International Journal of Business and Technopreneurship
Volume 5, No. 1, Feb 2015 [9-38]

Managing the Transition of Fossil Fuels to Renewable Energy: Application of Ocean Thermal Energy Conversion At Sabah

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ABSTRACT

Ocean Thermal Energy Conversion (OTEC) existed in the last decade was built in 1930 by Georges Claude, after the thermal energy of the ocean was tapped by Jacques Arsene D'Arsonval in 1881. However, the technology was put on-halt and discontinued from being developed wisely for realistic application. Since ocean covers more than 70% of the earth's surface, this makes them as the world largest solar collectors for thermal energy creation. The technology generates energy by using the difference of temperature in an ocean with least environmental impact and high sustainability. In this case study, Kota Kinabalu, Sabah has been selected as main location to investigate the geographical criteria, social acceptance and the technical of OTEC as energy generator and feasibility. The research used a mixed method for both data collection and data analysis. This study proved that the application of OTEC in Sabah brings a lot of benefits such as social acceptance, sustainability and energy efficiency compared to fossil fuels. As a conclusion, the OTEC might become one of the main energy sources for people living in Sabah. Transition from fossil to renewable energy, particularly the application of OTEC could be expanded and generalized, to harvest more energy in the coastal areas of all places around the world.

Keywords: transition, renewable energy, ocean thermal conversion

1. INTRODUCTION

1.1 Background of the Study

Energy sources are another challenge after human revolution. Limitation in energy sources had been the bottleneck of human in development of different fields. Over depending on fossil fuels as energy sources also bring direct negative impacts to our environment. Keep on burning fossil fuels will send greenhouse gases into the atmosphere, trapping the sun's heat and contributing to global warming.

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According to Public Citizen (2012), renewable technologies could address global climate change more quickly than nuclear power and without the production of radioactive waste or other significant types of pollution. Ocean Thermal Energy Conversion (OTEC), renewable energy that generates electricity by using the gradient of temperature in sea water. According to Vega (2003), for an OTEC efficiency of 3%, in converting OTEC to electricity, we would need less than 1% of this renewable energy to satisfy all of our desires for energy. According to New Straits Times (2012), The Sabah government is embarking on aggressive policies to promote large-scale use of renewable or green energy. OTEC could be another option of renewable energy to be applied.

1.2 Research Questions

Consumption of energy, increasing rapidly day by day, human should not only depend on fossil fuels as energy sources anymore. Thus, renewable energy becomes another option that able to generate clean energy for human. As we know, the ocean is covering around 70% of the surface of our earth, which mean the ocean is a biggest panel that collecting solar energy from sunlight. The energy that absorb by the ocean is equal to 4000 times the amount presently consumed by humans (Vega, 2003), we can see the potential of OTEC to contribute as our energy sources. According to Yunus (2012), Malaysia Prime Minister Dato' Seri Mohamad Najib Tun Abdul Razak said he approved the application of the Ocean Thermal Energy Corporation to conduct a study to generate electricity from the deep sea in Sabah.

Sabah is covered by coastal zone of 27549 km² in Malaysia, so there is a high potential to utilize ocean-based energy sources. However, this study is not considered implementing Ocean Wave Energy in Sabah because there are lands surrounding the coastal zone of Sabah such as the Philippines. Thus, OTEC has higher feasible to implement in Sabah compare with Ocean Wave Energy. Research question constructed as below:

1. How the technical criteria of OTEC affect in the transition of technology?
2. What the trend of social acceptance of Sabah residents on the OTEC implementation?
3. How to overcome current challenges of OTEC by innovative solution

1.3 Objectives

The objective of this study is to examine the technical criteria and social response of OTEC implementation at Sabah compared with fossil fuels as energy sources. The study also investigates how the implementation of OTEC at Sabah. Lastly, the report will come out with an innovative solution to overcome the weaknesses of OTEC to enable its application.

The objectives of the study is stated as below,

1.3.1 To investigate the technical criteria for the implementation of OTEC in Sabah, compare with fossil fuels power station.
1.3.2 To investigate the social acceptance of the application of OTEC in Sabah, compare with fossil fuels power station.
1.3.3 To suggest an innovative solution to overcome the challenges of OTEC and enable its application.

1.4 Scope

The scope of this research is to investigate the acceptance level of Sabah people for the implementation of OTEC around the coastal line of Sabah state, by considering the impact to the environment, economic growth and energy efficiency after the implementation compare with fossil fuels as energy supply. Besides, the study will also identify the technical criteria that need to consider during the implementation of OTEC in Sabah, with the opinions from experts in a particular field. Therefore, experts from energy field, including researchers, engineers and also experts from overseas are referred to investigate the applicability of OTEC in Sabah.

Respondents are mainly divided into two groups. The first group is for local residents, which are people from Sabah or who stayed in the Sabah coastal zone for a certain period, that they can feel the implementation of any facility will affect their living life. This group of respondents is providing the acceptable level, and satisfaction level of different type of energy sources. The second group will be from the expert in the particular field of study, engineers and researchers from the academic field, and also OTEC field experts. This group will provide a more detail, professional and technical information for the level of applicable for implementation of OTEC in Sabah, and also all the technical criteria that related on OTEC and fossil energy.

2. LITERATURE REVIEW

2.1 Introduction

This chapter was discussed the overview of fossil fuels and also Ocean Thermal Energy Conversion (OTEC) as current energy sources. The technical criteria for both energy sources will be mentioned, including effectiveness, power quality and environmental impact. The comparison of technical criteria among fossil fuels and OTEC also will be discussed. Social acceptance for new technology adoption will be mentioned too. The theory and technical criteria for OTEC will be discussed in section 2.2.1 and for fossil fuels will be discussed in section 2.2.2. To make a clear scenario, the comparison among OTEC and fossil fuels has been discussed in section 2.2.3. Start from 2.3, the researcher discussed about the acceptable level of society in the implementation of OTEC. Follow by section 2.4, the researcher described about

the innovation of OTEC with latest technology. Lastly, the framework of the theory of OTEC has been drafted in section 2.5.

2.1.1 Ocean Thermal Energy Conversion

According to SOPAC (2001), OTEC is an energy technology, which uses the ocean's natural temperature gradient to drive a turbine, which is connected to a generator. It is desirable that the temperature difference between the warm surface water and the cold deep water be at least 20ºC. Ocean as the biggest solar panel in the Earth will absorb major heat from the sun, which can be utilized as energy sources by implementation of OTEC. Masutani and Takahashi (2001) stated that the warm surface layer, which extends to depths of about 100-200m, is separated from the deep cold water by a thermo cline and the cold water ranging 8ºC - 4ºC might 800-1000m depths.

OTEC systems rely on the basic relationship between pressure (P), temperature (T) and volume (V) of a fluid, which can be expressed by the following equation:

$$\frac{PV}{T} = Constant$$

Pressure, temperature and the volume of a fluid can be closely controlled by manipulating the other two variables. Hence the differential in temperature of the fluid can be used to create an increase in pressure in another. The increase in pressure is utilized to generate mechanical work (SOPAC, 2001).

For a more detail of the study, the technical criteria of OTEC have been investigated and categorized as energy efficiency, temperature gradient, effectiveness, environmental impact and plant design. Vega and Masutani always mention about the efficiency of OTEC in their study. Besides, Vega and Kwak also mention the importance of effectiveness in OTEC. Lastly, many researchers do concern about the environment impact of OTEC such as Masutani et al., Vega and also National Oceanic and Atmospheric Administration.

a) Efficiency of Ocean Thermal Energy Conversion

Efficiency means the comparison of what is actually produced or performed with what can be achieved with the same consumption of resources (Business Dictionary, n.d.). To investigate the efficiency of OTEC, theory of Carnot efficiency has been applied, whether the heat supplied produced the similar amount of heat as work output. Base on second law of thermodynamics, not all supplied heat in a heat engine can be used to do work, the Carnot efficiency limits the fraction of heat that can be used.

Same theory has been applied in OTEC investigation, Masutani and Takahashi (2001) stated OTEC systems are characterized by Carnot efficiencies in the range of 6-8%. The actual efficiency is 2-3% since the water must be pumped and there are thermal

losses. The low energy conversion efficiency of OTEC means that more than 90% of the thermal energy extracted from the ocean‘s surface is wasted and must be rejected to the cold, deep sea water. This necessitates large heat exchangers and seawater flow rates to produce relatively small amounts of electricity.

b) Temperature Gradient

Temperature gradient means the temperature differences or gap that exists in a particular medium. For the implementation of OTEC, the temperature gradient in the ocean is the main criteria to success the implementation. Base on Vega (2012), the ocean thermal resource, defined as the difference between surface water and water from about 1,000 m depth, could be used to generate most of the energy required by humanity. Without this criterion, the implementation of OTEC wills not a success.

However, to have a gradient of temperature that fulfills the requirement of OTEC plant, it might require around 1000m or 0.6 miles of sea depth. According to Robert Upshaw (2012), the surface of the ocean absorbs and emits nearly all of the solar energy back out of the surface keeping the deep ocean water at a cold, constant temperature. In tropical locations with depths of 1000m or more, the water temperature is usually only 4 - 5 ˚C (39- 41 ˚F). Thus, certain areas of the tropics contain waters with temperature differentials of approximately 20 - 25 ˚C.

c) Environment Impact

Nowadays, environment impact has been the criteria that highly concern by a human instead of efficiency and effectiveness only. Especially in the energy field, monitoring and control of environment impact are a must since we Earth are being sick with those pollutions. Those pollutions that might cause by human activities are including air pollution, water pollution, noisy sounds, ecosystem damage and more.

For OTEC, environment impact is one of the criteria that investigated by scientist in a particular field. According to Vega (2003), OTEC offers one of the most benign power production technologies, since the handling of hazardous substances is limited to the working fluid (e.g., ammonia) and no noxious by-products are generated. The process cycle that drawing seawater from the ocean and returning it to the mix layer of the sea, which could generate energy with least environmental impact. Vega (2003) also mentioned the carbon that emitted by an OTEC plant estimated to be less than 1% of the approximately 700 grams per kWh amount released by fuel oil plants.

However, a sustained flow of cold, nutrient-rich, bacteria-free deep ocean water could cause sea surface temperature anomalies and bio stimulation if resident times in the mixed layer and the euphotic zone respectively are long enough (Vega, 2003). Thus, the ecosystem around the plant area might be affected especially for microorganism.

d) Plant Design

For the technology of OTEC, the design of the power plant definitely is the main factors that affecting the efficiency, cost and also the environment impact of the OTEC operation. It is a complex section that need to consider during the implementation of OTEC, but cannot just ignore. According to Robert Upshaw (2012), plant design of OTEC is included plant platform, ocean water system and cold water pipe, boiler and condenser heat exchanger, electrical power equipment and transmission, and last is the vapor turbines and power cycle working fluid. All of these criteria, giving different effects on the operation of OTEC.

2.1.2 Fossil Fuels

Nowadays, fossil fuels are the main energy sources for human daily activities. Even electricity generator, transportation and raw material, the major energy sources are all come from fossil fuels. According to Jolley (2006), the traditional fossil fuels – oil, natural gas and coal – continue to be the dominant sources of primary energy in the world economy. The IEA (2004) estimates that the contributed 79.8% of total primary energy supply (TPES) in 2002. Under the Reference Scenario, fossil fuels are expected to contribute 81.9% of TPES in 2030.

Currently, 24% of the world‘s energy needs are met with coal. The primary use of coal is in the generation of electrical power. Petroleum is the leading source of energy worldwide. Over 40% of total energy consumed is derived from petroleum products such as gasoline, diesel fuel, propane gas and domestic cooking and heating fuels. Natural gas is primarily composed of methane with varying amounts of other hydrocarbons such as ethane, propane and butane. It produces less air pollution than coal or petroleum (Canote et al., 2012).

According to Canote et al., (2012), fossil fuels have proven to be an abundant source of energy and have been critical in the development of our modern world. Regarding to current consumption levels, fossil fuels will become increasingly scarce in the next 100 years.

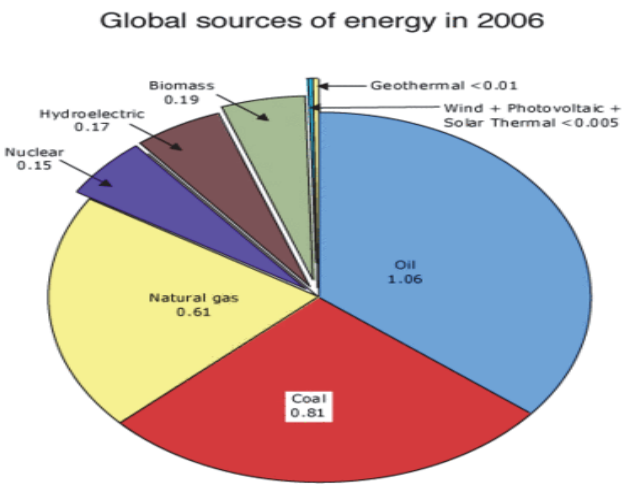


Figure 2.1: Global source of energy 2006 in Cubic Mile of Oil (CMO)
Source: SRI International

For a more detail of the study, the technical criteria of fossil fuels have been investigated and categorize as efficiency, effectiveness and also environment impact.

a) Efficiency

Efficiency of fossil fuels might consider the amount of electricity has been generated with the same amount of fuel input. The energy efficiency might be variable based on different types of fuels. According to International Energy Agency, worldwide coal-fired power plant efficiency averaged 35.1% in 2007.

b) Effectiveness

As fossil fuels can be used for other function or activities, the effectiveness of fossil fuels in aspect of generating power might be determined by the efficiency of power generated compare in efficiency as other uses.

Even nowadays major of fossil fuels are used to generate electricity, but according to Callahan (2010), fossil fuels still capable to be used as transportation fuels, heating and cooking fuels, lubricants, synthetic materials such as plastic and polyester, benzene as ingredients of medicine and more. Instead of using fossil fuels as power plant fuel, it is more preferable to keep for other uses since the reserves of fossil fuels might run out in the future.

c) Environment impact

While consuming fossil fuels, environment impact has become the major concern of peoples nowadays. The process of burning fossil fuels is very dirty. According to Singer (2011), incomplete combustion of coal and oil produces particulate matter. Heavier particulates produce an annoying dirty grit, and lighter particulates can be inhaled deeply and become a health hazard. Besides, fossil fuels are composed mainly of carbon by weight, so all fossil fuels produces carbon dioxide when burned. In general, burning of fossil fuels produces particulates, smog, acid rain and causing global warming.

2.1.3 Technical Criteria Comparison between Ocean Thermal Energy Conversion and Fossil Fuels.

Regarding all the technical criteria been discussed previously, a table has been created for the comparison of technical criteria among fossil fuels and OTEC as below:

Table 2.1: Technical Criteria for Fossil Fuels and OTEC

OTEC	
Criteria	**Description**
Efficiency	• Approximately low. • Only 2-3% of actual efficiency. • More than 90% of thermal energy is "wasted" in ocean.
Environment Impacts	• Benign power production technologies. • No noxious by-products are generated. • Very low carbon emission. • Might cause sea surface temperature anomalies and ecosystem affected.
Plant Design	• Factors affecting efficiency, environment impacts, and costing of the plant. • Still have space for improve.
Temperature Gradient	• Source of energy generation in OTEC process. • Affected by geographical factors.
Fossil Fuels	
Criteria	**Description**
Efficiency	• Average 39.3% of fuel been transformed into power.
Environment Impacts	• Burning of fossil fuels is dirty process. • Produce particulates, smog, acid rain, and causing global warming.
Effectiveness	• Power generated is only 39.3% with 100% of input. • Fossil fuels are not fully utilize • Effectiveness will decrease regarding the reserves of fossil fuels in Earth are dropping

Source: Vega (2012), International Energy Agency (2010), Singer (2011), Canote et al., (2012), Masutani and Takahashi (2001) & SOPAC (2001).

2.2 Social Acceptance

Technology development is leading us to the new era, but society also an important element playing important roles in civilization. Society have their rights to respond on the new technology adoption especially for technology that directly affecting their daily activities. The scientist must consider the level of acceptance and response by society, thus the new technology will be a success to commercialize and publish.

To study social response, a group of researchers from The Open University in United Kingdom executed an online survey with the title "Consumer Adoption and Use of Household Renewable Energy Technologies". This report presents results of research which surveyed UK householders' reasons for adopting - or considering but rejecting - domestic scale renewable energy systems.

By appointing this survey as a mirror of our study, the response from the respondent has been taken as a consideration for social response to renewable energy adoption whether in domestic or large scale. According to Roy et al., (2007), the survey found that household renewable energy systems were not widely adopted even among this group of largely middle class, green consumers ¨C only 10% of the 390 online respondents had installed solar thermal water heating, 3% had solar photovoltaic (PV), 2% a micro wind turbine and 16% a wood burning stove. However, The majority (83% to 90%) of adopters of the four renewable in the online survey described themselves as 'concerned' or 'very concerned' about reducing their impact on the environment.

As a conclusion, society is very concerned about reducing the environmental impacts, but due to high implementation cost, the percentage of people adopts a domestic scale renewable energy is approximately low. Renewable energy is waiting a leap to be fully developed and commercialize to society with affordable cost to public.

2.3 Social Acceptance Framework

The figure below has been created for of social acceptance of new technology adoption.

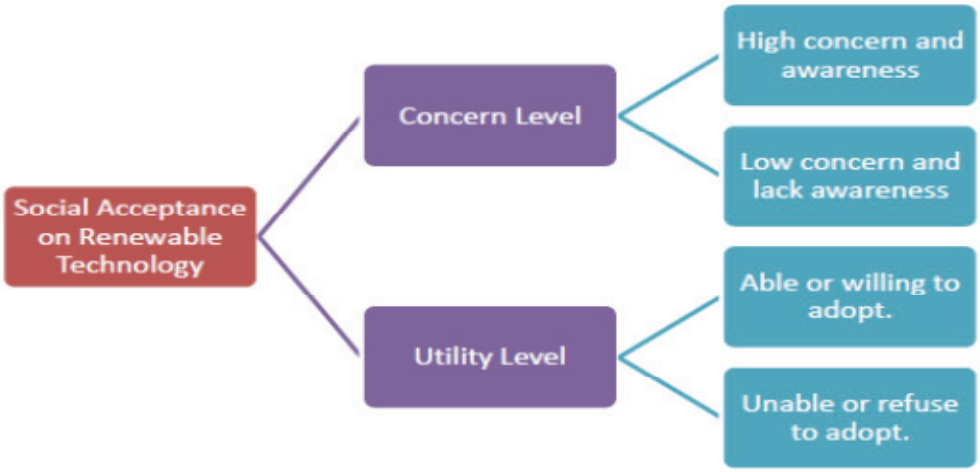


Figure 2.2: Social Acceptance of New Technology Adoption

2.4 Theoretical Framework

While adopting new technology, there are factors that need to consider. By then, a model has been constructed by the researcher for a better view of the framework.

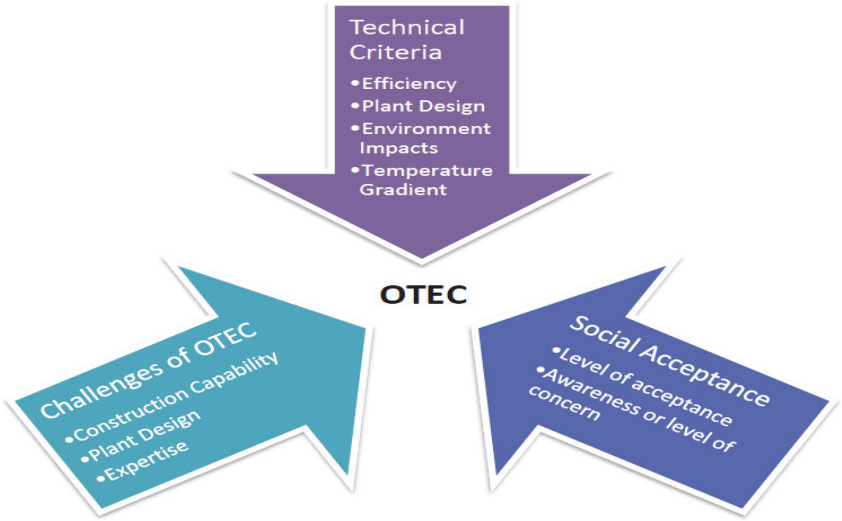


Figure 2.3: Theoretical Framework for OTEC

Technical factor is the main concern for OTEC adoption while considering demand and usage, competitive advantage and challenges. Besides, environmental factors also the factors need to be considered since society (social response) and environment impacts (pollution) might occur during the adoption process.

3. RESEARCH METHOD

3.1 Introduction

According to Ghauri and Gronhaug (2010), research methods are rules and procedures, and can be seen as tools or ways of proceeding to solve problems'. Research methods play roles such as logic or ways of reasoning to arrive at solution, rules of communication, and rules of inter subjectivity. For this research, case study was the main strategy has been conducted.

Yin (2009) stated that a case study is an empirical inquiry that investigates a contemporary phenomenon in depth and within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident. This means that case study is more exploratory and more explanation of a particular incident. Ghauri and Gronhaug (2010) also clarify that case study research is particularly useful when the phenomenon under investigation is a challenge to study outside its natural setting. Case study can also be used where the concepts and variables under study are difficult to quantify. The study of OTEC is difficult to apply due to the size of the plant is approximately bigger and offshore, therefore case study is adopted.

Those statements increased the appropriateness of using case studies as the research strategy. Problems were clearly addressed under real life situation of the case.

3.2 Research Design

Statement from Trochim (2006), research design can be thought of as the structure of research - it is the "glue" that holds all of the elements in a research project together. Elements of the project will be derived from research topic to research questions and also research objectives. The structure of research had been the framework, organization or configuration of the relations among variables of the study. A well planned research design expressed the research problem and blueprint of investigation used to obtain relevant data as evidence of the problem.

According to Saunders et al., (2012) an exploratory study is a valuable means to ask open questions to discover the activities and gain insights about a topic of interest. It was applied in helping researcher to allocate his available resources by appropriate choices. The methods include a search of the literature; interviewing experts' in the subject; conducting in-depth individual interviews or conducting focus group interviews. Thus, in this case study of Ocean Thermal Energy Conversion (OTEC) implementation in Sabah, it suits the exploratory study. In a place that never been a place for OTEC implementation, a discovery and exploratory base research is require finding out those questionnaires on the research question.

Firstly, the researcher has selected the experts or researchers from high institution as the main source of investigation. Besides, international experts in OTEC will also contribute in data accumulation process. Relevant information in a particular field will be collected throughout the mixed method interview with those experts to answer the research question and achieves the research objectives. The implementation of OTEC in Sabah will be the main findings of the study.

Secondly, the framework was set up for specifying the relations among the study variables.

Thirdly, the blueprint that outlines each procedure from the beginning of the analysis data is setup.

3.3 Mixed Method Research

This case study of OTEC implementation in Sabah was conducted using mixed method research. Mixed method research is a combination of qualitative and quantitative research in a research design. According to Saunders et al., (2012) a combination of methods may have a variety ways that range from simple, convergent forms to complex and filly integrated forms. This means that level of integration may vary in different cases, by then the characteristics of qualitative or quantitative research might still the same.

A statement from Hussey and Colliss (2009), qualitative data are normally transient. It is understood only within context and are associated with an interpretive methodology that usually results in findings with a high degree of validity; quantitative data, which are normally precise. It can be captured at various points in time and in different contexts and are associated with a positivist methodology that usually results in findings with a high degree of reliability. To obtain such social and scientific data through high institutions and Sabah peoples, both methods are required to grab a higher quality of data. Methods of data gathering as below:

a. Case studies as for an in-depth contextual analysis of few criteria. Circumstances able to be clearly described even it is difficult to study outside its natural setting.

b. In-depth interviewing that usually conversational rather than structured. It belongs to qualitative data collection, which purpose to obtain expert opinions that represent as high quality of information from higher institutions.

c. Quantitative questionnaire on public social response to trends of acceptance. Quantitative data collections are providing a trend of circumstances with an exact value and statistic. Acceptable level of Sabah people can be observed with this quantitative questionnaire.

Thus, to achieve generalization and complementry, mixed method is adopted. Whereas, 10 people from OTEC fields or high institution has been selected for an in-depth interview because the data collected for qualitative data is more on quality but not quantity, thus 10 respondents from the field is enough to collect high quality and useful data. Besides, 20 more respondents from Sabah been selected to investigate the social acceptance of Sabah peoples when discuss about the implementation of OTEC in the region. The questionnaire also been tested by pilot test, which have three people from society and three peoples from expert level.

4. DATA ANALYSIS AND DISCUSSION

4.1 Introduction

In this chapter, the result of the case study in Kota Kinabalu, Sabah is discussed. The data has been collected through the method of expert opinion from 12 respondents, including scientists, researchers and engineers. To answer the research question of the study, the research objectives will be discussed one by one in this chapter. Since the focus of the case study is about the implementation of Ocean Thermal Energy Conversion (OTEC) in Kota Kinabalu, Sabah, the results were presented based on the three research objectives mentioned in chapter one, including the technical criteria, social acceptance and also challenges in the implementation of OTEC.

Data is collected through the qualitative interview for the part technical criteria and challenges of technology. For social acceptance of OTEC, quantitative questionnaire

has been distributed to 30 respondents who are the residents of Kota Kinabalu, Sabah, to observe the trends of acceptance on this new technology adoption. Both questionnaires have been tested with a pilot test by a total of 6 respondents. The result of the case study will be elaborated further in 3 parts. Section 4.2 is about the first objective, the technical criteria for OTEC implementation. Section 4.3 will be from second objective, which is the social acceptance of Sabah residents toward the implementation of OTEC. The Section 4.4 is from third objectives, which is the challenges of OTEC implementation and innovative solution of it.

4.2 Investigate Technical Criteria of OTEC compare with Fossil Fuels

The first objective of the study is to investigate the technical criteria for the implementation of OTEC in Sabah, compare with fossil fuels power station. Thus, technical criteria for OTEC and fossil fuels will be mainly discussed, which including efficiency, effectiveness, temperature gradient, environment impacts and also plant design.

4.2.1 Technical Criteria of Ocean Thermal Energy Conversion

To provide a clear view on technical criteria of OTEC and fossil fuel, the researcher has separated accordingly and the results of OTEC will be seen first in this part.

4.2.1.1 Efficiency of OTEC

Efficiency of a power system is the main factor to determine the feasibility on particular technologies and cost efficiency in long term operation. For OTEC, the researcher found out it has a considerable efficiency to work as a source of electricity. Base on scientific interpretation, OTEC does not have a great significant efficiency in energy conversion. Even OTEC has lower efficiency in energy conversion compared to conventional power plants. However, there are experts believed, even the thermal efficiency of OTEC is not high, but it should not be the constraint to succeed the technology of OTEC.

"The ideal energy conversion for 26°C and 4°C warm and cold sea waters is 8 percent. An actual OTEC plant will transfer heat irreversibly and produce entropy at various points in the cycle yielding an energy conversion of 3 to 4 percent. These values are small compared to efficiencies obtained for conventional power plants; however, OTEC uses a resource that is constantly renewed by the sun."
(Director 1)

Based on the opinions from experts, OTEC has a lower thermal efficiency compared with conventional power plants, but the feasibility of OTEC not primarily limited by this criterion. Currently, the thermal efficiency of OTEC is considerable and it just consumes renewable sources, which is ocean water that tapped with thermal energy from sunlight. The researcher believes OTEC will supply sufficient and stable electricity to support resident's daily activities.

"Unlike most existing thermal power plants, ocean water "fuel" is free and its acquisition is not subject to market volatility. Therefore, thermal efficiency is not the primary measure of OTEC effectiveness."
(Manager 1)

4.2.1.2 Environment Impacts of OTEC

Gone through the process of civilization, human has created a bunch of environmental issues and now we started to taste the impacts by those issues. Thus, environment impacts of OTEC are a must to be considered as one of the criteria to succeed the implementation. Based on the concept of OTEC, the operation of the power plant to require huge volumes of ocean water to tapped thermal resources and condenses working fluid. There will be a significant environmental impact by larger flow rates of sea water.

"These large flow rates impose two primary environmental related design criteria:

a) Organism entrainment and impingement: requires thoughtful consideration for the design of intake screens, intake flow velocities and how much temperature delta is allowed across the heat exchangers, and

b) Oxygen, temperature, salinity and nutrient content: cold sea water is low in oxygen, but high in nutrients, warm seawater has higher oxygen and lower nutrient content; requires thoughtful consideration for the depth of seawater discharge from the heat exchangers and whether to mix the warm and cold seawater flows."
(Manager 1)

Based on the researcher opinion, even larger flow rates of sea water might impose environmental impacts, but the researcher believes the design of the platform is playing important roles. This issue can be solved by a better design of OTEC plant, and the depth of seawater discharge requires thoughtful consideration.

Besides of environment impact that caused by the flow rate of sea water, there are also normal environmental effects caused by OTEC due to the mooring of huge plant in the center of the ocean.

"Other than seawater flow rates, at-sea OTEC systems pose normal environmental effects from any offshore, marine project – biota attraction due to the presence of a platform, bird attraction to platform lights, power cable EMF, mooring and cable path effects on the sea floor, biocide releases from anti-fouling treatments and the need to prevent inadvertent fluid discharges from operational systems."
(Manager 1)

Even there are few environment effects created by OTEC power plants, however, experts do believe there are solutions for those impacts. According to Manager 1, he

believed he can design systems that will meet environmental regulatory agency requirements. Since no commercial OTEC system is in operation anywhere in the world at any scale, a pilot plant system is required to gather the data that will be needed by agencies to demonstrate his belief.

According to respondent 1, the surrounding area of the OTEC power plant will be affected. Ecosystem in the particular are and residents around the plant also will face direct impact. He believed a research or study on environment of the target area will succeed the technology adoption. Knowledge of oceanography definitely is a must.

Besides, there are also secondary data to prove the environmental effects that caused by huge entrainment of sea water can be solved by specific plant design. New software has been designed for modeling OTEC's environmental effects to date and the U.S. Department of Energy has released a report describing the simulated biological impact from operating large OTEC plants.

According to Makai Ocean Engineering INC. (2012), in all cases modeled in Hawaiian waters, no increase in plankton levels occurred in the upper 40 meters (130 ft) of the ocean. From 40 to 120 meters (130 - 400 ft) OTEC-induced plankton growth is low and well within the naturally occurring variability. These results suggest that suitably designed large OTEC plants will cause no significant increase in biological growth. This model will be important to developers and regulators as commercial OTEC develops.

4.2.1.3 Plant Design of OTEC

OTEC power plant is mooring in the center of ocean and the size of the plant is huge. Base on Vega (2012), the size of a 10 MW-net OTEC pilot plant ship is require at least 46080 m^3 (90m*16m*32m) of space. Therefore, plant design of OTEC basically brought significant effects in plant performance and enables the plant to operate under extreme weathers.

"Platform-design, mooring-design and the design of coupling of Cold Water Pipe and electrical cable to the platform would all have to incorporate the essential capability for the plant to operate in severe storms and to survive typhoons and earthquakes."
(Pro bono Consultant 1)

In the past, technology of OTEC met bottleneck while scientist and engineers fail to create a good solution to drain the cold water from the depth of 1000m in the ocean. Past technology still unable to build an effective Cold Water Pipe for cold water entrainment, and even does not have a matured offshore technology. However, the development of technology is driving the plant design of OETC to success.

According to respondent 2, plant design or plant layout is the criterion that constraining the most on the implementation of OTEC. However, this kind of technical criteria can be solving by government funding or policy.

"Floating vessels approaching the dimensions of supertankers, housing factories operated with OTEC-generated electricity, or transmitting the electricity to shore via submarine power cables have been conceptualized. Large diameter pipes suspended from these plant ships extending to depths of 1000 m are required to transport the deep ocean water to the heat exchangers onboard. The design and operation of these cold water pipes are major issues that have been resolved by researchers and engineers."
(Director 1)

4.2.1.4 Temperature Gradient

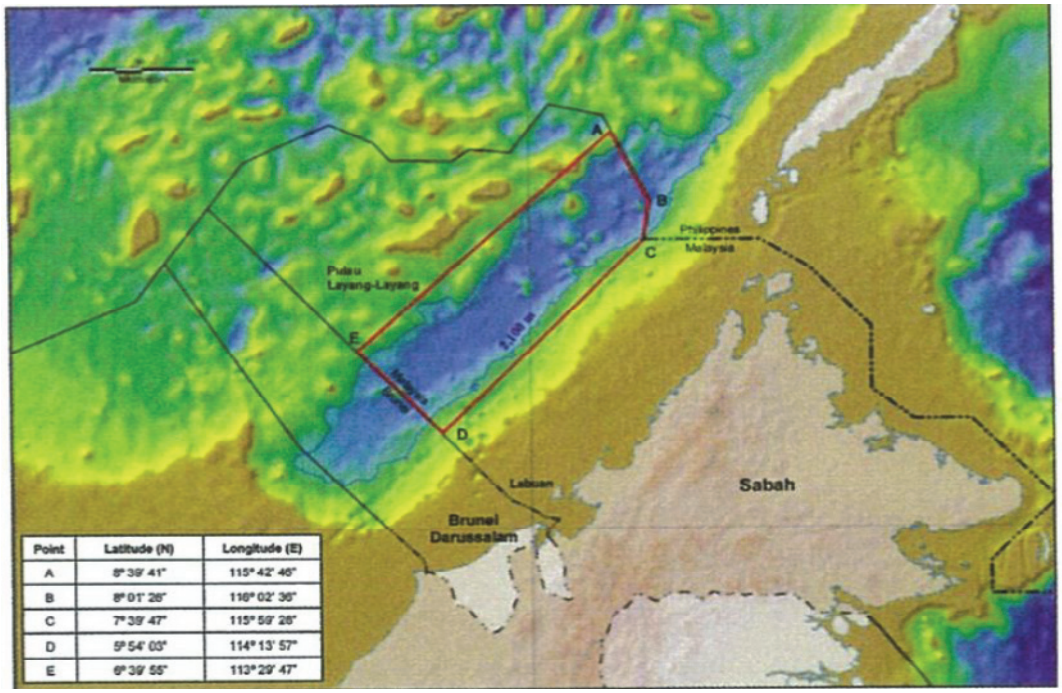
OTEC is a technology utilized thermal resources tapped in sea water to generate renewable energy. Therefore, temperature gradient of sea water in particular area is the main criterion to success the implementation of OTEC. At least, temperature gradient of sea water needed to be 20˚C or above, which the upper layer of sea water have around 24˚C and the bottom layer of sea water have around 4˚C. Temperature gradient of the sea water definitely is the thermal resource to operate whole OTEC system.

"You need the appropriate ocean thermal resource, typically defined as the difference in temperature between surface waters and waters from about 1,000 m depth (ΔT). In general need annual average of ΔT to be at least 20˚C and information about the distance from the 1000 m water depth to the electricity transmission lines."
(Manager 2)

The temperature gradient utilized by OTEC is just 20 ˚C, which mean thermal resource tapped within such temperature differences is not high. Therefore, to ensure OTEC having sufficient of thermal resources to sustain the operation of OTEC, it requires huge volume of sea water to extract those thermal resources.

"An OTEC system operates on a relatively small temperature delta, therefore large seawater flow rates are necessary to convert thermal ergs to useable electrical kilowatt-hours."
(Manager 1)

There are also secondary data mentioned that Sabah fulfill the temperature gradient that require for the implementation of OTEC. According to Jaafar (2012), a marine survey in the South China Sea in 2006-08, confirmed that the temperature at the bottom of the North-Borneo Through (also known as - Sabah Through‖) at a water depth of 2900 meters (m) is about 3 degrees Celsius, compared to surface temperature of about 29˚C. Any area with a temperature differential of over 22˚C has the potential for generating not only renewable energy but also fresh water.



Point	Latitude (N)	Longitude (E)
A	8° 39' 41"	115° 42' 46"
B	8° 01' 26"	116° 02' 36"
C	7° 39' 47"	115° 59' 26"
D	5° 54' 03"	114° 13' 57"
E	6° 39' 55"	113° 29' 47"

Figure 4.1: Sabah Through

Source: Jaafar (2012) Maritime Institute of Malaysia (MIMA) Bulletin

4.2.2 Technical Criteria of Fossil Fuels

Fossil fuels are the main energy sources to support human activities currently. Even technology to extract energy from fossil fuels is matured, however, there are still technical criteria and impacts to be considered and it was well known by most people.

4.2.2.1 Efficiency of Fossil Fuels Power Station

Conventional power plant is commercially used for electricity generation and now is very well developed to achieve human needs. There are plenty of secondary data to support that conventional power plant have a good efficiency of energy conversion and believed is the most competitive in cost of power generation. There are also expert believed conventional power plant have better energy efficiency compared to OTEC.

"An actual OTEC plant will transfer heat irreversibly and produce entropy at various points in the cycle yielding an energy conversion of 3 to 4 percent. These values are small compared to efficiencies obtained for conventional power plants."
(Director 1)
Based on the report from Sabah Electricity Sdn. Bhd. (2011), the major power plants in Sabah are operating under Gas-fired and oil-fired power system. In year 2011,

there is around 83% of power generation is from gas-fired and oil-fired power plant. Among these 83%, there is 18% from gas-fired power plant and another 65% is from oil-fired plant. Most of the electricity in Sabah state is still generated by fossil fuels.

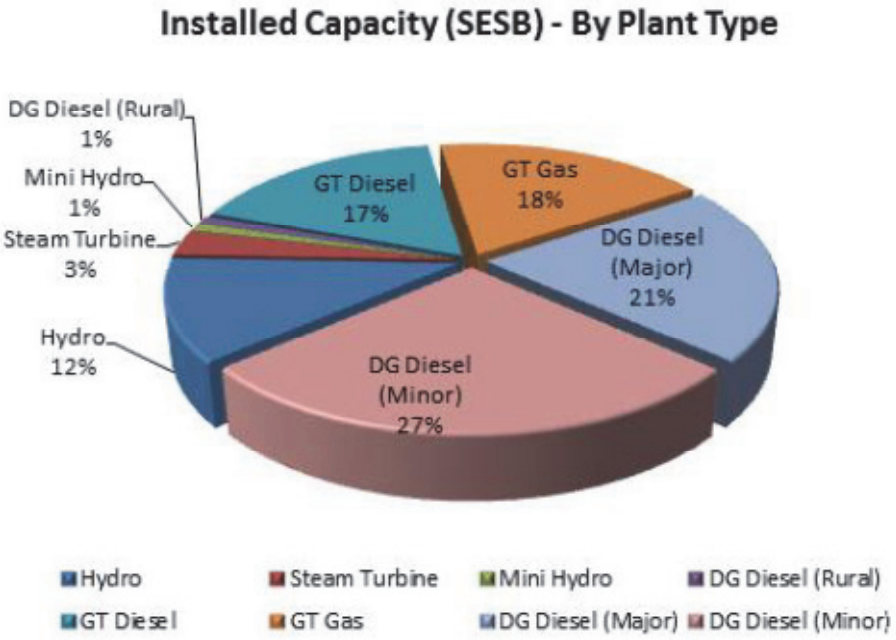


Figure 4.2: Sabah Energy Generation Capacity by Plant Type

Source: Sabah Electricity Sdn. Bhd. (SESB)

When we look at the efficiency for oil-fired and gas-fired power plant, it was around 33-35% of energy conversion with 100% of fossil fuels input. According to NPC Global Oil & Gas Study (2007), typical combustion turbine (CT) heat rates are 9,650 – 10,400 btu/kWh (33-35% efficient higher heating value).

4.2.2.2 Environment Impact of Fossil Fuels

Burning of fossil fuels definitely is a dirty process and this has been known by most of the people. There is rising of environmental issues after human over depending on fossil fuels as energy sources and keep burning on it. Peoples found that burning of fossil fuels brought harm and negative impacts to human and environment in the long term. Now days, there are bunch of environmental issues that caused by the combustion of fossil fuels such as greenhouse effect, depleting of ozone, air pollution, water pollution, soil pollution and more.

According to Green Energy Choice (n.d.), fossil fuels are the largest greenhouse gas emitters in the world, contributing 3/4 of all carbon, methane and other greenhouse gas emissions. Burning coal, petroleum and other fossil fuels at extremely high temperatures (combustion) is the primary means by which electricity is produced, but

also leads to heavy concentrations of pollutants in our air and water. The real problem is that the atmosphere already absorbs a ton of greenhouse gases naturally, but is trapping up to 25 percent more of the sun's radiation due to annual increases in greenhouse gas emissions. Just think of the atmosphere as a very thick blanket of insulation—a blanket of insulation that grows thicker and more absorbent by the year.

Besides, there are also direct impacts to organism by the environment issues caused by fossil fuels. Human and plants will be easily harm by those pollutant and affecting our daily activities. According to Chmielewski (n.d.), air pollution caused by particulate matter and other pollutants not only acts directly on the environment but by contamination of water and soil leads to their degradation. Wet and dry deposition of inorganic pollutants leads to acidification of environment. These phenomena affect the health of the people, increase corrosion, and destroy cultivated soil and forests. Most of the plants, especially coniferous trees are not resistant oxides. Following longer exposure leaves wither and fall.

4.2.2.3 Effectiveness of Fossil Fuels as Energy Sources

Fossil fuels are quite effective to use for other purpose instead of energy sources. Now days, oil, coal and natural gas supply nearly 88 percent of the world‘s energy needs, or about 350 quadrillion BTUs (McLamb, 2011). Every day, humans burnt high volume of fossil fuels to contribute in transportation, electricity and also raw material for plenty of products. Thus, the importance of fossil fuels is definitely high for human, in daily activities and also socioeconomic.

According to New Mexico Oil and Gas Association (2012), fossil fuels are used to fuel cars and airplanes, power electricity plants and heat our homes. They are also used to make medicines, cosmetics, plastics, synthetic fabrics and lubricants. Humans are over depending on fossil fuels as energy sources. According to Missouri Department of Natural Sources (n.d.), one of the reasons we rely so heavily on fossil fuels is that they are relatively cheap. However, all of the environmental costs of providing and using fossil fuels are not included in the price paid by the consumers. Use of fossil fuels is increasing the release of the greenhouse gases carbon dioxide and methane, as well as sulfur oxides to the atmosphere. Other costs of burning fossil fuels include the costs to human health and the environment from acid rain and smog.

Instead of burning fossil fuels for energy sources, they still can use for other purposes. It can reduce the rate of Carbon emission and also postpone the day of oil crisis. Effectiveness of fossil fuels to use as energy sources is cheap for current stage, but it will become less and less effective since the oil reserves is reducing and environment impacts caused by fossil fuels also increase from day to day.

4.3 Social Acceptance of OTEC Compare with Fossil Fuels

The second objective is to investigate the social acceptance of the application of OTEC in Kota Kinabalu, Sabah, and compare with fossil fuels power station.

Therefore, the responses of residents in Kota Kinabalu, Sabah will be used as parameter to measure on their acceptance level. It will be discussed base on the theoretical framework that has been constructed to measure on the social acceptance on new technology adoption.

4.3.1 Social Concern Level

To ensure the acceptance level being measure precisely, social concern level is one of the parameter that must be studied. When government is proposing to adopt OTEC technology as an alternative of energy sources, concern level is significant parameters to measure on their acceptance level. If society just accepted or agreed on the technology without concern on the development or impacts brought by particular technology, then the acceptance from particular society is meaningless.

The researcher has designed some questions within the questionnaire for quantitative study, which purposely for investigate the concern level of OTEC adoption among the residents in Kota Kinabalu, Sabah. Parts of my respondents are from Universiti Malaysia Sabah (UMS), including students and staffs, have well education background and range from 20-35 years old. There are also respondents from Center Point Shopping Complex and One Borneo Shopping Complex, which age range from 25-55 years old. There are also respondents from SME organization such as MiliMeter Sdn.Bhd and Mutiara Furnishing. Those respondents are range from 30-35 years old.

The researcher found that 22 of 30 respondents aware with current environmental issues created by fossil fuels station but there are 8 respondents not aware on this. The researcher also found that 73% of respondents aware with environmental impacts that rising recently. The researcher believes residents in Sabah are concern about the impacts brought by technology even it was a government project, especially in environment issues.

There are only 13 out of 30 (43%) respondents are clear with the development and future direction of energy project conducted by the Sabah energy company. However there are up to 17 (57%) respondents are did not know what really happening with the energy project in Sabah. The researcher believes residents in Sabah are aware with those significant impacts, but they did not concern with the future planning of technology adoption especially government project on renewable energy development.

This is the last question designed for testing the concern level of residents. 23 (77%) of respondents are shows that they did really concerned with the news in renewable energy and environment issues. However, there are still 7 (23%) respondents said that they are not concerning on all of these. This data shows that the majority of residents in Sabah started to aware on what happen in the energy field and minority might have different perspective in the development of renewable energy field.

4.3.2 Adoption and Utility Level

Regarding the framework constructed in Section 2.4, the willingness of adoption or utility level is one of the parameter to measure the social acceptance on new technology adoption. For the implementation of OTEC, it will bring direct and also indirect impacts to residents in Sabah; therefore their willingness of adoption on particular technology is important to be examined.

The researcher has designed few questions to test on the willingness level of residents in Sabah to accept the adoption of OTEC or any new renewable energy technology in Sabah.

Table 4.1: Descriptive Statistic for Quantitative Question No. 15

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Q15	30	1.00	4.00	3.6667	.75810
Valid N (listwise)	30				

Question above is a straight forward question that asking the acceptance of Sabah residents in implementation of OTEC. Through descriptive statistical analysis, the researcher found that there are only 3.6667 mean values on the acceptance level. Base on mean value among these 30 respondents, they are only slightly agreed on the implementation of OTEC in Sabah. This might due to the lack of understanding in technology of OTEC. The researcher believes, society start to have the least knowledge on renewable energy, and they believe it is good to replace conventional power station. Therefore, the mean values skewed more to agree.

4.4 Innovative Solution to Overcome the Challenges of OTEC

The third objective is to suggest an innovative solution to overcome the challenges of OTEC and enable its application. To achieve this objective, the challenges and innovative solution has been investigated by distribute qualitative questionnaire and perform in-depth interview. Besides, the researcher also referring on secondary data for details of challenges and better innovative solutions.

4.4.1 Challenges of OTEC

OTEC is a renewable energy technology that still under pilot testing; therefore, it will have some challenges to fully implement the technology.

4.4.1.1 Economic in Cost Competitive

OTEC is generating clean energy, but it is still under pilot testing phase. People would like to look for cheaper energy instead of cleaner energy. Comparing to fossil

fuels power plant, definitely OTEC involved higher initial cost, and cost per kW of electricity generated also higher than typical power plants. The huge cost of OTEC is come from the plant design and construction, power cable, and maintenance cost.

According to Vega (2012), the Installed Capital Cost for OTEC floating plant size 10 MW is estimate in 18,600 USD/kW. The materials that use for construction of OTEC power plant is important to ensure OTEC operate under extreme condition and smoothly, therefore it will be costing.

"The primary challenge to successful commercialization of an OTEC industry is economic. Most OTEC system challenges are associated with designing components that collectively are at the most optimal design points and are the least cost consistent with meeting environmental, performance and life cycle goals."
(Manager 1)

When the cost is too high, people do not like to invest due to high risk involved. People would like to stick on conventional power plants with better cost-effectiveness. OTEC is lack competitive in economic when fossil fuels power plants still generating cheap electricity due to large subsidies provided. According to Director 1, the construction cost is high and the payback period on investment is long and not commercially attractive for investors and banks. Hartman (2011) also said that the challenge to OTEC is not whether building an OTEC plant is possible, but whether it can be built economically.

4.4.1.2 Organism Entrainment and Impingement

Even OTEC is generating clean energy, but during the operation of OTEC, it will cause some environment impact to the surrounding area of the plant. OTEC operated with a huge mooring platform on the sea surface and required high volume of warm and cold water as ¨Dfuel¡¬ to perform energy conversion. Therefore, there will be 2 huge inputs for high volume of warm water and cold water. When sea water is drain for operation of energy conversion, organism inside the sea water definitely will be affected.

According to Vega (2012), OTEC plant construction and operation may affect commercial and recreational fishing. Fish will be attracted to the plant, potentially increasing fishing in the area. However, the losses of inshore fish eggs and larvae, as well as juvenile fish, due to impingement and entrainment and to the discharge of biocides may reduce fish populations.

4.4.1.3 Sea Water Discharge

The content of warm sea water and cold sea water is different. If the design for sea water discharge is not well, it will affect the biota in the water.

"Cold seawater is low in oxygen but high in nutrients, warm seawater has higher oxygen and lower nutrient content; requires thoughtful consideration for the depth of seawater discharge from the heat exchangers and whether to mix the warm and cold seawater flows."
(Manager 1)

According to Makai Ocean Engineering, INC. (2012), introducing deep nutrients into the ocean¡®s sun-lit upper layers could potentially increase plankton growth or cause algal blooms. Thus, seawater discharged from an OTEC plant should be returned into the ocean deep enough so that these nutrients do not trigger biological growth. Therefore, this is the issues that require thoughtful consideration.

4.4.1.4 Durability of OTEC Plant

OTEC floating platform need to operate on the surface of seawater, and it will face the problem in plant durability. Seawater has higher salinity and plenty of unknown content such as biota and organism. This created challenge for the plant to have longer lifespan and threaten the durability. To ensure the plant of OTEC can survive under such condition, the capital cost for OTEC plant will be high.

"The key ocean thermal technical requirement, all of which now can be satisfied at potentially viable cost at commercial plant sizes is heat exchangers that can withstand corrosion and enable control of bio fouling."
(Pro bono Consultant 1)

"The technical challenge includes the termination of the pipe to the platform. Our pipe design is free hanging from the platform and must survive weather conditions over a 30-year life span. A secondary technical challenge is affordable heat exchangers. Heat exchanger technology for marine applications typically is met by titanium material designs. Titanium is expensive for the large heat exchangers needed for OTEC applications."
(Manager 1)

4.4.2 Innovative Solution for OTEC Challenges

Few challenges been discussed, thus, the researcher here to find out some innovative solutions for those challenges. Those solutions are from experts, secondary data and also the researcher opinions.

4.4.2.1 Economic Challenge

In now days, OTEC definitely less cost competitive compared to fossil fuels. The capital cost for 10 MW floating OTEC plant is around 18,600 USD/kW and this is a huge number. However, this is only for current. Due to OTEC is using ¨Dfree¡¬ fuel for energy conversion, therefore in long term people can see the potential in economic term. Presently, the initial cost for OTEC plant is expensive, thus, experts started to

find a better alternatives on materials, technology or design to reduce the initial cost involved. The researcher believes, currently the technology of OTEC still undergo a series of evolution stage. In the future, the commercialization and maturity of OTEC will make it become more cost competitive.

"Titanium is expensive for the large heat exchangers needed for OTEC applications. Therefore, we are investigating aluminum designs."
(Manager 1)

Base on the researcher opinion, the reason experts investigated in aluminum designs to replace titanium designs is due to high resistance of corrosion by aluminum and having lower price compare with titanium. The size of heat exchanger for OTEC operation is huge and if the aluminum design is success, it will reduce the capital cost significantly.

Lack of competitiveness in economic also causing the investment in OTEC technology extremely low. Peoples feeling doubt to invest on a research that having unknown or even loss in Return of Investment (ROI) report. Base on the researcher opinion, government or banking system in local can play their rules to solve on this issue. Government should try to offer incentive for those investors in green technology for tax reduction, or extra benefits after the research is success. Government also can propose carbon tax or pollution tax on conventional power plant.

Instead of rule from government, banking system also do offering green financing for green technology investor. According to Dhesi (2010), more banks in Malaysia are going into green technology financing in view of the potential market for environmental business amid surging levels of greenhouse gases. The Government had set up an RM1.5bil Green Technology Financing Scheme (GTFS) under Budget 2010 to encourage the supply and usage of green technologies, especially in energy, water and waste management industries. CIMB Bank had also teamed up with Credit Guarantee Corp Malaysia Bhd to promote GTFS and would contribute up to RM150mil for the scheme.

4.4.2.2 Organism Entrainment and Impingement Challenge

Affect in organism is one of the environment impacts for the operation of OTEC. The most direct way to solve on this is create a better plant design. Due to technology of OTEC still under pilot testing phase, engineers in OTEC still do not have enough demonstration to design in detail. Therefore, Manager 1 suggested put thoughtful consideration for the design of intake screens, intake flow velocities, and how much temperature delta is allowed across the heat exchangers. Facing this kind of challenge, the researcher believes by collecting more data will reduce the risks on facing failure. Therefore, build more specific pilot plant to study on particular problem is applicable. According to Vega (2012), the only way to evaluate the OTEC environmental differentiator is to obtain field data with a pilot plant operating with

flow rates corresponding to at least a 5MW plant. Such plant must be operated and monitored through ongoing and adaptive experience for one to two continuous years, i.e., an adaptive management process. This will provide sufficient data for engineers to design OTEC plant, and also examine the rate of impacts, to increase the success rate of OTEC implementation.

Besides, some computer model software also might help to provide data instead of pilot plant demonstration. The data from computer model might be more precise but the data from pilot plant might be practical enough. According to Makai Ocean Engineering, INC. (2012), the discharge plume created by an OTEC plant is being studied by Makai using nested computer models simulating actual and complex 3-D ocean conditions at candidate OTEC sites. These results illustrate the low environmental impact of a properly-designed OTEC plant and the ability to successfully operate multiple OTEC plants in close proximity to each other.

4.4.2.3 Seawater Discharge Challenge

Another environment impact by OTEC is the seawater discharge challenge. It is very important for OTEC engineers to design an ideal discharge pipe for seawater. Due to the cold seawater and warm seawater have different content and nutrient level, so the seawater discharge will affect the environment in particular area. Therefore, Manager 1 suggested put thoughtful consideration for the depth of seawater discharge from the heat exchangers and whether to mix the warm and cold seawater flows. As to reduce the risk of failure, collect more data from pilot plant should be helpful to overcome this challenge.

"All of these items have well established design and process requirements imposed by regulatory agencies. We believe we can design systems that will meet environmental regulatory agency requirements. Since no commercial OTEC system is in operation anywhere in the world at any scale, a pilot plant system is required to gather the data that will be needed by agencies to demonstrate our belief."
(Manager 1)

Besides, computer modeling software is also helping to demonstrate a situation for OTEC engineers to refer. According to Hartman (2011), a numerical hydrodynamic model was recently completed to study these effects by simulating the large discharges of OTEC plants in the ocean environment. The 3D hydrodynamic model is based on the EPA-approved Environmental Fluid Dynamics Code and receives realistic oceanographic currents and density data supplied by the Hawaii Regional Ocean Modeling System. Dynamically coupled finite- element, jet-plume models simulate the entrainment and turbulent mixing of large OTEC plumes.

4.4.2.4 Durability of OTEC Plant Challenge

OTEC plant is facing problems to operate on the surface of ocean, such as corrosion, plant stability, natural disaster and more. Therefore, engineers need more efforts to

make the OTEC plant become resistance to all of these. The researcher believes OTEC power plant can adapt existing technology, which is oil drilling platform, to overcome this challenge.

"…fortuitous blossoming of the offshore oil industry, which began around 1978, with its outstanding development of platform and mooring engineering innovations, requiring the investment of billions of dollars in R&D during the next 30 years, as shown in the illustration at the bottom of the information packet attached to my e-mail. That development, along with invaluable experience at sea, unintentionally satisfied the platform and mooring needs of ocean thermal applications, largely making credible the potential for operating mammoth, stable and survivable commercial ocean thermal platforms."
(Pro bono Consultant 1)
Base on the researcher opinion, the process of design an OTEC plant should involve more experts from different fields instead of engineers from OTEC only. Experts from oceanography, composite materials, weather or natural disaster experts, architecture and more, all of them will play their roles to contribute within the process. It must be no technical limitation in the construction or operation of OTEC power plants. However, to ease the OTEC being commercialize, it still require effective and economic in construction and operation.

5. Conclusion

Due to the crisis of peak oil and rising of environment impacts, green technology has become more and more thriving and can be saying as is a must in future. OTEC is one of the renewable energy have high potential to replace typical power plants; therefore it is very worth to study and research. Even OTEC has undergone a long evolution, but it still has not been fully developed. The researcher believes there are still many spaces for OTEC to improve.

The researcher suggests do not limit the network for source of data. OTEC technology is still in development stage; therefore it is not easy to get valid data related to OTEC. Even in Malaysia, there is not much project or research has been done for the marine renewable energy. Government in Malaysia did not provide any funding to encourage on marine technology development too. Therefore, the sources of data were recommended to be wide and flexible.

The researcher noticed OTEC is a combination of few technologies to operate on energy conversion. The researcher believes reading in more types of related technologies will be helpful to provide more relevant data. Expand the secondary data also will provide more innovative ideas to solve on current challenges that facing by OTEC. Knowledge in chemical industry, oceanography, architecture, weather forecast and natural disaster are also helping in the development of OTEC.

Finally, the researcher suggest do not ignore the consideration on social acceptance. Perception from society is important to create an ideal system to fulfill social needs. The researcher believes survey and opinion from society will boost the development of OTEC and succeed the implementation.

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