Title:

'Investigating the appropriate Renewable Energy Technologies in the Mauritian context'

Name:

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Master of Science Thesis

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<th>Approved Date</th>
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<td>Dr. D. Surroop</td>
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ABSTRACT

With limited indigenous conventional energy resources, Mauritius imports over 80% of its energy supply from foreign countries, mostly from the Middle East. Developing independent renewable energy resources is thus of priority concern for the Mauritian government. A tropical island surrounded by the Indian Ocean, Mauritius has enormous potential to develop various renewable energies, such as solar energy, biomass energy, wind power, geothermal energy, hydropower, etc. However, owing to the importance of conventional fossil energy in generating remarkably cheap electricity, renewable energy has not yet fully developed in Mauritius, resulting from a lack of market competition. So, in order to reduce the external dependency of fuel, and also to cut down the expenses involved in the imported fuels, the Mauritius Government introduced attractive policies and invited investors of the homeland and abroad to invest in renewable energy technologies. Consequently, numerous promotional and subsidy programs have recently been proclaimed by the Mauritian government, focused on the development of various renewable energies. Thus, the Government of Mauritius has a long-term vision of transforming Mauritius into a sustainable Island. One important element towards the achievement of this vision is to increase the country’s renewable energy usage and thereby reducing dependence on fossil fuels. Democratisation of energy production is determined to be the way forward. A step in this direction is to transfer citizens the ability and motivation to produce electricity via small-scale distributed generation (SSDG), i.e. wind, photovoltaic, Hydropower. As a stepping stone the Government and the Central Electricity Board, with the help of the UNDP, established a grid code in May 2009 which encompasses tariffs and incentive schemes that have in many countries proved essential in order to achieve any substantial development in renewable electricity production based on SSDG.

In line with the government’s vision on renewable energy, the University of Mauritius is working as a partner with DIREKT team to promote renewable energy infrastructure locally. The DIREKT (Small Developing Island Renewable Energy Knowledge and Technology Transfer Network) is a teamwork scheme that involves the participation and collaboration of various universities from Germany, Fiji, Mauritius, Barbados and Trinidad & Tobago. The aim of the DIREKT project is to reinforce the science and technology competency in the domain of renewable energy through technology transfer, information exchange and networking, targeting ACP (Africa, Caribbean, Pacific) Small Island developing states.

This study was therefore initiated to investigate the main renewable energy technologies that stakeholders, institutions as well as businesses and organizations would like to invest in Mauritius based in the attracting incentive schemes provided by the Government.

From the study it was found that the majority of the Organizations, Institutions, Businesses and stakeholders are ready to accept and invest in the solar photovoltaic technology. Moreover, the economic evaluation for the implementation of the photovoltaic technology revealed that within a period of 4.3 years (payback period), the total capital invested can be recovered and after that, the capital generated from the excess electricity produced will contribute to the profit of the organization, Business or Institution.

Keywords:
Photovoltaic, hydropower, co-generation, renewable, non – renewable, fossil fuels, Market- Oriented
ACKNOWLEDGEMENT

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<tr>
<td>AC</td>
<td>Alternating current</td>
</tr>
<tr>
<td>ACP</td>
<td>African, Caribbean &amp; Pacific countries</td>
</tr>
<tr>
<td>BAI</td>
<td>British American Investment</td>
</tr>
<tr>
<td>BOO</td>
<td>Build-Own-Operate</td>
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<tr>
<td>CEB</td>
<td>Central Electricity Board</td>
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<tr>
<td>CEL</td>
<td>Consolidated Energy Ltd</td>
</tr>
<tr>
<td>CHNS</td>
<td>Carbon Hydrogen Nitrogen Sulphur analyzer</td>
</tr>
<tr>
<td>CHP</td>
<td>Combined Heat and Power</td>
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<tr>
<td>CSO</td>
<td>Central Statistic Office</td>
</tr>
<tr>
<td>CTBV</td>
<td>Central Thermique de Belle Vue</td>
</tr>
<tr>
<td>CTSav</td>
<td>Central Thermique de Savannah</td>
</tr>
<tr>
<td>CWA</td>
<td>Central Water Authority</td>
</tr>
<tr>
<td>DC</td>
<td>Direct current</td>
</tr>
<tr>
<td>DIREKT</td>
<td>Small Developing Island Renewable Energy Knowledge &amp; Technology Transfer Network</td>
</tr>
<tr>
<td>ESD</td>
<td>Energy Service Division</td>
</tr>
<tr>
<td>E10</td>
<td>10% Ethanol blend + 90 % gasoil</td>
</tr>
<tr>
<td>GEF</td>
<td>Global Environmental Facility</td>
</tr>
<tr>
<td>IPP</td>
<td>Independent Power Producers</td>
</tr>
<tr>
<td>LBOI</td>
<td>Land Based Oceanic Industry</td>
</tr>
<tr>
<td>LNG</td>
<td>liquefied natural gas</td>
</tr>
<tr>
<td>LPG</td>
<td>liquefied petroleum gas</td>
</tr>
<tr>
<td>MIE</td>
<td>Mauritius Institute of Education</td>
</tr>
<tr>
<td>MID</td>
<td>Maurice Ile Durable</td>
</tr>
<tr>
<td>MITD</td>
<td>Mauritius Institute of Technological Development</td>
</tr>
<tr>
<td>MPU</td>
<td>Ministry of Renewable Energy and Public Utilities</td>
</tr>
<tr>
<td>MRC</td>
<td>Mauritius Research Council</td>
</tr>
<tr>
<td>MSIRI</td>
<td>Mauritius Sugar Industry Research Institute</td>
</tr>
<tr>
<td>NGO</td>
<td>Non Governmental Organization</td>
</tr>
<tr>
<td>OTEC</td>
<td>Ocean Thermal Energy Conversion System</td>
</tr>
<tr>
<td>PV</td>
<td>Photovoltaic</td>
</tr>
<tr>
<td>RE</td>
<td>Renewable Energy</td>
</tr>
<tr>
<td>RET</td>
<td>Renewable Energy technology</td>
</tr>
<tr>
<td>STC</td>
<td>State Trading Corporation</td>
</tr>
<tr>
<td>UNDTCED</td>
<td>United Nations Department of Technical Co-Operation for Development</td>
</tr>
<tr>
<td>USP</td>
<td>University of South Pacific</td>
</tr>
<tr>
<td>WMA</td>
<td>Waste Water Management Authority</td>
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1.0 INTRODUCTION

For many centuries, abundant sources of coal, oil, natural gas, and nuclear energy have been used as a source of energy for the growth of the economy. However, with the emerging awareness about protection of the environment during the twenty-first century, two key factors have brought a change in this paradigm. The first is the extensive rise in the demand for energy in the new market economies. The second is the rapid exhaustion of the worldwide oil reserves together with a deficiency in new researches to substitute the depleted reserves, but also to meet the rising energy demand. This emergency has pushed various countries in focussing at the implementation of sustainable energy programs at diverse levels globally.

Sustainable energy implies reducing energy usage, increasing energy efficiency and enabling sustainable energy independence that serves to reduce carbon emissions and greenhouse effect thus providing energy sustainability for the future generations. Sustainable energy include all renewable sources of energy, such as solar power, wind power, hydro power, wave power, tidal and geothermal power.

Mauritius is an island situated in the Indian Ocean of volcanic origin and of the superficies of 1870 km². It is surrounded by coral reefs encircling lagoons of varying sizes. It has under its dependency another main island called Rodrigues and few other islands. The climate is sub-tropical where winter prevails from May to September and summer from October to April. Over the last five years, it has been found statistically by the Central Statistics Office that the Mauritian population has been rising at an average rate of 1 % per annum. In July 2009, the population of Mauritius was 1,275,323 with 1,237,286 in the Mauritius itself, 37,748 in Rodrigues and 289 in the other islands. As at July 2009, the population density was approximately 625 persons/ Km².

Mauritius, does not have any identified oil, coal or natural gas reserves, and consequently depends on imported petroleum products to meet the majority of its energy requirements. 80% of its energy is derived from burning imported fossil fuels which is costly. As a small island state with no indigenous reserves of fossils fuels, and no electricity interconnection, the country is exposed to the risks of being without power and transport due to geopolitical, economic or natural crises. The policy to ensure the security of energy supply involves diversification of energy raw material and the plan for sufficient stocks to the degree that it is financially feasible.

The government is in one way or the other obliged to lessen the reliance on fossil fuel for economic and environmental reasons. Local renewable energy sources that are most commonly available in Mauritius are hydro, solar, wind energy and biomass. Hydropower potential, with a combined installed capacity of 59 MW, is almost fully tapped in Mauritius and with aggressive use of the available water resources; hydro power now present very little capacity for any further development. Regarding biomass energy, in form of burning of bagasse, it contributes only to around 22 % (Ministry of RE and Public Utilities, 2009) of the primary energy supply. Mauritius being a tropical country, has a good solar regime with an average annual solar radiation of around 6 kWh/m²/day and very good wind regime in some areas of the island, with an annual average speed of 8.1 m/s at a height of 30 m above ground level. However, the wind regime is irregular. As a result, solar is the most established renewable energy resources that can benefit the country from economies of scale,
and is very much suited for the local climatic conditions. However, both the potential for solar (solar thermal and PV) and wind energies (farms and Distributed Energy Systems) have not yet been estimated till date for Mauritius.

Fortunately, the government of Mauritius has recently go forward with a Sustainable Island Program fund to support recycling and encourage more efficient use of renewable energy resources available locally for the protection of the environment. The government has planned to double the share of renewable sources of energy by 2025 to produce electricity through the exploration of these local renewable energy sources.

Furthermore, the extent to which prices on the oil markets has increased has created awareness amongst policymakers and stakeholders of the necessity to lessen the dependency on non-renewable fossil fuels by increasing use of sustainable renewable energies. This urges for a shift in the energy policies, strategies and mindset at governmental and Organizational level in both developed and developing countries.

As regards the Government of Mauritius, it is focusing on broadening our energy supply, improving energy efficiency and adapting our energy infrastructure through modernization in order to meet the challenges ahead. Besides the precautions of energy supply and affordability, Mauritians needs to adapt to a rapid shift in the practices of a low carbon, efficient and environmentally benign system of energy supply. Thus the government needs to put in place decisive policy actions for the total change in the habits of energy usage and consumptions at all level. In this course of action, it is of prime importance to get the collaboration and participation of the private sectors, local as well as overseas stakeholders, public organization and the help of each and every Mauritian citizen.

To be able to put such practices in place, the Government together with the Ministry of Renewable Energy and Public utilities have drafted a Long Term Energy Strategic plan based on practices of Renewable energy and has given it the name of Maurice Ile Durable vision. The Government also has a long-term vision of transforming Mauritius into a sustainable Island. One important element towards the achievement of this vision is to increase the country’s renewable energy usage and thereby reducing dependence on fossil fuels. Democratisation of energy production is determined to be the way forward. A step in this direction is to transfer citizens the ability and motivation to produce electricity via small-scale distributed generation (SSDG), i.e. wind and photovoltaic.

As part of its perspectives, the government intends to promote the setting up of a wind farm in the country on a Build-Own-Operate (BOO) scheme and to further promote the utilization of solar energy other than for domestic water heating. Moreover, in line with the Maurice Ile Durable (MID) vision, the government has targeted to achieve 35% of self-sufficiency by 2025 in terms of electricity supply through a progressive increase in the use of renewable energies, depending on further researches to be carried out on technologies like sea-wave energy, geothermal, OTEC and others. The above targets are motivating for the country and will therefore put a pressure on decision makers to adopt Renewable energy strategies in future.
This long term energy strategy is the roadmap for all the organizations, Institutions and Citizens of Mauritius to deal with future challenges associated with energy and environment. The spirit of the roadmap is based on innovation of new technologies through development in science. Diversification of energy supply towards Renewable Energy sources will definitely help in coping with the increasing environmental concerns and greatly reduce the dependency on conventional energy sources over time. Some of these practices have already been implemented by the Government since July 2008 with campaigns to promote energy efficiency and electricity savings. It comprises of the sale of 1 million Compact Fluorescent Lamps to domestic consumers at a subsidized price and a grant of Rs 10,000 for the purchase of solar water heaters to 29,000 households.

These plans show how our Government is willing to have a future of cleaner energy and environment. Furthermore, it is important to remember that there exist no single solution in meeting demand of energy and Mauritius will have to depend on a range of resources to meet its energy needs and to decrease the dependency on conventional fuel to have a cleaner and greener Island. Moreover, these interesting incentives for small-scale distributed generation have brought a shift in the mind set of the Mauritian Citizen whereby many of our stakeholders as well as various organizations and household are ready to invest in renewable energy technologies for electricity production for own consumption.

1.1 DIREKT- Small Developing Island Renewable Energy Knowledge and Technology Transfer Network

In line with the government’s vision on renewable energy, the University of Mauritius is working as a partner with DIREKT team to promote renewable energy infrastructure locally. The DIREKT (Small Developing Island Renewable Energy Knowledge and Technology Transfer Network) is a teamwork scheme that involves the participation and collaboration of various universities from Germany, Fiji, Mauritius, Barbados and Trinidad & Tobago. The aim of the DIREKT project is to reinforce the science and technology competency in the domain of renewable energy through technology transfer, information exchange and networking, targeting ACP (Africa, Caribbean, Pacific) Small Island developing states. The DIREKT project is financed by the ACP Science and Technology Program, which is a European Union (EU) program with the collaboration between the EU and the ACP region (Africa, Caribbean, Pacific). Thus the DIREKT is a tangible tool to promote the development of renewable energy issues which is of prime importance for the socio-economic development of ACP small island developing states in which Mauritius forms part. The project is split in different sections called Work Packages, each having specific objectives, aims and a set time frame. All the regional partners need to carry out surveys and analyze the outcome of their respective countries. The University of South Pacific (USP) will then be in charge of the collection and presentation of the overall results. As a partner of the DIREKT project, the University of Mauritius needs to work on all the packages. Thus, I was given the task to work on the Work Package 2(WP2) for my thesis: “Assessment of needs for market-oriented research and technology transfer”. The objectives of this WP2 consist of analyzing the requirements for renewable energy knowledge and technology transfer that will form the base for further work and carrying out a survey of the political and institutional frameworks at present within Mauritius.
For that purpose two sets of survey questionnaires have been prepared and target groups identified. The first set of survey questionnaire is to identify the requirement of businesses and organizations in Mauritius in terms of research, innovation and training needs. The second set is to spot out the training needs of universities and other tertiary institutions in Mauritius. The identified target groups for the first set of questionnaires are; renewable energy manufacturing, wholesale and retail companies, governmental and non-governmental organizations, public utilities like the Central electricity board (CEB) which is the main network for electricity provider in Mauritius, independent power producers, regional organizations, environmental and conservation organizations. For the second set of questionnaires the targeted groups are universities and other tertiary institutions.

1.2 Hypothesis

One of the major challenges that many small island developing countries are facing nowadays is to meet the energy demand of their country while supporting a future of cleaner energy to diminish harm on the environment. Consequently, in collaboration with the DIREKT scheme of work keeping in mind the Mauritian government’s vision, this study is based on investigating the appropriate Renewable Energy Technologies in the Mauritian context and the readiness of implementing the most appropriate technology at business and institutional levels. Starting with already developed renewable energy resources in Mauritius, a list of the most potentially promising renewable energy resources has been identified which consisted of solar energy, wind energy, biomass, hydro energy, geothermal and tidal energy. The use of these purely renewable energies will optimize the efficiencies of the energy sectors for Mauritius. This approach will also provide the bridge that will move the Mauritian economic sector from the traditional low efficiency energy model to the newer standard whereby they will be in a position to produce some or all of their own energy at their own facilities thus reducing the harmful impact on the environment and contributing towards reduction in greenhouse gas. Furthermore, the outcomes of this study will be used by the University of South Pacific (USP) together with results from other partners of DIREKT to create models for other ACP small island developing states who want to implement the renewable energy technologies in future.

1.3 Aims and Objectives

Based on the work package 2 of the DIREKT project, the aims and objectives of this study are as follows:

- Identify the availability of renewable energy regarding mainly solar, wind, hydro and biomass resources in Mauritius.
- Make out the level of awareness / willingness about renewable energies in the private sector like business and organizations and in Tertiary Institutions through the survey forms.
- Identify the most appropriate renewable energy technologies for fruitful investment for stakeholders
- Perform an economic analysis on the main renewable energy technology identified.
2.0 LITERATURE REVIEW

Energy helps to drive the economy and has a noteworthy impact on the quality of life and health of the population of any country. Due to the recent rise in prices of petroleum products, it has never been as important as it is to-day to go for reliable and affordable energy resources. Adopting Renewable energy sources is now becoming every country’s goal to ensure proper economic development and environmental sustainability. In fact all energy comes mainly in two forms: non-renewable and Renewable energy. In Mauritius, both types of energies are used but non-renewable energy is the dominant one. In 2008, imported fuels (petroleum products and coal) accounted for 81.2% while the remaining 18.8% were supplied through locally available renewable resources. The total local renewable energy production comes mainly from bagasse (93.2%), hydro electricity (3.5%), fuel wood (2.9%) and wind energy (0.4%) (Ministry of Renewable Energy and Public Utilities, 2009).

2.1 Non-Renewable Sources of Energy

Non-renewable energy sources are limited in amount and will sooner or later get depleted as they are not renewed. These types of resources take thousands of years to form and hence once consumed cannot be replenished that quickly. Moreover, for the time being, the non renewable energy type of fuel is meeting most of the world’s energy needs. The main Non-renewable energy sources are as follows:
- Fossil Fuels : Oil, Coal, Natural gas
- Nuclear Energy

2.1.1 Fossil fuels

Fossil fuels come from dead plants and animals that decayed for hundreds of millions of years ago. Their leftovers being buried in the Earth’s surface thereafter transforms into the fossil fuel which is the combustible materials.

Burning of fossil fuels emits carbon dioxide. Carbon dioxide is known to be the main greenhouse gas that contributes to global warning. Burning of these fossil fuels is known to contribute to a large extent to the amount of greenhouse gases present in the atmosphere. During the 20th century, the earth’s atmosphere experienced a one degree Fahrenheit (1 °F) rise in temperature. This is known to create a rise in sea level and other natural calamities as there has been an imbalance in the temperature profile (McLamb, 2010). The three main types of fossil fuels are coal, oil and natural gas.

2.1.2 Coal

Coal consists of carbon, hydrogen, oxygen, nitrogen and varying amounts of sulphur. In nature, it resembles a black rock-like substance. Coal is of three types; namely – anthracite, bituminous and lignite. Anthracite coal is the hardest, followed by Bituminous which is in between hard and soft and
finally Lignite which is the softest form of coal. The reason for these 3 forms is due to the varying carbon content whereby more carbon means higher energy content. (Taylor et al, 2009)

2.1.3 Oil

Oil comes from the remains of dead plant and animals that decomposed for millions of years ago in a marine (water) environment. With time, heat and pressure the remains together with layers of mud turned into crude oil. These crude oils are usually found in reservoirs that are deep into the earth and hence to explore these oils drilling is required. Before any drilling is done, scientists and engineers study rock samples to know whether a particular site has crude oil reserves or not. After drilling, a ‘derrick’ is built to protect the pipes leading to the well through which the oil comes out on the surface. These Oils are crude and therefore need to be refined for various uses. The products after refinery are as follows: gasoline, diesel fuel, aviation or jet fuel, home heating oil, oil for ships and oil that can be burnt to produce electricity in power plants.

2.1.4 Natural gas

Natural gas is the cleanest and most convenient fossil fuel. It consists primarily of methane (CH₄) which is odourless, colourless and highly flammable. It can easily be transported through pipes and it causes almost no air pollution. Natural gas is usually formed near petroleum reserves where the gas is pumped from below ground and sent to storage tanks. However, since it is odourless and colourless, a chemical is usually mixed with the gas to give it a strong odour (like rotten eggs) to facilitate detection of any leaks (Knight, 2010). Natural gas is mainly used for, cooking, heating buildings and providing energy for industries.

2.1.5 Nuclear Energy

Nuclear Energy provides only six percent (6%) of the world’s energy supplies. This energy is generated by fission of atoms. This type of fission is known to generate extremely large amount of energy. However, Nuclear energy is not a major practice globally due to public pressures and the catastrophic dangers associated with it. Yet, some head of states like the United States are in favour of exploiting nuclear energy because of its vast potential.

2.2 Renewable Sources of Energy

Renewable energies are energy resources that are replaced rapidly by natural processes. Renewable energy sources will therefore never be completely exhausted and are thus sustainable unlike fossil fuels. Moreover, renewable energy technologies are a lot friendlier to the environment than conventional energy technologies. The trouble that mankind is facing today is because of the environmental problems such as greenhouse gases; air pollution; and water and soil contamination caused by the utilization of fossil fuels. Renewable energy sources in known to cause very little or almost no pollution. The most common sources of renewable energies are:
• Solar energy
• Wind energy
• Hydroelectric power
• Bio-fuels
• Geothermal energy
• Ocean Thermal Energy Conversion System (OTEC)
• Wave Energy
• Tidal Energy

2.2.1 Solar Energy

Solar energy is energy given off by the sun which consists mainly of light, heat and other forms of electromagnetic radiation. However, this form of energy is not exploited to its maximum. It has been found that, the amount of solar energy being utilized globally is only about what the sun delivers for 40 minutes. Yet though the supply is so vast, people use only a very small fraction of the solar energy that reaches the earth (Morton, 2006).

But nowadays, there are a variety of technologies that have been developed to take advantage of solar energy. Some of the technologies are mentioned below.

2.2.1.1 Photovoltaic cells

Photovoltaic or solar cells convert light from the sun into electricity. Solar cells have since long been used in calculators and watches. They are made of semi conducting materials which are similar to those in computer chips. When sunlight falls on these materials, the solar energy removes the electrons from their atoms, allowing the electrons to flow through the material. It is this flow of electron that produces electricity. This process of converting sun light into electricity is known as the photovoltaic (PV) effect.

2.2.1.2 Concentrating solar power

Most of the power plants nowadays burn fossil fuel as a source of heat to boil water to produce steam that spins a large turbine, which in turn rotates a generator to produce electricity. However, we also have available a new type of power plants, where the heat source is obtained from the sun. The system works on the principle of capturing the sunlight by concentrating power systems made up of mirrors to concentrate the heat. There are three main types of concentrating solar systems: parabolic-through, dish/engine, and power tower.
2.2.1.3 Parabolic-trough

Parabolic-trough systems work on the principle of focussing the energy of the sun through long rectangular U-shaped mirrors. The mirrors are slanted toward the sun which concentrates the sunlight on a pipe containing oil that runs towards the centre of the trough. This heats the oil which is thereafter used for the production of steam in conventional steam generator to produce electricity.

2.2.1.4 Dish/engine system

A dish/engine system utilises a very large satellite type dish which is covered with mirrors. These mirrors focus the heat of the sun onto a receiver, which absorbs and transfers the heat to a fluid within the engine. This heat expands the fluid which pushes out a piston or turbine to generate mechanical power. This mechanical power is then used to run a generator or alternator to produce electricity.

2.2.1.5 Power tower system

A power tower system concentrates sunlight onto a receiver found on the top of a tower through fields of mirrors. The receiver contains molten salt which is heated up. This heat in the salt is then used to produce electricity by conventional steam generator. The main purpose of using molten salt as a medium is that, it retains heat very efficiently. Thus electricity can also be produced on cloudy days or after several hours of sunset since the heat can be stored for days before being converted into electricity.

2.2.1.6 Solar water heating

Solar water heating system for buildings consists mainly of: a solar collector (most common the flat plate collector) and a storage tank. The flat-plate collector consists of a thin, flat, rectangular box with a transparent cover mounted on the roofs of building to face the sun. Small tubes carrying water or other fluid, such as an antifreeze solution run through the rectangular box and are exposed to the sun to be heated. These tubes are connected to a black surface absorber plate to absorb the heat which in turn heats the liquid inside. The heated fluid is then stored in the storage tank which is very well insulated to prevent heat losses. Systems that use antifreeze solution or any other fluids other than water as the heat absorbing medium, in turn heat the water by passing on its heat to water flowing in a tubing coil through the tank of hot fluid (Kolb et al, 1993). This heated water can then be utilised for domestic and other purposes.

2.2.2 Wind Energy

The term “wind energy” or “wind power” is the process by which the Kinetic energy of the wind is converted to mechanical power or electricity. This mechanical power can further be utilised for various tasks like pumping water or can be converted to electricity by a generator to power homes,
businesses, schools, and many others. With the adoption of worldwide green policy in energy production, many countries have started to adopt RE practices where wind energy form one of the main tool. However, electricity production from wind power has various advantages and much more disadvantages than any other RE sources.

The advantages of wind energy are:

- Wind energy is a free, renewable resource, which can be used as much as is wished.
- Wind energy is also a source of clean, non-polluting, electricity. Unlike conventional power plants, wind plants emit no air pollutants or greenhouse gases.

Some drawbacks of using wind energy are:

- The rotor blades cause noise pollution
- Aesthetic impact
- Wind is intermittent and hence there can be shortage of electricity when needed.
- Good wind sites are often situated in isolated locations which are far from areas of high electric demand.
- There can be competition for land use between wind resources development and other uses such as agriculture (Grog, 2005).

### 2.2.3 Hydroelectric Power

Flowing water contain kinetic energy that can be captured and turned into electricity. This is called hydroelectric power. The most common type of hydroelectric power plant consists of a dam on a river to store water in a reservoir which is released from a height. This water is then directed through a turbine, rotating it, which in turn activates a generator to produce electricity. But some hydroelectric power plants also use only a small canal to direct the river water through a turbine.

A pumped storage plant is another type of hydroelectric power plant that stores power where a generator is used to spin the turbines backward, which thereafter pump water from a river or lower reservoir to an upper reservoir, where the power is stored. This stored power is then used by releasing the water from the stored upper reservoir back down into the river or lower reservoir to spin the turbines this time in a forward direction causing the generators to produce electricity (Graham, 1999).
2.2.4 Biofuels

Biofuels are products from biological origin that have been converted into liquid, solid and gas depending on the raw material and the technology employed for the energy generation. Liquid biofuels can be used for transport, heating, cooking, power generation and lighting. The most common forms of liquid biofuels are bio-ethanol, bio-diesel and pure plant oils.

Biofuels are considered to be carbon dioxide neutral as the carbon dioxide it releases in combustion is taken from the atmosphere by the plants used to produce the biofuels in the first place (barber et al, 2006).

In Mauritius, the transport sector represents 48.3% of final energy consumption (CSO, 2009). Undoubtedly, it is the largest source of fuel consumption. The mostly used fuels for transportation are gasoline (109.5 Ktoe) and diesel oil (154.4 Ktoe) (CSO, 2009). However, gasoline emits pollutants which are harmful to the environment and contribute to greenhouse effect. Switching from gasoline to bio-ethanol can prove to be a good initiative towards having a sustainable country. This project has already been conducted on a trial basis by the Alcodis Ltd in partnership with Total Mauritius Limited. Alcodis was the only firm producing ethanol from molasses in Mauritius. It initiated the E10 (10% Ethanol – 90 % gasoline) with Total (fuel station pump) which has proved to be a success. Surroop et al (2009) projected that using E10 as a biofuel in the transport sector will save about 80,755 tonnes of gasoline by the year 2017.

2.2.5 Geothermal Energy

Geothermal energy is generated from the Earth’s core. Geothermal power plants use steam produced from reservoirs of hot water found a couple of miles or more below the Earth’s surface. The steam is piped directly from underground wells to the power plant, where it is directed into a turbine/generator unit (William, 2010). The Philippines is currently the leader in the utilization of geothermal energy. Compared to fossil fuels, geothermal energy is a clean and renewable energy source which is available 24 hrs a day. It must also be noted that, the emissions associated to geothermal energy are relatively low.

Mauritius being of volcanic origin has the potential of tapping geothermal energy sources. According to Lrichter (2010), the Mauritius Research Council (MRC) is planning to drill exploration holes of about 3000 meters deep. It has also been pointed out that, a German company Honet Badger will invest together with a local company to produce electricity from geothermal energy. A representative of Honet Badger said that one geothermal station in Mauritius can produce about 5 MW of electricity.
2.2.6 Ocean Thermal Energy Conversion System (OTEC)

Mauritius is surrounded by sea and yet OTEC system has not been extensively deployed. OTEC uses the difference in temperature between deep and shallow waters to produce electrical energy. Earlier, OTEC system had an overall efficiency of about only 1 to 3% (the theoretical maximum efficiency lies between 6 – 7%). However, with extensive research, it has been found that OTEC will work efficiently at a temperature difference of just about 20 °C.

OTEC is a renewable, stable and abundant source of energy which can be exploited by both rich and poor countries. It can produce power 24 hours a day all year round. An analysis of temperature profiles carried out in Philippines revealed that surface seawater is in the range of 25 – 29°C throughout the year while seawater at 500 m to 700 m depth remains at a low temperature of 8 – 4 °C (Uehara et al, 2003).

2.2.7 Wave Energy

Wave power is the ocean surface wave’s energy which are transported and captured to produce useful work. Attempts to generate power from waves have been existent since the 1890; however, currently it is not a widely employed technology (Cruz, 2008).

The amount of power produced by wave energy is directly related to the average speed and height of the wave. The working principle consists of using this kinetic energy to spin a turbine. The waves rise into a chamber which forces air out. This in turn spins the turbine to finally produce electricity. Till now, no feasible study has been performed for wave energy in Mauritius. Being surrounded by the sea, Mauritius can certainly try to explore the means of generating electricity from wave energy.

2.2.8 Tidal Energy

Tidal power has the potential of converting the energy of the tides into electricity. This type of renewable energy is more predictable than solar and winds. The tidal turbines draw power from the kinetic energy of the water.

The foremost advantage of tidal energy is that it is free and renewable. No fuel is needed for the production of electricity and hence there is no emission of greenhouse gases. The main disadvantage is that the initial cost as well as the construction of tidal barriers is rather high.
3.0 ENERGY SECTOR OVERVIEW OF MAURITIUS

Mauritius is composed of many organizations which are responsible for energy management in the island. The Ministry of Renewable Energy and Public Utilities (MPU) is responsible for energy policy which includes the energy sector, water and wastewater management sector.

The Central Electricity Board (CEB) established in 1952, is responsible to "prepare and carry out development schemes with the general object of promoting, coordinating and improving the generation, transmission, distribution and sale of electricity" in Mauritius (Ministry of Renewable Energy and Public Utilities, 2009). The CEB has under its regime 4 thermal power stations and 8 hydroelectric plants that produce around 40% of the country's total power requirements. The remaining 60% is bought from Independent Power Producers who produce electricity from bagasse/coal.

Regarding the import of petroleum products (Mogas, gasoil, kerosene and fuel oil) the whole responsibility falls on the State Trading Corporation (STC).

3.1 Electricity Production In Mauritius

In Mauritius, the majority of the fuel imported is used for electricity production. The rest is shared among the transport, domestic, manufacturing, commercial and tourism sectors.

From the Central Electricity Board (CEB) Annual Report (2009), the total electricity generated was 2557 GWh in 2009 and the electricity consumption was 2054 GWh. Around 36.8 % of electricity are produced by CEB generating facilities and the remaining 63.2 % by the Independent Power Producers (IPP) of the sugar industry that burn bagasse and/or coal. This is shown in table below:

<table>
<thead>
<tr>
<th></th>
<th>GWh</th>
<th>% of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>CEB</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thermal Diesel/Gas Turbine</td>
<td>888.40</td>
<td>40.4</td>
</tr>
<tr>
<td>Hydro</td>
<td>83.86</td>
<td>3.8</td>
</tr>
<tr>
<td>IPP</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FUEL-CEL-CTBV</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bagasse/coal</td>
<td>1182.65</td>
<td>53.8</td>
</tr>
<tr>
<td>Other Sugar Estates, Bagasse/Hydro</td>
<td>44.01</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>2198.92</td>
<td>100</td>
</tr>
</tbody>
</table>

Table 1: Energy Generation in Mauritius for the year 2009(Source: CEB, 2009)

The combined bagasse / coal steam power station produced a total of 1182.65 GWh in 2009 of which 447.52 GWh came from burning of bagasse and the remaining 735.13 GWh from burning of coal (CEB, 2009).

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As it can be seen, electricity production in Mauritius is undertaken by the CEB and IPP. The CEB generating facilities consists of:

- Hydropower stations and
- Diesel power plants

The detailed % contribution of electricity generation by the different hydro and diesel power plants owned by the CEB can be summarized in the doughnut diagram:

![Doughnut diagram showing the percentage contribution of electricity generation by the CEB](image)

**Figure 1: Percentage contribution in electricity generation by the CEB**

### 3.1.1 Hydropower Stations In Mauritius

There are 8 hydropower stations in Mauritius namely, Champagne, Tamarin, Magenta, Le Val, Ferney, Réduit, Cascade Cécile and La Ferme, all owned by the CEB. The total hydro production has an installed capacity of 59 MW (Ministry of Renewable Energy and Public Utilities, 2009) which can vary slightly over the years depending on the amount of rainfall available. These hydro facilities are situated mainly in the catchments areas of the southern hilly regions.

### 3.1.2 Diesel Power Stations In Mauritius

Most of the CEB’s generating thermal facilities is based around the port where on-shore fuel handling facilities are available. The CEB has 4 thermal power stations as follows:

- Fort George with energy generation of 574.0 GWh
- St Louis with energy generation of 145.9 GWh
- Fort Victoria with energy generation of 101.3 GWh
- Nicolay with energy generation of 45.7 GWh

These values are for the year of 2009 (CEB, 2009).
3.1.3 Independent Power Producers (IPP)

In Mauritius, the participation of the private sector in the energy area is very much appreciated. These are mainly sugar estates which are present almost evenly all around the island and major power plants that are located in the northern and the north-eastern region of the island.

The IPP consists both of firm and continuous power plants. The firm power plants generate electricity all year round with either bagasse/coal or coal only, while the continuous power plants produce electricity with bagasse only during crop seasons. The four firm power producers are namely,

- Central Thermique de Belle Vue (CTBV)
- Central Thermique de Savannah (CTSav)
- FUEL Steam and Power Generation Co. Ltd and
- Consolidated Energy Ltd (CEL)

In 2009, all the four firms produced a total of 860 GWh of electricity. The individual firms produced 254 GWh, 226 GWh, 152 GWh and 101 GWh of electricity respectively. The remaining 127 GWh were generated by the continuous power stations owned by the IPPs (CEB, 2009).

3.2 Energy in Mauritius

Mauritius is deeply dependent on imported conventional fuels as it has no identified oil, natural gas or coal reserves. Table 2 shows the different % of energy forms that is imported every year.

<table>
<thead>
<tr>
<th>ENERGY SOURCES</th>
<th>2009</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Energy unit (Ktoe)</td>
</tr>
<tr>
<td>Gasoline</td>
<td>117.19</td>
</tr>
<tr>
<td>Diesel oil</td>
<td>331.74</td>
</tr>
<tr>
<td>Kerosene</td>
<td>6.15</td>
</tr>
<tr>
<td>Aviation fuel</td>
<td>272.69</td>
</tr>
<tr>
<td>Fuel oil</td>
<td>279.40</td>
</tr>
<tr>
<td>LGP</td>
<td>68.16</td>
</tr>
<tr>
<td>Sub Total (Petroleum product)</td>
<td>1,075.33</td>
</tr>
<tr>
<td>Coal</td>
<td>376.05</td>
</tr>
<tr>
<td>Total</td>
<td>1,451.38</td>
</tr>
</tbody>
</table>

Table 2: Imports of Energy sources for 2009 (Source – CEB, 2009)

Moreover, the local renewable energy resources used in Mauritius are solar (mainly solar water heaters), hydro and biomass in form of bagasse (by-product of sugar cane processing) and to some extent wind. In 2009, the total energy production from local renewable sources stood at 3070 GWh being an increase of 7.3 % from the previous year. This was due to a higher production of bagasse which produced more electricity (Ministry of renewable energy & public utilities, 2009).
3.3 Primary Energy Requirement In Mauritius

The total primary energy requirement of Mauritius is around 16, 328 GWh per year. In 2010, the non renewable fuels imported (petroleum products and coal) accounted for 81.2% of the energy demand. The remaining 18.8% were supplied by locally available renewable resources. In Mauritius, the petroleum products are normally imported in the following percentages; fuel oil (28.9%), diesel (27.8%), aviation fuel (18.5%) and gasoline (14.8%). The local renewable energy supply comes from bagasse (93.2%), hydro electricity (3.5%), fuel wood (2.9%) and wind energy (0.4%) (Ministry of renewable energy & public utilities, 2009).

3.4 Non-Renewable Energy In Mauritius

The different non-renewable energy sources used in Mauritius are:

- Oil (including gasoline, diesel oil, dual purpose kerosene and fuel oil)
- Liquefied Petroleum Gas (LPG)
- Coal

3.4.1 Gasoline

Also called motor-spirit or petrol, gasoline is mostly used in the light transportation industry, which comprises of automobiles, motorcycles, auto cycles and certain category of light trucks and vans in Mauritius. It is also used as solvents to dilute paints and other products.

3.4.2 Diesel Oil

Diesel oil is also known as gas oil and it is supplied to the heavy transport that consists mostly of buses and trucks utilized for transportation of goods and sugar cane. It is also used in the light transportation of goods, public cars (taxis) and vans. Diesel oil is also supplied to the CEB and industrial sector for energy production (Rohomon, 1998).

3.4.3 Dual Purpose Kerosene (DPK)

DPK is also called “petrol lampant” is used mainly by the CEB for electricity generation. DPK can also be used as cooking fuel, in lamps and stoves. It is also used as solvents in weed killers and insecticides in Mauritius.
3.4.4 Fuel Oil

Fuel oil (or heavy oil) is mainly supplied to the CEB to produce electricity. It is also widely used in the manufacturing sector mainly in textile industries to heat boilers.

3.4.5 Liquefied Petroleum Gas (LPG)

LPG is distributed in pressurized gas cylinders and is mostly used for cooking in the residential sector and commercial sector, i.e., restaurants and hotels. In Mauritius it is usually supplied in cylinders of varying weight. Moreover, LPG is also used in some motor vehicles in Mauritius which are equipped with cylinders.

3.4.6 Coal

Coal is mostly used for raising steam in the sugar sector for generation of electricity during inter-crop season and also in the manufacturing sector. During crop seasons, coal is used together with bagasse for the co-generation of electricity by Independent power producers. When there is no bagasse available, the IPPs burn 100% coal to produce electricity.

3.5 Renewable Energy Practices In Mauritius

The driving force behind the application of renewable energy technologies in Mauritius has been the obligation to clean up the energy sector in terms of its environmental impact and reduce dependence on finite energy resources. Mauritius has extensive potential to utilize many renewable energy options. Most of these would require very high initial capital investments, with benefits accumulating in the long-term, both environmentally and economically. The most common practices of RE in Mauritius are the solar, Wind, Biomass (bagasse) and Hydro.

3.5.1 Solar Energy

Mauritius receives between 8 and 10 hours of sunshine daily and the average annual solar radiation is 6 kWh/m². To promote the development of solar energy, the Government issued tenders for the supply and installation of 125 units of photovoltaic systems for street lighting and lighting of Government offices as a pilot project in early 1998.

However, this form of energy is not sufficiently tapped, though the potential is very high. But, one of the means actually used to take advantage of this source of energy is through the use of solar water heaters. Due to the abundance of the solar energy resource in Mauritius, some 35,000 solar water-heating units have been installed all over Mauritius, which represents an 8% penetration of the household market. Solar water heating is the most common form of solar energy conversion, used in Mauritius.
With the setting up of the MID Fund in July 2008, the solar water heater loan scheme controlled by the Development Bank of Mauritius has been increased to Rs 10,000 so as to double the number of solar water for domestic use by end 2011. The outcome of this new scheme has been above expectations with some 49 thousand applications received by the Bank. Based on the constructive experience, the Government is now planning another scheme to encourage wider use of solar energy in terms of photovoltaic in household and other sectors of the economy.

The Government of Mauritius has also anticipated the production of 300 kW of electricity via solar photovoltaic to displace the diesel fuelled Mauritian generation. To lessen the impacts from new road and power line construction, the project will be constructed near the existing diesel generation plant. This project is expected to reduce greenhouse gas emissions by 470 metric tonnes per year. It is also projected to reduce around 16,000 metric tonnes of CO₂ over a period of 35-year which is expected to be the life-time of the project.

Moreover, the Government of Mauritius and the Central Electricity Board, with the help of the UNDP have set out a grid code which has been designed for small-scale distributed generators in order to allow the integration of small-scale renewable energies in the power system of Mauritius mainly through the use of photovoltaic panels and wind turbines.

### 3.5.2 Wind Energy

From the year 1987 to 1990, wind energy was being produced from wind turbines at Grand Bassin. The plant capacity was 0.1 MW and the average annual electricity production was 0.16 GWh. However, the wind turbines were damaged by cyclones.

The wind potential in Mauritius and Rodrigues (forming part of Mauritius) are very good in some areas since they are most of the time exposed to the South East Trade Winds which are, therefore, favourable for wind energy development. In the 1980s, experts from the UNDP carried out a Wind Energy Resource Assessment Study in Mauritius. The study confirmed that there are potential sites on the two islands for the setting up of wind farms, with some areas having an annual average speed of 8.0 m/s at heights 30 m above ground level (Palanichamy, 2004). With the technological advancements in the design of turbines, the Government intends to support the setting up of more wind farms in different regions of the country (Ministry of Renewable Energy and Public Utilities, 2009).

Wind Farm implementation on a pilot projects in Rodrigues have already been a great success with a plant load factor above 30%. The wind farm at Trefles consists of three wind turbines of 60 kW each. There are two additional units of 275 kW each, which has also been set up at Grenade in 2010 which contribute to around 10% of the total electricity consumption in Rodrigues. Mauritius and Rodrigues being of tropical origin are prone to cyclones. Therefore, the wind turbines are of tilted type that can be protected during cyclonic periods.

In the current years, the interests in wind energy have gained impetus in Mauritius, and wind turbine manufacturers from India are also enthusiastic to invest in such practices. In line with this strategy
for wind energy development, a wind farm of 25-40 MW will be set-up at Curepipe Point (Bigara) on a BOO scheme and will be operational by end 2012. Besides the project, two private sector operators have expressed interest to set up wind farms at Plaines des Roches and Britannia with a minimum of 10 MW installed capacity.

3.5.3 Biomass Energy

Biomass energy in Mauritius consists mainly of bagasse, wood and charcoal. Bagasse is the fibrous residue of the cane stalk after crushing and extraction of juice (Patura, 1989). Bagasse is the most plentiful primary energy resource representing about 15% of the country’s primary energy supply (Ministry of Renewable Energy and Public Utilities, 2009).

In 2009, the amount of bagasse produced was 1.67 million tons (MSIRI, 2009). Bagasse is almost entirely used by the sugar industry to meet all their energy requirements in terms of heat and electricity generation. In addition, surplus power from bagasse is fed into the national grid and this currently represents about 15% of the CEB’s total annual generation. There is still potential to increase this contribution through rehabilitation/centralization program of sugar industries (Ministry of Public Utilities, 2009).

Mauritius currently has an installed capacity of 50 MW of biomass energy. It is the only island in the Indian Ocean where sugar mills sell energy on a large scale to the electricity grid. The private sector participation is very active, and the market expansion potential for this technology is very strong. As regards to fuel wood and charcoal, their use for cooking is not as significant as LPG.

3.5.3.1 Energy from sugar industries (bagasse as biomass)

Mauritius has made noteworthy investments in highly developed bagasse cogeneration systems. However this technology has the following obstructions for further expansion:

- Sugar production has already reached both its physical and technological limits.
- No more land is available for more sugar-cane plantation
- There is a call for improvement of the Combined Heat and Power (CHP) systems of the local cane sugar factories to generate more electricity from bagasse.
- The power plants run on bagasse only during the six to seven month of the harvest season, and run on coal for the remainder of the year. Due to this, power plants still depend on fossil fuel.
- Proper bagasse storage is required for continued power plant operations.
- Mauritius is often affected by cyclones and heavy winds that affect the sugar cane production, which thereafter influence the energy production.
- In Mauritius, the pricing and institutional limitations continue to hinder the generation and sale of electricity from the sugar industry.
- Because of the saturated cultivation of sugar cane, financial loan facilities are becoming more and more difficult, and;
• Though the energy production from bagasse is environmentally friendly, the burning of sugar cane fields before harvest and use of artificial fertilizers can result in environmental degradation in future.

3.5.4 Hydropower

A large number of small hydro systems were installed in the 1970's to supply power to remote mines, towns and industries in Mauritius. Nowadays, hydropower potential has been almost tapped in Mauritius and there are competitive uses of the existing water resources. There are eight hydropower plants with a combined installed capacity of 59 MW. The total installed capacity can be exploited only during wet periods with heavy rainfall. The Champagne, Tamarind, Magenta, and Le Val power stations are run with dam storage facilities while the remaining stations at Ferney, Réduit, Cascade Cécile, and La Ferme are of run-of-river type. The amount of energy that can be generated from each hydro power station depends on the rainfall amount over the year. It can generate a minimum of 5 GWh in the driest month to an average of 20 GWh in the wet season. A total of around 100 GWh per year can be generated from the eight hydro power plants (Ministry of Public Utilities, 2009).

As a consequence, due to seasonal rain conditions and limited storage capacity, only two of the hydro plants can generate electricity throughout the year during peak hours whereas the other six generate electricity as and when water is available, mostly during the period of January to March (Ministry of Public Utilities, 2009).

Thus, the Government has planned to commission a 375 kW micro hydro power plant on La Nicolière Feeder Canal by end of 2011. This plant will generate around 2 GWh/year of electricity. Other potentials sites, such as the Midlands dam will also be constructed. Thus, by 2025, the energy consumption in Mauritius is expected to increase by nearly four times from the current level (Ministry of Public Utilities, 2009).

3.5.5 Future plans for other renewable energies in Mauritius

3.5.5.1 Waste-to-Energy Strategy

The Waste-to-energy strategy normally forms part of the solid waste management strategy. In 2005, the Government together with expertise from abroad conducted a feasibility study for a waste-to-energy system. They came up with a designed of a solid waste management policy to reduce the pressure on the sole landfill at Mare Chicoose.

The strategy consists of incinerating waste to produce electricity from the heat of the process. The electricity produced will be supplied to the national grid competitive rates in order not to affect the financial sustainability of the CEB.
It is planned to implement a 20MW Waste-to-Energy plant at La Chaumiere, in the West of the island on a BOO scheme. However, it has been noted that electricity production from waste are usually very cost intensive which include environmental costs. But the Government has agreed to support financially the protection of the environment through the incineration and recycling of waste via the MID Fund.

Moreover, at the existing landfill at Mare Chicose, a 3 MW Gas-to-Energy will be installed that will generate around 20 GWh of electricity annually.

**3.5.5.2 Geothermal energy technology**

Mauritius being of volcanic origin has a huge potential of inborn geothermal sites. However, exploration costs are very expensive as deep drilling is necessary to reach the thermal source. The strategy is to allow private operators to take the exploratory risks. Moreover, geothermal energy technology is site dependent and land consuming. As a consequence, the Government’s strategy is to provide incentives to private sectors and external bodies to explore this potential in Mauritius.

**3.5.5.3 Ocean Thermal Energy Conversion (OTEC) technology**

Ocean Thermal Energy Conversion (OTEC) technology in Mauritius is still under study and has not up till now been commercialised. The Government’s plan on this energy resource is to base itself on studies and implementation done by other countries in the medium to long term.

**3.5.5.3 Other technologies**

The Government has also in plan for the future to encourage technology transfer through special programs under funds from Global Environmental Facility and from joint and multi-lateral cooperation organizations. Hydrogen-based electricity, gasification and fuel cells technologies could also be explored on a pilot basis.

One of the innovative projects set by the NGO, Land Based Oceanic Industry, together with the private sector operators is the exploitation of deep sea water to be used for air conditioning of green data centre buildings at Flic-en-Flac near the sea.
3.6 Targets for Renewable Energy over period 2010-2025

On the basis of the Long term Energy Strategic plan set by the Government and the Ministry of RE and Public Utilities, a target in terms of percentage of total electricity generation from renewable and non-renewable sources of energy over the period 2010 – 2025 has been set up as shown in Table 3 below.

<table>
<thead>
<tr>
<th>Fuel Source</th>
<th>Percentage of Total Electricity Generation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2010</td>
</tr>
<tr>
<td>Renewable</td>
<td></td>
</tr>
<tr>
<td>Bagasse</td>
<td>16 %</td>
</tr>
<tr>
<td>Hydro</td>
<td>4 %</td>
</tr>
<tr>
<td>Waste to Energy</td>
<td>0</td>
</tr>
<tr>
<td>Wind</td>
<td>0</td>
</tr>
<tr>
<td>Solar PV</td>
<td>0</td>
</tr>
<tr>
<td>Geothermal</td>
<td>0</td>
</tr>
<tr>
<td>Sub-Total</td>
<td>20 %</td>
</tr>
<tr>
<td>Non-Renewable</td>
<td></td>
</tr>
<tr>
<td>Fuel Oil</td>
<td>37 %</td>
</tr>
<tr>
<td>Coal</td>
<td>43 %</td>
</tr>
<tr>
<td>Sub-Total</td>
<td>80 %</td>
</tr>
<tr>
<td>Total</td>
<td>100 %</td>
</tr>
</tbody>
</table>

Table 3: Forecast of energy mix over the period 2010 – 2025

Assumptions

It must be noted that these predictions have been possible by taking certain assumptions. The assumptions are that

- Coal and waste energy projects approved by Government would be operational by 2013
- New and more reasonably priced PV technology would be available.

However, there can be some changes in the prediction depending on the progress in RE acceptance and development in technology, outcomes from local energy resource and affordability.
4.0 METHODOLOGY

This section presents the methodology adopted in this study to carry out the survey. The purpose is to show in details the process for designing the questionnaire that was used for the research work. It discusses the details of the research, including the problem formulation, research design, sample design and size. This research tries to find out the extent to which private and public sectors have implemented or are ready to invest on renewable energy technologies in Mauritius. To measure the effectiveness, both quantitative and qualitative data have been used.

The study aims primarily to have an insight on how well the renewable energy technologies are being implemented till date in Mauritius and what are the views of stakeholders to implement these technologies in the future. For the purpose of this project, the primary concern of the population size was based on those involved in the renewable energy sectors. As a result, a random selection process was used to build a survey population (i.e. the people who will participate in the survey). All organizations and Institutions throughout Mauritius which are in some ways or the other involved in renewable energy were identified. Through a preliminary screening, the most appropriate companies and institutions were selected. In this respect, 45 organizations and institutions were targeted for this study, which included namely, the Universities, research institutions, ministries, utility companies, private companies involve in renewable energy technologies and NGOs among others.

Data was collected using the Questionnaire based survey approach over a period of two months. Questionnaires were sent to the targeted groups by post, electronic mails, faxes and some were also delivered in person. The informal personal interview that is face-to-face approach was also used to some of the target groups due to the nature and content of the questionnaire. Prior meeting was arranged with the directors, managers and employees via the phone and emails one week before. Each face-to-face interview lasted for approximately 15 minutes. The face-to-face method provided an opportunity to probing (i.e. asking for addition information) if the answers given by the respondents were incomplete or ambiguous. Furthermore, it provides rich and descriptive data. Some filled questionnaires were returned by post while others forwarded by emails. Observations was also carried out at the meteorological stations for a period of 3 months to observe the trends in solar and wind speed to have gain in-depth understanding of the weather trends in Mauritius.

The returned questionnaires were scanned individually immediately after the respondents had answered the questionnaire. All filled up questionnaires were considered usable as they were appropriately completed. Since the survey aimed at obtaining much quantitative data, tables and figures were used to present the information obtained in an understandable manner and their significance appreciated.

Moreover, this research also tries to perform an economic analysis of the most appropriate renewable energy technologies identified from the survey.
4.1 Problem Formulation

This study aims primarily to have an insight on how well the renewable energy technologies are being implemented till date in Mauritius and what are the views in the coming future. Additionally the study has the following objectives:

- Conduct a feasibility study to analyze the Mauritian energy scenario.
- Determine awareness of Renewable energy in Mauritian Organizations and institutions.
- Conduct meetings with stakeholders, Government and Tertiary Institutions to be in-line with their vision.
- Determine willingness of respondents to accept renewable energy.
- Identify the most appropriate renewable energy technology for fruitful investment for stakeholders in Mauritius.
- Perform a cost analysis on the main renewable energy technology identified.

4.2 Research Design

According to Kinnear et al (1991), research design can be considered as the plan for the study at hand, and is used as a guide for collecting and analyzing data. Research design frameworks are classified in terms of the fundamental objective of the research:

- Explanatory
- Descriptive
- Causal

4.2.1 Explanatory Research

Explanatory research, according to Burns and Blush (2003), is used to “gain background information, to define terms, to classify problems and to establish research priorities”.

Exploratory Research was conducted among some employees at Top Management level of the renewable energy sectors in Mauritius. Their views and ideas about renewable energy technologies were taken into consideration in the formulation of the objectives and in designing the questions. Some general questions were asked to these persons and they can be summarized as follows:

1. How far is your company ready to invest in renewable energy technologies?
2. Are your staffs sufficiently trained or do they need further training?
3. Which renewable energy technology will you opt for if you were to choose one to be implemented in your company?
4.2.2 Descriptive Research

Following the literature search and exploratory research, the descriptive research approach was adopted. Two questionnaires were designed (Please refer to Appendix 2 and 3) to collect primary data;

(1) Business and other organization (appendix 2) and
(2) Universities and other Tertiary Institutions (appendix 3).

4.3 Sources of Data

Data can be classified into the following categories:

- **Primary Data**
  - Data obtained on the internet, in books, magazines and dissertations.
- **Secondary Data**
  - This comprises of people’s response, that is, data collected in the survey.
- **Tertiary (Indexes, Online database)**

For the purpose of this study, all the three types of data sources were utilised.

4.4 Questionnaire design

Based on an extensive literature search, two questionnaires (Appendix 2 & 3) were designed to investigate the objectives initially set out. Taking into consideration the literature review, together with the exploratory research findings, questions were formulated to gather specific data on RE and their use for further analysis. The questionnaires consisted of fixed, open-ended and a combination of fixed and open-ended questions in order to get a wide range of response. In designing the questionnaires, the following criteria were taken into considerations:

- Survey was kept short and simple
- No combination of two questions in one
- Avoiding unnecessary jargons and abbreviations
- Un-use of biased questions
- Including ‘don’t know’ or ‘not applicable’ options
- Being specific and right to the point in the questions
- Allowing participants to make other comments at the end of the questionnaire
- Ensuring the layout is simple and clear
- Ordering of questions
- Including initial information about who the researcher is and what exactly the researcher intends to do with the findings.

The flow of the questionnaire was such that it moves the respondents smoothly through the questions.
4.5 Sampling

Sampling is a process of selecting participants for a piece of research. It is the means by which we obtain a sample or a survey population. Sampling is therefore a sub-set of the population selected for inclusion in the research. The principle objective in sampling is to obtain a representative selection of the sampling units within the population.

For this study, simple random sampling was used. The subject in this study consisted of targeting the various stakeholders, public as well as private sectors and tertiary Institutions which are already involved in renewable energy technologies to be in line with their vision. The major advantage of this type of sampling was its convenience, reliability and generalization.

4.6 Sample population

A population may be defined as including all people or items with the characteristic one wish to understand. Because there is very rarely enough time or money to gather information from everyone or everything in a population, the goal becomes finding a representative sample (or subset) of that population. It is important to have the right choice of the group for the element of sample so as to make it representative of our population. Depending upon the objective of the data, a target group is identified.

For the purpose of this project, the primary concern of the population was based on those involved in the renewable energy sectors. As a result, a random selection process was used to build a survey population (i.e. the people who will participate in the survey). All organizations and Institutions throughout Mauritius which are in some ways or the other involved in renewable energy were identified from the phone book. Through a preliminary screening, the most appropriate companies and institutions were selected. In this respect, 45 organizations and institutions were targeted for this study which included namely, the Universities, Institutions, Ministries of Environment, renewable energy and public utilities, Ministry of Education, Maurice Ile Durable (MID) fund, Mauritius Institute of Training and Development (MITD), Central Electricity board (CEB), Central Water Authority (CWA), Waste Water Management Authority (WMA), Energy Services Division (ESD), Land Base Oceanic Industry (LBOI), Non-Governmental Organizations (NGOs), Independent Power Producers (IPPs), British American Investment (BAI) energy sector, solar water heaters companies and companies involved in importing renewable energy technology equipments like photovoltaic panels, wind turbines etc.

4.7 Sample Unit

The sampling units consisted of all the 45 organization and institutions but only those managers, directors and employees who deal with renewable energy and environmental issues in their day-to-day operation were targeted. In this respect, of all the 45 organization and institutions an average of 2 employees were involved in the environmental and energy sector.
4.8 Sample size

This deals with the number of people to be surveyed. Large samples provide reliable results than smaller samples. However, it is not necessary to sample the entire target population or even a substantial portion to achieve reliable results. Nevertheless, samples can often provide good reliability given the sample is representative of the population. For this study, a total of 90 managers, directors and employees were targeted.

4.9 Research Tools

Basically, four devises were used to collect data, namely:

- Questionnaires for Universities and tertiary institutions
- Questionnaires for Business and other Organizations
- Observation
- Informal Interview
- Formal Interviews on site
- Going in person to help fill questionnaires
- Phone calls to help in filling of questionnaires
- Electronic mails through which queries were solved

4.10 Data collection method for original data

To collect original data among Top Management level and employees, of the various organizations and Institutions, the Questionnaire survey approach was used. Data was collected for a period of two months. Questionnaires were sent to the targeted groups by post, electronic mails, faxes and some were also delivered in person. The major advantages of a questionnaire are that it is relatively quick to collect information, they are easy to analyze and are familiar to most people. Nearly everyone has had some experience completing questionnaires and they generally do not make people apprehensive and they are very cost effective when compared to face-to-face interviews.

The informal Personal Interview approach was also chosen because of the nature and content of the questionnaire. Each face-to-face interview lasted for approximately 15 minutes. According to Fraenkel and Wallen (1993), the careful asking of relevant questions is an important way for a researcher to check the accuracy of, to verify or refute, the impressions he/ she has gained from observation. Fetterman describes interviewing as the most important data collection technique. In addition, the researcher believed that this approach would lead to a higher response rate. The face-to-face method provided an opportunity to probing (i.e. asking for additional information) if the answers given by the respondents were incomplete or ambiguous. Furthermore, it provides rich and descriptive data.
Observations was also carried out at the meteorological stations for a period of 3 months to observe the trends in solar and wind speed to have gain in-depth understanding of the weather trends in Mauritius.

### 4.11 Collection of filled forms

The questionnaire was administered using an interview approach, whereby respondents were physically met and questionnaires were filled in the presence of the researcher. Prior meeting was arranged with the directors, managers and employees via the phone and emails one week before. Some filled questionnaires were returned by post while others forwarded by emails.

### 4.12 Processing and Analyzing Data

The returned questionnaires were scanned individually immediately after the respondents had answered the questionnaire. All filled up questionnaires were considered usable as they were appropriately completed. Since the survey aimed at obtaining much quantitative data, tables, graphs and figures were used to present the information obtained in an understandable manner and their significance appreciated.

### 4.13 Preparing the Report

Writing up the report is the last step of a project work. Accuracy and clarity were the main criteria that were used to communicate the results obtained.

Problems encountered during the survey

- The survey is subject to the truthfulness of the respondents.
- The sample size is limited to only 45 companies which might not be representative of Mauritius as some companies are situated in nearby locations.

### 4.14 Triangulation

Triangulation is the cross-checking of data using multiple data sources or multiple data collection sources. Triangulation is often used to show that more than two methods are used in a particular study. The idea behind is to double check if the same result is obtained via both methods. It can be utilized in both quantitative (validation) and qualitative (inquiry) studies. In this study, a variety of data like published papers and other reports related to renewable energy were used to enhance the validity of the research.
4.15 Research Ethics

In any research, ethics have to be considered to keep the confidentiality of any company, institution or organization. The following ethics were considered

- The researcher orally got the permission from the University of Mauritius (Dean and Supervisor) to carry out the questionnaire based approach.
- For ethical reason the anonymity of the Institutions, organizations and companies were guaranteed in the report and questionnaire by including the option phrase “I do not wish to disclose the name of my company/Institution/Organization”
- The investigator also sought verbally the approval of the directors and managers of the targeted groups to conduct interviews for the study.

4.15 Costing of Photovoltaic

As per the objectives set in this study, the economic evaluation of the most appropriate renewable energy technology to be obtained by the survey was to be conducted. From the survey, it was found that the solar photovoltaic outstood all the other RE technologies. Thus, the costing analysis was carried out using the following table and equations:

<table>
<thead>
<tr>
<th>Unit (KW/hr)</th>
<th>Price (R)</th>
<th>Price (Euro)</th>
</tr>
</thead>
<tbody>
<tr>
<td>First 25</td>
<td>2.87</td>
<td>0.07</td>
</tr>
<tr>
<td>Next 25</td>
<td>3.98</td>
<td>0.1</td>
</tr>
<tr>
<td>Next 25</td>
<td>4.31</td>
<td>0.11</td>
</tr>
<tr>
<td>Next 25</td>
<td>4.95</td>
<td>0.12</td>
</tr>
<tr>
<td>Next 100</td>
<td>5.59</td>
<td>0.14</td>
</tr>
<tr>
<td>Next 50</td>
<td>6.38</td>
<td>0.16</td>
</tr>
<tr>
<td>Next 50</td>
<td>7.18</td>
<td>0.18</td>
</tr>
<tr>
<td>Remaining</td>
<td>7.97</td>
<td>0.2</td>
</tr>
</tbody>
</table>

**Price of Units of Electricity in Mauritius**

**Parameters:**

1 Unit = 1 KW/hr

Let S be the Amount of Units produced per year from Renewable Resources in KW/hr

Please note that all the cost is in Mauritian Rupees (£). This can be converted to euro with the following conversion (1 euro = £ 40)
Calculations for the Amount of money saved per year:

If S is < or = 25 Units
Amount = (S*R 2.87)

If S is > 25 Units but < or = 50 Units
Amount = (25*R 2.87) + (S -25)*R 3.98

If S is > 50 Units but < or = 75 Units
Amount = (25*R 2.87) + (25*R 3.98) + (S -50)*R 4.31

If S is > 75 Units but < or = 100 Units
Amount = (25*R 2.87) + (25*R 3.98) + (25*R 4.31) + (S -75)*R 4.95

If S is > 100 Units but < or = 200 Units
Amount = (25*R 2.87) + (25*R 3.98) + (25*R 4.31) + (25*R 4.95) + (S -100)*R 5.59

If S is > 200 Units but < or = 250 Units
Amount = (25*R 2.87) + (25*R 3.98) + (25*R 4.31) + (25*R 4.95) + (100*R 5.59) + (S -200)*R 6.38

If S is > 250 Units but < or = 300 Units
Amount = (25*R2.87)+(25*R3.98)+(25*R4.31)+(25*R4.95)+(100*R5.59)+(50*R6.38)+(S-250)*R7.18

If S is > 300 Units

Calculation for Payback Period:

Payback Period = Total Initial investment / Total S for first year
5.0 RESULTS AND DISCUSSIONS

All the results obtained during the course of the project work and surveys are presented in this section in the form of graphs, tables, bar charts and pie charts. The survey forms are annexed in the appendix A1 and A2. An interpretation and discussion of the results obtained are also outlined in this chapter.

5.1 Presentation of findings

The survey carried out is divided into the following parts:

Part 1: About the Organizations
Part 2: Research and innovation need of the organizations
Part 3: Staff training needs of the organizations

Each part will have a number of questions set and the question will be presented individually in the following format:

1. Reasons for including questions
2. Analysis of responses
3. Interpretation of responses

5.2 Part 1: Renewable Energy Capacity building needs of Business and Organizations

5.2.1 Question 1.1 - About the Business and Organizations

The idea behind this question was to know from which branch respondents came from. It was found that the majority (55 %) came from the governmental section. Out of the remaining 45 %, 25 % came from Non - Governmental organization and the rest from private sectors.

5.2.2 Question 1.2 - Number of employees

The objective of this question was to determine the number of staffs involved in the renewable energy sectors in various organizations. The analysis gave the following results:
<table>
<thead>
<tr>
<th>Business and Organizations</th>
<th>Total no. of employees in Organization</th>
<th>Number. of employees in Renewable Energy Area</th>
<th>Percentage (%) of employees in Renewable Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wastewater Mgt Authority(WMA)</td>
<td>150</td>
<td>5</td>
<td>3.3</td>
</tr>
<tr>
<td>Environment Protection Org</td>
<td>4</td>
<td>4</td>
<td>100</td>
</tr>
<tr>
<td>Le Cercle D'Epaisonnement Feminin</td>
<td>2</td>
<td>2</td>
<td>100</td>
</tr>
<tr>
<td>Mauritas</td>
<td>7</td>
<td>3</td>
<td>42.9</td>
</tr>
<tr>
<td>Ecofuel Limited</td>
<td>70</td>
<td>7</td>
<td>10</td>
</tr>
<tr>
<td>Sotratech Limited</td>
<td>64</td>
<td>12</td>
<td>18.8</td>
</tr>
<tr>
<td>Ministry of Renewable Energy</td>
<td>50</td>
<td>30</td>
<td>60</td>
</tr>
<tr>
<td>Aquaflo Limited</td>
<td>14</td>
<td>5</td>
<td>35.7</td>
</tr>
<tr>
<td>Energy Services Division</td>
<td>241</td>
<td>21</td>
<td>8.7</td>
</tr>
<tr>
<td>Falcon Citizen League</td>
<td>11</td>
<td>4</td>
<td>36.4</td>
</tr>
<tr>
<td>Maurice Ile Durable Fund</td>
<td>4</td>
<td>2</td>
<td>50</td>
</tr>
<tr>
<td>Ministry of Env &amp; Sustainable Devpt</td>
<td>35</td>
<td>20</td>
<td>57.1</td>
</tr>
<tr>
<td>Central Water Authority (CWA)</td>
<td>1541</td>
<td>13</td>
<td>0.8</td>
</tr>
<tr>
<td>Central Electricity Board (CEB)</td>
<td>1897</td>
<td>80</td>
<td>4.2</td>
</tr>
<tr>
<td>Ministry of Energy &amp; Public Utilities</td>
<td>50</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>Green zone Limited</td>
<td>10</td>
<td>6</td>
<td>60</td>
</tr>
<tr>
<td>Megasun</td>
<td>14</td>
<td>8</td>
<td>57.1</td>
</tr>
<tr>
<td>Solartech Company Limited</td>
<td>9</td>
<td>4</td>
<td>44.4</td>
</tr>
<tr>
<td>Extreme solar</td>
<td>12</td>
<td>8</td>
<td>66.7</td>
</tr>
<tr>
<td>British American Investment (BAI)</td>
<td>8</td>
<td>6</td>
<td>75</td>
</tr>
<tr>
<td>OMNICANE</td>
<td>489</td>
<td>137</td>
<td>28</td>
</tr>
<tr>
<td>Environment Care Association</td>
<td>7</td>
<td>4</td>
<td>57.1</td>
</tr>
<tr>
<td>MAUDESCO</td>
<td>16</td>
<td>8</td>
<td>50</td>
</tr>
<tr>
<td>Land Based Oceanic Industry (LBOI)</td>
<td>34</td>
<td>18</td>
<td>52.9</td>
</tr>
<tr>
<td>Green Sun</td>
<td>11</td>
<td>5</td>
<td>45.5</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>4866</strong></td>
<td><strong>388</strong></td>
<td></td>
</tr>
</tbody>
</table>

Table 4: Percentage staff involved in renewable energy sector

From the table above it can be noted that the majority of the organization have more than 30 % of employees related to the renewable energy fields. Moreover, the NGOs Environment Protection & Conservation Organization and Le Cercle D’Epaisonnement Feminin have 100 % of its staff involved in renewable energies which implies that these organizations have been set up to work exclusively towards renewable energies.
5.2.3 Question 1.3 – Interest in renewable energy sectors

The types of Renewable energies organizations in Mauritius are interested in or they have already implemented are expressed in terms of percentage through the following bar chart.

![Percentage Interest of Organization/stakeholders in RE](chart)

**Figure 2**: Types of renewable energy organizations in Mauritius are interested in

It can be deduced from the above chart that most organization are very much interested in Photovoltaic (56 %) followed by solar thermal energy (52 %), Wind Power (48 %), Hybrid systems (40%), Biomass (24 %), Biogas (24 %), Bio-fuel (16 %), Hydropower(16 %), Geothermal (12 %), Ocean Energy (12 %) and Hydrogen fuel cells (8 %). It must be noted that in the surveys, most organizations specified a hybrid system of wind / photovoltaic and solar thermal/ Photovoltaic. The objective of this question is to determine the interest and in turn the most appropriate renewable energy technologies to be applied in Mauritius in the coming future. Using this definition the sample surveyed reveals that stakeholders and organizations are mostly interested in Solar Photovoltaic technologies.
5.2.4 Question 1.4 - Nature and the field of interest

To obtain an idea regarding the nature and the field of interest of the various organizations, the question 1.4 was set in the survey form. The result obtained for the Nature of the organization is represented in the following pie chart:

![Pie chart showing the nature of organizations in Mauritius](image)

**Figure 321: Nature of Organization in Mauritius**

As regards the field of interest of the targeted group the results are shown in the bar chart below:

![Bar chart showing the field of interest in Mauritius](image)

**Figure 4: Field of Interest of Organizations in Mauritius**
It can be noted that the targeted group were mostly from the private sectors followed by government sectors and non-governmental organizations and only a small percentage were from regional/international sections. The nature of work of the majority of the organizations consisted of Service, repair and maintenance. The fields of interest were mainly Energy Trade, Engineering, Research and Development. This means that most organizations are targeting to be in line with the government’s vision to be 35 % auto sufficient in electricity by 2025 as they are involved in energy trade, research and development.

5.3 Part 2: Research and innovation needs of the organizations

5.3.1 Question 2.1- Ability to meet future research innovation needs

This part consisted of analyzing the ability of the various organizations to meet the coming future research and innovation needs set by the government. From the charts it was found that 40 % of the targeted group has a satisfactory up to excellent ability to design and produce new renewable energy products and system for the specific users where and when required and 56 % of the organizations can carry renewable energy resource assessment up to a satisfactory level. Regarding gathering of renewable energy (RE) data from established sources only 52 % of the targeted groups have a good level. However, 40% of the group is only fairly satisfactorily able to evaluate the economics on RE technologies and 24% are able to manage RE projects. As regards writing of funding proposals for RE projects, only 40 % of the organizations have a good level of ability. As a whole, it can be concluded that the majority of the group are able to deal with the coming future innovations and research needs though some efforts have to be put in the field of evaluating the economics and managing RE projects.

(i)

![Diagram](image)

Figure 22: Ability to Design and Produce Renewable Energy Products
Figure 23: Ability to carry out Renewable energy resource assessment

Figure 27: Ability to obtain Renewable Energy data from established data sources
Figure 8: Ability to evaluate economics of Renewable Energy technology

Figure 9: Ability to manage Renewable Energy projects

Figure 10: Ability to write funding proposals for Renewable Energy projects
5.3.2 Question 2.2- Incentive schemes for Renewable energy business

This question aims at finding the level of knowledge the respondents have of the government and other assistance and incentive schemes for RE businesses. This is shown in the bar chart below:

![Knowledge level on RE business](chart.png)

**Figure 11: Knowledge level on Renewable Energy business**

From the bar chart, it can inferred that 81% of the targeted group are well aware about the incentive schemes set by the government on RE. As expected, the result shows that those organizations which are involved in RE are well aware of all the benefits involved in using and promoting RE will bring to the economy and the environment of Mauritius.
5.3.3 Question 2.3 – Benefits of the services provided by Tertiary institutions

This question was set in order to have an idea on which of the information or services if provided by universities or technical institutes will be most beneficial or least beneficial to the organizations.

(1 = most beneficial, 6 = least beneficial)

Figure 12: Benefits of information and services on renewable energy provided by tertiary institutions

The outcome of the survey has shown that the targeted groups found that information on Evaluation of Economics of RET and Design, construction & installation and seminars, workshops and short courses would be of utmost importance to them and training in project management would also benefit their organization. None of the organizations found that the proposed services would not be beneficial to them.
5.3.4 Question 2.4- Services offered by Tertiary institutions

This question identifies the types of services / opportunities that can be offered by tertiary institutions that would be of interest for the targeted group. The results are shown in the chart below.

![Types of services/opportunities offered by tertiary institutions](chart.png)

(1= most interested, 5= least interested)

**Figure 124: Type of services on renewable energy offered by tertiary institutions**

91 % of the targeted groups were mostly interested in consultancy and advisory service and monitoring & evaluation of RE projects. Only 4 % of the group specified other services which were not mentioned.

5.3.5 Question 2.5- Market oriented service expected from Tertiary Institution

This question assesses types of market oriented services that the organizations would prefer to have from tertiary institutions. The responds obtained were very fruitful which included among others; trainings to put RE practices into practice, providing information related to funding grants by international organizations for RE projects and partnership with private firms in consultancy. Moreover, many organizations are very much interested in getting training in construction and installation of RE devices mainly in the field of wind and solar energy and to get international and regional market surveys. Concern among targeted group were also diverted towards carrying out feasibility studies and to have complete assessment of sites in terms of RE sources up to implementation of project, including installation, testing and commissioning. The sample results show that the organizations are very much willing to be well informed and guided on the RE technologies to the extent of installation and commissioning.
5.4 Part 3: Staff training needs of the organizations

5.4.1 Question 3 (a) - Knowledge of Renewable Energy Technology

The aim behind this question was to analyze the extent to which staffs of the targeted group are aware about RE resources and technologies.

![Figure 25: Level of knowledge on Renewable Energy among staffs](chart)

Interestingly, the majority of managers (72%) have a good level of general awareness of RE, 44% have adequate academic training in RE science and technology amongst their staffs, 48% of managers are academically trained in RE management amongst their staffs, 52% of the staffs of the targeted group have had previous work experience in RE area. It must be noted that a high percentage (68%) of the finance staff do not have academic training in RE finance. Based on this, tertiary institutions can devise a training service or course which would be beneficial to the finance staff in terms of RE practices. Moreover, though not substantial, but around 8% of staffs of the targeted group have acquired knowledge and know-how via other means through seminars and technical trainings and through suppliers and foreign universities.
5.4.2 Question 3 (b) - Training requirements

Figure 26: Types of training on renewable energy the staffs of the organizations require

The purpose of this question was to analyze the types of training the staffs of the organizations require in order to be in a better position in the future to deal with RE technologies. The analysis revealed that most of the finance and middle managers/supervisors require an academic training in the field of RE science and technology.
5.4.3 Question 3 (c)-Most appropriate training/instruction

To assess the importance of the labelled training for the staffs of the organizations the question 3 (c) was designed. The results obtained are demonstrated below:

![Graph showing the most appropriate training for staff]

(1= most important, 7= least important)

**Figure 16: Types of Training required**

56 % of the organizations suggested that an in-house training would be very much beneficial for their staffs, while 32 % considered formal technical education and Learning through job experience to be most important. 28 % agreed that seminars are most important for the development of their staffs in the RE sector. However, 16 % of the organizations found that formal university education was least required for the smooth going and understanding of appropriate RE technologies by their staffs.
5.5 Part B: Renewable Capacity Building needs of Universities and tertiary institutions

5.5.1 Part 1: About the Universities and other tertiary institutions

5.5.1.1 Question 1.2 - The structure of the institution

The goal behind setting this question was to find out which faculties or sections in the tertiary institutions are delivering renewable energy courses.

![Pie chart showing % of faculties in tertiary institutions delivering renewable energy courses]

Figure 27: Faculties or sections in the tertiary institutions delivering renewable energy courses

The survey showed that 53.85 % of renewable energy courses are run in the Engineering department, 38.46 % in the Science Department and 7.69 % in the Agricultural department.

5.5.1.2 Question 1.3 - Number of staff in renewable energy-related departments

The % of staff related to Renewable energy in the various tertiary institutions is shown in the table below:

<table>
<thead>
<tr>
<th>Institution</th>
<th>% in Year 2000</th>
<th>% in Year 2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>University of Mauritius</td>
<td>0</td>
<td>35</td>
</tr>
<tr>
<td>University of Technology of Mauritius</td>
<td>0</td>
<td>20</td>
</tr>
<tr>
<td>Mauritius Institute of Technological Development (MITD)</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>Mauritius Institute of Education (MIE)</td>
<td>0</td>
<td>10</td>
</tr>
</tbody>
</table>

Table 5: Percentage of staff related to Renewable energy in the various tertiary institutions
The table shows that all the tertiary institutions are now delivering renewable energy courses on either full time or part time basis which was not the case in the year 2000. Furthermore, the MITD has 100% of its staff delivering renewable energy courses for business and Organizations. This implies that this institution has been set up exclusively to work towards renewable energy technologies.

5.5.2 Part 2: Awareness / experience amongst staff of market needs

5.5.2.1 Question 2 - Market-oriented experience in renewable energy

The idea behind setting up this question was to find out whether staffs of the institution have had market-oriented experience in renewable energy with business, industry or other profit making bodies.

It has been found that 42.9% of the staffs of tertiary institutions who deliver renewable energy classes to businesses and Organizations have no such experience as working in the renewable energy sector of any organization or profit making body. The remaining 57.1% have had various natures of such experiences in terms of consultancies and project drafting. The consultancies and project were mainly based on environmental / energy management schemes, economic viability of wind and solar photovoltaic panels installation in Mauritius, wind and solar potential in the local context, potential of ocean waves as a source of energy production and potential of off-grid/ grid-tied utilization of wind & solar hybrid system.

5.5.3 Part 3: Current involvement of institutions in providing market oriented training in renewable energy

5.5.3.1 Question 3 - Market oriented training in renewable energy

This question tries to identify the extent of involvement of the universities and other tertiary institutions in providing market oriented training in renewable energy to the working sectors. For that purpose, the most demanding issues were chosen which were as follows: - Renewable energy policy & infrastructure development; Renewable energy management; Renewable energy economics; environmental and policy issues; Renewable energy science & technology to market; Renewable energy project management; Renewable energy related legal matters. The chart below illustrates the % of tertiary institutions offering the above mentioned issues.
Figure 28: Involvement of the universities and other tertiary institutions in providing market oriented training in renewable energy to the working sectors

However, it must be noted that these issues are taught not as a whole course but as part of a course or a module and that also occasionally.

5.5.4 Part 4: Adequacy in providing program of study in renewable energy at tertiary level

5.5.4.1 Question 4 (a) & (b) - Areas of renewable energy where trained staff and resources are required

In view of promoting learning in Renewable energy field, this question was set in order to have an idea of the actual areas where Renewable energy courses are taught at tertiary level and areas where additional staffs are required to service the branch.

<table>
<thead>
<tr>
<th>Areas of Renewable energy</th>
<th>% Actually taught</th>
<th>% of Additional staff required</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydro, biomass, biofuel, solar, wind</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Geothermal, Ocean energy &amp; others</td>
<td>83.3</td>
<td>83.3</td>
</tr>
<tr>
<td>RE economics, environment &amp; policy issues</td>
<td>66.7</td>
<td>66.7</td>
</tr>
<tr>
<td>Renewable energy project management</td>
<td>16.7</td>
<td>66.7</td>
</tr>
<tr>
<td>Others</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

Table 6: Areas where Renewable energy courses are taught at tertiary level and where additional staffs are required

54
5.5.4.2 Question 4 (c) - Programs of study in renewable energy

The aim of this part was set to know if these tertiary institutions have adequate program of study in renewable energy to provide capacity building seminars, workshops and short courses to the business sector.

From the survey, it has been found that modules on renewable energy, short courses of sustainable and renewable energy, part-time distance courses on sustainable energy engineering and full time courses on chemical & environmental/ sustainable energy are actually being offered by tertiary institutions to train business sectors.

However, there are also, new programs of study that the tertiary institutions are willing to offer to business sectors. The proposed programs are short courses on grid connection of photovoltaic panels for electricians; Energy potential of sea waves; Design, construction & installation of wind turbines; and Renewable Energy resources assessment at specific sites.

5.5.4.3 Question 4 (d) - Laboratory, equipment and research facilities

The aim of this question was to enquire whether tertiary institutions are sufficiently equipped and have adequate research facilities to offer the proposed programs of study. It has been noted that only 28.6% of the institutions are fully equipped and the remaining 71.4% lacked equipment. The equipment and facilities that are lacking are mainly photovoltaic solar panels, facilities for micro generation of electricity, hydrolysis reactors, fractional distillation column, CHNS analyzer and a pilot scale wind turbine. Moreover, if some of the equipment could be made available, it would be very fruitful for the businesses and other organizations.
6.0 ECONOMICS OF PHOTOVOLTAIC PANELS

The outcome of the surveys revealed that respondents are much more willing to adopt the photovoltaic system as a source of producing electricity than any other type of renewable energies. Furthermore, with the motivating scheme provided by the government for citizens to produce electricity via small-scale distributed generation, most organisations, stakeholders and businesses are willing to converge towards photovoltaic panels rather than wind turbines because of two main reasons; firstly due to the better aesthetic of PV and secondly sunshine insolation is much higher in all parts of Mauritius as compared to wind resource. As a consequence, the focus has been on photovoltaic panels, its working principle and the its costing.

Data on amount of sunshine in Mauritius collected by the meteorological station showed that there is a good potential for exploiting solar energy in Mauritius. Sunshine is available in abundance all year round in Mauritius, be it summer or winter. This is shown in the table below in terms of hours of sunshine that yields the amount of insolation per m² per day:

<table>
<thead>
<tr>
<th>MONTH</th>
<th>SUNSHINE</th>
<th>Insolation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Daily hrs per day</td>
<td>Mean Monthly</td>
</tr>
<tr>
<td>January</td>
<td>7.0</td>
<td>216.3</td>
</tr>
<tr>
<td>February</td>
<td>6.6</td>
<td>186.1</td>
</tr>
<tr>
<td>March</td>
<td>6.7</td>
<td>209.4</td>
</tr>
<tr>
<td>April</td>
<td>6.0</td>
<td>179.1</td>
</tr>
<tr>
<td>May</td>
<td>6.3</td>
<td>193.9</td>
</tr>
<tr>
<td>June</td>
<td>6.1</td>
<td>182.8</td>
</tr>
<tr>
<td>July</td>
<td>6.1</td>
<td>187.6</td>
</tr>
<tr>
<td>August</td>
<td>6.1</td>
<td>187.7</td>
</tr>
<tr>
<td>September</td>
<td>6.3</td>
<td>189.5</td>
</tr>
<tr>
<td>October</td>
<td>6.8</td>
<td>210.1</td>
</tr>
<tr>
<td>November</td>
<td>7.3</td>
<td>219.8</td>
</tr>
<tr>
<td>December</td>
<td>7.0</td>
<td>216.8</td>
</tr>
</tbody>
</table>

Table 7: Yearly Sunshine Data in Mauritius

It can be seen that, the average daily sunshine intensity in Mauritius is very much suitable for solar photovoltaic technologies thus having a good potential. It must be noted that these values are the average of the entire island taken at the 8 stations located throughout the island. Moreover, it must also be noted that these stations are situated quite far from the coastal regions and hence regions nearer to the coast will have even higher insolation values. It has been predicted that in the near future, solar (PV panels) will contribute about 34 % in the domestic sector and total electricity consumption.
6.1 Working principle of photovoltaic panels:

Photovoltaic cells are made up of special material called semiconductors such as silicon, which is currently the most commonly used one. When light falls on the cell, a certain amount of the light is absorbed by the semiconductors material. The energy of the absorbed light is then transferred to the semiconductor which is used to loosen up the electrons, allowing them to flow freely and thus create electricity.

PV cells also have one or more electric fields that force electrons freed by light absorbed, to flow in a certain direction thus producing current. Thus by inserting metal contacts on the top and bottom of the PV cell, one can direct the current for external use. This current combined with the cell’s voltage due to the built-in electric field, defines the power that the solar cell can produce.

For the purpose of this thesis, the Independent Power Producers (IPP) has been taken as an example. Assuming that the below figure represents the IPP in Mauritius, steps 1 to 6 are as follows:

![Diagram of photovoltaic panels](image)

Figure 29: Working principle of photovoltaic panels (Source: www.soltage.com/how-it-works/index.php)

1. **Solar Panels**: The solar panels collect molecules of sunshine, which are considered as little packets of energy, and generate direct current (DC)

2. **DC to AC Inverter**: DC to AC inverters convert the DC current generated by a solar panel into AC current that can be used to power appliances in your home.

To convert the DC power to AC, an inverter is used. Each solar panel comprises of an individual inverter.
3 **Meter** – The meter registers the additional required energy imported from the grid to supply the loads or the excess energy exported to the grid. Your home solar power system can actually cause your electric meter to spin backwards as it feeds the electricity it generates into the main power grid and you earn credit on your electric bill.

4 **Electrical Distribution Panel** - This is the panel that feeds all of the homes circuits.

5 **AC Loads** - Once your solar panels have converted the Sun's light into an electric current and that current has been converted from direct current (DC) to alternating current (AC), it can then be used to power your lights and appliances.

6 **Main Power Grid** - Once electricity generated by your residential solar power system is directed onto the power grid, it can then be used by someone else and adds to the overall total of kilowatt hours produced by a clean and renewable energy source – that is the Sun.

### 6.2 Costing for Solar Panel:

For the costing, quotations were taken from different solar companies in Mauritius and the Solar Electricity's Company quotation was selected since it was at a lower price. The quotation was as follows for various delivery capacities for a grid tied inverter all in Mauritian rupees (1 Euro = 40 MUR):

<table>
<thead>
<tr>
<th></th>
<th>1000W/Hr</th>
<th>2000W/Hr</th>
<th>3000W/Hr</th>
<th>4000W/Hr</th>
<th>5000W/Hr</th>
<th>6000W/Hr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solar Panel (monocrystalline)</td>
<td>103,941</td>
<td>197,992</td>
<td>280,946</td>
<td>323,927</td>
<td>448,967</td>
<td>519,882</td>
</tr>
<tr>
<td>Inverter</td>
<td>33,020</td>
<td>52,960</td>
<td>80,840</td>
<td>92,682</td>
<td>117,714</td>
<td>142,948</td>
</tr>
<tr>
<td>Wiring + Installation Fee</td>
<td>41,300</td>
<td>44,700</td>
<td>51,257</td>
<td>52,956</td>
<td>63,754</td>
<td>76,300</td>
</tr>
<tr>
<td>Total excluding VAT</td>
<td>178,261</td>
<td>295,652</td>
<td>413,043</td>
<td>469,565</td>
<td>630,435</td>
<td>739,130</td>
</tr>
<tr>
<td>+ Vat (15 %)</td>
<td>26,739</td>
<td>44,348</td>
<td>61,957</td>
<td>70,435</td>
<td>94,565</td>
<td>110,870</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>205,000</strong></td>
<td><strong>340,000</strong></td>
<td><strong>475,000</strong></td>
<td><strong>540,000</strong></td>
<td><strong>725,000</strong></td>
<td><strong>850,000</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Units saved monthly</th>
<th>120</th>
<th>240</th>
<th>360</th>
<th>480</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total</strong></td>
<td>205,000</td>
<td>340,000</td>
<td>475,000</td>
<td>540,000</td>
</tr>
</tbody>
</table>

For the purpose of this study, the independent power producer (IPPs) has been taken as the example to calculate the costing for the production of 10 MW of electricity per year. It must be noted that a typical household has not been taken since the consumption for household differs from region to region and on the number of family members. The above cost include the installation and production cost.

It has been found that the IPPs produce around 10 MW of electricity per year which amounts to 1141.55 W/ hr. Thus from the available quotation, we can opt for the 2000 W/Hr solar panel since taking the 1000 W/hr will deliver less than the actual demand. Thus the installation and production cost for 10 MW/year of electricity will cost 340,000 Mauritian rupees (MUR) amounting to 8500 euro (1 euro = 40 Mauritian rupees). However, this cost excludes the profit when sold to grid.
Mauritius, the units of electricity are sold according to the amount of units consumed. This is shown in the table below:

<table>
<thead>
<tr>
<th>Unit (KW/hr)</th>
<th>Price (Rs)</th>
<th>Price (Euro)</th>
</tr>
</thead>
<tbody>
<tr>
<td>First 25</td>
<td>2.87</td>
<td>0.07</td>
</tr>
<tr>
<td>Next 25</td>
<td>3.98</td>
<td>0.1</td>
</tr>
<tr>
<td>Next 25</td>
<td>4.31</td>
<td>0.11</td>
</tr>
<tr>
<td>Next 25</td>
<td>4.95</td>
<td>0.12</td>
</tr>
<tr>
<td>Next 100</td>
<td>5.59</td>
<td>0.14</td>
</tr>
<tr>
<td>Next 50</td>
<td>6.38</td>
<td>0.16</td>
</tr>
<tr>
<td>Next 50</td>
<td>7.18</td>
<td>0.18</td>
</tr>
<tr>
<td>Remaining</td>
<td>7.97</td>
<td>0.2</td>
</tr>
</tbody>
</table>

Table 8: Price of Units of Electricity in Mauritius (Source: CEB Utility Bill)

Since 1 unit of electricity means 1 KWh, thus IPPs produces 10,000 units. Using the above table, the selling price for the 10,000 units amounts to 78,948 Mauritian rupees (1974 euro) (Calculations in Appendix 4).

With a production of 10,000 units per year at a selling price of 78,948 rupees the payback period is found to be 4.3 years (Calculations in appendix 4) as shown in the graph below:

Figure 30: Payback period for the installation of PV panel to produce 10 MW of electricity/year

However, it must be noted that the payback period will be slightly higher as this quotation is based on the price of watt produced per hour.
7.0 CONCLUSION

This section outlines the conclusions of each part of the questions set in the survey form and finally provides an overall conclusion for the whole study.

1. Organizations and Businesses have good abilities to carry out renewable energy resource assessments and obtain data from other data sources. But to a large extent, organizations have a poor ability in managing and evaluating economics of RE projects. Consequently, it is noted that, majority of the organizations are for information, services and opportunities to be offered by tertiary institutions. Hence, tertiary institutions must promote awareness and courses related to economics and management of RE projects.

2. It can also be concluded from the results obtained that managers of Organizations have a good level of renewable energy awareness which is not the case for the finance people. Thus organizations are very much interested in having academic training in RE science and technology amongst the finance, supervisors and salespersons. Moreover, organizations are more favourable for in-house training and learning on job through experience rather than formal technical and university education.

3. It has been observed that in the year 2000, almost no courses based on renewable energy were run at tertiary level. However, with new governmental and environmental policies, now, all the tertiary institution are providing renewable energy courses in their institutions to businesses and other organizations which is in line with the government’s views and needs. This shows the shift in the mind set of institutions and a sense of responsibility towards promoting renewable energy utilization by creating awareness and delivering the appropriate tools and training to businesses and organizations in Mauritius.

4. Since a high percentage of staffs (42.9 %) delivering renewable energy courses at tertiary level do not have working experiences in any business or organization, this may imply that they might be unaware about the real needs of the organizations. Moreover, they could be running courses which are obsolete. Thus, this survey can serve the purpose of bridging the gap between the tertiary institutions and business life by providing market oriented program in renewable energy.

5. It has been found that a high number of tertiary institutions are actually running most of the market oriented issues. Nevertheless, these form part of a module only, thus the required in-depth knowledge may not be achieved by the targeted group. Thus, these institutions can make further provision in running these issues as a whole course in itself.

6. Though staffs of the tertiary institutions have enough expertise to provide capacity building workshops and short courses to business and industrial sector, the majority of these institutions do not have the required equipment and facilities. Thus it is recommendable that these institutions be fully equipped since the government of Mauritius has budgeted 100 million Mauritian rupees for research and other facilities to promote renewable energy and sustainable development of the country.
7. The surveys revealed that the renewable energy that is most in use in Mauritius is the solar energy, followed by wind, a hybrid of wind and solar technologies, hydro and biomass. But, the implementation of all the renewable energy sources at a time is not feasible for a small island like Mauritius. We should explore each and every aspect of the Renewable energy sources before embarking on them. However, the type of renewable energy which is most known to the Mauritian population and which is most ready to be accepted at household as well as at business and Organization level is the solar energy through the use of photovoltaic panels.

8. Based on another survey carried out by Doolaree (2010), the findings tallied with this study revealing that among all the renewable energy sources, 45% of the respondents firmly believed that Mauritius should invest in solar while 21% suggested to invest in wind energy. Thus PV is expected to be the most prosperous RE in the long term due to the presence of sunlight everywhere. Moreover, with the introduction of net metering and awareness campaign, the use of PV will certainly be improved and well accepted at all levels.

The main reason behind this shift in the mindset might be probably due the interesting incentive schemes launched out in 2009 by the Government in collaboration with the Central Electricity Board, with the help of the UNDP.

Certainly, the initial investment prices for PV panels still remain an important aspect but with the small grid incentive provided, this will certainly encourage citizens to invest and promote renewable energy usage for electricity production. Based upon the worldwide statistics, the energy production of solar panels has been found to cost around 25 cents/KWh but with the new government long term energy strategy of 2009 - 2025, investment subsidies are possible where part of the cost for PV system installation can be refunded. Moreover, it has been found that, within a period of slightly more than 4.3 years itself, the total capital cost will be covered thus; any revenue after that period will contribute to the profit. Hence, solar panels in Mauritius are economically viable and can be implemented on a pilot scale at organization level as well as at household level. However, incentives must be provided by government to encourage such environmental friendly practice which will leave our country to enjoy a safe and clean future.

It is high time for Mauritian to realize that we are too much dependent on imported fossil fuels. Mauritius should have a change in habit. The on-grid PV system will be quite a success – according to the survey. If such a technology is initialized, Mauritians will certainly consume less, in the sole aim of selling the excess to the grid. Thus, being 35% self sufficient in electricity production by 2025 specified by the Government in its long term energy strategic plan for renewable energy will soon be met in the near future.
8.0: FUTURE WORKS

From the surveys carried out, it was found that beside solar energy, many organizations and tertiary institutions are interested in providing their service as well as implementing other forms of sustainable energy namely wind technologies and biomass extract energies like bio-fuel. Thus the future works can consist of putting into operation wind turbines and promoting bio-fuel especially bio-ethanol in cars as E10. It must be noted that the government of Mauritius is already on a pilot project of putting up wind turbines at Bigarré in Curepipe.

8.1 Analysis of Data on wind and bio-fuel

8.1.1 Wind data analysis

It has been is found that the East side and South East side of Mauritius is a well exposed area and has very good wind energy potential with quite vast land area. It has also been noted by the Meteorological Services Department that, during winter, the winds have a more southerly component than during the summer. They are also concentrated around the SE direction which is best suited if ever there were wind turbines situated in the eastern direction.

Moreover, data of wind potential, can be tallied from a study carried out in the 1980’s by Battelle, Pacific Northwest Laboratories under a UNDTCD funded project entitled ‘Wind Energy Resource Assessment for Mauritius’. Under the project, eleven sites were selected for wind measurements and, at each of the sites, a wind data collection system was installed at a level of 10 m. Wind data has also been collected by the Meteorological Services department. The average wind power potential for all the eleven sites for the past 5 years is given in Table below:

<table>
<thead>
<tr>
<th>MONTH</th>
<th>WIND DATA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean wind speed</td>
</tr>
<tr>
<td></td>
<td>Km/hr</td>
</tr>
<tr>
<td>January</td>
<td>7</td>
</tr>
<tr>
<td>February</td>
<td>9</td>
</tr>
<tr>
<td>March</td>
<td>8</td>
</tr>
<tr>
<td>April</td>
<td>8</td>
</tr>
<tr>
<td>May</td>
<td>9</td>
</tr>
<tr>
<td>June</td>
<td>9</td>
</tr>
<tr>
<td>July</td>
<td>9</td>
</tr>
<tr>
<td>August</td>
<td>12</td>
</tr>
<tr>
<td>September</td>
<td>11</td>
</tr>
<tr>
<td>October</td>
<td>11</td>
</tr>
<tr>
<td>November</td>
<td>9</td>
</tr>
<tr>
<td>December</td>
<td>9</td>
</tr>
</tbody>
</table>

Table 9 : Yearly Wind Data in Mauritius
The following information on Wind should also be noted:

(i) Mauritius is exposed to very high winds from tropical cyclones. These cyclones occur during the summer season and may be harmful to wind turbines. The highest recorded wind gust in Mauritius was about 280 km/hr and occurred in 1975 during the passage of cyclone Gervaise.

(ii) Seasonal wind frequency curves of the Meteorological Services Department show that winds over Mauritius are stronger during winter. This is due to the fact that the south-easterly trades are enhanced during winter, and especially during anti-cyclonic conditions that follow frontal systems.

From all the data collected, it can be concluded that there are good potential for wind power mainly in the south East and Eastern region of Mauritius. The wind speed is more than enough for power generation since most of the commercial wind turbines have a cut in wind speed of 3–4 m/s. Moreover, based upon the worldwide statistics, the wind energy production cost is in the range of 4–7 cents/kWh; hence wind turbines in Mauritius are economically viable for future needs.

9.1.2 Bio-ethanol from biomass data analysis

With emerging environmental concerns, the government of Mauritius has set a commitment to reduce its dependency on fossil fuels in the recent Budget (Budget Report, 2008). As, the automotive industry is a major consumer of fossil fuels, the government of Mauritius has mounted a national framework so as to promote the use of renewable energy while reducing the import of conventional fuels by boosting the extensive use of ethanol in motor vehicles. So far, ethanol has proven to be a very reliable auto motive fuel in countries like Brazil, Canada, India and the United States. And today, gasoline replacement by liquid ethanol produced from renewable biomass resources is also becoming a high-priority goal in many other countries (Martin et al, 2005) and is the only proven commercial-scale renewable transportation fuel that has the potential to replace at least 10 percent of the nation's gasoline supply (Dawson and Boopathy, 2006). According to Berg (1999) and Hansen et al (2004), ethanol blends of 15 – 20% can be used in automobile engines with essentially no engine modifications. The commercial feasibility of ethanol production from locally available renewable lignocellulosic resources depends both on its ease of availability and its low cost (Nigam, 2000). Hence, locally produced renewable fuel; ethanol, has the potential to broaden the energy portfolios, to lower dependence on foreign oil and to improve trade balances in oil-importing nations (Cheung, 1997).

Lignocellulosic biomass such as agricultural, forest products (hardwood and softwood) and their residues are renewable resources of energy (Wyman and Hinman, 1990). Approximately 90% of the dry weight of most plant material is stored in the form of cellulose, hemi-cellulose, pectin, and lignin. Conversion of cellulose and hemi-cellulose from waste materials to sugars provides a feedstock for the production of fuel ethanol and substantially reduces the amount of wastes that would otherwise exert pressure on municipal landfills (Jamshid et al, 2001). Furthermore, the production of ethanol from lignocellulosic biomass results in a no net contribution to global warming, since the carbon
dioxide produced by the combustion of ethanol is consumed by the growing raw material (Sivers & Zacchi, 1995; Galbe et al, 2005).

Mauritius being an agricultural island has a great potential for easily available lignocellulosic biomass. Sugar cane cultivation occupies the highest function in the agricultural sector, with more than 70% of arable land under cane (Digest of Agricultural Statistics, 2007). The major biomass formed is bagasse, which is currently being burnt to produce energy. Molasses are also formed which contain between 30% and 60% sugar (MSIRI, 2009). They represent today the most commonly used raw material in Mauritius for ethanol manufacture. According to Ragen A.K (1989), around 4 million litres of ethanol was produced by 80 distilleries all over the island. However, molasses being limited, other sources such as agricultural wastes (500 tons/day) (Central Statistic Office, CSO 2007) which are highly abundant in the local context were being looked into by P. Khadoo in 2009. Lignocellulosic biomass like fast – growing trees, grasses, forestry and agricultural residues and municipal wastes is an abundant and comparatively cheap raw material (Galbe et al, 2005).

One of the major challenges is to optimize the combination of process engineering, fermentation technology, enzyme engineering and metabolic engineering (Hahn-Hagerdal et al, 2006). Consequently, a study was carried out by P. Khadoo (2009) to investigate the optimum conditions required for acidic (acid concentration and hydrolysis reaction time) as well as enzymatic hydrolysis (enzyme loading and hydrolysis reaction time) on five cheapest and most easily available lignocellulosic feedstock (cane tops and leaves, elephant grass, acacia, coconut husk and peels of cane stalk) in Mauritius, to attain the highest ethanol yield from each feedstock. It was found that around 200 L – 360 L of ethanol could be produced from these feedstock at different operating conditions. Thus bio-ethanol has a high potential in Mauritius and can thus be implemented on pilot scale in motor cars. The introduction of biofuel in terms of bio-ethanol (E10) in the transport sector will prove to be a success. This will help in reducing the amount of gasoline imported and reduce vehicular emissions.
BIBLIOGRAPHY

5. Central Electricity Board. 2009. CEB annual report


44. Zyga, L. 2007. 40% efficient solar cells to be used for solar electricity.

**Websites:**

45. Energy Division of the state of Hawaii – Department of Business, Economic Development and Tourism, OTEC. Available at: [http://sustainablehawaii.com/otecengy.html](http://sustainablehawaii.com/otecengy.html)


APPENDIX

Appendix 1 - A1: Attached Paper on:-

Fostering renewable energy in small developing island states through knowledge and technology transfer: Findings from a labour market survey undertaken in Mauritius under DIREKT project
Appendix 2 - A.2: Survey form for Business and organizations

<table>
<thead>
<tr>
<th>Survey of Renewable Energy Capacity Building Needs of Businesses and Other Organizations (revised 2 March 10)</th>
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</table>

Thank you for agreeing to answer this questionnaire on renewable energy needs. Your answers will be kept strictly confidential.

Notes:
1. Some of the questions may not apply to your organization. Please answer only those questions that you think apply to your organization.
2..N/A means “not applicable”, i.e. the question is not applicable to you.

Date:.....................

1. About your organization:

1.1 Name of organization: ........................................................................

☐ I do not wish to disclose the name of my organization

Type of organization: .................................................................

Year established: .................................................................

1.2 What is the approximate number of employees in your organization:

a) males ....... females ...... total ............ ☐ N/A

b) number working in the renewable energy area

- males ...... females ....... total ............ ☐ N/A

1.3 number according to rank

- managerial: males ....... females ...... total ............ ☐ N/A

- finance/accounts: males ......females ...... total ............ ☐ N/A

- middle managers/supervisors: males ...... females ...... total ............ ☐ N/A

- clerical/shop-floor/

- production workers: males ...... females ...... total ............ ☐ N/A
1.3 Which of the following renewable energy sectors is your organization mainly interested in? (Multiple answers possible)

- [ ] Biofuels
- [ ] Biomass
- [ ] Biogas
- [ ] Wind power
- [ ] Hydro power
- [ ] Geothermal
- [ ] Solar thermal
- [ ] Photovoltaic
- [ ] Hydrogen/fuel cells
- [ ] Hybrid systems (please specify)
- [ ] Ocean energy (please specify)
- [ ] Others (please specify) ……………………

1.4 Which of the following categories best describes the nature and the field interest of your organization? (multiple answers possible)

- [ ] Private
- [ ] government
- [ ] regional/international
- [ ] Non-governmental organization
- [ ] Planning and production
- [ ] Education and training
- [ ] Aid and development
- [ ] Human rights
- [ ] Engineering (please specify) ……………………
- [ ] Service, repair and maintenance
- [ ] Operation and administration
- [ ] Assessment and certification
- [ ] Energy trade
- [ ] Research and development
- [ ] Legislation/policy
- [ ] Finance
- [ ] Consultancy (please specify) ……………………………
- [ ] Others (please specify) …………………………………………………

2. Your Research and Innovation Needs

2.1 What in your opinion is your present ability to

i. design and produce new renewable energy products and systems for specific users

   1  2  3  4  5

   poor [ ] [ ] [ ] [ ] [ ] excellent [ ] N/A

ii. carry out renewable energy resource assessments

   1  2  3  4  5

   poor [ ] [ ] [ ] [ ] [ ] excellent [ ] N/A

iii. obtain data on renewable energy resources from established data sources

   1  2  3  4  5

   poor [ ] [ ] [ ] [ ] [ ] excellent [ ] N/A
iv. **Evaluate the economics of renewable energy technology (RET)**

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v. **Manage renewable energy projects**

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vi. **Write funding proposals and reports for renewable energy projects?**

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2.2 **What is your knowledge of government and other assistance and incentive schemes for renewable energy businesses?**

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2.3 **Which of the following information/services provided by tertiary institutions (universities, technical institutes etc) will be of benefit to you (most beneficial =1, least beneficial = 6)**

- ☐ the design, construction and installation of renewable energy devices and systems
- ☐ basic research and development
- ☐ seminars, workshops and short courses in renewable energy
- ☐ renewable energy resource assessment at the installation sites
- ☐ evaluating the economics of the use of renewable energy technology (RET)
- ☐ training in project management, funding proposal and report writing
- ☐ other (please specify) .................................................................
2.4 Which of the following types of service/opportunities that can be offered by tertiary institutions are you most interested in (most interested =1, least interested = 5)

☐ joint research and development with the institution
☐ consultancy, advisory service
☐ monitoring, evaluation of renewable energy projects
☐ networking with business or research partners
☐ database service for renewable energy (please specify type of data)

...................................................................................................................................................

☐ other services/opportunities (please specify)
...................................................................................................................................................
...................................................................................................................................................

2.5 What type of market-oriented service would you like tertiary institutions to provide for you? (Please specify)

...................................................................................................................................................
...................................................................................................................................................
...................................................................................................................................................

3. Your Staff Training Needs
a) The type of renewable energy knowledge your staff currently have:
   i. the level of **general awareness of renewable energy** is good amongst your managers
      ☐ Yes ☐ No ☐ N/A

   ii. your staff have adequate **academic training in renewable energy** science and technology
       ☐ Yes ☐ No ☐ N/A

   iii. your managers have academic training in renewable energy **management**
       ☐ Yes ☐ No ☐ N/A
iv. your finance staff have academic training in renewable energy finance
   □ Yes     □ No     □ N/A

v. your staff have had previous work experience in the renewable energy area
   □ Yes     □ No     □ N/A

vi. your staff have knowledge and know-how acquired by other means
    (please specify) .............................................

b) The type of training your staff require:
   i. which of your staff require basic renewable energy awareness training?
      □ managers     □ finance and middle managers/supervisors
      □ science officers     □ clerks/salespersons/production workers     □ N/A

   ii. which of your staff require academic training in management and finance?
       □ managers     □ finance and middle managers/supervisors
       □ science officers     □ clerks/salespersons/production workers     □ N/A

   iii. which of your staff require academic training in renewable energy science and technology?
        □ managers     □ finance and middle managers/supervisors
        □ science officers     □ clerks/salespersons/production workers     □ N/A

   c) What type of training/instruction is most appropriate for your staff (1 = most important, 7 = least important)
      □ seminars – specify staff category ...........................................................
      □ formal technical education – specify staff category ....................................
      □ formal university education – specify staff category ..................................
      □ in-house training – specify staff and type of training
      ..............................................................................................................
      ..............................................................................................................
      ..............................................................................................................
☐ informal training/education – specify what and for who

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☐ learning on the job through experience – specify how important (relative to formal education)
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☐ training in research and development

Other (please specify)
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Thank you for your time!
Appendix 3 - A.3: Survey form for Universities and other tertiary Institution

Survey of Renewable Energy Capacity Building needs of Universities and Other Tertiary Institutions
(revised 2 March 10)

Thank you for agreeing to answer this questionnaire on renewable energy. Your answers will be kept strictly confidential.

Notes:
1. Some of the questions may not apply to your organization. Please answer only those questions that you think apply to your organization.
2. N/A means “not applicable”, i.e. the question is not applicable to you.

Date: …………………

1. About your tertiary institution:

1.1 Name of institution: ………………………………………

☐ I do not wish to disclose the name of my institution

Type of institution: ………………………………………

Year established: ………………………………………

1.2 The structure of your institution

List the Faculties/Sections of your institution, and indicate those in which renewable energy-related programs are conducted (with the nature of the program)

……………………………………

……………………………………

……………………………………

……………………………………
1.3 What is the approximate number of staff in your renewable energy-related departments:

a) all staff in all departments of the renewable energy-related faculties:
   males……… females……… total ………

b) approximate number working in the renewable energy area:
   males……… females……… total ………

c) number according to rank:
   academic staff: males …… females…… total ………

   Technical staff: males …… females …… Total ………

   finance/accounts: males…… females …… total ………

   section heads: males …… females …… total ………

   clerical/secretarial males …… females …… total ………

1.4 Approximate annual recurrent budget of your institution:
   ...........................................................................

1.5 Does your institution have a pro-active gender policy?

☐ No – please go to question 2.

☐ Yes

   Describe the nature of this policy and its implementation
   ...................................................................................
   ...................................................................................
   .................................................................
2. Awareness/experience amongst staff of market needs
   i. Have the staff of your institution had market-oriented experience in renewable energy (i.e. experience working with renewable energy businesses, industry and other profit-making bodies)?

   □ No – please go to question 2 (ii).
   □ Yes
   % of staff with such experience: .................................................................
   Nature of such experience: .................................................................
   Do they currently have such associations with the market? .................................

   ii. Have any of your staff had any experience in delivering courses/programs in renewable energy to businesses and other organizations?

   □ No – please go to question 2 (iii).
   □ Yes
   % of staff with such experience: .................................................................
   Nature of such experience: .................................................................
   Do they currently have such associations with the market? .................................

   iii Have your staff carried out consultancies in renewable energy for the business sector?
   □ No – please go to question 3.
   □ Yes

   % of staff with such experience: .................................................................
   Nature of such experience: .................................................................
   Do they currently have such associations with the market? .................................
3. The current involvement of the institution in the provision of market-oriented training in renewable energy:
   i. Does your institution provide training in renewable energy policy and infrastructure development to the market (i.e. to business and industry)?
      ☐ No – please go to question 3 (ii).
      ☐ Yes ☐ regularly ☐ only occasionally
      Nature of such training: .................................................................

   ii. Does your institution provide training in renewable energy management to the market?
      ☐ No – please go to question 3 (iii).
      ☐ Yes ☐ regularly ☐ only occasionally
      Nature of such training: .................................................................

   iii. Does your institution provide training in renewable energy economics, environmental and policy issues to the market?
      ☐ No – please go to question 3 (iv).
      ☐ Yes ☐ regularly ☐ only occasionally
      Nature of such training: .................................................................

   iv. Does your institution provide training in renewable energy science and technology to the market?
      ☐ No – please go to question 3 (v).
      ☐ Yes ☐ regularly ☐ only occasionally
      Nature of such training: .................................................................

   v. Does your institution provide training in renewable energy project management to the market?
      ☐ No – please go to question 4.
      ☐ Yes ☐ regularly ☐ only occasionally
      Nature of such training: .................................................................
vi. Does your institution provide training in renewable energy-related legal matters to the market?

☐ No – please go to question 4.
☐ Yes ☐ regularly ☐ only occasionally

Nature of such training: .................................................................

4. In what areas of renewable energy does your institution require trained staff and resources most urgently?

a) The areas of renewable energy that you teach now (include gender statistics)

☐ hydro, biomass, biofuel, solar, wind (number of male and female staff) .................................................................

☐ geothermal, ocean energy, other (number of male and female staff) .................................................................

☐ renewable energy economics, environmental and policy issues (number of male and female staff)

........................................................................................................

☐ renewable energy project management (number of male and female staff) .................................................................

☐ other (please specify)

........................................................................................................

b) The areas of renewable energy where you require additional staff

☐ hydro, biomass, biofuel, solar, wind (number of staff required) .................................................................

☐ geothermal, ocean energy, other (number of staff required) .................................................................
☐ renewable energy economics, environmental and policy issues (number of staff required)………………………………………………

☐ renewable energy project management (number of staff required)…………………………………………………………….

☐ other (please specify)
……………………………………………………………………………………………………

c) Does your institution have adequate Programs of study in renewable energy to provide capacity building seminars, workshops and short-courses to the business sector?

Nature of renewable energy programs you now offer to train the business sector (include mode of delivery)

…………………………………………………………………………………………………….

…………………………………………………………………………………………………….

New programs of study that you would like to offer to the business sector

…………………………………………………………………………………………………….

…………………………………………………………………………………………………….

d) Does your institution have adequate Laboratory, equipment and research facilities to provide capacity building training workshops and short-courses to the business and industrial sector?

Nature of present lab facilities, and research facilities

…………………………………………………………………………………………………….

…………………………………………………………………………………………………….

…………………………………………………………………………………………………….
Additional lab/research facilities that you would like to have
........................................................................................................................................
........................................................................................................................................

e) Do your staff have adequate research experience to provide capacity building workshops, short-courses and seminars in research and development to the business and industrial sector?

Nature of present expertise (include projects and consultancies)
........................................................................................................................................
........................................................................................................................................
........................................................................................................................................

Additional expertise that you would like your staff to have
........................................................................................................................................
........................................................................................................................................
........................................................................................................................................

5. Which areas of renewable energy training would you like to see developed further amongst your renewable energy staff?
........................................................................................................................................
........................................................................................................................................
........................................................................................................................................
........................................................................................................................................
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........................................................................................................................................

Thank you for your time  !
Appendix 4 - A4: Costing for 10,000 units which is an equivalent of 10 MW of electricity per year

\[ \text{Amount} = (25 \times R\ 2.87) + (25 \times R\ 3.98) + (25 \times R\ 4.31) + (25 \times R\ 4.95) + (100 \times R\ 5.59) + (50 \times R\ 6.38) + \\
(50 \times R\ 7.18) + (9,700) \times R\ 7.97 \\
= R\ 78,948 \text{ (Total amount of money obtained for first year)} \]

Calculation for Payback Period:

\[ \text{Payback Period} = \frac{\text{Total Initial investment}}{\text{Total amount of money obtained for first year}} \]

\[ = \frac{R\ 340,000}{R\ 78,948} \]

\[ = 4.3 \text{ years} \]