SUSTAINABLE RENEWABLE ENERGY POLICY ON ENERGY INDICATORS, ELECTRIC POWER AND RENEWABLE ENERGY SUPPLY CHAINS

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MPhil

2020

Sustainable Renewable Energy Policy on Energy Indicators, Electric Power and Renewable Energy Supply Chains

A study of renewable energy policies, energy indicators and electrical power distribution

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Submitted for Degree of Master of Philosophy

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2020

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Keywords: Renewable energy supply chain; Electric storage; Hybrid energy system; Fuel cell; Social impacts; Distributed generation; Potential; Global warming; General sustainability indicators; Environment; Pollution; Sustainability assessment; Emission;

Abstract

Due to the result of the sudden fossil fuels over-night price rises of 1973/1974, coupled with the depletion of the traditional energy resources, many initiatives globally have addressed the efficient use of these resources. Since then, several renewable energy sources have been introduced as alternatives to traditional resources to protect environmental resources and to improve quality of life. Globally, there are more than a quarter of the human population experiencing an energy crisis, particularly those living in the rural areas of developing countries. One typical example of this is Nigeria. This is a country with approximately 80% of her population consistently relying on combustible biomass from wood and its charcoal derivative. Nigeria has an abundant amount of both renewable and fossil fuel resources, but due to the lack of a reasonable energy policy (until recently), it has concentrated on traditional fossil fuels alone. Renewable energy is now Globally considered as a solution for mitigating climate change and environmental pollution. To assess the sustainability of renewable energy systems, the use of sustainability indicators is often necessary. These indicators are not only able to evaluate all the sustainability criteria of the renewable energy sources,1 but also can provide numerical results of sustainability assessment for different objective systems.

Acknowledgement

I am grateful to my Supervisors, Dr Andrew Carruthers, and Dr Eduardo Munive-Hernandez, for their academic support and advice during my research and the completion of the Thesis.

I also want to express my gratitude to my fellow researchers at the Post Graduate Research Lounge for their constant help with my computer.

Finally, and Most importantly, I am thankful and grateful to my Wife and family, for their constant support and encouragement.

Key Acronyms

OECD	Organization of Economic Co-operation and Development
R & D	Research and Development
ECN	Energy Co-operation Network
UNDP	United Nations Development Programme
NERC	Nigeria Electric Regulatory Commission
NEPA	National Electric Power Authority
REF	Rural electrification fund

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CHAPTER 1

Introduction

1.1 Background

In the field of energy utilization, a series of objects can be brought together successfully to achieve a composite result. This is how a number of indicators are brought together to generate a larger comprehensive end result. The reason for quantifying and simplifying this system, is to understand its complexity in the field of energy utilization

In 1993, the OECD defined indicators as the value derived from different sources to give information concerning a system. However, this definition is not all encompassed as in real-world scenario. Indicators as we know it, never actually represent reality. This usually follow the truth, in processing multiple data.

Generally, indicators are known to be popular in various fields of work. Examples of these are, in the field of energy utilization, environment and many more. Energy indicators are extensively used for correlating energy.

The basic type of indicators depends on usage, to a particular kind of activity, known as intensity. This gives the advantage in comparison within similar activities. It enable potential monitoring to be carried out on the evolution of corresponding information in time. In accordance to Patlitzianas and Psarras, when energy indicators are used, they can reveal some important information.

For instance, they can reveal information like the characteristics of energy market. This is even so, when the analytical data are not available. The sustainable renewable energy policy is known to be directed by security of supply. Similarly, the competitiveness of energy industry, couple with environmental protection are equally directed by the same security of supply.

This is stationed on European Union with energy objectives. According to Kagiannas.A.G et al., energy indicators are known to be very useful energy policy tools. This is used for supporting the procedure of decision making, and can also be used as guide for making decision.

Indicators are equally used for monitoring the evolution of policies already implemented. These are the indicators that allowed communication between the policy makers, the analysts, and the Citizens. According to the OECD specifications, all indicators must be as clear as practicable, and this can be very helpful to the policy makers:

- Monitoring the targets that are already set by national and international level
- Estimation of polices impacts that had already been implemented
- Planning of the future policy actions, establishing the priorities, recognising the basic key parameters that can influence the energy market.

It is the use of energy indicators that enabled communication between the policy makers, the analysts and the citizens. These indicators as specified by the OECD, should be well understood and acceptable to the above stated actors:

Indicators can be used for measuring the influence of changes in the energy demand. It can also be used for changes in all activities using energy.

In addition to this, indicators can help to show how the use of energy is related with the economical and technological parameters. This can also show the energy prices, the economy's evolution, and the new technologies.

Similarly, there are the indicators and the comparisons which they provide. These are both in country level and internationally. They provide the analysts with the ability of comprehension of changes.

These are the changes that involve the relative policies and strategies This project's approach was adopted and incorporated in the desk analysis for the review in the investigation of the role of the international developers.

The development and proposed methodological framework of this project, is the objective of the integrated review of the methodologies of the energy indicators.

This recommends an operational framework of appropriate indicators supporting the policy makers, analysts and citizens, towards the sustainable energy policy making.

The second part of this project is devoted to the review of widely spread indicators, methodologies and the related activities.

The third part is devoted to the recommendation of an operational framework of energy policy indicators towards sustainability. Finally, in the last section the main points drawn up from this project are summarised.

1.2 Aim of the research

The main aim of this research is to develop a framework for the implementation of energy indicators used for measuring or estimating parts in the field of energy utilization. These energy indicators are extensively used in measuring parts in the energy sector, thereby revealing gaps and needs for amendments.

1.3. Objectives of the research

- To carry out literature review on all aspects relating to the key elements of the energy indicators design.
- Identify the critical issues affecting the energy indicators implementation by way of comprehensive questionnaire; by taking advantage of the literature review, including the available empirical research in the field.
- Carry out a detailed quantitative and qualitative analysis on the data collected from questionnaire.
- Evaluate and develop a framework for the energy indicator implementation. To ensure the production of environmentally friendly products.
- Evaluate the above and upon conclusion of this recommend further research work, where applicable.

1.4. Scope of the research

In this research, the scope of energy security has expanded, with a growing emphasis on dimensions such as environmental sustainability and energy efficiency.

Hence the overall, scope of this paper is to highlight, examine in detail,, discuss and finally ensure,(while evaluating) energy security.

1.5 Organization of the Dissertation

The report is organised as follows:

Chapter 1 presents an overview of the entire research. One of the challenges faced in this research project includes, the “ indicators policies “ as already highlighted. Research aim and objectives, scope and organisation of the report are also considered.

Chapter 2 presents a comprehensive electric power renewable energy policy in Nigeria. The electric energy policy is being reviewed, and then examined for the purpose of adjustment to ensure fair electricity distribution within the population. This has been an outstanding problem to the nation, and the rural dwellers are now eagerly waiting for their own shares.

Chapter 3 gives a comprehensive detail of the energy supply chains; discussion centres on system performance, application barriers, and strategies for further development. Moreover, the chapter centres on renewable energy, as a result of the recent decline in dependence on traditional fossil fuels to improve climate change which is heavily depleted.

Chapter 4 discusses the barriers to renewable energy development. The benefits of renewable energy are highlighted. The chapter further considered the several examples of barriers that includes, conversion cost, location selections, and distribution network.

Chapter 5 considered areas of improving renewable energy supply chains. Government and private sector energy policies are discussed with emphases on research and development.

Chapter 6 gives the conclusion of the present research

CHAPTER: 2

Renewable Electric Power Energy

2.1 Introduction

It was in 2004, that the National Energy Policy provided a framework for the optimal use of the country's energy resources. This took the form of both renewable energy and conventional resources. It included, as stated below:

- Ensure adequate growth of the country's energy resources, with varying energy resource options, for the implementation of national energy security, efficient energy supply system and a balanced energy mix,
- Ensure increased contribution of energy productive activities to federal income,
- Guarantee adequate, reliable and sustainable energy supply at competitive costs and in an environmentally sustained manner, to the different segments of the national economy for substantial development,
- Ensure an efficient and cost-effective utilization form of energy resources,
- Speed up acquisition and dissemination of technology and managerial competence in the sector and strengthen local content for adequate stability and self-sufficiency,
- Promote increased investments and expansion of the energy sector industries with significant private sector participation,
- Develop a comprehensive, integrated and well-defined plan for the sector and initiate successful developmental programs,
- Promote international cooperation in energy marketing and projects developments in both the African continent and the entire world,

- Manage the nation’s abundant energy resources to promote international cooperation.

2.2 Sustainable energy development strategies

One of the major strategies to meet energy demand is through the adoption of energy-efficient appliances. The ECN/UNDP through their project, has completed energy efficiency and the conservation plan. This is carried out in order to reduce the energy consumption at the residential sector. By so doing, it is to ensure the replacement of incandescent bulbs with the energy saving bulbs, also referred to as compact fluorescent lamps CFL

This is as a result of the commission’s recognising the fact that lighting alone takes more than 18% of the total power consumed in the residential sector. The knowledge of this came from the comparison of about 8 to 11% survey carried out in the advanced countries.

As a result of this, it was then projected that Nigeria needs about 50 million CFL’s to replace the incandescent lamps in the residential sector. It is considered that with this replacement, a saving of approximately 1,500 MW of electricity can be achieved. However, other efficient master plan includes, the phasing out of backward generating capacity that are having low efficiency.

Rather, it was decided to invest on the smart grid. This would enhance the electrical equipment through the technological innovation for the improved energy efficiency. It then introduced a national building codes, including the establishment of the federal efficiency standards. This was to reduce electricity consumption, ensure appliances labelling and certification. Also, to include energy conservation, and management in industries.

Furthermore, the following sustainable strategies were then pronounced according to the Renewable Energy Master Plan (REMP) viz the need to move from a fossil economy to one driven by a growing reliance on renewable energy. Harnessing said energy resources in a manner and price, that should support the implementation of equitable and sustainable development going forward.

It is within this framework, that the projected energy demands in the sectors of the economy are presented as shown in Table 2.1 below. This Table 2.1 is based on the 7% growth rate to meet with the growing demand. The aim was to get solar contribution of 5, 75, and 500 MW to the energy mix structure in 2012, 2015 and 2025, respectively. While, the wind power contribution is set at 1, 19, and 38 MW for the same years for short term and long term in both cases.

Table 2.1: Projected sectoral energy demand based on 7 % growth rate

Sector	2010	2015	2020	2025	2030
Industry (%)	28.92	37.01	40.75	14.69	48.78
Transport (%)	27.62	24.56	22.92	22.27	21.62
Household (%)	38.16	33.05	30.62	27.27	24.12
Service (%)	5.30	5.39	5.72	5.78	5.49

2.2.1 Patterns of energy expansion strategies

The government expansion strategy in the energy sector includes the integration of the energy resources that are non-fossil into the energy mix structure. Renewable energy is expected to contribute about 14, 23 and 36% for short, medium and long term of the overall energy and electricity supply in Nigeria by 2030. The targets for these renewable energy production are as shown in Table 2.2 below.

Furthermore, the wind energy resources in the short term will require an increase of more than a hundred percentage to produce 30MW in 2015 and 40 MW in 2030. Although some of the wind power projects are already known to be existence and operational, but only on a small scale. It is the solar energy photovoltaics installations that are certainly on the increase. About 1 MW total dispersed installations are known to be going on in all over the country. They are yet for low energy applications, such as water pumping, street lighting, vaccine refrigerators, and community lighting.

Table 2.2 : Targets for renewable power generation MW in Nigeria

Resources	Short term 2008	Medium term 2015	Long term 2030
Hydro (large)	11,259	15,930	48,000
Hydro (small)	3,500	7,430	11,900
Solar PV	5	120	500
Solar thermal	–	1	5
Biomass	–	100	800
Nuclear	–	1,000	4,000
Wind	1	30	40
All renewable	14,765	24,611	65,245
All energy resources	17,000	30,000	190,000

2.3. Energy Generation and Distribution Issues in Nigeria

Nigeria is known to be the largest and most populated country in Africa. This is a fast-developing nation, and a major player among the oil producing countries in the world. The country’s energy consumption has been on increased within the last three decades.

The energy consumption rate increased by 3.6% in 2011 over 2010, resulting in total energy utilization of about 4.4 quadrillion with the traditional biomass. Biomass, as a waste, contributes to about 82% of the overall energy consumption. The estimated conventional energy reserve in 2011 stood at 2.7 billion tons for coal, 37.2 billion barrels for crude oil, and 5.1 trillion cubic meters for natural gas.

The country is known for its rich naturally resources in vast deposit including renewable energy resources. Key challenge facing the energy sector is the imbalance in energy demand and supply. This is dependence on the external energy resources for domestic consumption, low energy efficiency, and environmental pollution.

Therefore, in a bid to address these problems, the government has introduced several strategies including reduction of energy consumption in the residential and industrial sector. These strategies serve as effective energy conservation and management system, which is with the integration of renewable and clean energy resources implemented in a sustainable way. Moreover, such strategy is to enable it to achieve the total energy mix. Within this new policy, the energy demand and supply is needed to balance the economic development, social development, and the eco-friendly protection

2.3.1 Electric renewable energy policy

Nigerian electricity regulatory commission, NERC, is to serve as the main regulatory body of the reformed electric power sector. This is to act as an independent body, with seven full time commissioners to be chosen from both public and private sector, (BPE, 2002a).

The settings and selection of criteria for the commissioners is known to be expressly stipulated.

This is well embedded in the power sector reform act in the current review and the responsibilities of the (NERC) include as follows:

- Licensing of the successor power companies
- Establishment of the electricity tariffs
- Enforcement of performance standards, and
- Protection of the consumer rights (BPE, 2002b).

2.3.2. Rural electrification fund

Rural electrification fund, REF, is a Nigerian-based agency saddled with the electrification of rural areas. This is expected to facilitate the expansion of the electrification of rural and unserved areas within the country, which should be rapid and cost-effective. (BPE,2002a).

REF' main responsibility lies in the promotions, support and provision of rural electrification programmes via public and private participation. This is geared towards achieving more equitable regional access to electricity, thereby maximising the socio-economic and environmental benefits of rural electrification subsidies. By this process, the expansion of grid and the development of off-grid electrification becomes a necessary requisite, which consequently stimulates innovative approaches to rural electrification.

To achieve these objectives, the agency will have to set up an administer, that would carry out the following responsibilities including:

- Development of fund proposal to consist of electricity levy on customers, federal subventions, states funds and donations from international agencies.
- Inclusion of private companies, community contributions and the interests and other benefits accrued to the REF.

2.3.3. Key objectives of reform energy policy

One major task of the reform is to ensure the maximum benefits, that is, the complete corporatisation of the electric power industry. This would enable energy supplier to acquire commercial orientation and be able to generate surpluses to ensure long term growth and achieve cost competitiveness to increased customer focus.

This invariably implies complete separation of the utility enterprise from the government agencies plus the adoption of a private rights statue and recognition of greater autonomy for the company (Berg, 1998, Girod and Percebois, 1998).

In the present scenario where power generation and distribution is deemed as government responsibility, that is, power needs to be distributed by the government. An attempt to account for the true social cost of electric power production is usually met with stiff public resistance because Government lack the courage of taking decisive action in such situations. Therefore, they are unable to implement other reforms that would enhance efficiency and viability of the power sector.

A new regulatory body, National Electricity Regulatory Commission, NERC remains a main regulatory body that oversees the activities of the electric power industries by ensuring equity in pricing. They have the responsibility of ensuring wider access to electricity across the populace in order to achieve a good practices among the companies. This will, therefore, ensure the required independence and composition. It is worth noticing that tackling the low access to electric power and severe power outages affect the Nigerian economy in so many ways.

Although, earlier study shows that there is considerable reform in economic generation capacity and financial performance in many parts of Africa. However, the needs for the increased electrification of the poor and increased the local participation in the power sector still needs urgent attention, Karekezi and Kimani, 2002. In the case of Nigeria, it is only 10% of the rural households, and approximately 34% of Nigeria's total population that currently have access to electricity, Adeoti et al., 2001.

It is with the preview of significance of provision of REF that the Electric Power Sector Reform Act was evaluated. Whilst the shape and form of the fund is still under deliberation, decision is often guided by an understanding of the nature of the natural electrification problem. As stated above, there is clear evidence that low rural electrification is known to be caused by a variety of factors including financial and technical factors.

However, it is hoped that in all probability, the privatisation exercise will solve the financial problems. This is expected to bring in fresh injection of capital into the sector. In addition, privatisation of the power sector would bring a sort of contribution towards the rehabilitation of the old facilities and the acquisition of new ones. By doing this, would increase the access to unserved rural areas.

Furthermore, this would contribute towards the modernisation of the electric power sector generally. To ensure the sustainability of a solvent cash flow, the emergent utility company should increase its tariff collection rate and minimise losses via the "ghost-consumers".

From the technical side, the focus of investments would be generation of utilities. This was in the past manifested to bridge in the huge gap, between the installed and the used generating capacity in the country. However, there is still a need to shift the focus now to the transmission and distribution. The transmission network has to be extended and modernised. This is to enable all the power plants to be linked to the high power grid lines that can maximise the generation capacity. Obviously, this should in connection with the various generation plants in the country and then minimise the outage power.

While social costing of electricity is advocated in this project, the policing of tariff by the appropriate government regulatory agency, which in this case is NERC, is also vital to minimise excessive tariff charges. Beside the implication for the poor, excessive tariff charges could encourage the inefficiencies among the utility companies, as it would give the illusion that any inefficiency in cost minimisation can be transferred to the consumer.

Hence, discouraging efforts to improve cost performance at generation, transmission and distribution, (Badelt and Yehia, 2000).

The use of regulatory provisions to nudge utility operators towards social objectives is very common in the developed countries. For example, in the United Kingdom, the non-fossil fuel obligation NFFO requires the regional electricity companies in England and Wales to secure specified amounts of electricity from the renewable energy sources Street and Miles, 1996. There are also instances where the specification of emission quotes for electricity generating companies was used to drive efficiency of generation Eikeland, 1997.

Although, environmental concern is not an immediate agenda on Nigeria's electric power reform. However, the opportunities offered by the process for laying solid foundation for the sustainable development of the electric power industry cannot not over-emphasised. This includes the promoting of the energy efficiency in electric power production and consumption as well as instituting a programme for increasing the share of the renewable energy in the electric power generation.

One clear step in this direction is in the setting of goals and timetables for the increasing of the share of renewables in the electricity power supply mix. However, the present dependence on fossil fuels for electric power generation must change.

This is to allow the long-term environmental sustainability objectives to be realised.

Various studies have demonstrated the efficacy and suitability of renewable energy for African energy needs. Martinot 2000 reported the success of a GEF solar project in Zimbabwe, which provided lighting for over 10,000 households. In a similar report from Kenya, were between 20,000 and 40,000 small PV systems are installed between 1986 and 1996 Acker and Kammen, 1996.

Other studies showed consumer satisfaction with renewable energy. Van der Plas and HanKins 1998 are known to have carried out a survey among the actual users of solar electricity systems in Kenya. These results are known to have a general satisfaction among users, and their willingness to recommend the solar electricity to friends.

By building on this experience, the Nigeria's reform program should incorporate measures that will encourage the development of de-centralised renewable energy powered electricity. This is especially in those parts of the country, where houses are known to be situated far from each other. In such a case, making extension of grid electricity uneconomical.

Also, this provides a veritable avenue for increasing the access to areas where gird electricity is difficult. This is where the potential contribution of solar photo-voltaic based rural home electrification application towards this objective has been well recognised Bugaje, 1999, Adeoti et al, 2001

To ensure energy efficiency and renewable energy development in Nigeria, a tariff reform in the electric power sector is necessary to remove the subsidy on the electric energy prices. It is the subsidisation of fossil fuel-based energy sources, that is known to be impeding the energy efficiency.

This also contributes to the slow pacing of transition to renewable energy sources (Birol et al., 1995). As have stated earlier, this tariff reform should not be in such a way as to penalise the poor and small businesses. What is needed should have been a progressive tariff structure that will guarantee the access to a minimum amount of energy to the lowest income earners.

It is the taxing of the increasing consumption beyond the minimum level that should be well considered. Also, the money realised from the increased tariffs, should be directed towards further enhancement of the quality and efficiency of the electric power sector.

Similar strategies have been used to a resounding success in many developed countries. For example, in the United Kingdom, much of energy conservation projects in the electric power sector were funded through a £1 annual levy on each of the domestic consumer collected.

This is carried out through the Public Electricity Suppliers PES. It is this channel that distribute electricity in Great Britain. The PES are required by the government to spend £100 m over a period of four years on domestic energy efficiency schemes under criteria as laid down in the Standards of performance (SOP) programme OFFER, 1994.

By borrowing a leaf from this, the Nigerian government can institute a standing regulation, requiring the utility companies to re-invest the extra income generated from the increased price of electricity towards developing and expanding the share of the renewable energy sources in electricity generation.

The current initiative is being carried out by both the Nigeria Energy Commission, and the Solar Energy Society of Nigeria. They are working towards the development and implementation of solar power systems. This is to ensure meeting the needs of the rural villages, including the communities that are not currently served. However, the NEPA power gird is thus a step in the right direction.

Thus, this focused initiative, on renewable energy, should also be directed to exploit Nigeria's massive hydropower potential. This already, has been estimated to be in the region of about 36,000 GWh/yr (IEA, 2001). The development of this, should be at a relatively low-cost. It should be the small-scale hydro-electric sites. This is as opposed to the environmentally destructive large-scale projects.

There is also a particularly worrying feature of Nigeria's electric power sector that also need to be addressed in the form of exercise. This is in its peculiar dependence on inflows from external sources for its hydro-power generation.

The three major hydro-power stations are known to be constructed along the River Niger. This has its origins in Guinea and courses through Mali and Niger Republic, before flowing into Nigeria. This definitely portends serious energy risk to the country. As it leaves the fate of hydro-electric power production entirely at the mercy of the external factors. However, towards tackling this issue, it has been suggested that the country should initiate the formation of an International Basin Authorities involving countries. These are the countries from which the inflows originate.

Another area where action is required in the reform process, is in an assessment of the potential impact of climate change on electric power supply. There is the possibility that climate change may have a tremendous impact on hydro-based electric power systems of many sub-Saharan African countries which includes Nigeria (Greoc et al., 1994; Ikeme, 2003).

But on the demand side, may distort the expected load, and peak on demand pattern. It may even cause a reduction in the reservoir inputs, on the generation side. The preliminary studies by Gbuyior et al. (2001), show that climate change is already having some negative impacts on water availability for Kianji dam, Nigeria's first hydro-power dam. This suggests that greater understanding of the interplay between the climate change, and Nigeria's electric power sector is necessary.

This is for the formulation of any effective and sustainable electric reform strategy Workshops and research exploring the dynamics of climate change, with the electric power supply in Nigeria deserve the support from the reform agency. The electricity supply reform appears to have dominated in this project. However, it must also be realised that efficiency in the electricity generation and supply that is not accompanied with sustainable consumption at the end use will yield minimum fruit.

Hence, policies that would encourage electricity end-use efficiency should be formulated side-by-side with the supply side reform.

Also, in addition to the removal of subsidies, the educational programmes that will enhance the awareness among consumers appear intuitively appealing. In the same vein, the Standards Organisation of Nigeria charged with quality control of imports to the country should be re-organised and re-awakened to its responsibilities.

This is especially with regards to controlling the quality and efficiency of energy consuming appliances that is imported into the country. The current situation where Nigeria is made a dumping ground for obsolete and inefficient electrical appleades not augur well for the sort of effective electric power reform Nigeria aspires to achieve.

2.4 Electric power

This project has reviewed the issues surrounding Nigeria's electric power reform. The key observation in the analysis is the importance of the reform. This is for sustaining economic development and poverty alleviation in Nigeria. As a result, this is mainly because of the strong correlation between the increase in wealth over time and the increase in the electricity consumption. This is found in the experience of the developed countries.

The analyses clearly showed that the long-term success of Nigeria's reform campaign will depend on how far the reform process goes in laying a solid foundation for the sustainable development of the electric power sector.

This agrees with the social, economic, and global environmental objectives. It is suggested that the reform process should be all encompassing and transcend mere disengagement of the government.

This was to include tight regulatory framework that will confine the operations of the emergent utility companies. Which should be within the overall economic, social and environmental objectives of the country.

The main objectives of the reform should include the Corporatization of the electric power industry.

Also, increasing the power delivery capacity, constraining the costs of the power industry, and increasing efficiency. Increase the share of the renewables in energy generation, as well as minimising the environmental damage.

It is also recognised that efforts at reform will not yield the desired result if the current end-user inefficiency is not constrained.

The educational and promotional information seem to be intuitively appealing. As Nigeria implements its national privatisation programme, it is hoped that this will benefit the policy makers, emerging managers and providers of electricity service in the country.

Chapter 3

Renewable energy supply chains, with application barriers and Strategies for further development

3.1 Introduction

For many centuries, fossil fuels have been the only means of energy use in both our dwellings and places of work. This has been going on, for years. However, recent events like climate change and the depleting of fossil fuels, tells us that the traditional energy is gradually running out. We as Human beings are fully aware that without the use of energy, life will be extremely dull to live in.

Hence, our alternative is to quest for a sustainable renewable energy. This is the energy globally known as user friendly. It does not pollute our earth, as does the fossil fuels; and does not harm us in usage, as does the traditional.

Globally, fossil fuels is now losing its advantages as a result of the environmental and economic concerns. Sustainable renewable energy is now becoming energy of the future, with the effort to preserve the earth. This could be defined as a free source of energy, and typical examples of this are the wind and solar energy. During their conversion process, they do not produce any negative effects.

The not long-ago eco-consciousness set up in a number of countries, is now fixed as an example for the improvement of renewable energy. This is particularly to ensure its efficient use in changing to useable energy. What posed barriers to such development includes, such a large cost for its conversion, restricted spaces, and other factors. In order to overcome these obstacles, external institutions including the National government is recommended to work together.

This project looks into the renewable energy from the supply chains perspective. It shows the values of each node that flows in the system, which include restrictions and break-through points. The comparison is with the electric power system. It is this, that enable the project to present the objective of the study. As a result, this then examines the four main components of the renewable energy supply chains. This is to identify the values of each node in the flow. The limitations and break-through points are then compared, with the current electric power generation. This then presents the objective of the study, that examines the three main components of the renewable energy as follows:

- Renewable energy supply chain
- Renewable energy performance, and
- Barriers and strategies to its development.

This project is organised as follows:

- Section 2 enumerates the types of renewable energy; the renewable energy supply chains, that illustrates the flows and issues of the renewable energy supply chain
- Section 4 discusses the performance of renewable energy
- 5 Barriers to renewable energy development
- 6 Improving the renewable energy supply chain consider the barriers and strategies to the development of renewable energy respectively.
- Section 4 presents the conclusions drawn from the study.

3.2 Renewable energy resources

Many renewable energy resources have now been developed and successfully implemented. There is the secondary process, that converts renewable energy into other energy resources. This is required to fully utilize renewable energy in a variety of applications. This is the section that describes biomass, hydropower, geothermal, wind, and solar energy sources and process as flows:

3.2.1 Biomass

Biomass contains a variety of organic resources, such as wood and other plant-based materials from agricultural, forestry, and industrial waste. In order to convert this waste into usable energy resources and products, there are very many other technological processes that can be used. For instance, biomass can be converted, in order to provide an electric power source for automobiles.

Examples of these are ethanol, biodiesel, electric power, and plastics.

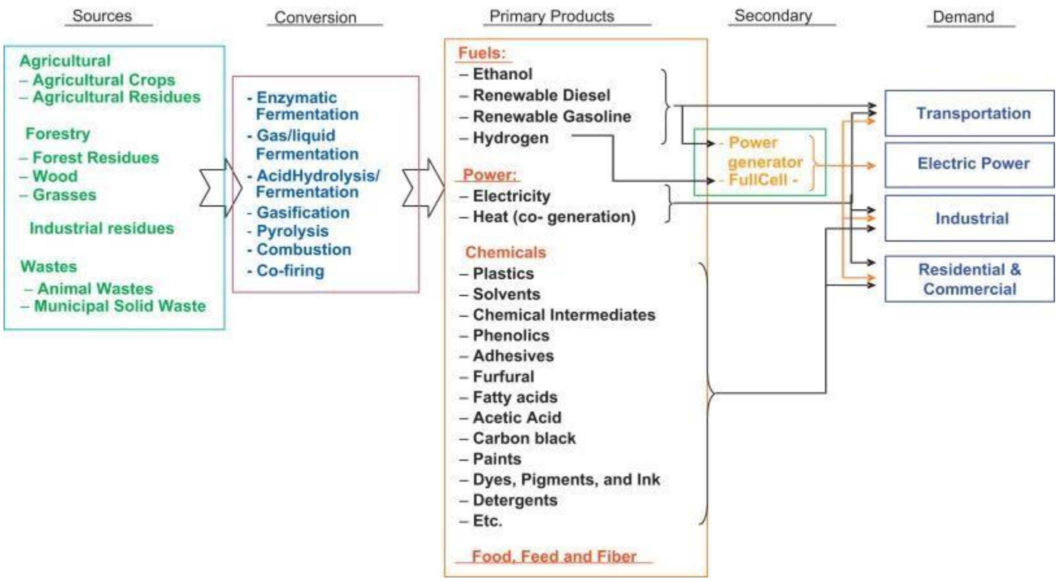

Figure 3.1. Biomass energy flows [2]

Figure 3.1 shows how the biomass energy flow. Ideally, it is understandable that by given different types of biomass resources, does not reduce its applications to the production of fuel or electricity. During its conversion process, the actual subsidiary products can still be produced.

In addition, Figure 3.2 below, also shows Biomass energy can be changed into fuel, electricity or heat, as shown in Figure 3.3. This is carried out by using, the three main conversion technologies. These are thermochemical, biochemical, and extraction processes.

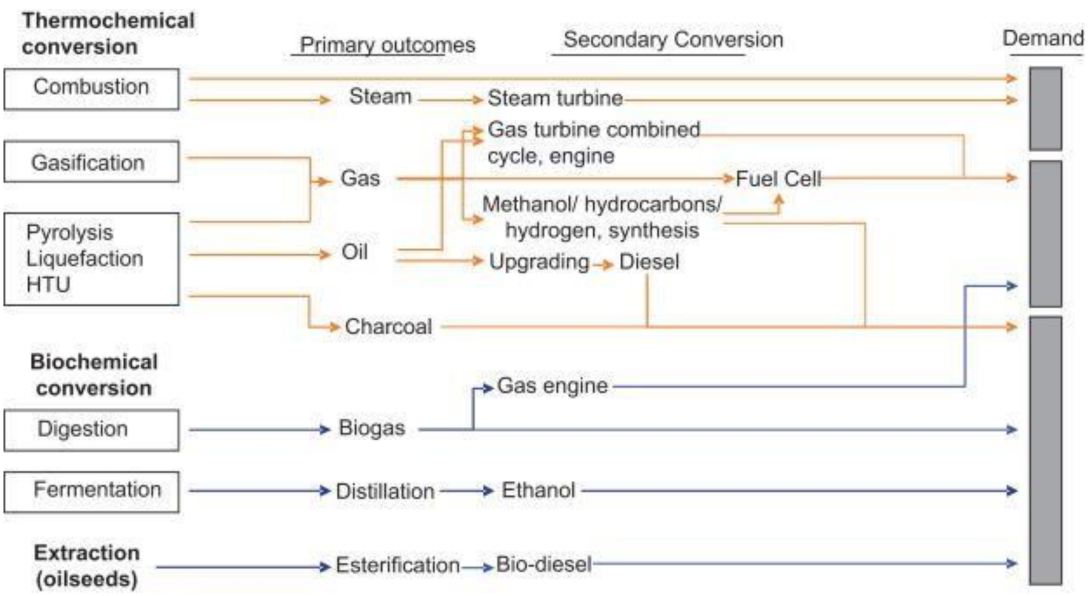

Figure 3.2. Biomass technologies and conversion outcomes [3].

3.2.2 Hydro-power and tidal renewable energy

Both rain and seawater are known to be very valuable in usage. The generation of electric power as a result of water flowing through the system or turbine is a typical example. Water is also heavily used in both industries, as well as domestic in our homes. In industry, agriculture may not survive without water. Similarly, in residential, our living may not be comfortable without water.

. It is generally known that tidal wave is constantly moving. They do not attempt to be stationery by themselves, unless if an external action act on their movements.

This is the obvious reason why storage system is required. It is this that enabled us to reserve energy during the off-peak hours. Figure 3.3 illustrates the hydro-power process as shown below.

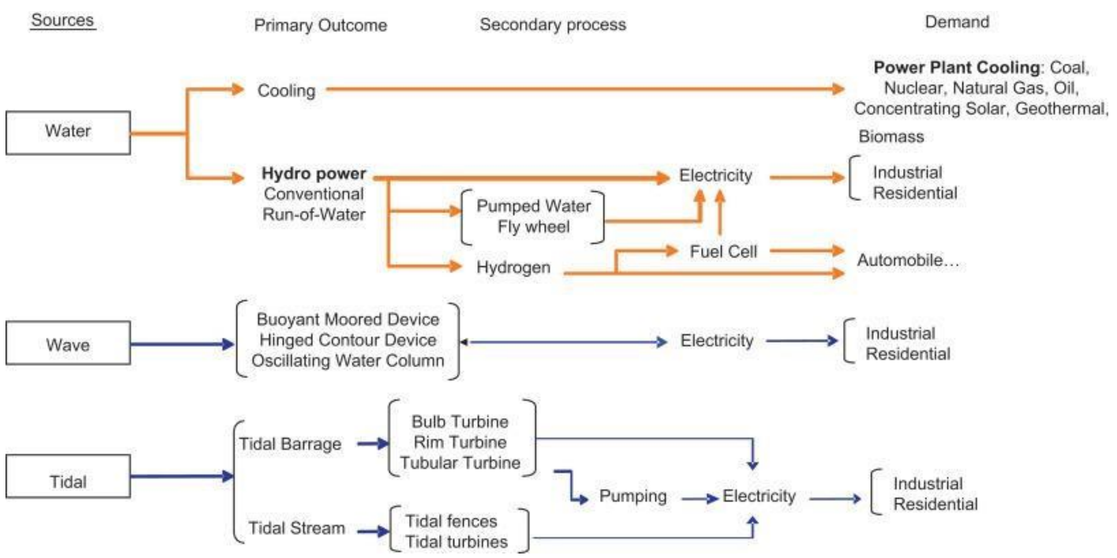

Figure 3. 3: Types of hydropower process flow [4 – 6]

3.2.3 Geothermal energy

Geothermal energy is normally dug out from earth. This is as a result of the energy stored between the earth's surface at a specific depth in the crust. It was Dickson and Fanelli that gave it this description. They are graded in accordance to the depth in which they are found. However, the components of geothermal include water, heat, and minerals. As we are aware, heat by itself can be converted into other forms of energy. Their utilizations entirely depend on the depth in which they are found. The different types of their uses is as illustrated in Figure 3.4 diagram below.

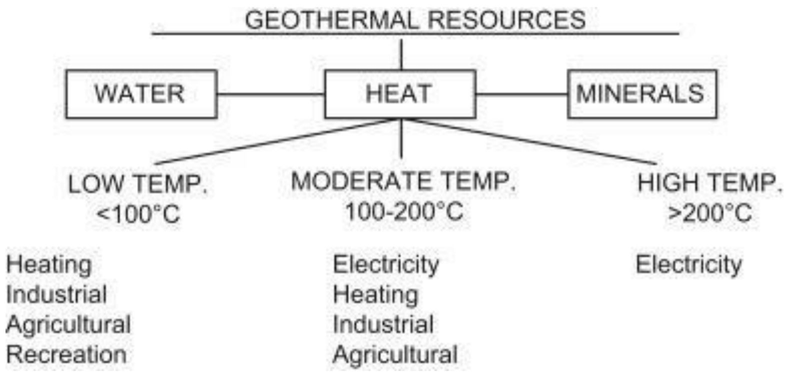

Figure 3.4

Components of Geothermal energy [8]

Apart from the direct utilization of resources of heat, compared to other energy sources; energy heat has to be changed from other forms of energy for industrial and agricultural purposes. The pump heat type can be reserved as geothermal energy, thereby tidying and balancing the low and high demand peaks.

This is the obvious reason why electricity is widely used for supporting both the residential and the industrial daily usage. Geothermal energy acquisition is known to be restricted to certain locations.

. This is to ensure the realization of its most efficiency outcome. The collection with conversion requires a considerable amount of investments as well. Figure 3,5 shows the flowing process of geothermal energy.

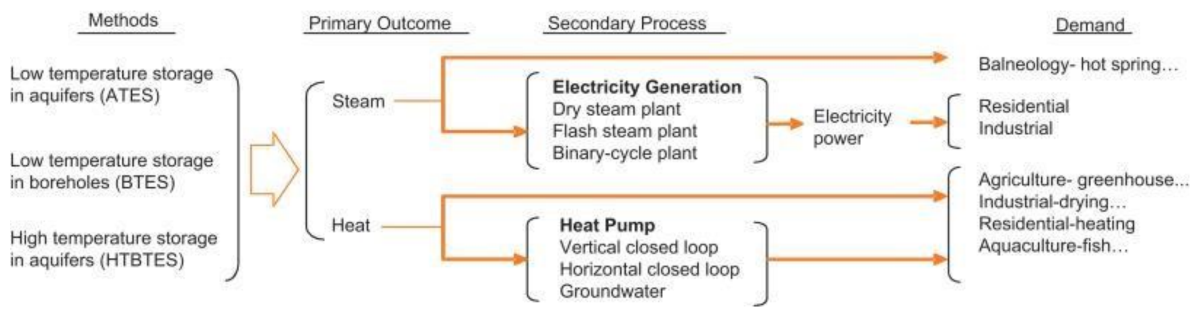

Figure 3. 5. Geothermal energy process flows [9 – 12]

3.2.4 Wind energy

The use of renewable wind energy is not necessarily new. For some time now, it has been used considerably for pumping water. Since the start of the sustainable renewable energy development, the wind turbines have been widely chosen for the generation of electric power. Most of these turbines are known to have been installed in offshore areas.

This is carried out, in order to ensure the collection of massive wind power. Also, this helps to lower the pollutive effects on the environment. Similarly, it reduces the amount of land installation. Furthermore, the smaller wind turbines have been developed to generate energy for both the rural and urban dwellers.

Somehow, occasionally, wind strength is known to be unpredictable and dynamic. Hence, this is usually stored and used to balancing the electricity demand cycles. In addition, wind energy can join other energy like hydro-power energy for a constant and stable energy source. Figure 3.6 bellow shows the wind energy generation flows

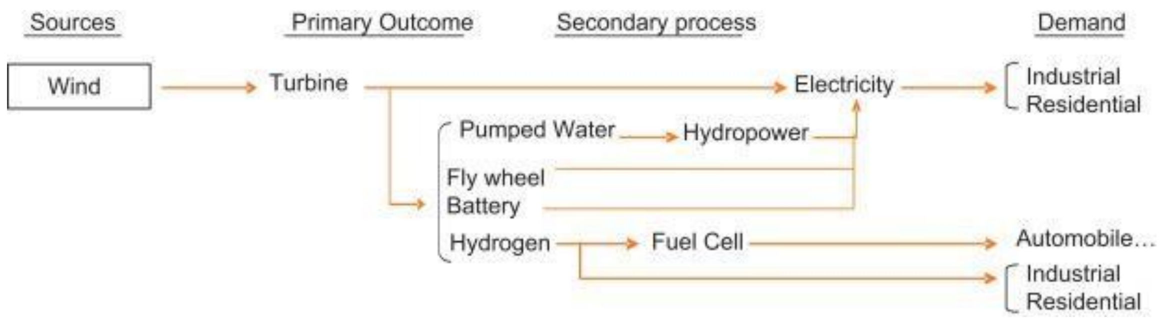

Figure3.6: Wind energy generation flows [13]

3.2.5 Solar energy

Solar power energy is known to be particularly important. This is the most widely used renewable energy. It is this solar radiation heat that is converted into solar energy. This is what is used, when generating electric power. Solar renewable energy source is abundant. Particularly so in the sub-Saharan and tropical countries.

Beside being used in electric power generation, solar energy is known to have been widely used to supply electric power to many personal portable devices. This renewable energy device source is more flexible than the other renewable energy sources. Its initial setup requires a relatively small investment. However, the use of energy storage is essential, since this is to supply the energy demands in the absence of sunlight. Figure 3.7 below shows the solar energy generation process flows.

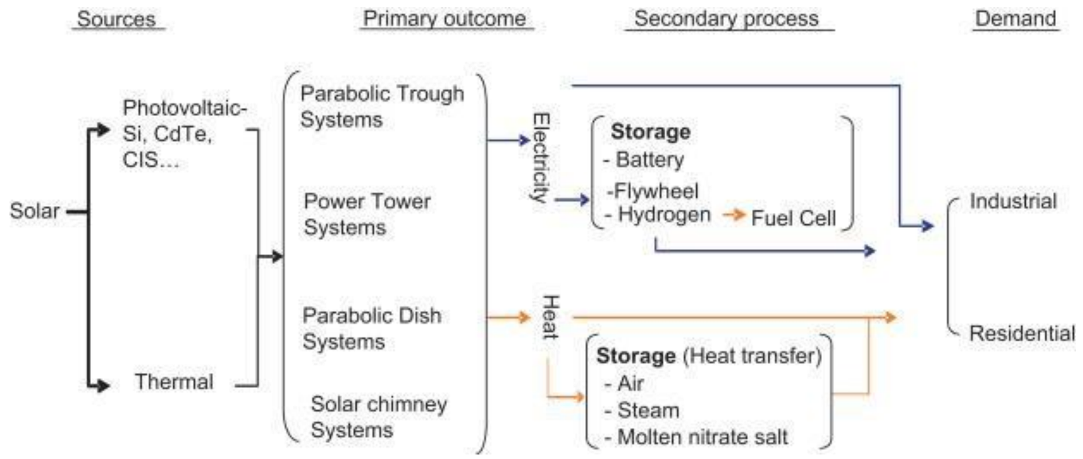

Figure 3.7 Solar energy generation flows [14]

3.3 Renewable energy supply chains

Renewable energy sources are known to be enormous and inconstant. This is known to be always changing, and very unpredictable. It is as a result of the uncontrollable weather conditions. There are also other factors that are included, in which the renewable energy resources are dependent. It is in view of this that the utilization and distribution of renewable energy are the major tasks, in the renewable energy supply chain.

3.3.2 Supply chain process flows

The elements of renewable energy supply chain include the physical information, with the financial flows. It is from this physical flow perspective, that industries are now increasing their awareness of green manufacturing processes. Their logistics and products have now greatly become relevant to the supply chain management performance.

These are the issues that have drawn the attention of very many researchers. This is as a result of the potential contribution of renewable energy, which is to the alleviation of the global environmental problems. Both Ilgin and Gupta have since reviewed the environmental conscious manufacturing, and product recovery researches. They have since classified more than 540 published studies, into four categories of research.

These are as follows:

- Environmentally conscious product design
- Reverse and closed-loop supply chains
- Remanufacturing, and

- Disassembly

A pure renewable energy supply chain flow is as shown in Figure 3.7 This is as presented by the United Nations development Programme. The electricity of the nation has been used to portray this example of the supply chain flow. This is to show the relationships within the loops. For the case of the renewable energy supply chain, the technology is the key success factor. This was to improve its efficiency, and to innovate the distribution network.

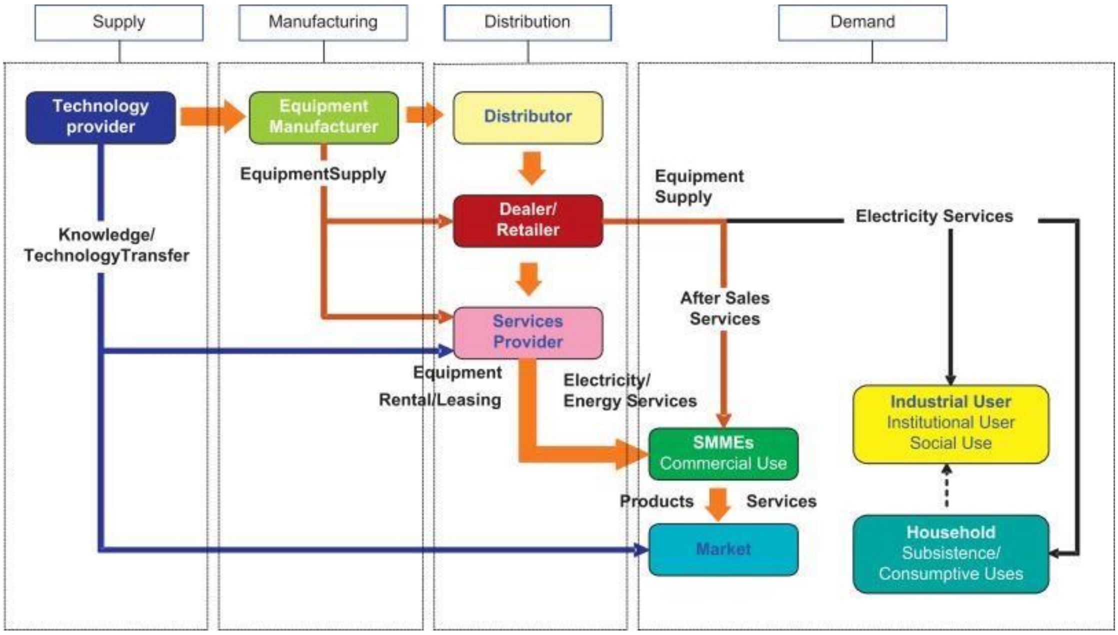

Figure3.7. Pure renewable energy supply chain process [16]

The commercialization of renewable energy in terms of demand, would be an important step taken to replace the traditional fossil fuel energy. In such case, the efficiency of the renewable energy generator and storage technologies, are the crucial innovations for the renewable energy.

3.3.3 Renewable energy supply chain issues

Each renewable energy is limited, by the inherent characteristics of the energy source. This is as a result of the traditional source, of the electric power generation the three key variables of renewable energy resources that require effective management and control, are the intermittency, variability and manoeuvrability. A second conversion process to save the energy for use in the off-hours is necessary, in addition to the nature of renewable energy. For each stage in the renewable energy supply chain, Figure 3.8 shows the factors used.

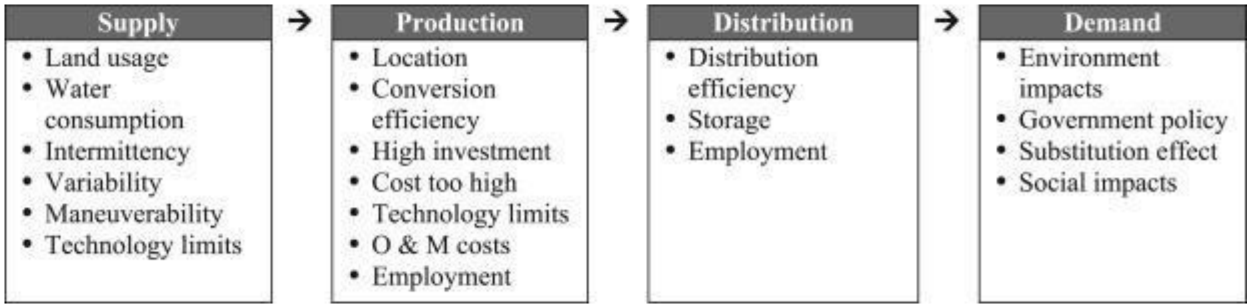

Figure 3. 8. Concerns of renewable energy [17 – 19]

3.4 Performance of renewable energy supply chains

The source of energy with other applications, are linked with the renewable energy supply chains. Hence, the performance of renewable energy supply chain, are known to be related to its conversion efficiency. This include storage, distribution, efficiency, and secondary applications efficiencies that relates to its conversion efficiency.

3.4.1 Conversion efficiency

That which is considered as a key indicator for the use of a given energy resource, is the conversion efficiency. Among the renewable energy, this is known to be differed. Costs associated with primary energy Sources such as from fossil fuels, are the critical costs associated with the primary energy. Presently, efforts are being made to reduce the cost of renewable energy acquisition with negative results. May be the technological improvements is not yet enough to compete with the fossil fuels production. The displaying of the energy technology cost and performance data that include all the renewable energy, is as shown in Figure 3.9 below.

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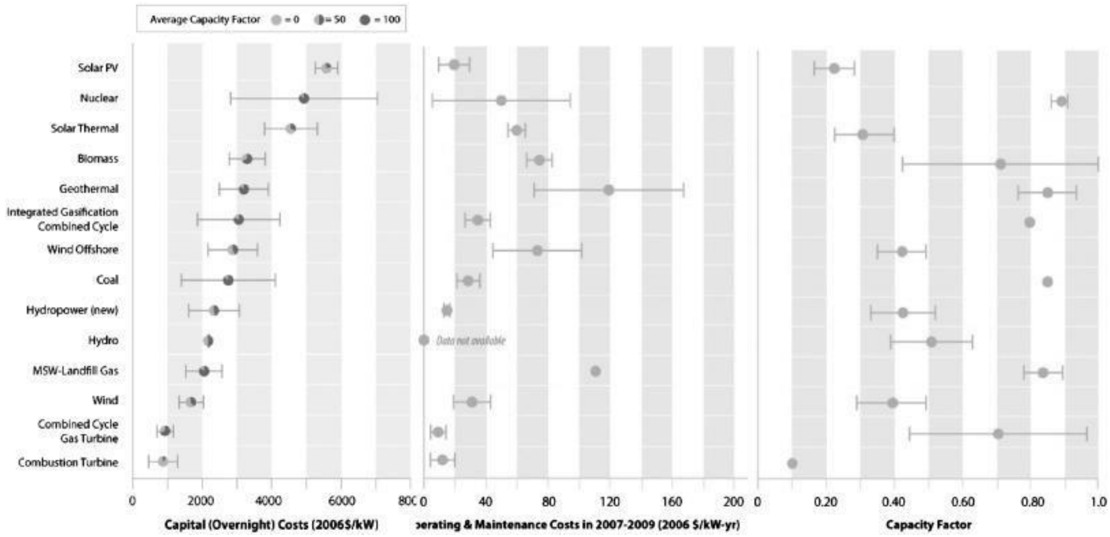
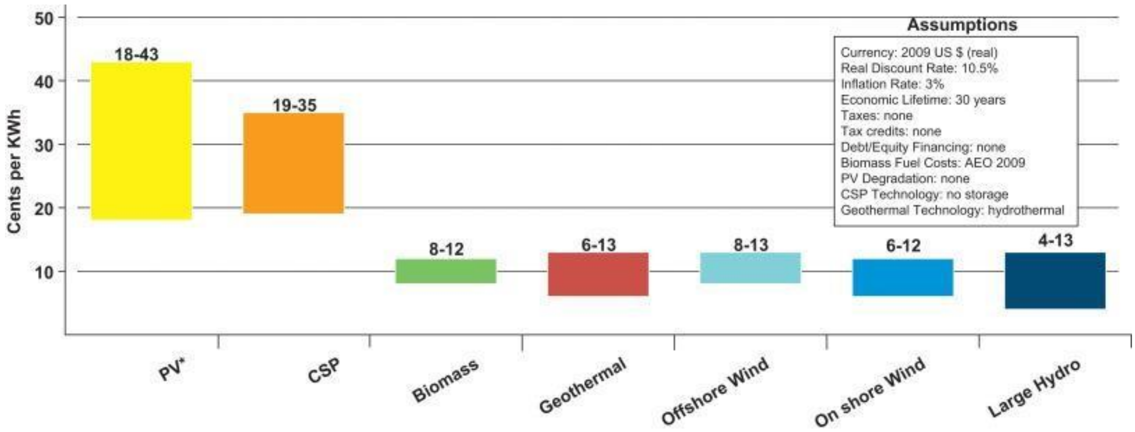


Figure 3.9. Energy technology cost and performance data [9]

In order to assess the investment for renewable energy, a levelized cost of electricity (LCOE) was engaged. This has been identified for decision making. It is frequently used in the field of solar energy project. United States Department of Energy's (DoE) Energy Efficiency and Renewable energy publication, has listed higher (LCOE) costs for photovoltaic (PV). The concentrated solar power for renewable energies, is as shown in Figure 3.10, In addition, renewable energies are not only assessed in terms of its performance and investment. Similarly, its environmental impacts are also taken into account.



Current range of utility scale (greater than 5MW) PV in the U.S.

Figure 3.10 Levelized cost of energy (LCOE) of renewable electricity by technology (2009) [21]

3.5 Technology

The furthered development of the renewable energy industry is as a result of the State-of-art technologies. It is the growth of this renewable energy and the conversion efficiency, that adds to the improvement of the technology. The industry requires the development of technologies such as this energy storage, fuel cells, and hybrid systems. It is this that enable renewable energy conversion processes, and expansion of renewable energy applications.

3.5.1 Types of storage technologies

According to Akorede et al., the classification of energy storage technologies can be carried out in more than one way. However, in this particular case, the classification is carried out as follows:

- Battery systems of energy storage
- Flywheels
- Magnetic superconducting energy storage
- Compressed air
- Pumped storage

It is the National Renewable Energy Laboratory (NREL) that categorised the energy storage into three stages as follows:

- Quality of power
- Power bridging and
- Energy management

A specific range of discharging times is then devised for each of them. It is this that enable each discharging times to be carried out precisely There are very many various factors leading to the selection of an electricity storage technology. Examples of this include as follows:

- Capacity storage
- Discharge duration
- Level power
- Time response
- Cycle of efficiency,
- Lifetime

According to Denholm et al, the choice of an energy storage device, depends on its application. For instance, this could be either in current grid, or in the renewable driven grid. It is their length of discharge, that these applications are largely determined. Table 1below illustrates a summary of energy storage and applications.

3.5.2 Classes of energy storage

There are three classes of energy storage, as shown through the recent works from the literature review. This is as shown in Table 3.1 below.

Table3. 1: Three classes of energy storage

Common applications	Example	Technology name	Discharge time
Power quality	Transient stability, frequency regulation	Flywheel, Capacitor, Superconducting magnetic energy storage	Seconds to minutes
Bridging power	Contingency reserves, ramping	Battery energy storage system - Lead-Acid, Ni–MH, Ni–Cd, Li-Ion	Minutes to 1 h
Energy management	Load leveling, Firm capacity, T&D deferral	Compressed air energy storage, pumped storage, high-energy batteries	Hours

3.5.3 Applications for fuel cell

It is for several purposes, that the fuel cell technology has been applied. Initially, the space exploration and military purposes were the earliest applications to be considered. However, following years of development, this has since been successfully implemented in the power generation.

Particularly in the automobile industry, where fuel cells have been used successfully in gas-electric hybrid vehicles. It is the different types of fuel-cells power generators, which are classified as alkaline fuel cells, polymer-electrolyte-membrane fuel cells, and solid-oxide fuel cells, that provide the various levels of power.

These various applications for each fuel-cell technology are largely based on its energy generation capability. This is the device type that include, the stationary, transportation, and portable devices.

Table 3.2 below presents the U.S. DoE’s comparison of fuel-cell technologies. .

Table 3.2 Comparison of fuel-cell technologies [20]

Fuel cell type	Common electrolytic	Operating temperature e	System output	Electrical efficiency	Combine d heat & power efficiency	Applications	Advantages
Polymer electrolyte membrane	Solid organic polymer poly-perfluorosulfoni	50−100 °C (122–212 °F) c	<1 kW–250 kW	53–58% (transportation), 25–35% (stationary)	70–90% (low-grade waste heat)	• Backup power • Portable power • Small distributed generation • Transportation, • Specialty vehicles	• Solid electrolytic reduces corrosion & electrolyte management t problem • Low temperature • Quick start up

Fuel cell type	Common electrolytic	Operating temperature e	System output	Electrical efficiency	Combined heat & power efficiency	Applications	Advantages
Alkaline	Aqueous solution of potassium hydroxide soaked in a matrix	90–100 °C (194–212 °F)	10 kW–100 kW	60%	>80% (low-grade waste heat)	• Military • Space exploration	• Cathode reaction faster in alkaline electrolyte, leads to higher performance • Can use a variety of catalysts
Phosphoric acid	Liquid phosphoric acid soaked in a matrix	150–200 °C (302–392 °F)	50 kW–1 MW (250 kW module typical)	>40%	>85%	• Distributed generation	• Higher overall efficiency with CHP • Increased tolerance to impurities in hydrogen
Molten carbonate	Liquid solution of lithium, sodium, potassium carbonates, soaked in a matrix	600–700 °C (1112–1292 °F)	<1 kW–1 MW (250 kWmodule typical)	45–47%	>80%	• Electric utility • Large distributed generation	• High efficiency • Fuel flexibility • Can use a variety of catalysts • Suitable for CHP

• High efficiency

Solid oxide	Yttria stabilized zirconia	650–1000 °C (1202–1832 °F)	<1 kW–3 MW	35–43%	<90%	• Auxiliary power • Electric utility • Large distributed generation	• Fuel flexibility • Can use a variety of catalysts • Solid electrolyte reduces electrolyte • MGMT problems • Suitable for CHP • Hybrid/GT cycle

3.5.4 Hybrid energy systems

The production of electric power and hydrogen simultaneously, is as a result of the hybrid energy systems. Within the green transportation industry, this system is known to have played a key role. Honda has already developed a solar hydrogen power station, to ensure the support of commercialization of gas-electric hybrid vehicles.

For the individual usage, similar systems are then designed. Also, to power the residential electric appliances, this can equally be used. Yilanci et al., described a solar-hydrogen hybrid system that has been applied to fuel cells, gas turbines, internal combustion engines, boilers, and catalytic burners to produce electrical, mechanical, and thermal energies. This is as shown in Figure 12

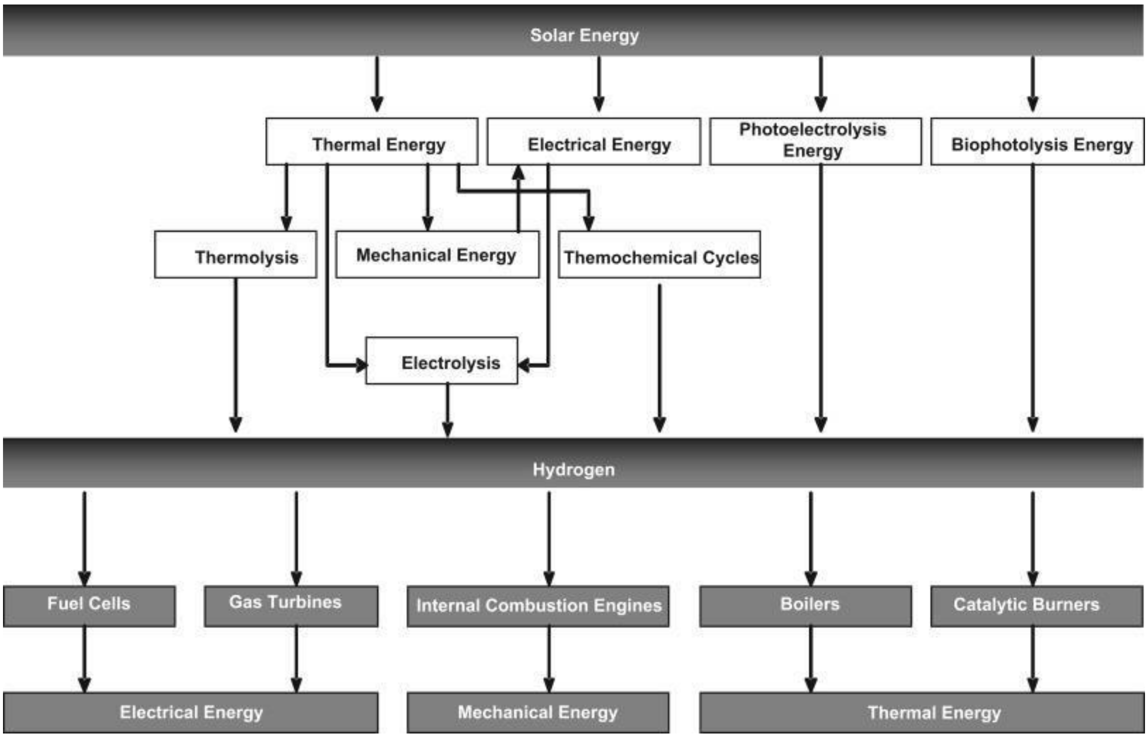


Figure 3.11. Production and utilization paths of solar-hydrogen energy [26]

Chapter: 4

Renewable energy development barriers

4.1 Introduction

There are enormous benefits, from the use of renewable energy. Particularly since this is a natural resource with inconsistent or limited availability. In this case, the installation of power-storage facilities in a variety of geographical locations is found to be very necessary. Undoubtedly, it is the development and utilization of renewable energies that faces very many obstacles. This definitely need the attention of both the producers and the utility end users. Like many other obstacles already solved, a solution to this, will eventually be found. The humans are always very good in looking for and solving problems. They usually arrive at the required solution, no matter how tedious.

4.2. Conversion cost

The primary and the secondary conversion processes are known as the conversion efficiency However, the major issue in the utilization of renewable energy, lies in the distribution. It is for this that a solid arrangement will have to be made, to ensure adequate deliveries. On the other hand, lies the costs of the energy generation. The range of the associated energy-generated costs are known to be such large investments. It is in view of this, that a lower conversion cost should be arranged This will then enable the penetration into the market.

The current conversion costs of renewable energies cannot compete with the traditional energy. This is true, because we have invested heavily on the fossil fuels. This has been going on for centuries Currently, fossil fuels are very reasonable for heating our homes and offices. It is the investment we started centuries ago, that we are now enjoying. However, the renewable energy could not compete as a result of its initial investment. But as time progress, changes will follow. This is when we will start to enjoy renewable energy. One of the methods to illustrate the differences of each energy source is by using its coefficient efficiency. This would then give us the ratio of the output energy to the input of energy, which is what is required. Table 4.1 below presents the efficiency coefficients for each type of the power plant. This is cited from the International Atomic Energy Agency, 2002.

Table 4.1. Efficiency coefficient of power plants [27]

Type of power plant	**Efficiency coefficient (%)**
Coal/lignite	39.4
Oil	37.5
Natural gas turbine	39
Natural gas combined cycle	54.8
Nuclear	33.5
Type of power plant	**Efficiency coefficient (%)**
Hydroelectric	80
Wind	35
Solar photovoltaic	9.4
Biomass	28
Geothermal	6

The fossil fuel in this process, is seen to be linked with the prices of the electric power. Hence, this is seen to be affecting and influencing the selling prices directly. This also have similarly influenced the consumption of the renewable energy. Globally, government policies are known to have been implemented in very many countries. It is to ensure the improvement of the gap between these prices through tax refund. Figure 4.1 below shows the sources of income for the renewable energy generators

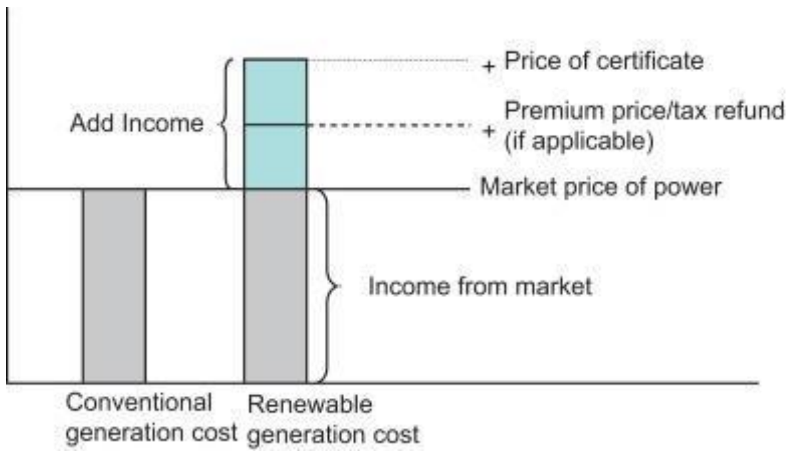


Figure 4.1 Sources of income for generators [28]

4.3 Selections location

The technologies and facilities for renewable energy conversion, should be located near their natural sources. Each of the renewable energy facility should be installed in a strategic location. This will ensure the maximization of the energy collected. Although, it is well known that some of renewable energy sources have considerable geographical constraints. For example, geothermal resource is known to be available primarily, in an area called the “ring of fire” This is usually found along the major plate boundaries where earthquakes and volcanoes are concentrated.

The tidal-energy generators should be located at coastlines or riversides. As we are aware, this has to do with wind. Hence, the wind turbines should be employed and installed. This should be placed, in locations with strong winds. The photovoltaic (pv) solar-cell facilities should be located in high-radiation zones. No disturbance should be allowed to interfere into its operations. Renewable energy facilities should be placed in locations that ensure the provision of a sufficient and continuous resource supply.

This location selection is known to be extremely important. It is the same as the determination of the best location for manufacturing products. However, this involves the consideration of significant costs. A typical example of this is the transportation and storage costs. Similarly, locations that are further away from the market entail higher costs. Figure4.1 below shows the locations of solar radiation zones and the "ring of fire" around the Pacific rim

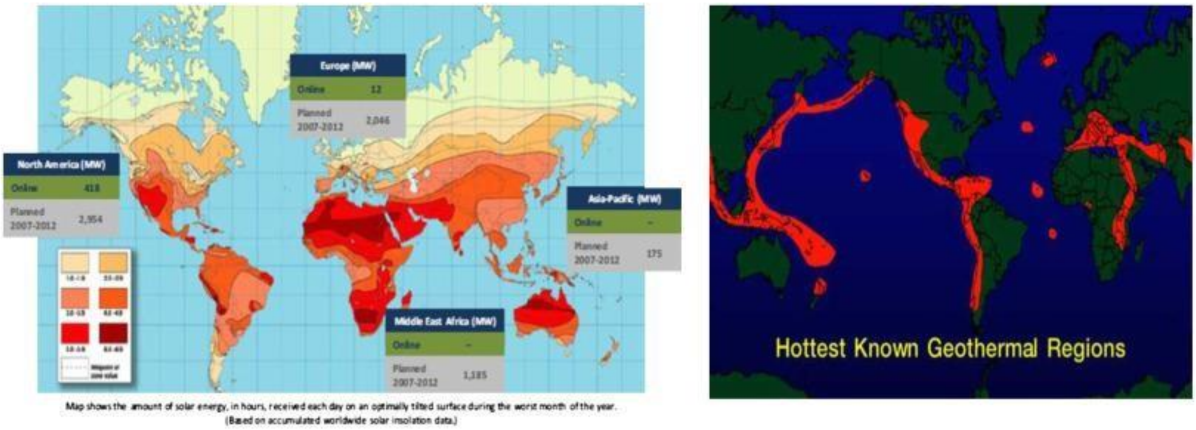


Figure 4.1 Solar radiation distribution and geothermal "the ring of fire [29,30]

4.4 Network Distribution

The electrical power network distribution complex is known to have resulted from the need for an efficient system. This is the system that balances the supply and demand. The backup also should be ensured, since we already realized its importance. It is this that manages disruptions, say as a result of an earthquake, flood or fire. Renewable energy networks are currently linked with traditional energy networks. This is to enable it to support regional power needs. It is the maximization of renewable energy resource utilization throughout the entire traditional power network that presents a typical challenge for the renewable energy industry.

Certainly, for the distribution of electricity, this we know to be quite complicated. Similarly, we are all fully aware of how complicated it is for the distributions to ensure adequate balances. This is as a result of a sophisticated network. A sophisticated network distribution is required, to be able to deliver electric power to each single user Hence, renewable energy when joined with other networks distribution, should ensure that there is an adequate supply of electrical power. Object of this is to balance the demand fluctuation within a set time. Similarly, it can also be used to balance the intermittent, or variability of renewability of renewable energy resources. Another important factor includes the manoeuvrability of electric power. It is this that employed, the rapid response to demand.

The traditional fossil power plants are known to have been built, with a centralized or decentralized network concept. This was to ensure, the needed economic power generation. As soon as any disruptions happen, take for example, the recent tsunami that hit Japan. In this case, the control system would not be able to quickly respond and resume back to normal condition immediately.

As a result of the current conversion costs, renewable energies cannot compete with the traditional energy sources, such as the fossil fuels. One of the methods to illustrate the differences of each energy source is the efficiency coefficient. This is the ratio of the output energy to the input. Table4.2 below presents the efficiency coefficients for each type of the power plant. This is from the International Atomic Energy Agency, 2002 cited in [27].

4.5 Other Various Barriers

The demonstrated costs for renewable energy development assessment model was initially carried out by Chatzimouratidis and Pilavachi. This included the capital investment, operation and maintenance costs, and capacity factor costs.

Apart from the above factors, there are still three other dimensions of sustainability for renewable energy development, as stated by Munashinge and Shaerer. This is as shown in Figure 4.2 below. They are the environmental, economic, and social factors of the system. Also they can be barriers to the development of renewable energy.

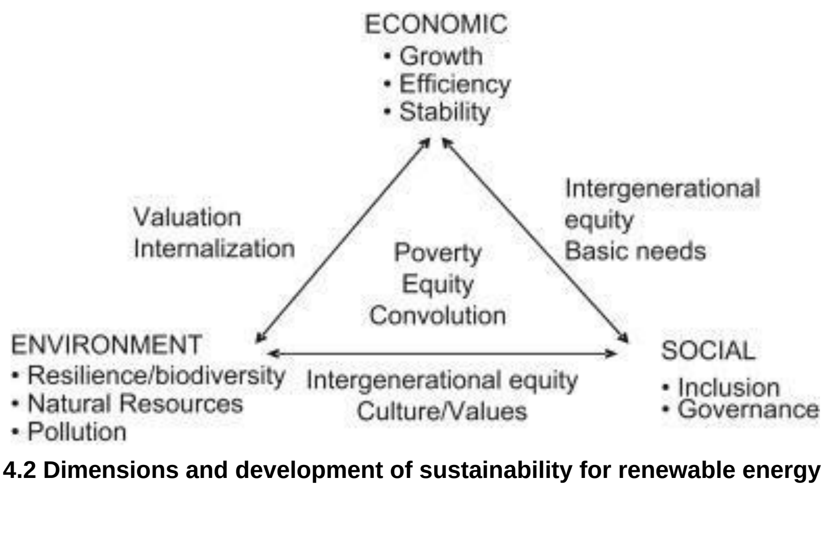


Figure 4.2 Dimensions and development of sustainability for renewable energy [17]

The renewable energy development was hindered by several other barriers. Both commercialization market and institutional barriers to renewable energy development are present, according to the Union of concerned Scientists.

The underdeveloped infrastructures included the commercialization barriers. It is this unequal government subsidies and taxes, that resulted it to be lacking economies of any scale. The values and the benefits of renewable energies are also included in the failure to market. The lack of renewable energy information refers to the market barriers. The small size business, high transaction and financing costs, split incentives, energy transmission costs, and green market restrictions, included the institutional barriers. The summarization of the potential negative impacts of renewable energies, was carried out by Li, from the environmental perspective. This is as shown in Table 4.2 .below .

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Table 4.2 Energy sources and their potential negative impacts on the environment

Energy sources	Potential negative impacts on the environment
Fossil fuel	Air pollution, acid rains, ozone depletion, global warming potentials.
Hydrogen	Thermal and chemical changes in atmosphere, ozone depletion, influence on microorganisms in the soils and waters, accelerated corrosion of man-made structures.
Wind	Landscape change, soil erosion, reduced air circulation and deterioration of local are quality.
Solar	Landscape change, soil erosion, reduced solar irradiation for plants and vegetation.
Hydro	Change in local eco-systems and local weather conditions, social and cultural impact, induction of earthquake.

Geothermal	Landscape change, underground water resource, acceleration cooling of earth core.
Tidal/wave	Landscape change, reduced water motion/circulation and deterioration of local water quality.
Biofuels	May not be CO_2 natural, may release global warming gases like methane during the production of biofuels, landscape change, deterioration of soil productivity.
Nuclear	Radiation leakage and contamination; the disposal and safe storage of nuclear waste for hundreds of years up to hundred thousand years in geological repositories.

4.6 Renewable energy supply chain improvement

The enumeration of the barriers in the development of renewable energy, resulted from the barriers to renewable energy development section. To overcome these barriers, requires the governmental and scientific research involvement. This is necessary, so as to ensure the improvement of the system. Also, this will necessarily help to improve the renewable energy distribution network. Similarly, the advanced storage technology should be included.

4.6.1 Government and researcher's involvement

The involvement of government is necessary, to ensure the improvement of financial aid, or tax compensation in the promotion of renewable energy. Government is known to have played key role in the commercialization of renewable energy to the market. The definition by Menz and Vachon of the three aspects of a government policy regime for renewable energy, is as shown in Figure 4.4 below.

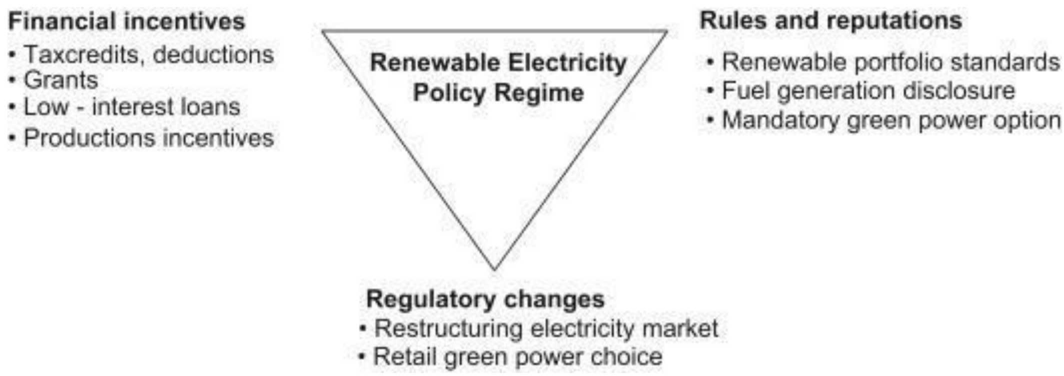

Figure 4.4 Renewable electricity policy regime [33]

The implementation roles were played be the Scientific Research, by implementing the efficient conversion processes. This is carried out by creating and employing advanced technologies that reduce the cost of renewable energy. Similarly, the facilitation of the construction of the efficient renewable energy supply chain.

4.6.2 Use of renewable energy commercialization

It is by the desire to improve environmental conditions, that triggered the utilization of renewable. The designs of renewable technology of turbines. This is with the inclusion of the thin-film PV cells, and other devices. The use for this is to promote market acceptance. Object of this is to make renewable energy to become an affordable economic commodity. With such development, this will then increase market consumption. It will also ensure the replacement of the use of fossil fuel energy in the future. This is as illustrated in Figure 4.5. below.

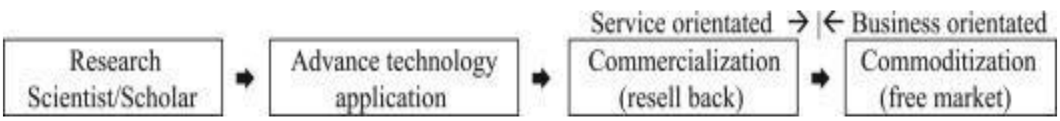

Figure 4. 5 Renewable energy development stage

To enable the expansion of the utilization of renewable energy, hence the development of the hybrid system. For example, hydrogen is a renewable energy resource that can replace the depleting fossil fuels. It has a storage system that supports industrial and residential power needs. During the off-peak period, hydrogen can be converted from solar, wind, water, or geothermal processes. Similarly, there are other outcomes, which can be generated from the biomass. Examples of these are such as bioethanol or biodiesel and fertilizers like other commodities, these outcomes can also be offered to the market.. ,.

4.6.3 Renewable energies realization values

The promotion of renewable energy depends upon stakeholders. They have to know and understand about the profit and value, that will come out of the situation. Stakeholders have a vested interest in the promotion of policy such as the generation and utilization of renewable energy. Similarly, stakeholders can be grouped into the categories as shown in Table 4.3 below.

Table 4.3 Stakeholders in the development and utilisation of renewable energies

International donors invest
National political (legislators, officers' governors)
Public services (ministry of health, social security agency, ministry of finance)
Scientific research
Renewable-energy generators and investors
Local population
Substitute energies
Labour (unions, medical associations)
Commercial/private for-profit organizations
Non-profit (nongovernmental) organizations, foundations
Civil society
Users/consumers

A value chain that links all stakeholders in the fulfilment of customer's needs, was developed by Porter. It is the value identification of customers and stakeholder that determines a business strategy. This also, include the target profit performance.

According to Loucopoulos and Karakostas, value refers to the relative usefulness of an object. Hence in the case of a product or business like this, value defines the relative benefit of acquiring a product. Similarly, this can be referred to as the existence of a particular business.

In some cases, very many stakeholders with different roles, are referred to as renewable energy supply chain. Figure 4.6 below shows the stakeholders and values of renewable energy in the supply chain.

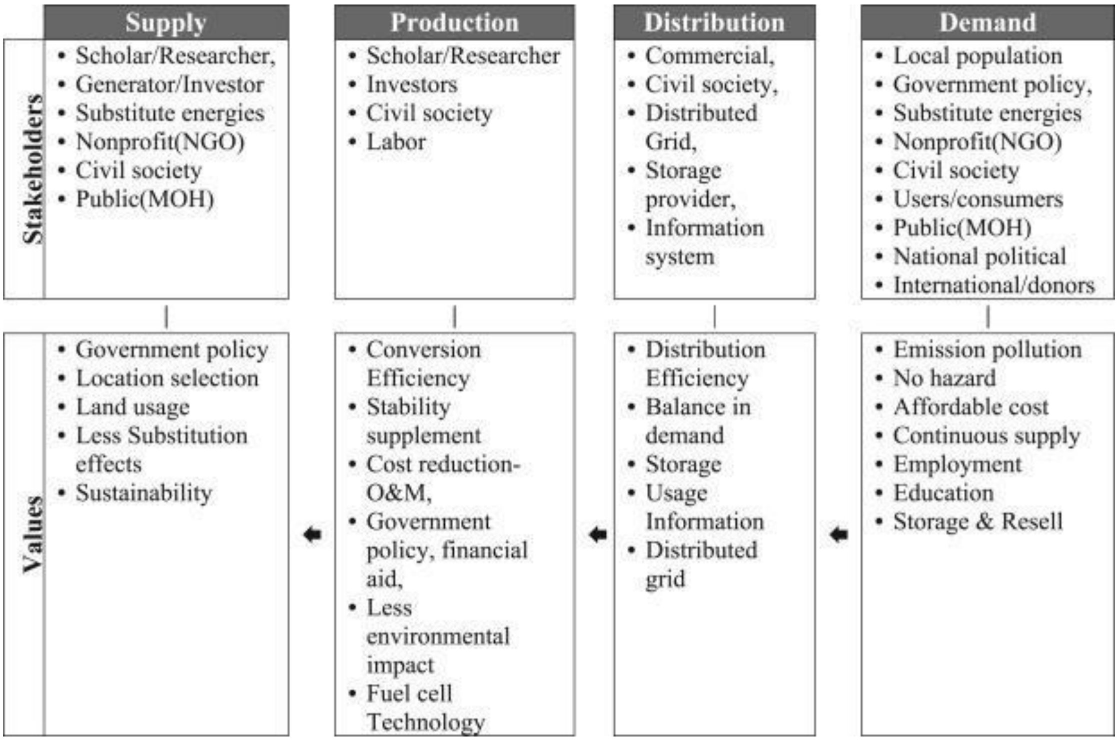

Figure 4.6 The stakeholders and the values of renewable energy supply chain [19,33,36,37]

4.6.4 Network distribution

Renewable energy sources should employ the highly efficient operation processes, which is in accordance to Denholm. It was Jones et al., who suggested how to cope with the uncertainty of the supply and demand. They described this as decoupling points to support the supply efficiency, and flexibility in meeting customer needs. They also suggested that such decoupling would undoubtedly provide such a flexible distribution network. This system is known to have been supported by the Leanagile supply chain system, which is as shown in Figure 4.7 below. It is also known to be supporting the system. To manoeuvre electrical power to the rapidly respond to the considered demand, is what is its ability.

Also, the efficiency of the electrical distribution during utilization of smart grids may have contributed improvement. It is this that monitors the energy distribution network, so as to enable it to maximize the power utilization.

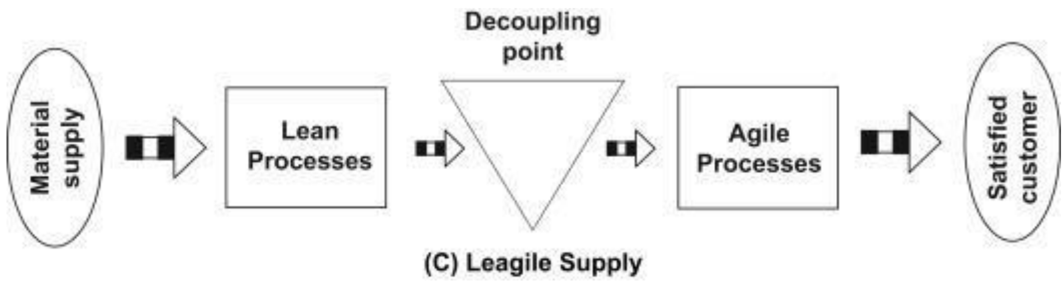

Figure 4.7 Decoupling distribution networks [38]

4.7 Smart Grids

To improve reliability, maximize throughput, increase energy efficiency, provide consumer participation, and allow diverse generation and storage options, are the basic concept of smart grid. This is as stipulated by the National Electrical Manufacturers Association. The definition of the smart grid as a technology that integrates information technologies, is known to be The Korean Smart Grid Institute. This is with the power networks, in order to optimize the energy efficiency through the interactive. Also, this enabled the exchange of real-time information between suppliers and consumers.

Smart grids are known to be such useful Information Technology. It is for monitoring and controlling electricity distribution, that the system is extensively used. Similarly, the system also facilitates financial control function for the energy providers. The information collected from each user in the chain must be well-managed, and effectively structured, in order to achieve maximum success of this.

4.7.1 Energy Network Centralized, Decentralized and Distributed

The utilization of the centralized networks are known to have been carried out by the most traditional power plants. However, it is known that such networks cannot respond rapidly, in the event of distribution. This is in order to make the necessary changes, to enable it to resume its normal operation.

One typical example of this is the Japan Fukushima nuclear power plants. This was damaged by the tsunami that caused serious impact on industry's productivity due to power shortage. Work could not be started, until the damaged plants are repaired. The decentralized networks consist of several centralized sub-networks. Each is known to be covering a specific area of distribution, that is commonly limited by geographical location.

Similarly, for the centralized network, if one sub-network failed, the subsidiary would not be able to get support from other energy network. It is as a result of these limitations, that the distributed-energy-generation networks have been restricted in both United States and Europe for decades. The Power distributors in these networks are known to be interconnected to the main distribution network, as shown in Figure 4.8 below.

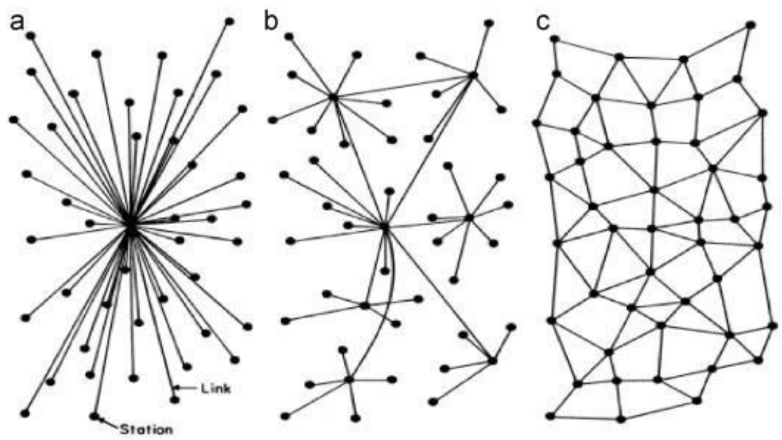

Figure 4.8 Distribution network [41] (a) Centralized, (b) decentralized and (c) distributed (Source: 41)

4.8 Storage technologies selection

, In the renewable energy development, storage systems are the key technologies. They support energy, during their intermittent supply and demand. For the conversion of primary energy into another energy forms, such as steam and hydrogen, storage systems may also be used. It was Naish who classified storage technologies into five categories as shown below:

- Advanced battery systems
- Fluid storage
- Mechanical systems
- Electro-magnetic systems, and
- Hydrogen

The suitable applications of these storage systems are as shown in Table 4.4 below:

Table 4.4 Storage technologies

Category	Technology type	energy density	of recovery	economic costs	Advantage	Disadvantage
	Sodium sulphur batteries	150– Wh/kg	>86% 240	170 €/kW	Environmentally High power and energy densities High efficiency	lifetime benig High production cost, requires recycling
	Pumped hydro-electric	N/A	75–85%	140 m- >680 m € for 1000 MW plant capacity	High capacity, relatively low cost per unit capacity	Disturbs lo low wildlife and a water levels
Fluid Storage	Compressed air energy systems	N/A	80%	400€/kW h	High capacity, relatively low cost per unit	Problematic obtaining sites at pla for use,
batteries	420 Wh/kg	50%		cost,	short recharge	
					capacity	

	Super capacitors	0.1– 5 Wh/kg	85–98%	2002: 200–1000 (€/kWh)	Long life cycle, high efficiency	Low energy density Toxic and corrosive compounds
	Nickel Batteries	20– 120 Wh/kg	60–91%	200–750 (€/kW h)	High power and energy densities, Good efficiency	NiCad: Cadmium highly toxic, NiZn, NiMH and Na-NiCl2 require recycling
	Lithium Batteries	80– 150 Wh/kg	–100% 90	150–250 (€/kW h)	High power and energy densities, High efficiency	
	Lead-acid batteries	25– 45 Wh/kg	60 –95%	50–150 (€/kW h)	Low capital cost	Lead requires recycling
Advanced battery systems	Zinc Bromine flow batteries	37 Wh/kg	75%	2 MW h battery (1.8 m€)	High capacity	Low energy density
	Vanadium flow batteries		85%	1280 €/kW	High capacity	Low energy density
	Metal-air	110–			High energy density, Low	Poor electrical rechargeability,

System **Efficiency Illustrative**

~

Category	type	System energy density	Efficiency of recovery	Illustrative economic costs	Technology Advantage	Disadvantage
Mechanical Systems	Flywheel	30–100 Wh/kg	90%	3,000–10,000 (€/kW h)	High power density	Low energy
Electromagnetic Systems	Supper conducting magnets		97–98%	350 €/kW h at plant	High power	Health impacts for large scale sites
Hydrogen	H_2 fuel cell	1 KW–3 MW	25–58%	6,000–30,000 (€/kW h)	Can be stored long term, Range of cell catalysis or types for different applications	Expensive processing often required
	H_2 internal combustion engine(ICE)	N/A	N/A			

For the selection of a storage technology, there are other criteria that can be uses. It was the Electrical Storage Association that provided the four categories for the evaluation of economic applications of storage technologies. These include size and weight, capital cost, line efficiency, and per-cycle cost. Also, storage technologies may similarly be evaluated by using the Ragone plots. This incorporate energy density, power density, and discharge times as selection parameters as shown in Figure 4.9 below.

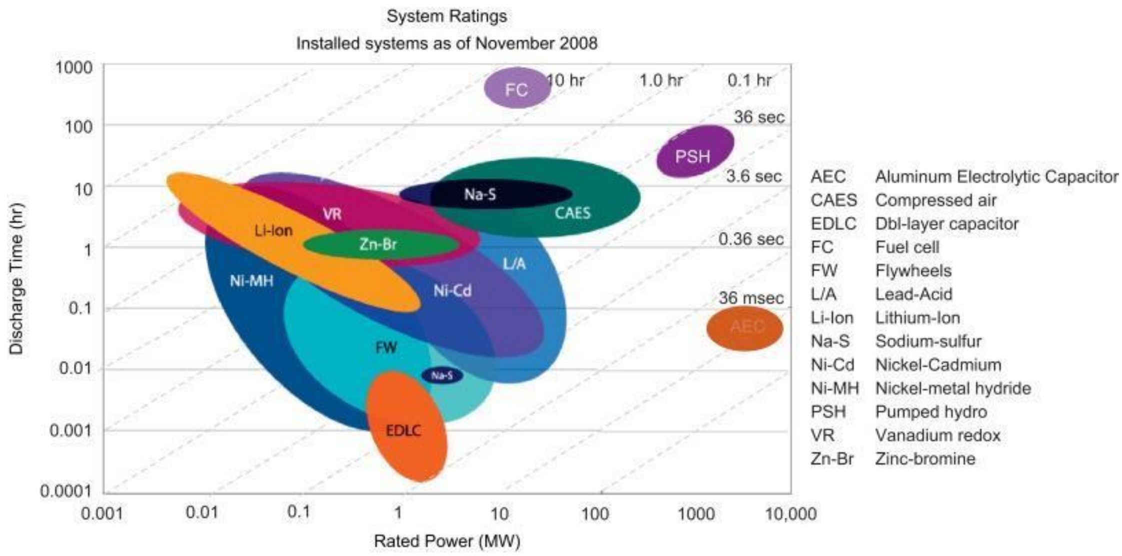

Figure 4.9 Energy density, power density and discharge times as selection parameters [25,43]

4.9 Conclusion

There is the potential for wind and other renewable energy forms, to play a significant role in meeting the growing global energy demands. However, this will require much more ambitious investment in the renewable energy programs than is currently the case. Various studies have been focused on this particular subject for sometimes now. This was in search of results to the barriers that is affecting its development programs.

Although such studies are important, but there is also the need to understand the cause of this multi-dimensional barriers. Understanding the barriers will surely lead to finding the right solution. We are aware that much of the political and social barriers are also rooted in the knowledge barriers. But not certain about the level of the barriers. Similarly, the appropriate level of investment is not certain.

Furthermore, neither knowledge nor agreements were explicitly identified as barriers by study participants, thereby increasing worries. Even if additional resources are directed towards this program, the presence of these underlying barriers may likely still remain. However, we suggest that a more systems-based approach that integrates investment in renewable energy development should be carried out. This should be with the specific mechanisms to identify and address the underlying barriers. Hopefully, this would result in greater penetration of the renewable energy in a more cost-effective way.

Chapter: 5

Assessment of renewable energy sources

5.1 Introduction

Within this part of the project, it is the assessment of renewable energy sources that are carried out. The focusing was on the renewable energy supply chains. It is from this, that the performance and the barriers to the renewable energy development were clearly identified. Suggestions are then carried out for the renewable energy utilization .and generation. Both the government and the research institute involvements were then initiated.

The commoditization of renewable energy, realization of renewable energy value, and the improvement of distribution networks are the required strategies that stipulated for further development of renewable energy.

Similarly, the progressing of the advanced storage plus its technology, are included in the recommended strategies. This is where further development of renewable energy is required.

It is the identification of the barriers to the generation and utilization of renewable energies, that are the conversion cost. The location constraints, complex distribution networks, and other considerable barriers, are included in the process. Hopefully, these through resolved barriers may have been the involvement of governments, researchers, and stakeholders, in the development of renewable energy.

5.2 Importance of sustainable renewable solar energy

In the year 2005, the worldwide electricity generation was estimated to be 17,45o TWh. From this, 40% was known to originate from coal, 20% from gas, 16% from nuclear, 16% from hydro, 7% from oil, and only 2% from the renewable sources. These sources are such as the geothermal, solar, combustible renewables, wind and waste. The current fuel mix are known to have fossil and nuclear fuels. They are known to be contributing approximately 70% of the total generation. The coal energy is known to have the highest carbon dioxide emissions per kWh.

Coal is also known to be emitting other pollutants at such high levels. Irrespective, coal energy continues to dominate the market, which is as a result of its low cost, and high availability. It is also challenging the principles of sustainability. Significant efforts are now being made, to ensure the reduction of the amount of the emissions produced. The number of coal fired power stations will have continued to rise significantly. Also, the developing countries alone will produce more CO_2 than the entire OECD power sector for the year between 2020 – 2030.

In order to be able to effectively direct the future investment, it is necessary to understand the environmental footprint of the projected energy growth scenarios. This is by focusing on the sustainable energy generation practices.

The full environmental footprint accounts for the entire energy chain lifecycle. This is from the mining and processing to direct and indirect emissions, waste disposal, and recycling. With the assessment of each stage of the chain, key indicators must be identified to allow the quantification of impact. These indicators will be based upon environmental and societal impacts, greenhouse gas emissions, resource depletion, availability of renewable energy sources, and the value that they add to the economy. There are several, though very significant research in the literature, so as to understand the impact of electricity generation to the environment and economy. Most of the work already carried out seeks to quantify parameters like emissions, energy payback periods, and costs.

Several authors have completed full life cycle analysis (LCA) of individual energy generation technologies. The life cycle analysis (LCA) is an internationally accepted tool for the evaluation of the impact for a product or service. It is the life cycle analysis of energy generation technologies that allows direct comparison of a range of impacts. This is by breaking them down into relative consequences. That is by saying that the effect wind power generation on migratory birds, potential incidence of Leukaemia clusters surrounding nuclear power plants etc.

There are also other methods of assessing sustainability, such as input – output analysis, mass and energy balances, energy, which is the embodied energy accounting. However, life cycle analysis is a combination of these tools, providing the most comprehensive method currently available.

The life cycle analysis as a tool to assess sustainability has got its own limitations. This was as identified by Bergeson and Lave. It is the analyst responsibility to ensure all the necessary inputs and outputs are considered and weighted. Gagnon et al. highlighted the fact that LCAs are unable to account for the dual function of hydroelectric dams or the reliability of electricity supply. Of all the analysis methods, there is also the difficulty in attributing the full value to more flexible generation options.

The most comprehensive examples of previous LCA studies on electricity generation have been produced by Bilker et al. [3], Hondo [4], Gagnon et al. [15], Denholm and Kolinskis [17], Uchiyama]18] and Weise [19]. These studies are known to have used one or more indicators to provide the assessment. This is typically greenhouse gas emissions and possibly energy accounting. Gagnon et al. [15] consider the widest range of indicators of sustainability in their assessment but avoid the consideration of social impacts.

In the previous studies, discussions were only centred on a small number of indicators. It is then limited in variation of the energy generation technologies. This was to ensure the gaining of full understanding of the sustainability of all the modern electricity generation technologies. There is a range of other significantly important indicators that must be considered, this is when evaluating sustainability of energy generation technologies. It is quite reasonable to understand and bear in mind that, it is not only the traditional form of the environment that is impacted by electricity generation.

The human social and economic environments are also significantly impacted. This is by the choice of method. The works that is presented here, seeks to assess and rank the relative sustainability of non-combustion renewable energy technologies, photovoltaic, wind, hydro and geothermal. This is carried out by using the data collected from the literature. However, the key indicators of sustainability used in this assessment with the main justification for their selection are:

- Price of electricity generation unit must be considered, since unfavourable economics are not sustainable.
- Greenhouse gas emissions are increasingly becoming one of the key parameters that define sustainability of energy generation.
- Availability and limitations of each technology must be considered since some technologies or fuels may be heavily resource constrained.
- Efficiency of energy transformation must be known for meaningful comparison. Efficient processes will typically have lower process requirements, capital and operating costs. Less efficient processes may have more significant room for technological advancement and innovation.
- Land use requirements are important as renewable energy technologies are often claimed to compete with agriculturally available land or to change biodiversity.
- Water consumption is particularly important in arid climates such as Australia. It is not sustainable to have high water consumption and evaporation rates to support the energy generation process when already water shortages are problematic. Previous LCAs often ignore the high-water requirements of thermal technologies such as coal when it must be considered.
- Social impacts are important to correctly identify and quantify the human risks and consequences will allow better acceptance and understanding of some technologies that are often subject to public objection.

After assessment of selected indicators, the renewable energy technologies were ranked against each other, with each indicator given equal importance

5.3 Sustainability indicators of renewable energy technologies

5.3.1 Price of electricity generation

The average prices for electricity generation for each energy generation technology are as shown in Table 5.1. Each technology is known to offer production of electricity at a very wide range of costs.

These comprise of a range and an average cost of production of electricity over the full life cycle of each energy generation technology. This is accounting for construction, installation, commissioning, operation, maintenance, decommissioning, recycling, and disposal.

The price of electricity generation from coal and gas as illustrated in Figure 5.1 are as shown for comparative purpose only. Most of the figures found in the literature also include the interest calculations on its capital. However, none of them accounts for the cost of transmission, which can add up to 1.5 c/kWh..

This is only carried out when long transmission lines are necessary. Long distances for transmission are more common with renewables than the non-renewables. This is particularly within the offshore wind farms. The intermittent renewables such as the photovoltaics and wind may require backup. These have not been included in the cost calculations.

The upper limit for the photovoltaics was cropped just for convenience. The highest value found was $1.25/kWh. There was no explanation as to why the value is so high. The next greatest value was found from Kannan et al at $0.57/kWh. However, this was given with an explanation of calculations an assumption.

The photovoltaics have the widest range of prices for electricity generation as a result of the large range of types of solar cells available. The location specific variations such as the cost of electricity to manufacture the cells and sunlight intensity during the operation.

Table 5.1 Mean prices of electricity and average greenhouse gas emissions expressed as CO2 equivalent for individual energy generation technologies.

Source of energy	USD/kW h	g CO_2/kWh
Photovoltaic	$0.24	90
Wind	$0.07	25
Hydro	$0.05	41
Geothermal	$0.07	170
Coal	$0.042	1004

Gas	$0.048	543

Journal homepage: www. Elsevier.com/Locate/ser [2, 3, 20 – 63].

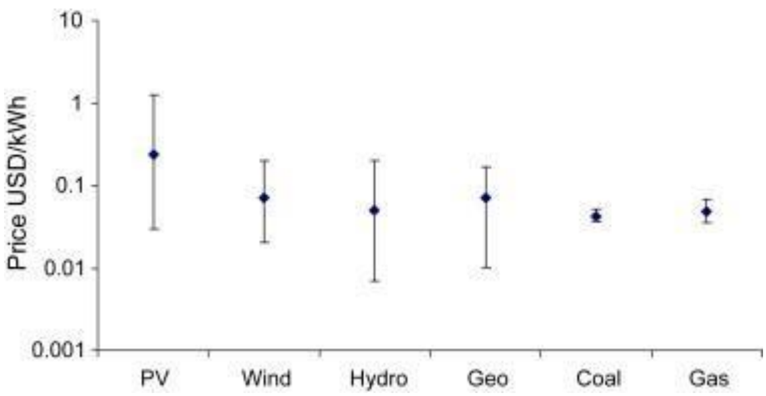

Figure 5.1 Cost of electricity generation per kWh

The price profiles for each non-combustion renewable energy technology show the high capital intensity and low running costs. This is due to the zero fuel requirements. In the case of the photovoltaics, the most significant cost is the silicon purification. This is by using the 60% of the production energy of the frameless multi-crystalline module [64]. The overall capital costs, account for over 95% of the life cycle costs for the photovoltaics. This implies that the interest variations have a large impact on the life cycle prices.

This would be expected with all other capital-intensive technologies the wind costs can be minimized by careful selection of suitably sized generators. This is according to the quality of the site-specific wind resource. The construction of hydro dam construction accounts for the nearly all hydro costs. This is with the low operation, maintenance and refurbishment costs and long plant lifetimes [65]. The geothermal prices are known to be heavily increased by the long project development times. So also, is the high costs and risk of exploratory drilling. The drilling alone can account for up to 50% of the total project cost.

From the study, the hydro had the lowest average cost. The geothermal and wind had the same average cost. However, geothermal is exhibiting lower range in price variations. In most cases, the photovoltaics are by far the most expensive technology.

5.4 Greenhouse gas emissions

The greenhouse gas emissions, which is shown as the grams of CO_2 equivalent (CO_2-e) in Figure 5. 2, were generally estimated according to the full operational life cycle of each renewable energy

The emissions are found to vary widely, within each technology the mean values of CO_2-e emissions for each technology are summarised in Table 5.1. In overall, the wind has the lowest CO_2-e emissions. This is with only around 25 g/kWh CO_2-e.

The hydro and photovoltaics also have low emissions. They are with the average reported values at less than 100 g/kWh CO_2-e. \The average emissions from that of geothermal are known to be fair at 170 g/kWh. However, the range includes all possible values for gas emissions.

This may be as high as a low-emitting coal fired power station. For all the technologies except hydro, CO_2-e emissions account for all the significant carbon emissions.

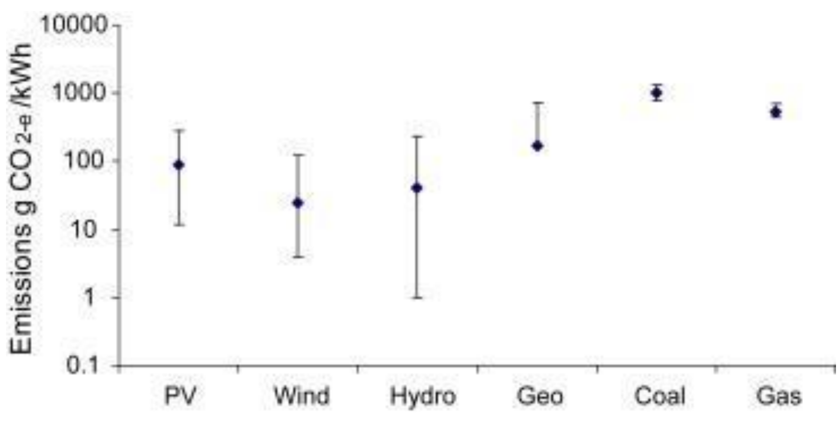

Figure 5.2 Carbon dioxide equivalent emissions during electricity generation

In the case of the photovoltaics and wind power, most of their emissions are the result of electricity use during manufacturing. Within these cases, an average grid mix for the region of manufacture is typically used to calculate emissions.

It is the grid that mixes vary widely with location. For example, the typical grid mix in Australia in 2005 was 76% coal, 15% natural gas, 2% oil, 6% hydro and 1% non-hydro renewables.

In the case of hydroelectricity, cooler climates, lower biomass intensities and dams with higher power densities (a ratio of the capacity of the dam to the area flooded) have lower emissions per kWh. It is well known that the type of the terrain flooded in dam construction significantly impacts CO_2-e emissions. The more biomass present during dam inundation and the higher draw down zones, the higher emissions. The Tropical and the Amazonian reservoirs typically, are known to have the highest emissions. Most of the greenhouse gas emissions from dams are methane from the anaerobic decomposition of biomass at depth.

Geothermal emissions are known to be most significantly impacted by technology choices. Waste gases are well known to be over 90% CO_2 by weight. Hence, if directly released, emissions will be high. In the most modern plants however, they either capture the CO_2, and then produce dry ice, or simply reinject it back into the well.

5.5 Availability and technological limitations

The availability of renewable energy technologies, including their limitations to reduce their base power, are another limiting factor that requires assessing. It is obviously known that Earth intercepts over 170,000 T.W h/year from the sun [46].

These irradiations are known to be varying greatly, depending on the location and season. The photovoltaics are known to be currently limited, as a result of storage complications during the nights and cloudy days, when the sun cannot power the cells.

Similarly, wind also suffers from this intermittency problems. However, it was Edmonds et al., that suggests the distributed capacity over a wide geographical area, for the purpose of elevating the fluctuations. The turbines must not operate, at the times when wind speeds are too high (>25m/s). This speed could damage the turbine. Similarly, this will not turn when the wind speeds are too low (<3m/s). The IEA estimate a global wind potential of 40,000 T W h/year. It is the hydropower that has the highest availability, reliability, and flexibility of any technology.

Hydro plants in their nature can be started, stopped, or output rates changed within minutes. In view of this, in where water resources are plentiful enough, the hydro power can provide both base and peak load power. In the year 2005, hydropower is known to have provided 20% of the world's electricity demand with 2600 T W h. This is known to have a global economically feasible potential of over 8100 T W h/year. The geothermal power is geographically limited to the appropriate sites, in where the resource is present. However, there are many such sites world-wide. This is known to have spread to over 24 countries, with an operating potential of 57 T W h/year. Geothermal is known to be very attractive, for its ability to provide base load power 24 h a day. The extraction rates for power production will always be higher than the refresh rates. It is the reinjection that helps to restore the balance.

Significantly, this helps to prolong the lifetime of the geothermal sites. It is always essential to carefully select the site tor the reinjection. The main reason is to ensure short-circuiting does not occur. Reinjection is known to increase the frequency, but not the severity of seismic activity.

5.5.1 Efficiency of energy generation

Hydropower is known to have the highest efficiency, of all the electricity generating technologies that is currently available. The wind is known to have the second highest efficiency. This is generally comparable to coal or gas. Photovoltaics and geothermal power are known to have the lowest efficiencies, which is far less than other technologies.

Table 5.2 Efficiency of electricity generation

Photovoltaic	4–22%
Wind	24–54%
Hydro	>90%

Geothermal	10–20%
Coal	32–45%
Gas	45–53%

The photovoltaics efficiency is known to be highly variable. This is due to the large range of cell types available. It is with an ideal cell efficiency of 30%. The crystalline silicon cells (including multi – and poly-crystalline) have the highest efficiencies, and amorphous silicon the lowest.

The wind efficiency is also wide ranging. This is due to the wide variation in quality of wind resources at different locations. However, a good wind resource, with locations carefully selected will give greater than 40% efficiency. That of geothermal values are low, due to the low temperatures of the steam.

5.5.2 Land use

The photovoltaics and wind power are known to have similar land use characteristics. This is with the impacts from materials for unit manufacture and disposal or recycling. Neither requires any further mining footprint. Both are also equally characterised by the opportunity for dual use sites.

That of solar can be roof-mounted, providing a negligible footprint during use. The wind can be incorporated into the agricultural lands, thereby reducing its share of the footprint. Gagnon et al. give a total footprint of 72 km^2/T W h for the wind power. This was without allocating any share of this to agriculture.
Similarly, Lackner and Sachs [46] find a photovoltaic land occupation of 28-64 km2/T W h with no dual-purpose allocation. The hydro footprints are known to vary significantly, depending on local topography. This is where a generic land requirement is given as 750km2/T W h per year, by Evrendilek and Ertekin. However, Gagnon and van de Vate [80] give the land requirements as low as 73 km2/T W h. That of the geothermal power plants is known to have relatively small surface footprints. Its major elements are known to be located underground [106]. Due to the risk of land

subsidence above the field, hence the whole geothermal field is used in the footprint calculation. A typical geothermal foot plant is known to be in the range 18 – 74 km2/T W h

5.5.3 Water consumption

The accurate data for the quantifying water consumption during the electricity generation is really very difficult to obtain. This is so, particularly for the renewable energy technologies, as already discussed by Inhaber [129]. However, this is difficult to distinguish between water withdrawal, i.e. (water that is taken then return later to the circulation), and water consumption, i.e. (water removed from circulation outside the plant/unit).

It is the water consumption that seems to be the more accurate indicator of sustainability. In this case, it is the water lost from circulation that will have an impact. However, a summary of water consumption values, is as given by Inhaber, which is as shown below in Table 5.3.

Table 5.3 presents the water consumption in kg per kW h of electricity generation.

Table 5.3 Water consumption in Kg per kWh of electricity generation

Photovoltaic	10
Wind	1
Hydro	36
Geothermal	12–300
Coal	78
Gas	78

The storage dam is certainly essential to the hydroelectricity plants. These dams are known to withhold enormous volumes of water from the surrounding areas. They also caused water losses, as a result of the surface evaporation. The magnitude of this varies greatly. This is in accordance to the dam size, volume per square meter, including the ambient temperatures [129]. However, this water may have naturally evaporated, depending on weather it is from river or lakes.

The geothermal power is usually associated with large amount of water required for cooling. However, water consumption can be controlled. This is by the total reinjection of the polluted, with the foul-smelling wastewater, with the non-evaporative cooling general pressure management, and the closed-loop recirculating cycles [50]. In the concluded work of Inhaber [129], and Axtmann [131], both concluded that the geothermal plants produce more wastewater than thermal power plants, at up to 300 kg/kWh.

Similarly, water is also consumed in the production of photovoltaic modules, and wind turbines. However, little is used during its operation and maintenance, thereby giving very low life cycle water consumptions. It is the wind power that has the lowest water consumption of the technologies considered. This is then closely followed, by the photovoltaics.

5.5.4 Social impacts

There is a very wide range of social impacts. Both the positive and the negative, are from the production of electricity. Also, in some places, renewables offer the opportunity for electricity supply that otherwise may not exist. Very many countries are known to be less fortunate than Australia in their reserves of the thermal fuels. Renewable technologies are known to offer independence from the fossil-fuels imports and price fluctuations. The impacts and relative magnitudes for the technologies under consideration are as summarised below in Table 5.4.

Table 5.4 Qualitative social impact assessment

Technology	Impact	Magnitude
Photovoltaic	Toxins	Minor–major
	Visual	Minor
Wind	Bird strike	Minor
	Noise	Minor

	Visual	Minor
Hydro	Displacement	Minor–major
	Agricultural	Minor–major
	River Damage	Minor–major
Geothermal	Seismic activity	Minor
	Odour	Minor
	Pollution	Minor–major
	Noise	Minor

Solar cells offer an attractive source of power without fuel dependence. Also, without the need for the conventional power plants and reduced mining. The manufacture of solar cells is known to involve several toxic, flammable, and explosive chemicals. With constantly reducing mass requirements during cell manufacture due to thinner cells, masses involved, and hence risks are reduced. However, all chemicals must be carefully handled to ensure minimal human and environmental contact.

The selection of solar farm locations must be carefully selected. This is to ensure the reduction of competition with agriculture, soil erosion and compaction. It is the wind that suffers so much from the public outrage due to aesthetic degradation, noise and the potential bird strike. Krohn and Damborg [132] found that public acceptance gradually increased, following the local wind farm installation the bird strike risk can be heavily mitigated by thorough research of the proposed site prior to installation.
Noise is the typically, heavily masked.

This is mostly by the noise of the wind itself. The installation of hydropower is almost usually controversial. The rates of the development of large hydro have slowed significantly. This is significantly following the lack of public acceptance. It is well known that the dam inundation is usually resulting in the displacement of people and their animals from the homes or habitats.

In most cases, the numbers of the people affected can really be very large. The agricultural pastures, in most instances, can equally be affected. This is either by the direct inundation, or loss of river and fertilising silt flow down the river. Somehow, hydro dams may also benefit the communities. This may be due to the improved flood control. It may access the communities to the question of irrigation of water all the year round. Also, it may result in having the recreational water sports. Geothermal adversely affects the communities where wastes are not properly managed.

The geothermal process waters are known to be offensive smelling. This comes from the hydrogen sulphide, and is contaminated with the odorous ammonia, mercury, radon, arsenic, and boron. However, the geothermal fluids can be processed in a completely closed-loop system, and then reinjected, mitigating these problems.

5.5.5 Ranking process

Ranking is the process used for selecting the sustainability indicators. This is where each technology is ranked. The ranking is between 1 and 4. It is in accordance to the corresponding indicator, as shown in the Table 5. 5 below. This is with 1 being the very best technology for that particular indicator. In where values are quantifiable, the average and range are then considered together. This is as there is often the significant overlap between values. The impact categories that are unable to be quantified, I e the availability and limitations as well as the social impacts are assessed qualitatively.

In the case of limitations, hydro was chosen as the least limited. This is as a result of its ability to provide the base load power, flexibility of operation, and number of suitable sites globally. The wind was considered to be the second best for similar reasons. Geothermal is slightly more limited world-wide, with less suitable locations. Solar is considered to be the most limited, since excess power during daylight hours is not yet able to be stored enough. This is to provide adequate power during the nights, and on cloudy days. When the social impacts were considered, the wind was allocated the least negative social impacts, due to its benign nature.

The solar was second, as careful management during manufacture and proper site selection mitigate its potential negative impacts. Geothermal is known to be placed third. This was due to the increased seismic activity, and pollution potential. It was hydro that had the largest impact. This may have been due to the large number of people and animals which are displaced during the dam inundation.

Table 5.5 Sustainability rankings

	Photovoltaics	**Wind**	**Hydro**	**Geothermal**
Price	4	3	1	2
CO_{2-e} Emissions	3	1	2	4
Availability and limitations	4	2	1	3
Efficiency	4	2	1	3
Land use	1	3	4	2
Water consumption	2	1	3	4
Social impacts	2	1	4	3
Total	20	13	16	21

This ranking in Table 5, as shown above, suggests the electricity production from wind is the most sustainable, followed by the hydro power. The geothermal was found to rank the lowest from the four non-combustion renewable energy technologies.

It should be highlighted here, that the ranking was provided for the global international conditions. In view of this, each technology can be significantly geographically affected. In general, for a certain geographical location, some of these listed sustainability indicators may become more important than others.

Chapter: 6

Conclusion and Future Plan

6.1 Summary and Conclusion

The summary of works carried out in this research is:

- Sustainable renewable energy indicators, for the purpose of energy measurement. Particularly realising that, the instrument will give wrong measurement when damaged.
- Renewable electric power, to enable the population to live happily. Also, to ensure this is extended to the rural dwellers to join and enjoy modern life.
- Sustainable renewable energy supply chains is now becoming a moving force in the field of energy. It's effort here is to ensure the preservation of the earth's natural resources, and also to avoid the pollution of our atmosphere. The project is mostly assessed from the supply chain perspective. It is this that enabled us to observe the flow rate of the system. This is where the system's secondary process convert renewable energy into most of the other energy resources.

6.2.2 Reflection on originality of work done, and contribution to knowledge in the field of Engineering

The reflection on the originality of the work done, and contribution to knowledge in the field of engineering are:

The assessment of renewable energy technologies are based on several critical sustainability indicators, These selected indicators are the price of the generated electricity. This include the greenhouse gas emissions, during the full life cycle of the technology. Also included are the availability of renewable sources, efficiency of energy conversion, land requirements, water consumption, and social impacts.

It is assumed that each of the indicators have equal importance to sustainable development. For ranking the renewable energy technologies against their impacts, is where they are frequently used the ranking revealed that wind power is the most sustainable. This was followed by the hydropower, photovoltaics, and the geothermal. The relative ranking was provided using the data collected from the extensive range of literature. It only considers the global international conditions.

Renewable energy resources and their utilization are known to be intimately related to sustainable development. For societies to attain, or try to attain sustainable development, it is necessary for as much as possible efforts should be devoted, to discovering sustainable energy resources in terms of renewables. In addition to this, the environmental concerns should be addressed. However, the following concluding remarks can be drawn from this project:

- Certainly, there are a number of environmental problems, as we are facing today. These problems are known to have span a continuously growing range of pollutants, hazards, and ecosystem degradation over wider areas. The most significant of all these hazards are the acid precipitation, stratospheric ozone depletion, including the global climate change.

- Potentially, the most important environmental problem relating to energy utilization is the greenhouse effect. Increasing the atmospheric concentrations of greenhouse gases are increasing the manner in which these gases trap heat radiated from the Earth's surface, thereby raising the surface temperature of the Earth. It is this that consequently caused the risen of the sea levels.

- Not long ago, a variety of potential solutions to the current environmental problems that is associated with the harmful pollutant emissions has evolved. However, no matter what happens, renewable energy appears to be one of the most important solutions.

- In general, renewable energy technologies are some- times seen as the direct substitutes for existing technologies, so that their benefits and their costs are conceived in terms of assessment methods developed for the existing technologies. For example, solar and other renewable energy technologies can provide small incremental capacity additions to the existing energy systems with such lead times. It is such a power generation that is usually provide more flexibility in incremental supply than large, long lead-times units such as nuclear power stations

- The development of advanced renewable energy technologies that serve as cost-effective and environmentally responsible alternatives to conventional energy generation. Both the technical and market potential exists to significantly increase the current contribution of renewable energy sources to country's energy demands by the year 2000. This would result in many more employment, coupled with its economic benefits many times the R&D investment. It is well known that very many government energy institutions and agencies recognize this sort of opportunity, and there by support their renewable energy industry's efforts to exploit the near-term commercial potential.

- In order to attain the energy, economic and environmental benefits that the renewable energy offer, an integrated set of activities such as R&D technology assessment, standard developments and technology transfer should be conducted as required.

6.2. Recommendation for further research

Check to ensure the basic calculations adopted for the manufacture of the energy indicators are correct. Otherwise, amend as may be required. Similarly, check for the sustainable renewable energy supply chains. Ensure their storage are well kept, to avoid delay when required.

For the electric motor, check the standard specification, and amend as may be required.

6.2.1 Recommendations for future work

the following recommendations are made

- The training of the staff is extremely important, to ensure the well running of the organisation
- The government of the nation should be a strong party to the company
- Stakeholders and agencies should be encouraged to join the membership
- Users and staff should also be encouraged to become members
- Adequate maintenance is needed, to avoid system break down
- Staff meetings encouraged, to ensure mutual understanding

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