, Economic, Environmental, and Political) |
| **Level 3** | **Criteria** | Selected based on literature review |
| **Level 4** | **Alternatives** | Selected based on diverse worldwide locations |

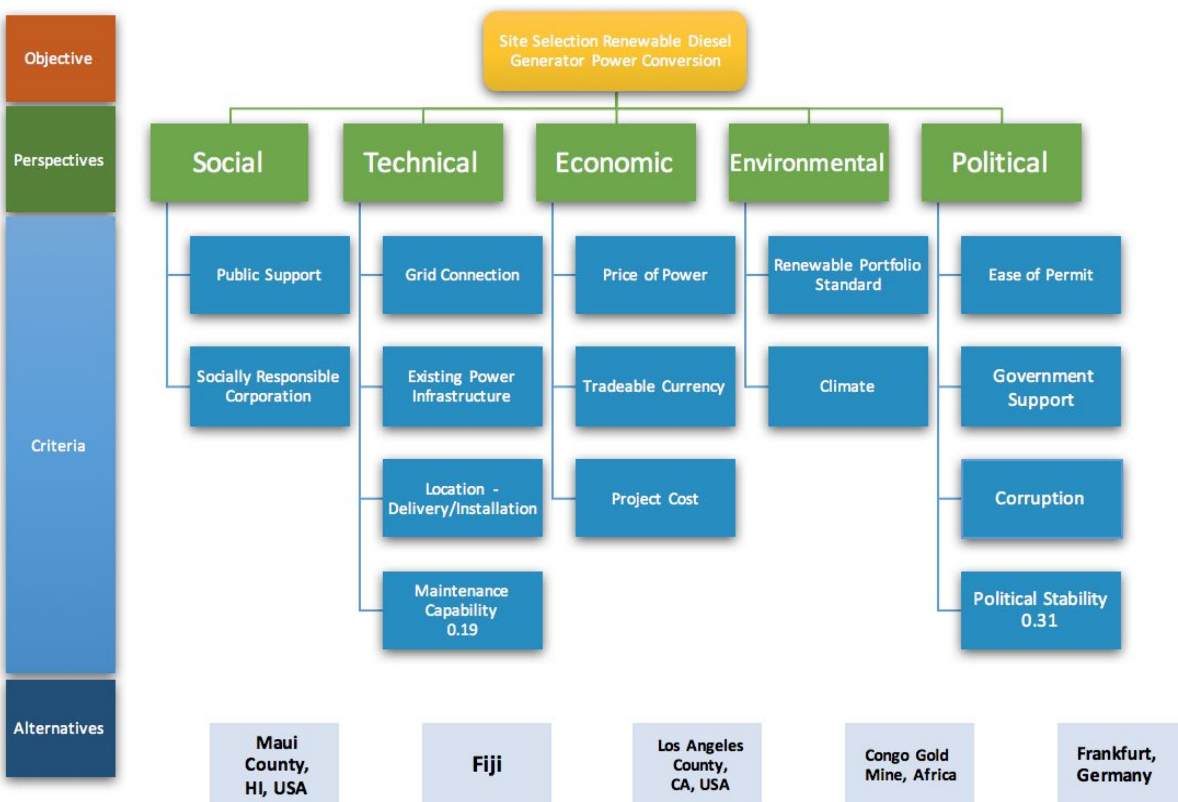


Figure E: Hierarchical Decision Model (HDM)

## Perspectives Ranking

Pairwise Comparison Method (PCM) software were utilized to determine the relative importance of the perspectives to the objective. Table 2 below shows experts weighting of the perspectives with respect to the objective. In addition, the mean of experts weighting for each perspective was calculated. This indicates the relative weight of each perspective. Figure F below shows perspective ranking.

Table 2 - Perspectives Ranking

| **Perspectives Ranking** | | | | | | |
|---|---|---|---|---|---|---|
| **Level-2** | **Social** | **Technica l** | **Economic** | **Environmental** | **Political** | **Inconsistency** |
| Expert 1 | 0.14 | 0.19 | 0.31 | 0.12 | 0.24 | 0.01 |
| Expert 2 | 0.11 | 0.17 | 0.36 | 0.11 | 0.25 | 0.03 |
| Expert 3 | 0.28 | 0.14 | 0.15 | 0.23 | 0.20 | 0.01 |
| Expert 4 | 0.10 | 0.26 | 0.23 | 0.13 | 0.28 | 0.07 |
| Expert 5 | 0.19 | 0.15 | 0.26 | 0.17 | 0.23 | 0.01 |
| Expert 6 | 0.15 | 0.25 | 0.30 | 0.12 | 0.17 | 0.00 |
| Mean | 0.16 | 0.19 | 0.27 | 0.15 | 0.23 | 0.02 |

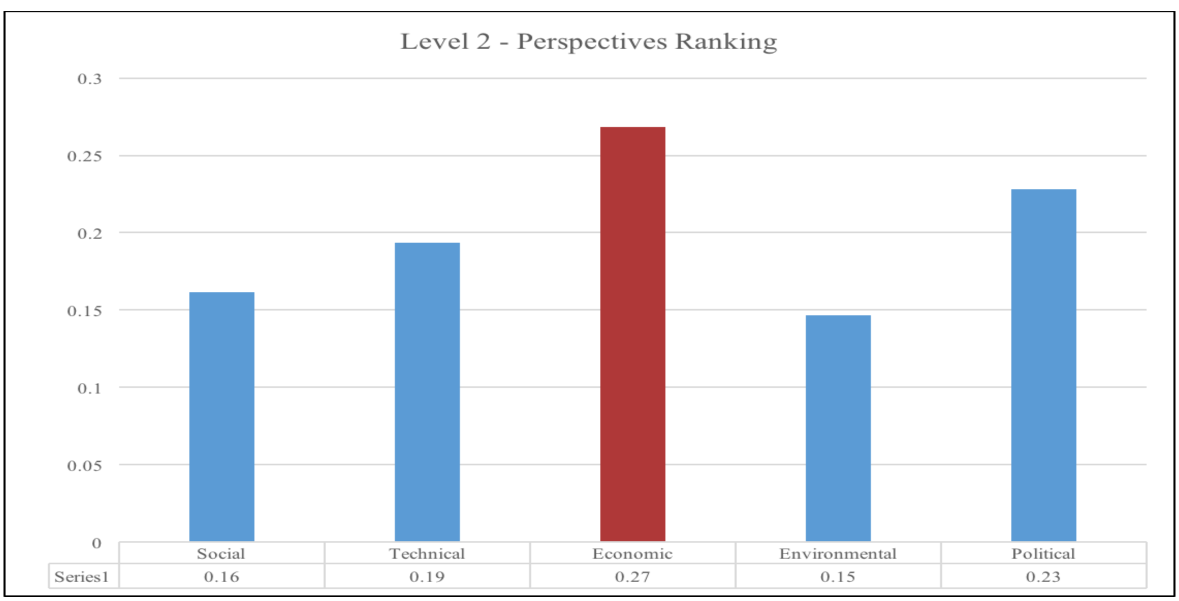


Figure F: Perspectives Ranking

At level 2, based on expert's judgment, Economic perspective was ranked the highest compared to the other perspectives at 0.27. This is not surprising as profit was identified as the most important criteria. Political perspective was a close second with a weight of 0.23. This indicates the importance of politics in such energy projects. Technical perspective was the third with a weight of 0.19. This makes sense considering the complexity nature of the renewable diesel generators. Finally, social and environmental perspectives are ranked the lowest with weights of 0.16 and 0.15 respectively.

## Criteria Ranking

The model has 15 criteria. The experts ranked each criterion with respect to its perspective. The higher the value that a criterion has the higher impact it has on its perspective. After that, the value of each criteria was calculated by the following equation:
*(The value of Criterion = The importance of criterion * The weight of its perspective)*
Figure G below shows the importance of each criteria to the objective (Refer to Figures J to N in Appendix A for more details on criteria ranking with respect to their perspectives).

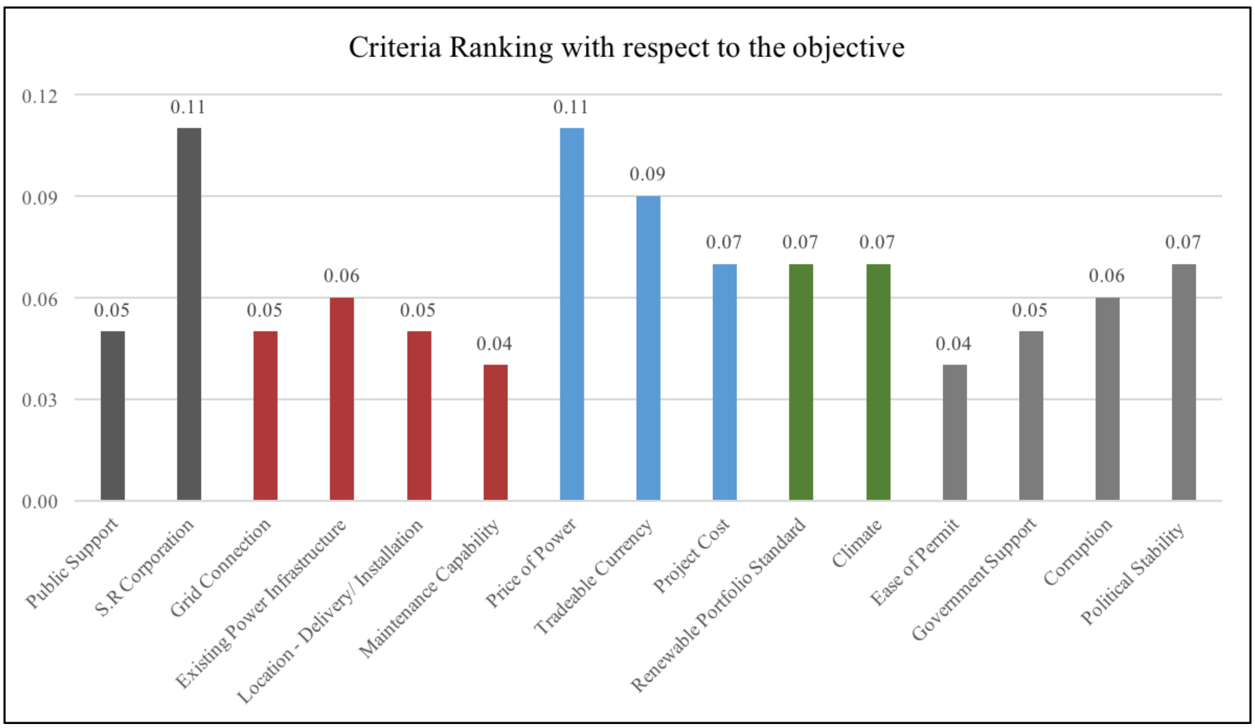


Figure G: Criteria Ranking

As shown in Figure G above, Socially Responsible Corporation and Price of Power were ranked as the highest important criteria with weights of 0.11. As we have seen in the Figure F that Economic perspective ranks the highest, which means that ROI is big deciding factor for site selection and Price of Power has higher impact on ROI which is why Price of Power is ranked highest in the criteria ranking. Any business needs to flourish and make profits to be sustainable in the long run. Also, Socially Responsible Corporation is ranked the same as Price of Power because Pyramid's power product has to be used in various industries to collect waste heat that will be converted into energy. Hence, the corporation that is socially responsible and wants to reduce their Carbon Footprint would favor the business.

Tradeable currency is the second most important criteria that impacts our decision for site selection as currency needs to tradeable so that business can transfer the profits easily instead of dealing with different forms of payments which have to be traded further. For instance, Although the price of power is the highest in Congo, they pay in gold. One the other hand, Maintenance Capability and Ease of Permit were ranked last with weights of 0.04.

## Site Selection Ranking

The experts weighed each site with respect to the criteria. The higher the value the more significance is the certain criterion in that city. There were five cities and fifteen criteria. Table 2 below shows the weighting values of each expert for each alternative. Los Angeles has the highest value with slight difference from Frankfurt, which means they are the preferable sites according to experts' judgments. Figure H below shows the final ranking of the candidates.

Table 3- Candidate Ranking

| **Site Selection Ranking** | | | | | | |
|---|---|---|---|---|---|---|
| **Level-4** | **Maui County, Hi, USA** | **Fiji** | **Los Angeles County, CA, USA** | **Congo Gold Mine, Africa** | **Frankfurt, Germany** | **Inconsistency** |
| Expert 1 | 0.27 | 0.13 | 0.26 | 0.08 | 0.25 | 0.01 |
| Expert 2 | 0.26 | 0.12 | 0.25 | 0.16 | 0.21 | 0.02 |
| Expert 3 | 0.19 | 0.2 | 0.22 | 0.16 | 0.24 | 0.01 |
| Expert 4 | 0.17 | 0.18 | 0.27 | 0.11 | 0.27 | 0.06 |
| Expert 5 | 0.19 | 0.13 | 0.26 | 0.15 | 0.27 | 0.02 |
| Expert 6 | 0.24 | 0.15 | 0.25 | 0.15 | 0.21 | 0.00 |
| Mean | 0.22 | 0.15 | 0.25 | 0.14 | 0.24 | 0.02 |

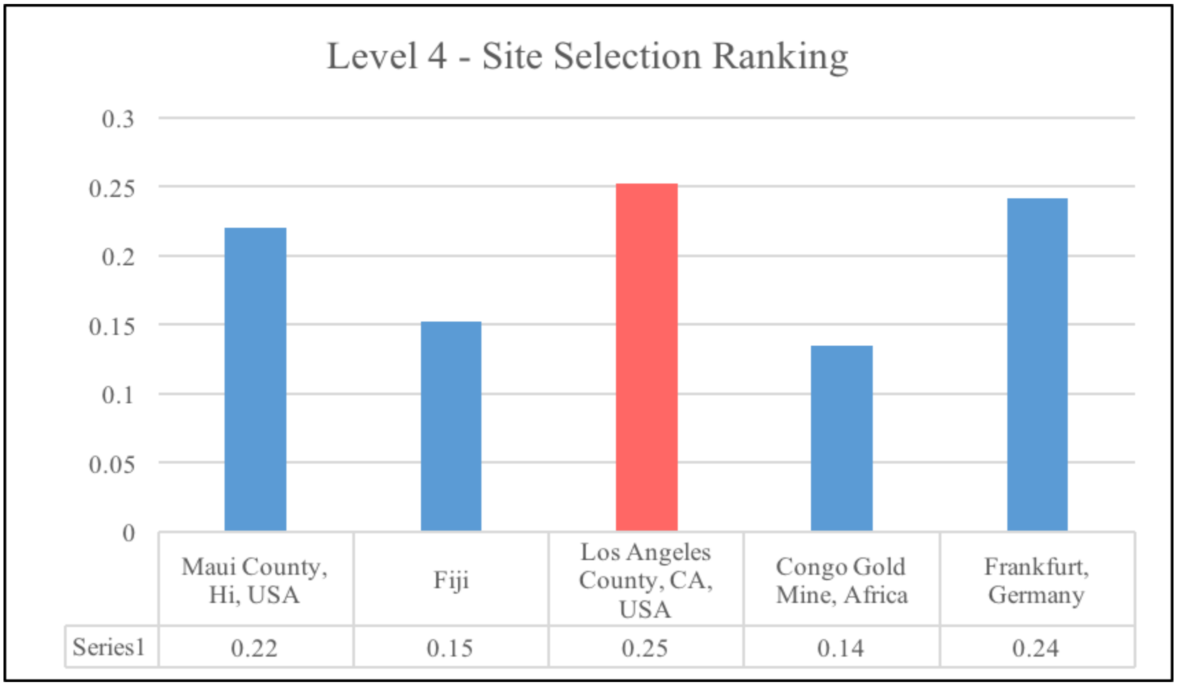


Figure H: Candidates Ranking

Maui County, HI, USA was ranked the highest in Tradeable Currency and Renewable Portfolio Standard. This is accurate as Hawaii currency is U.S dollar, and that it has set a goal of achieving 100 percent clean energy by 2045 [25]. Los Angeles was ranked the highest in Public Support, Location, Climate, Project Cost and Government Support. This is reasonable as Los Angeles city council created a Renewable portfolio standard that requires a transition from fossil fuels to powering Los Angeles with 100% clean energy [26]. Fiji was ranked the highest in Economic opportunity, or Price of Power. Finally, Frankfurt, Germany was ranked the highest in Socially Responsible Corporation, Grid Connection, Existing Power Infrastructure, Maintenance Capability, Ease of Permit, Corruption, and Political Stability. This is reasonable as Germany receives almost all its power from renewable energy [27]. Table 3 below shows that sites ranking with respect to the criteria (Refer to Figures O to AC in Appendix B for more details).

Table 4 - Sites Ranking with Respect to the Criteria

| Perspectives | Criteria | Maui County, Hi, USA | Fiji | Los Angeles County, CA, USA | Congo Gold Mine, Africa | Frankfurt, Germany |
|---|---|---|---|---|---|---|
| **Social** | Public Support | 0.21 | 0.17 | 0.25 | 0.15 | 0.23 |
| | Socially Responsible Corporation | 0.23 | 0.15 | 0.25 | 0.10 | 0.28 |
| **Technical** | Grid Connection | 0.19 | 0.13 | 0.27 | 0.14 | 0.28 |
| | Existing Power Infrastructure | 0.21 | 0.12 | 0.27 | 0.10 | 0.30 |
| | Location – Delivery / Installation | 0.20 | 0.11 | 0.31 | 0.11 | 0.28 |
| | Maintenance Capability | 0.19 | 0.11 | 0.24 | 0.18 | 0.27 |
| **Economical** | Price of Power | 0.19 | 0.24 | 0.16 | 0.23 | 0.19 |
| | Tradeable Currency | 0.31 | 0.10 | 0.28 | 0.11 | 0.22 |
| | Project Cost | 0.19 | 0.21 | 0.25 | 0.18 | 0.17 |
| **Environmental** | Renewable Portfolio Standard | 0.28 | 0.14 | 0.24 | 0.08 | 0.27 |
| | Climate | 0.19 | 0.16 | 0.27 | 0.19 | 0.19 |
| **Political** | Ease of Permit | 0.20 | 0.18 | 0.20 | 0.20 | 0.23 |
| | Government Support | 0.21 | 0.18 | 0.27 | 0.13 | 0.22 |
| | Corruption | 0.25 | 0.16 | 0.23 | 0.11 | 0.26 |
| | Political Stability | 0.23 | 0.13 | 0.27 | 0.07 | 0.30 |

## Final Results and Analysis

Figure I below, shows the final results of our HDM. The dark color indicates the perspective, criteria, and site that have the highest value among its peers.

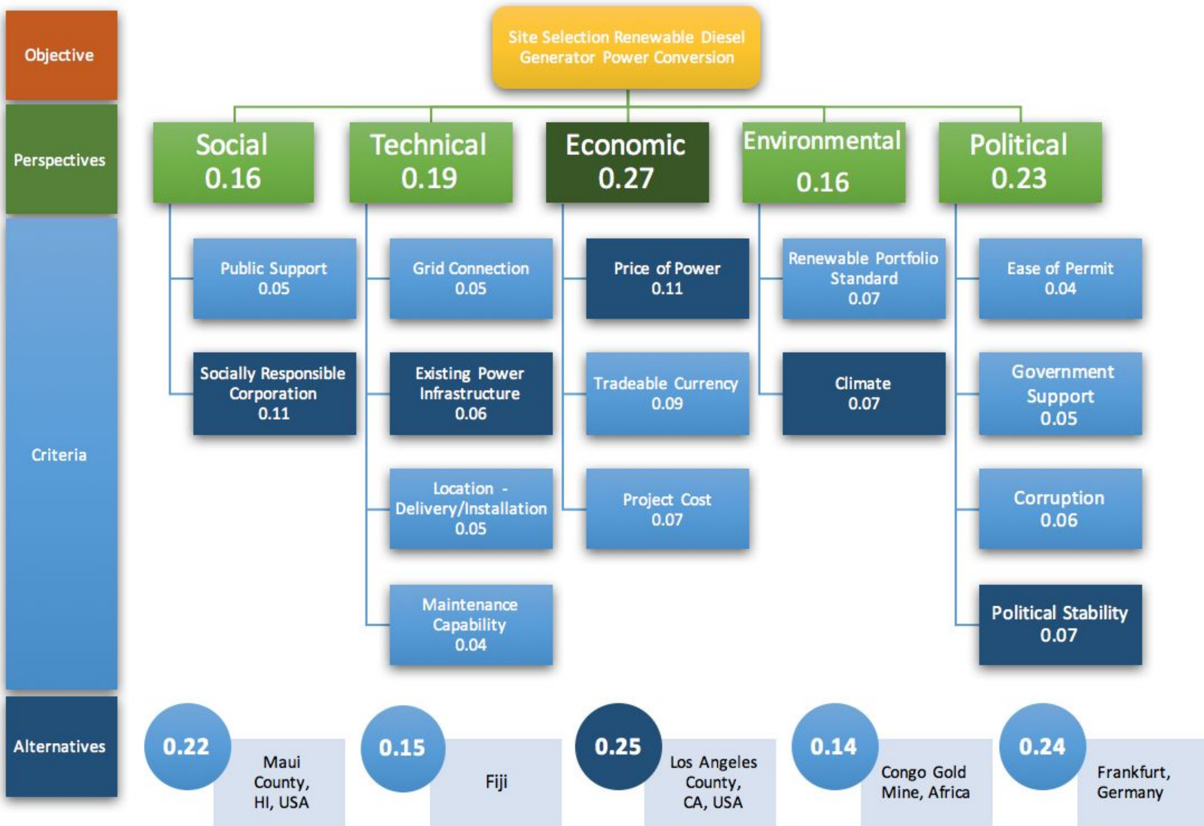


Figure I: HDM - Final Results

The result of the experts' judgment indicates that Los Angeles has the highest value with slight difference from Frankfurt, which means they are the preferable sites according to experts' judgments. Congo is ranked the lowest with a value of 0.14. This was surprising as the price of power is the highest in Congo. However, the model shows that by considering all the criteria, the developed countries are the optimal place for such energy projects.

There are two ways for validating the result in HDM. One is the degree of inconsistency by the individual expert. This means that expert's response should show inconsistency level of less than 0.1. As shown in table 2 above, the sex experts in this study have a very low inconsistency where the maximum incontinency is of 0.06 by expert 3 and a minimum inconsistency of 0.00 by expert 6. Hence, the result can be considered as valid in terms of inconsistency values of individual experts. The second way of validating the result is the degree of disagreement between the experts. The role of thumb in in disagreement is 0.1. However, the disagreement between the experts in this study is 0.028. Therefore, the result can be considered as valid in terms of disagreement value between the experts.

# Conclusion

Upon discussion and preponderance of a “green energy” project typically people would tend to think of 3rd world or remote places, where costs are high and NGO sponsorship would help ensure efficiency in power were possible. However, as the results from this model indicate, two of the top three criteria are financial related (Price of Power and Tradeable Currency) an indicative of the installation company succeeding and not focusing on the environmental outcome. The third is focused on the existence, and thus possible partnership of, socially responsible corporations. It is very easy to initially look at project like this and heavily focus on the environmental benefits over all else, as this is focused squarely on reducing greenhouse gases through fuel efficiency improvements. However, when a methodical decision making process is applied, experts in their relative fields are allowed relevant input, the output shows a much truer picture. In this case that picture clearly states that economic and financial solvency of a project is important while there also needs to be socially-responsible companies to invest in such a project.

This model is designed as seed for companies to expand upon with their information, goals, and project specifics. As Pyramid Power is a real company with a real need to select a site, they are planning on expanding upon this model to add more specific criteria, allowing them to use this model and output as a tool in their overall decision making process.

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# Appendix A: Level 2 - Criteria Ranking with respect to its Perspective

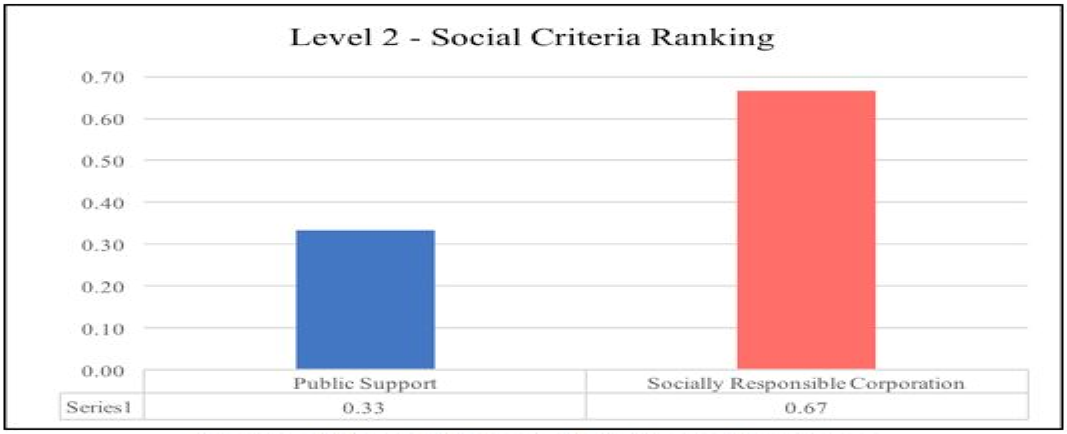


**Figure J-Level 2-Social Criteria Ranking**

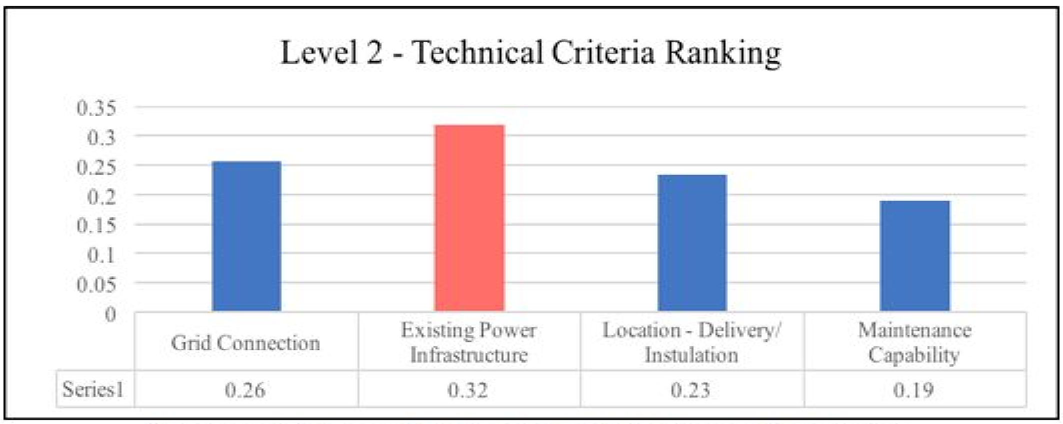


**Figure K-Level 2-Technical Criteria Ranking**

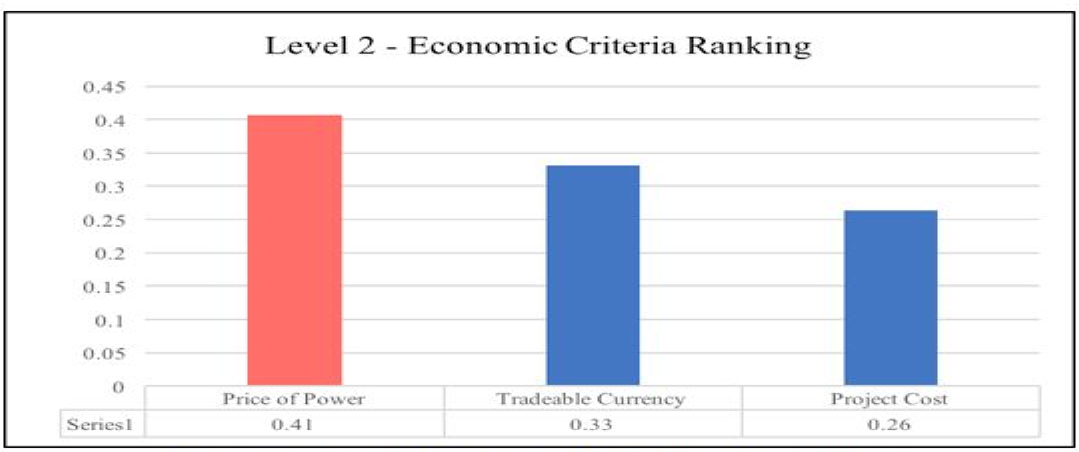


**Figure L-Level 2-Economic Criteria Ranking**

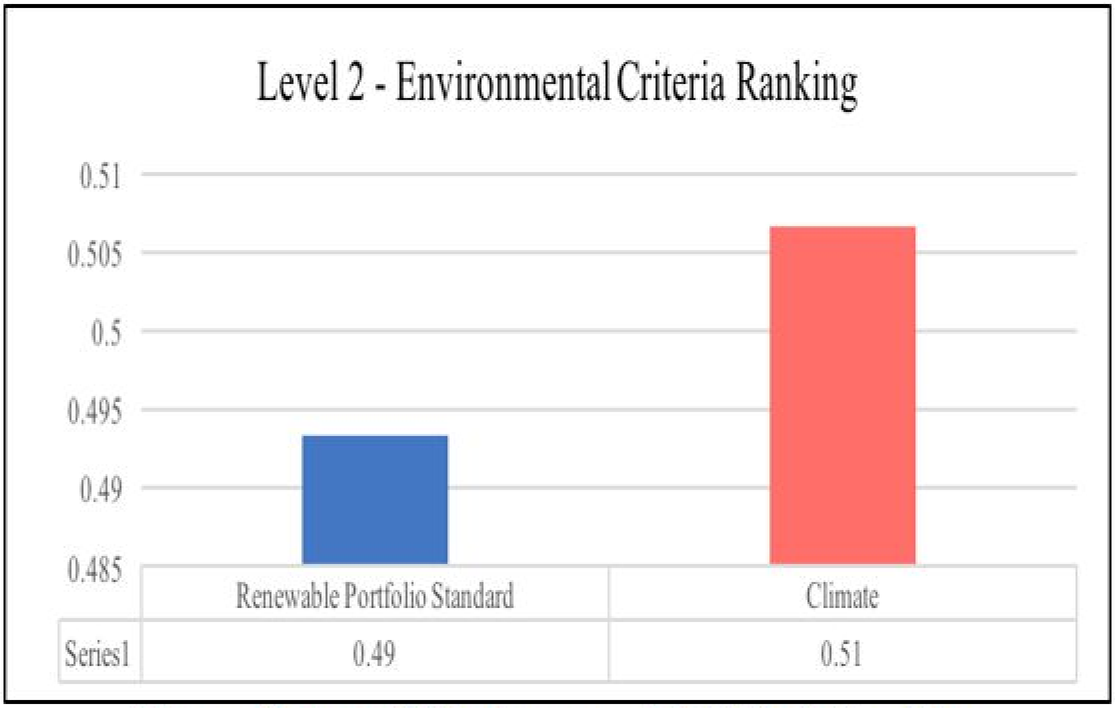


**Figure M-Level 2-Environmental Criteria Ranking**

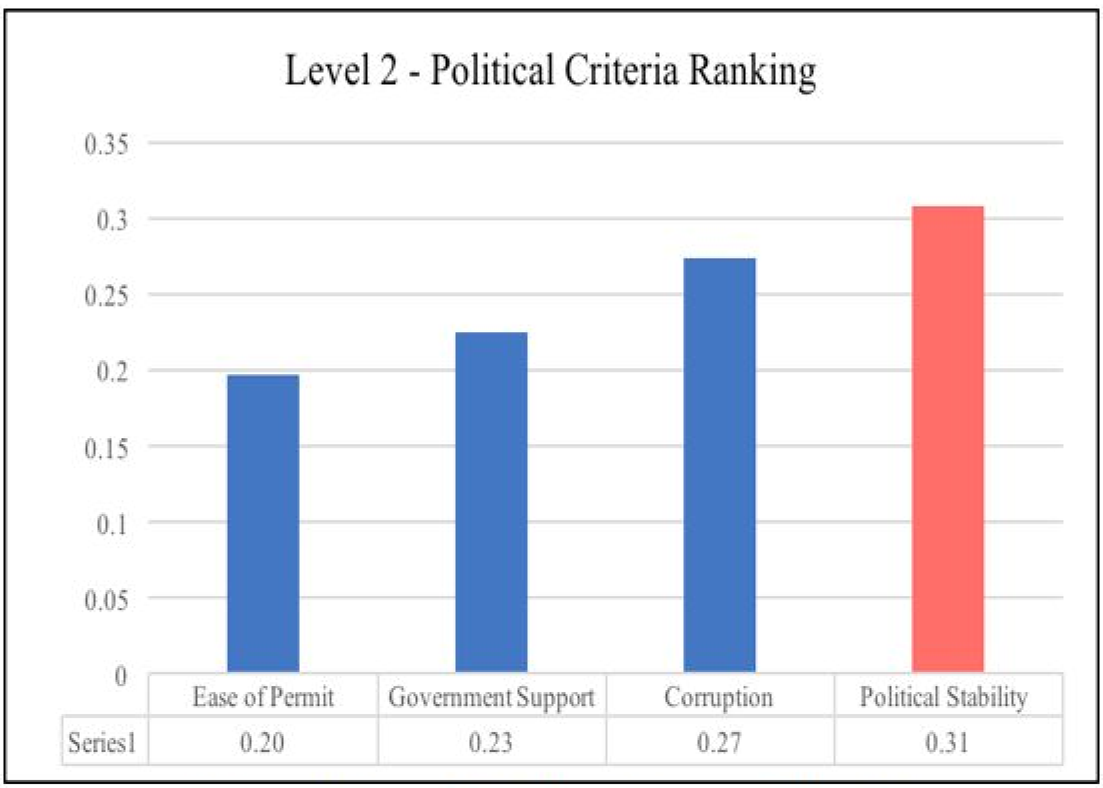


**Figure N-Level 2-Political Criteria Weight**

# Appendix B: Level 3 - Criteria Ranking with respect to Objective

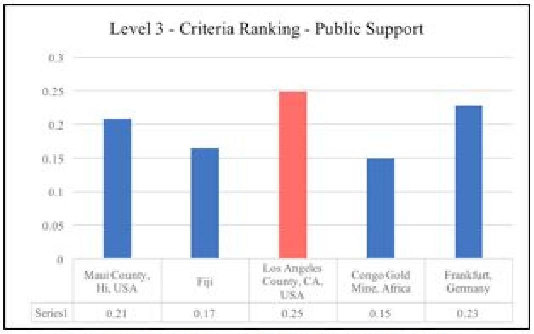


**Figure O-Level 3- Public Support in Each Site**

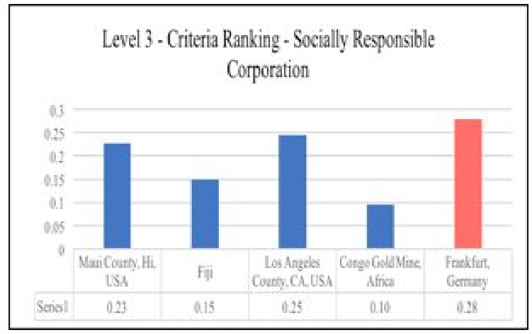


**Figure P-Level 3-SRC in Each Site**

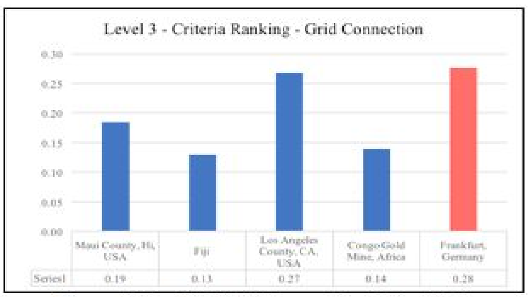


**Figure Q-Level 3-Grid Connection in Each Site**

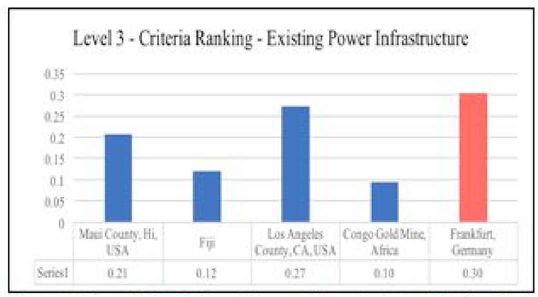


**Figure R-Level 3-Existing Power Infrastructure in Each Site**

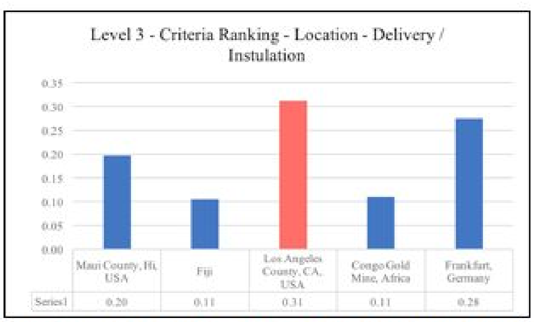


**Figure S-Level 3-Location - Delivery / Instullation in Each Site**

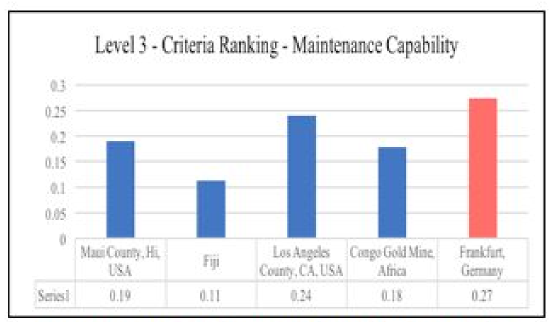


**Figure T-Level 3-Maintenance Capability in Each Site**


**Figure U-Level 3-Price of Power in Each Site**

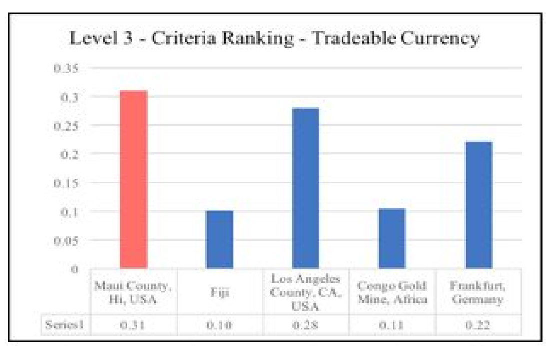


**Figure V-Level 3-Tradeable Currency in Each Site**

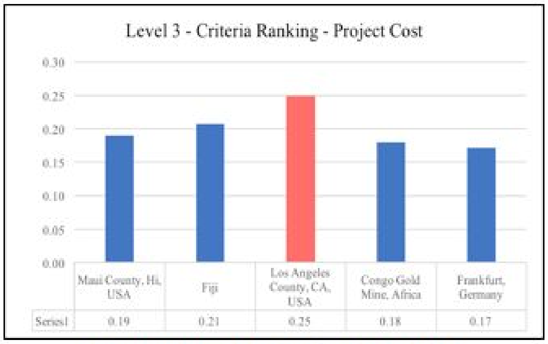


**Figure W-Level 3-Project Cost in Each Site**

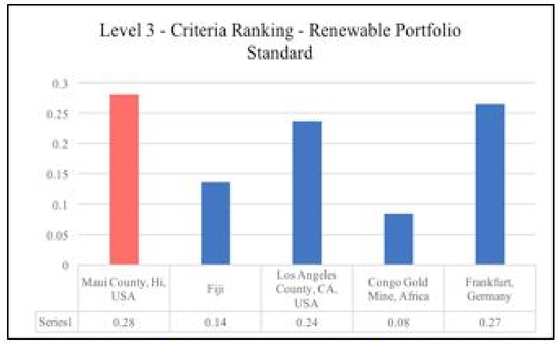


**Figure X-Level 3-Renewable Portfolio Standard in Each Site**

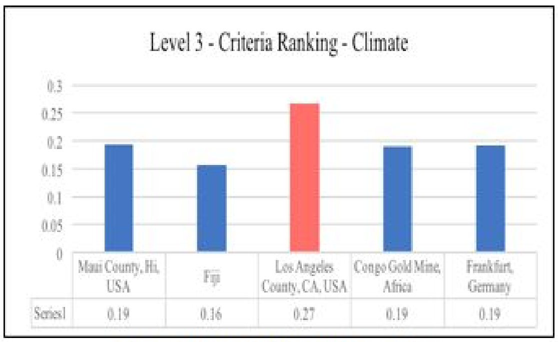


**Figure Y-Level 3-Climate in Each Site**

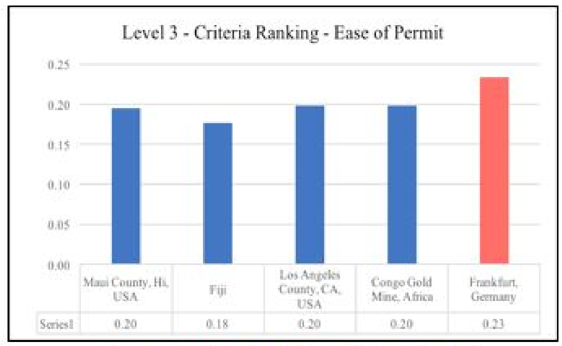


**Figure Z-Level 3-Ease of Permit in Each Site**

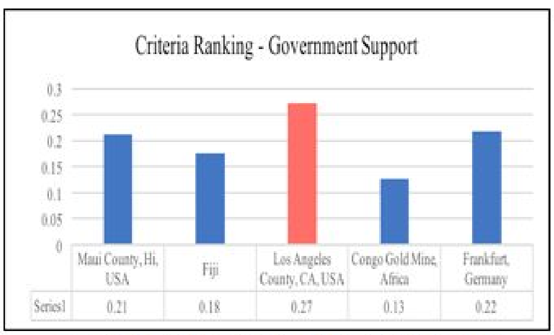


**Figure AA-Level 3-Government Support in Each Site**

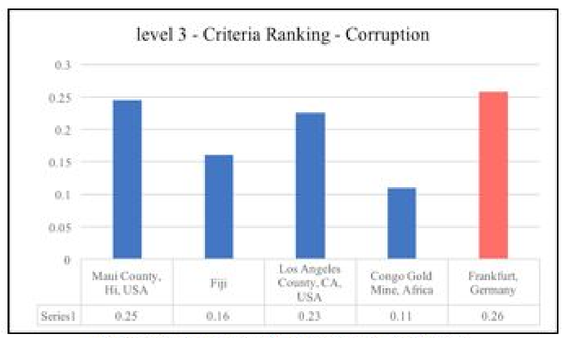


**Figure AB-Level 3-Corruption in Each Site**

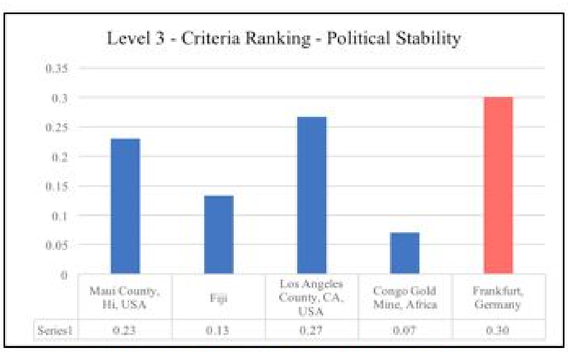


**Figure AC-Level 3-Political Stability in Each Site**