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INTERNAL RATE OF RETURN FOR RENEWABLE ENERGY INVESTMENTS – “REVIEW OF HOW MUCH MONEY PEOPLE ARE MAKING ON BIO, WIND AND SOLAR”

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ABSTRACT

Lappeenranta-Lahti University of Technology LUT
LUT School of Energy Systems
Master's Degree in Energy Technology, Sustainable Technology and Business

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Internal rate of return for renewable energy investments – "Review of how much money people are making on bio, wind and solar"

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Studies have shown that non-renewable fuels have contributed to majority of greenhouse gas emissions which has led to global warming. For this reason, it has led to the current global warming challenges we are facing today. Thus, the utilization of renewable energy is very important. The primary objective of this thesis is to review the economics of three different renewable energy systems: wind energy, solar PV and biomass energy systems. Financial analysis metrics such as Internal Rate of Return (IRR) were used to assess the economic competitiveness of the three different technologies.

In addition, extensive study of the different energy systems was done including the levelized cost of the electricity of each energy system. The results reveal that wind energy performs very well in the economic landscape with a higher rate of return. Solar PV is challenging to advocate due to many factors and biomass energy shows to be the average. In each of the three energy systems, the conclusions differ depending on various interrelated factors.

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Lastly, I would like to thank my family and friends for supporting me during my studies and being patient with me. All that I have achieved is because of your prayers, love, encouragement and support towards me. I appreciate you all and may the Lord bless you.

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Yvonne Esther Akiding

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LIST OF SYMBOLS AND ABBREVIATIONS

ACRONYMS

PV	Photovoltaic
LCOE	Levelized Cost of Electricity
LUT	Lappeenranta University of Technology
CSP	Concentrating Solar Power
IRR	Internal Rate of Return
O&M	Operating and Maintenance
MW	Megawatt
MWh	Megawatt Hour
A&G	Administrative and General
E&OBS	Errors and Omissions in Balance Sheet
E&OCF	Errors and Omissions in Cash Flow Statement
PPA	Power Purchase Agreement
FCFF	Free Cash Flow to the Firm
FCFE	Free Cash Flow to Equity
IRENA	International Renewable Energy Agency
GWh	Gigawatt Hour
EPC	Engineering, Procurement and Construction
WACC	Weighted Average Cost of Capital
rpm	Revolutions per minutes
V	Volts
AC	Alternating Current
t/y	tonnes per year
ha	hectares

1 INTRODUCTION

Traditional energy sources consist of coal, oil and gas (natural) have demonstrated to be greatly effective promoters to economic growth. Nevertheless, with the fast extinction of these fossil sources of energy and the growing energy demand, the fundamental energy utilization has grown since 2012. Because of several environmental issues, a lot of research has been carried out for greener and more efficient sources of energy and as well as power plants which can use this advanced technology. Due to the increase of environmental conservation, new energies and cleaner technologies are being extensively investigated. Actually, renewable energy prices and fossil fuels, environmental and social prices/costs are growing but in opposite directions but there is significant evolution regarding the commercial and governmental mechanisms in order to support the extensive multiplication of sustainable markets for green/clean energy. It can be seen that the development of the energy sector is primarily focusing on renewable energy. For that reason, changing to clean energy can aid in the reduction of greenhouse gas emissions, hence curbing climate impacts, and providing timely, reliable and cost-efficient transmission of energy. Investment in clean energy can have tremendous rewards in our energy security (Omar Ellabban et al, 2014).

Green energies are energy sources that are constantly restores by nature and obtained directly from the sun for example solar energy, wind, hydropower and photosynthetic energy which is stored in biomass, or from natural motions of the environment like tidal and geothermal energy. Renewable energy excludes energy resources got from fossil fuels, or waste products from inorganic products and fossil fuels. Clean energy technologies convert energy sources into applicable forms of energy like heat, fuels and electricity.

Renewable energy markets – heating, transportation and electricity have grown rapidly over the decade. The arrangement of well-established technologies like hydro including current technologies such as solar photovoltaic and wind, has grown thus increasing assurance in the technologies, reduced costs and has paved a path for new opportunities. Global electricity generation of clean energy is predicted to expand/grow 2.7times over the decade (2010-2035). The utilization of biofuels is also expected to grow triple over the same time space (Omar Ellabban et al, 2014).

1.1 Structure of the thesis

This thesis consists of seven chapters. The system utilized in this research is the review of different renewable projects and how much money is made is made if one wants to invest in renewables (IRR). An overview of the main features of the recommended methodology have been provided and illustrated below and described/discussed in this thesis:

1. Introduction
2. Objectives, research objectives/methods and thesis organization
3. Literature review
4. Analysis and review on case studies
5. Results and sensitivity analysis
6. Conclusions
7. References

The work is presented with intent to allow readers at different levels of education to understand the drive behind this research, the objective of the research and the methods that were used to review the different types of technology and analysis of their cost structure.

Chapter two which entitles the literature review. In this chapter there is a general description of the renewable energy systems mainly solar, wind and biomass. The investment and operation costs are then discussed and finally how to calculate the LCOE on a general basis and of each of the different forms of renewable energy systems.

The last chapters consist of the analysis of the case studies (projects) of this research, the results and the sensitivity analysis to help the readers understand how the project data was collected, reviewed and how the conclusions came up. The sensitivity analysis was done to illustrate how the impact of different factors affect the outcome of results and lastly the final section shows the summary and conclusion of the objectives of the research/thesis.

2 LITERATURE REVIEW

2.1 Different renewable energy systems

The main precedent to differentiate between non-renewable and renewable energy systems is whether the replaced by natural means or not. Renewable energy sources are sources of energy that can be replaced by natural means equivalent to its consumption while non-renewable energy sources are energy sources that cannot be replaced by natural means equivalent to its consumption. There are renewable energy sources are constrained in their flow (solar PV, biomass and wind) but are still renewable energy sources. A deep study and review of these different energy systems was carried out. In this chapter, we focus on the general knowledge and description of the different types of energy systems.

In addition, the other distinction between non-renewable and renewable energy sources is their emissions. Non-renewable energy sources are known to emit very toxic emissions into the atmosphere hence leading to greenhouse emissions. While renewable is referred to as green/clean sources of energy due to the fact that they don't emit toxic gases/emissions into the atmosphere hence the latter will be focused on this thesis.

2.1.1 Biomass Energy

Biomass is the term utilised for all organic material generated from plants, trees and crops, and is typically the acquisition and storage of the sun's energy through photosynthesis. Bioenergy is the conversion of biomass into useful forms of energy such as electricity, heat and liquid fuels (biofuels).

Biomass utilised for bioenergy comes either specially from the land for example energy crops, or from waste residues created in the preparation of crops for food or different products. (Omar Ellaban et al, 2014) Bioenergy is sustainable and renewable, however shares with non-renewable energy sources numerous attributes. While biomass can be precisely burnt to acquire energy, it can likewise serve as a feedstock to be transformed to different fluid or gas fuels (biofuels). Biofuels can be transferred and stored and used for heat and power generation once on demand that is fundamental in an energy blend with a high dependency on periodic sources for example wind. This correlation accounts for the main role biomass is expected to perform in the future energy scenarios. For this reason, a recently rising strategy is to create bio refinery and biotransformation innovations to convert biomass feedstock into clean energy fuels (green energy). Interconversion of different biomass and energy forms in the carbon cycle is shown in figure 1.

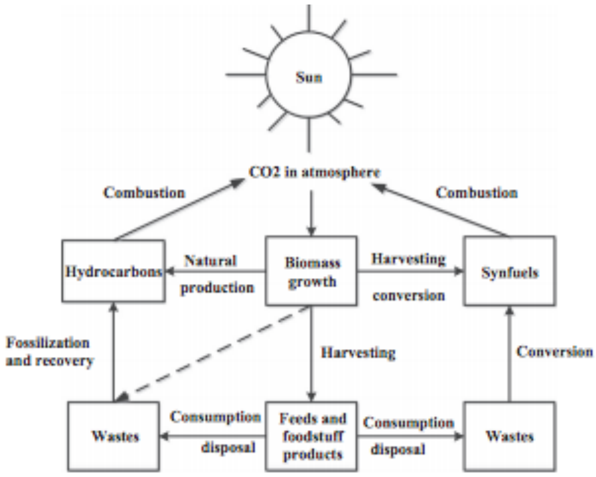

Figure 1: Characteristics of biomass energy technology.

Biomass feedstock can be transformed in to bioenergy by means of bio-chemical and thermo-chemical processes. These procedures incorporate ignition, pyrolysis, gasification and anaerobic digestion as demonstrated figure 2.

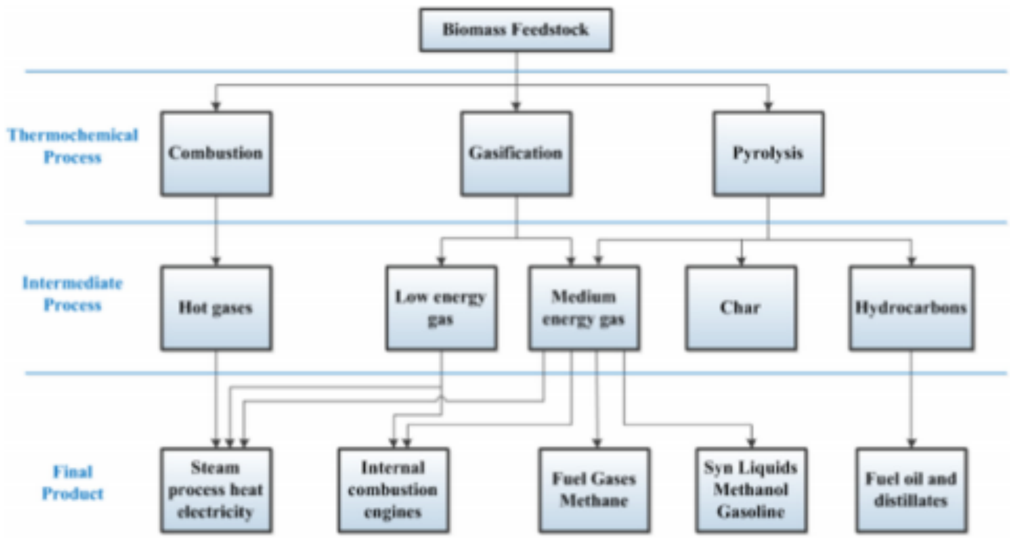

Figure 2: Bio energy conversion procedures for different end products

Additionally, the usage of biomass-derived fuels will enormously alleviate the current trade balance and energy security issues, and promote socio-economic developments for a lot of countries, as demonstrated in the table 1.

Potential Benefits
Environmental gains
• Reduced dependency on environmentally damaging petroleum products and fossil fuels
• Decreased levels of greenhouse gas emissions
• Reduction in smog and toxic chemical emissions
• Reduction in the need for landfills sites by the use of waste materials
Economic benefits
• Comparatively inexpensive resources
• Provision of constancy and reliability due to locally distributed energy resources
• Extensively distributed access to energy
• Price stability
• Creation of employment opportunities in rural communities
• Biomass and bioenergy technology export opportunities
• Usage of underutilized biomass resources as a renewable and inexhaustible fuel source
Technical Limitations
Environmental risks
• Local water supplies depletion
• Increased carbon emissions from wood burning like particulate
• Soil pollution and industrial cultivation of favoured crop species which has led to reduced biodiversity.
• Increased demand for herbicides, fertilizers and pesticides, leading to rise in soil and air pollution
• Increased atmospheric carbon dioxide production hence the global climate change
• Ecosystems destruction due to the use of microorganisms and genetically engineered crops
• Destruction of protected land for biomass production.
Associated Technologies
• Enzyme production
• Cost of technology manufacturing and maintenance
• Pre-treatment of biomass
• Collection storage of feedstock

Table 1: Benefits and limitations of biomass energy

As opposed to the advantages, there are huge obstacles to the biomass-to-energy facilities. Fuels from biomass have low vitality densities and furthermore, accumulation and transportation can be cost restrictive.

Utilizing biomass to create power is innovatively well built up, however the cost paid for power hardly balances the full cost of biomass fuel. Bio fuels are comprehensive in the usage of inputs, which incorporate water, land, crops and fossil energy all of which have opportunity cost.

Generally installed biomass plants capacity ascended from 66W in 2010 to 72GW by the end of 2011 and with a yearly average growth rate of approximately 5% in 2012 and the accumulated capacity came to 76GW. In the long haul, biomass and waste power production could increase. From 62GW in 2010 to 270GW in 2030 as represented below.

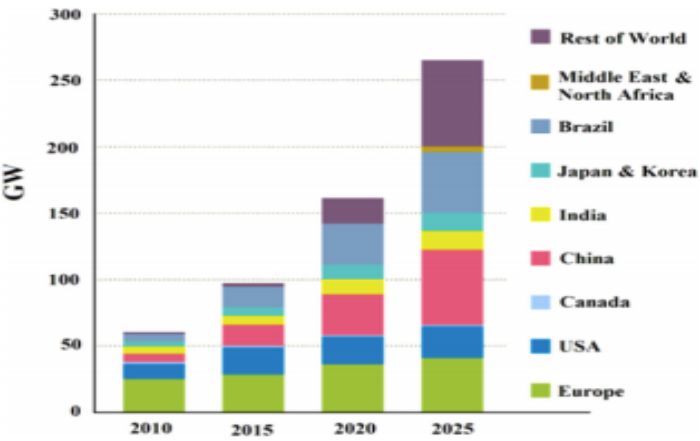

Figure 3: Projection of biomass and waste installed capacity for power production from 2010 to 2025.

2.1.2 Wind Energy

Wind energy is described by the transformation of wind energy by the use of wind turbines into a useful form for example utilizing wind turbines to generate electricity, wind pumps for pumping water and drainage, wind mills for mechanical power or sails to sail ships. The first wind turbines for production for electricity production were created at start of the 20^{th} century. The innovations have greatly improved since the mid 1970s. To the end of the 1990s, wind energy has re-developed as a significant economical energy resource (Omar Ellabban et al, 2014).

Producing power from wind requires that the kinetic energy of the flowing air be transformed to mechanical and after that electrical energy, thus demanding the industry to invent cost effective wind turbines and power plants implement this transformation. The measure of kinetic energy in the wind that is theoretically accessible for extraction raises with the cube of the wind speed. Nonetheless, a turbine just catches a small amount of that accessible energy (40% - 50%), so wind turbine configuration has concentrated on magnifying energy capture over the area of wind speeds experienced by wind turbines, while considering reducing the price (cost) of wind energy bearing all limits in account. To reduce cost, the framework of wind turbines is additionally spurred by a desire to lessen material utilization while proceeding to expand turbine size, raise system and component reliability, and enhance wind power plant activities (Omar Ellabban et al, 2014).

From 1970 to 1980, a diversity of onshore wind turbine arrangements was examined, including both vertical and horizontal axis designs. Progressively, the horizontal axis design ended up dominating in spite of the varied designs, especially the quantity of blades and the orientation of blades. Onshore wind turbines are commonly assembled together into wind power plants, also called wind farms. These wind plants are usually 5 to 300 MW in size, however smaller and bigger plants do exist. Offshore wind energy technology is less developed than onshore, and it has higher investment. The reasons for promoting offshore wind energy include: higher-quality wind resources situated at sea, the capacity to construct bigger power plants than onshore, the capability to utilize significantly larger wind turbines and the potential rebate in the demand for land-based transmission infrastructure (Omar Ellabban et al, 2014).

From an electric system framework perspective, a critical part of the wind turbine is electrical conversion framework. For extensive grid-connected turbines, electrical transformation systems come in three distinct structures. Fixed- speed induction generators were prevalent in prior years for both pitches controlled and stall-regulated turbines; in these plans, wind turbines were net users of reactive power that had to be provided by the electric system. For current turbines, these designs have now been reinstated with variable- speed machines. Two frameworks are dominant, synchronous generators with a full power electronic converter and doubly-fed induction generators, both of which are quite combined with pitch-controlled rotors. These variable speed plans basically decouple the rotating masses of the turbine from the electric scheme, hence providing various power quality merits over prior turbine designs. These turbines can produce reactive and real power, likewise some fault ride-through competence, all of which are mandatory by electric network operators. (Omar Ellabban et al, 2014).

During 2012, approximately 45 GW of wind power capacity started operation, rising global wind capacity 19% to approximately 283 GW, as shown in figure 4a. Almost 44 countries increased capacity amid 2012, at least 64 had more than 10 MW of recorded capacity by the end of the year, and 24 had more than 1 GW in operation. At the end of 2007 via 2012, yearly growth rates of cumulative wind power capacity were moderately 25%. The United States and China together represented about 60% of the worldwide market in 2012, distantly followed by Germany, the United Kingdom and India. Others in the top 10 for capacity included Spain, Italy, Canada, Brazil and Romania as shown in the figure 4b.

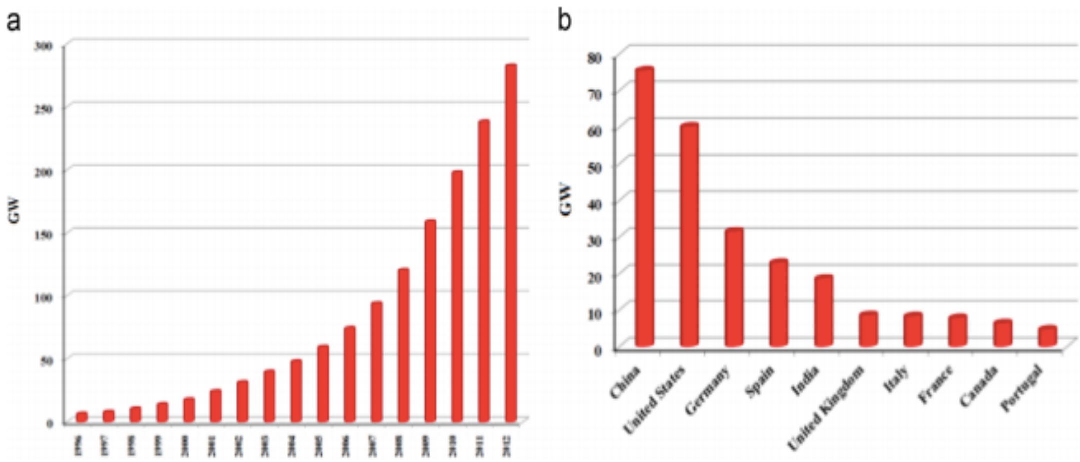

Figure 4. (a) Total world wind power capacity, 1996-2012, (b) Top 10 countries, wind power capacity, 2012.

General components of wind energy systems

The whole principle of wind energy systems is demonstrated in figure 5. As shown in figure 5, the essential units of the wind energy systems are the foundation, tower, nacelle, rotor, gearbox, generator, controller and transformer. Each of these units will be described in the sections below.

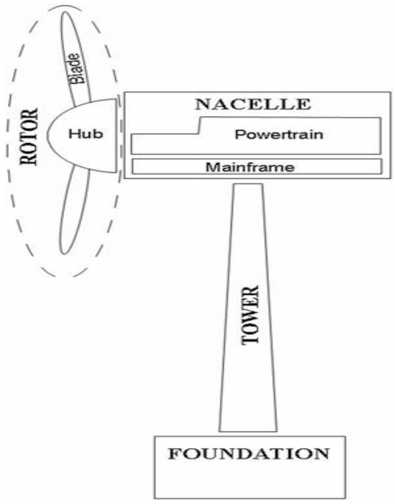

Figure 5. The main components of the wind energy systems (Anil, 2015)

Foundation: The foundation is the support system of the wind turbine. The body of the foundation hugely alters with the soil composition, water bed in the construction site and the turbine unit. In the normal type of foundation, the height could vary from 4 to 25 meters and it is normally a hollow steep pile where supplementary is added between the pile and transition piece. Ground/Surface level foundations rest on a terrain and is a wide base which is made of concrete. (Anil, 2015)

'Jackets' class of foundations can range from 30 to 35 meters in height and are akin to lattice towers which are commonly utilized in offshore oil and gas drilling sites. In comparison, 'multiple' foundations can go up to 40 meters in height, with various layers of several construction materials and having a distinctive footprint than the monopile foundations. In this criterion, there could be many diverse types of foundations copied from the elementary monopile structure. Certainly, the unit of foundation is dependent upon area of location, which could comprise of many factors such as height of the sea-bed, even if it is onshore or offshore location and also consistency of the soil. (Anil, 2015)

Tower: Most of the design of the tower is reliant on the rotor and the weight of the nacelle and it is constructed to carry the pressure caused by the fluctuations in the speed of wind. Furthermore, the load of the tower is also dependent upon the diameter of the rotor blade and the power of the turbine. (Anil, 2015)

Tower height (m)	Power (kW)	Diameter (Rotor) m
65	600 – 1000	40 - 60
65 – 115	1500 - 2000	70 - 80
120 – 130	4500 – 6000	112 - 126

Table 2: Comparison of the power, rotor diameter and the height of the tower

In regard to the design of the tower, the common kinds of tower designs are: concrete towers constructed on site, steel tabular towers, preconstructed concrete towers and the hybrid towers. The steel tabular towers are commonly used in large wind turbines. In such circumstances, the towers are constructed in 20 – 30-meter areas with flanges bolted at both sites. So, to effectively utilize materials/products and boost the strength of the towers, they are commonly secured towards the end.

Nonetheless, there might be height limitations when considering concrete towers built on ground/site. Prefabricated concrete towers are identical in design but the put-on top of another as separate areas. Lattice towers also look similar in design but consist of steel latticed areas. They are utilized in order to be effective in the utilization of materials as the quantity of the materials utilized are rather low than in other types of designs while being buoyant in the same degree. These, nonetheless are not used widely due to some factors. For these factors, lattice towers are more potent to be used in developing countries than in developed countries. Nonetheless, in regards of big turbines with high-energy generation, usually the mix of several methods and can be utilized together as hybrid designs. For instance, the bottom piece of the tower is made of steel while the upper piece is built with tabular steel. (Anil, 2015)

Nacelle: Nacelle is a part that composes of the binds the components and parts of the wind turbine. Considering the wind turbine needs to rotate according to the direction of the wind, to aid this rotation, the nacelle is connected to the tower with bearings. The architecture of the nacelle is greatly dependent upon the manufacturer and other units that are linked to the nacelle in the system. (Anil, 2015)

Rotor: Rotor is the main component which aids to convert wind energy to mechanical energy by rotation. Because the revolutions per minute (rpm) of rotor is reliant upon the size and design of the turbine; commonly the rotor of the turbine with hub assemblage revolve at a rate of 10-25 revolutions per minute. This hub is linked to low speed shaft, which is also linked to turbine gearbox. The hub is the integral of the rotor is commonly made of iron and cast steel. Hub can either be linked to low-speed shaft of the gearbox, assuming that the turbine has gearbox or directly linked to the generator if the turbine has no gearbox.

The typical form of architecture consists of a rotor with three blades and a horizontal shaft. The breadth of the rotor blade can be customarily from between 40 and 90 meters in diameter. This traditional design of three blades is known to apportion weight evenly allowing for more applicable rotation and hence, effectively generating power. The materials used to assemble rotor blades are normally fiberglass or carbon fiber galvanized with plastic. In several ways, the material utilized and the assumption behind rotor blades is very familiar to airplane wings. Yet the definite look of the rotor blades is dependent on the manufacturer. (Anil, 2015)

Gearbox: It comprises of the hub and the turbine blades which links the blades to the main shaft. Normally gearbox joins the revolutions of the rotor to the speed of the generator and is detected in most of installed wind turbines. In other news, it is the gearbox which converts the movement/rotation of the rotor blades, which is low in speed and high in torque, into high speed (normally 1500 rpm) and low torque input suitable for the generator. It has been implied that since gearboxes need constant maintenance, large-scale turbines may not gearbox so that they can reduce maintenance costs.

Generator: It is positioned inside the nacelle and it is the main segment which converts mechanical energy of the rotor to electrical energy. Normally the voltage level of operation of generators is 690 Volts (V) and engages with three phases of alternating current (AC). This kind of doubly-fed induction generators are the benchmark in wind energy design. Nonetheless asynchronous and permanent generators are still used in direct-drive structures (Anil,2015).

Controller: This segment of the wind energy system controls and monitors the turbine by gathering operational data. This operational information can be hydraulics temperature, rotational speed, pitch of the blade and nacelle yaw angles to wind speed. The structure of the controller enables the turbine is mostly facing the wind enhancing energy output and loading of turbine. Progressively advanced controller structure has enhanced remote location control of the wind energy system (Anil, 2015).

The substantial power that can be produced by wind turbines is fluctuating according to different aspects such as wind speed, wind resource, capacity of the turbine (in MW or kW), the height of the turbine tower and the diameter of the rotor blade. Most of the utility scale wind turbines utilize horizontal axis technology. Many analysts advocate that vertical axis wind turbine is less popular as they are said to be less effective aerodynamically. Hence, they do not automatically dominant the market share (Anil, 2015).

Transformer: It is a segment which converts the voltage output from the generator to the local grid unit. For instance, the medium level of voltage output from generator is converted in the dimension of 10kV to 35kV, which is the usual specification of the local grid. Transformers are normally positioned in the tower of the wind turbine (Anil, 2015).

Types of wind energy systems

Wind energy systems are extricated based on two main aspects: the axis of the wind turbine and the location of the plant. The wind turbine axis can either be horizontal (HAWT) or vertical (VAWT) while the location can be offshore and onshore (IRENA, 2017).

Differentiation based on location

Offshore wind systems are built in water bodies like seas while onshore wind systems are built in the mainland. The distinction between these systems is that offshore surroundings; wind turbines are constructed to be more resistant to wind velocity, to fight corrosion because of water and other demerits in the harsh offshore surroundings. These systems can also be more expensive because large installation costs of foundations and other segments and to protect the structures from bad marine environments. The architecture of the offshore foundations which can be single pile, multi-pile design is more difficult and expensive compared to mainland systems (Anil,2015)

The real power that can be produced by a wind turbine is comparable to different aspects like wind speed, wind resource, capacity of the turbine (in MW or kW), the height of the turbine tower and the diameter of the rotor blade. Many of the utility scale wind turbines utilize horizontal axis technology. Many researchers advise that vertical axis wind turbine is less popular as they are considered to be less efficient aerodynamically hence they do not significantly dominant market share (Anil,2015).

Differentiation based on axis of wind turbine

The major distinction between horizontal and vertical-axis turbine is arbitrated by factors like the number of blades, rotor placement (either downwind or upwind), hub linkage to the rotor (either hinged or rigid), output regulation system of the generator, capacity of the turbine and rotational speed of the rotor. The most common utility scale wind turbine can have three blades, diameter varying between 80 to 100 meters, the capacity of the wind turbine varying from 0.5 MW to 3 MW and the number of wind turbines varying from 15 to 150 connections to a grid (Anil, 2015).

2.1.3 Solar energy

The generation of energy by the utilization of sun’s rays to produce solar thermal systems or electricity through concentrating solar power (CSP) and photovoltaic (PV) systems. These technologies have been successfully used and installed all over the world over the decades.

Photovoltaic

These systems directly transform solar energy into electricity. The fundamental component of a PV system is the PV cell, which is a semiconductor device that transforms solar energy into electricity. PV cells are interconnected to create a PV module, generally from 50 to 200 W. The PV modules, connected with a set of supplementary application-dependent system segments (e.g. batteries, inverters, mounting systems and electrical components), design a PV system. PV systems are extremely modular, i.e., modules can be connected together to produce power ranging from a couple of watts to tens of megawatts.

The most entrenched solar PV technologies are silicon-based systems. As of late, supposed thin film modules, which can likewise comprise of non-silicon semiconductor material, have become progressively essential. Despite the fact thin films broadly have a lower efficiency than silicon modules, their capacity in price per unit is lower. Concentrating PV, where sunlight is focused/concentrated onto a smaller area, is on the rise of full market deployment.

Concentrating PV cells, possess very high efficiencies of up to 40%. Alternative technologies, for example organic PV cells, are still in the research phase. Photovoltaics entitle two merits. For instance, module manufacturing can be carried out in large plants, which enables economies of scale also it is a very modular technology. In comparison to concentrating solar power (CSP), Photovoltaic has the leverage that it utilizes not only direct sunlight but as well as the diffuse element of sunlight, e.g. photovoltaics generates power even though the sky is not completely clear. This proficiency allows the efficient deployment in many other regions in the world than for CSP. (Omar Ellabban et al, 2014).

Photovoltaic systems are grouped into two main types: grid-connected and off-grid applications. Off-grid photovoltaic systems have a symbolic opportunity for economic application in the areas that do not have electricity especially in developing countries, and off-grid centralized PV mini-grid systems have developed into a reliable substitute for electrification throughout villages for the past few years. Centralized systems for local supply of power have various technical merits regarding availability of energy, decrease of storage needs, electrical performance and dynamic behaviour. Centralized photovoltaic mini-grid systems could be the utmost cost efficient for a given level of service and can have a diesel generator installed as an optional balancing system or serve as a hybrid PV-wind-diesel system. These types of structures are important for decreasing and preventing diesel generator use in remote areas.

Grid tied PV structures utilize an inverter to convert electricity from direct current to alternating current, and then distribute the generated electricity to the electric grid.

Correlated to an off-grid installation, the costs are lower due to energy storage is not required because the gird is utilized as a buffer. Grid-connected PV arrangements are grouped into two categories of applications: centralized and distributed. Grid-connected distributed PV structures are set up to produce power to a grid-connected client or directly to the electric network. These structures have a lot of advantages: distribution losses in the electric network are decreased since the framework is set up at the point of utilization; no need for extra land for the PV systems, the mounting costs of the PV structures can be decreased if the structure is mounted on an already existing structure; and the PV design itself can be utilized as a roofing or cladding material, for example in building-integrated PV. Usual sizes are 1 to 4KW for residential systems, and 10KW to certain MW for rooftops on industrial and public buildings. (Omar Ellabban et al, 2014).

Grid-connected centralized PV structures execute the functions of centralized power stations. The power provided by such a system is not linked with a specific electricity customer, and the system is not situated to precisely implement functions on the electricity grid other than to provide bulk power. Generally, centralized systems are installed on the ground, and they are larger than 1MW. The economic benefits of these systems are the optimization of installation and operation costs by bulk buying, the cost effectiveness of the PV components and balance of schemes on a large scale. In addition, the reliability of centralized PV systems can be bigger than distributed PV systems because the total maintenance cost can be reduced by the using monitoring equipment on the maintenance structures.

In 2012, the total global solar generation power capacity grew from 30.2 GW to 100 GW by the end of the year due to new installations. Capacity has increased more than ten-fold over the past 5 years, with higher growth in capacity in Europe, led by Germany (7.6 GW) and Italy (3.4 GW). Germany continues to be the world's leader for cumulative installed capacity (32.6 GW), and Italy (16.2 GW) in second place. The highest markets – Germany, Italy, China, the United States, and Japan – were also the leaders for total capacity as shown by figure 6 Also, figure 7 indicates the global PV annual market scenarios until 2016. (Omar Ellabban et al, 2014).

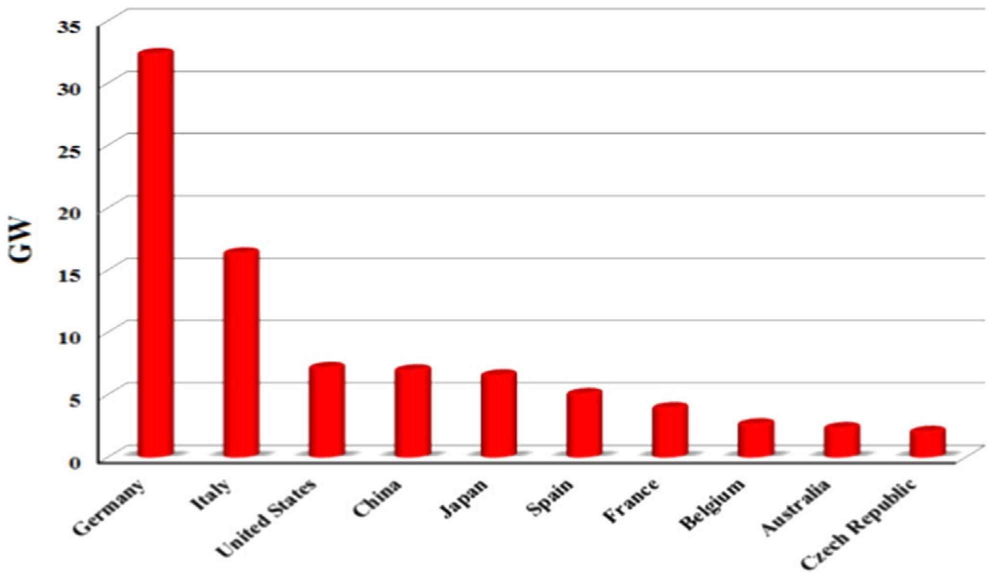

Figure 6: Global Solar PV capacity, (top 10 countries). (Omar Ellabban et al, 2014)

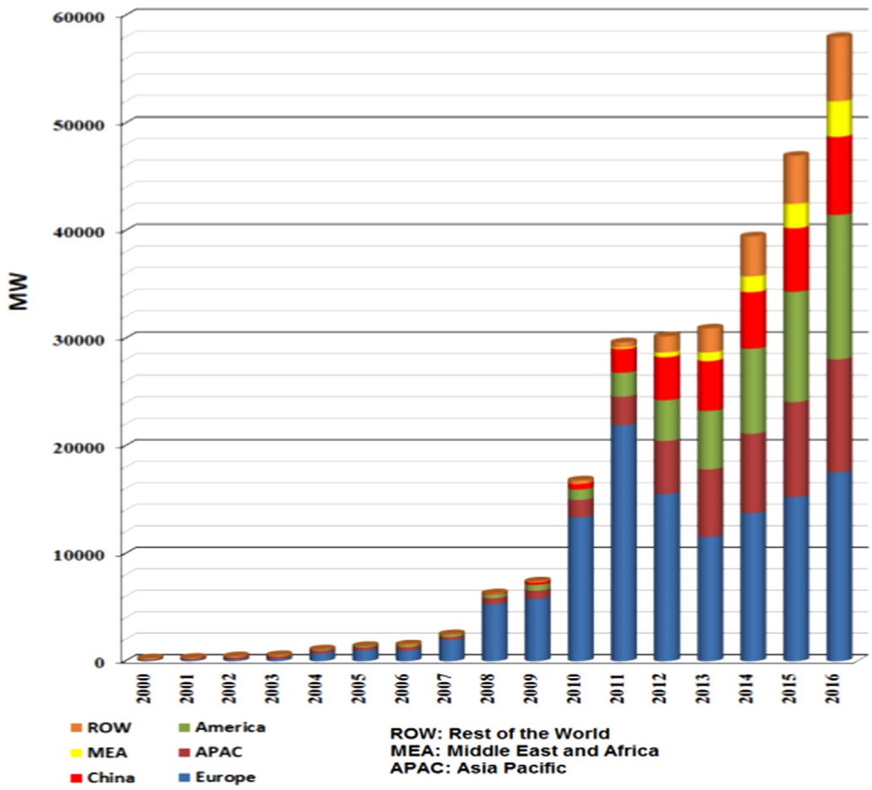

Figure 7: The global annual PV share per region worldwide 2016 (Omar Ellabban et al, 2014)

Concentrating solar power

Concentrating solar power (CSP) technologies create electricity by concentrating direct-beam solar irradiance to heat a solid, liquid or gas that is then utilized in a downstream process for generation of electricity. Large-scale CSP plants generally concentrate sunlight by reflection, as opposed to refraction with lenses. Concentration is either to a linear focus as in trough or linear fresnel systems or to a point focus as in central-receiver or dish systems. Concentrating solar power operations range from small-scale systems of tens of KW to large centralized power stations of hundreds of MW. The first commercial CSP plants were the 354MW of solar electric generation stations in California that still operate commercially till today. Due to the positive outcomes and lessons learnt from these first/early plants, the trough systems are most frequently used today as the CSP industry grows.

In regard to CSP electricity generation, at the start of 2009, more than 700 MW of grid-connected CSP systems were set up worldwide, with others 1500 MW in the process of construction. Most of the installed solar power structures utilize parabolic trough technology. A central receiver consists of an increasing share of plants under construction and those announced.

The market of concentrating solar thermal power (CSP) plants continued to progress in 2012, with an absolute global capacity up more than 60% to about 2550MW. The market increased respectively to 2011, with Spain contributing the highest capacity of about 970MW introduced into operation (Omar Ellabban et al, 2014).

Flat plate and evacuated tube solar collectors

In contrast to CSP systems, flat plate or evacuated tube solar collectors can be used to collect solar energy in a non-concentrated manner for cooling and heating purposes. Because of their high efficiency and cost-effective attributes, the growth of this technology is increasing worldwide and can be used year-round especially in cold temperatures, high humidity but mostly in poor weather conditions. Partially due to the increased efficiency in electric water heating, as of 2010, over 70 million residences worldwide held active installations of this technology. Images illustrating both evacuated tube solar collectors and flat plate are shown in the figure below.

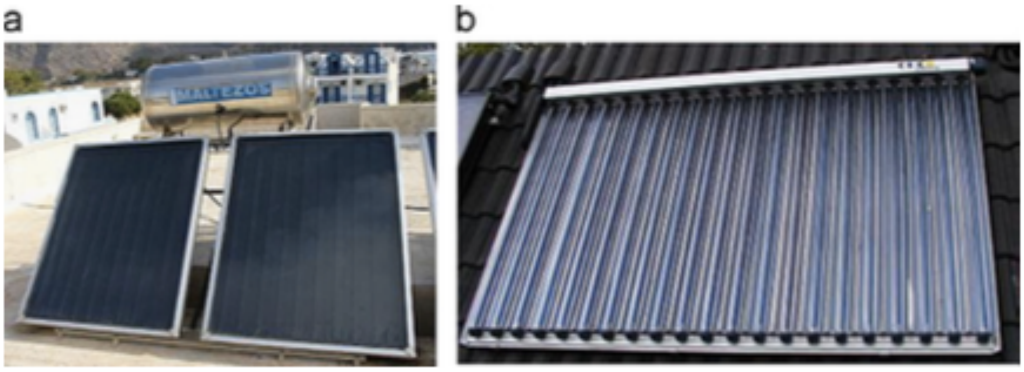

Figure 8: Examples (a) and (b) of flat plate and evacuated tube solar collectors (Vijay Devabhaktuni et al, 2013).

The vital structure of these systems subsists of some kind of absorption mechanism, a transfer device, and some kind of storage. The absorption mechanism is generally some kind of copper tubing in several configurations that are designed with a coating to improve efficiency. Numerous pipe compositions may include serpentine, harp, boundary layer or completely flooded. Air or water is distributed through the piping system where it is heated and returned to storage. A more efficient alteration of this technology is the evacuated tube collector. In this structure consists of a containment unit where heat pipes are vacuum sealed. These pipes are then utilized in the transmission of heat using a manifold. The evacuated tube structure is often favoured because it is. 20-45% more efficient than flat plate solar collectors, attains decreased heat loss by alleviating convective/conductive forces by vacuum sealing, utilizes cheap pipes that are and economical to replace, and, because of the cylindrical feature of the pipes, tracks the sun calmly leading to increase in efficiencies at low costs (Vijay Devabhaktuni et al, 2013).

2.2 Investment and operation costs

The electricity sector is rapidly growing due the development of clean energy all over the world. Over the decade, the contributions from renewable technologies in the electricity mix has been doubled. The contributed was about 2000 GW by the end of 2016. (IRENA, 2017).

The growing demand for development of the expansion of renewable energy can be seen globally for example in China. There has been an increase in solar PV expansion globally hence setting another record in the year 2017. The increments in solar PV have been around 90GW and in wind approximately 40GW.

Cleaner energy production is presently advancing from a noble cycle; hence policy support for renewable energy generation technologies experiences increased stationing/positioning., improvements in technology and cost reductions which leads to the reduction of electricity costs from energy production. By 2016, onshore wind projects persistently contributed to competitive electricity rates and biomass was authorized for power production (IRENA, 2017)

The development of renewable technologies (solar and wind) has accelerated their production greatly. The LCOE of solar PV has dropped by 73% over the last ten years thus increasing its cost effectiveness at the utility scale. Due to established cost reductions and technology improvements, on shore wind has become one of the greatest competitive technology. Regardless, offshore wind and CSP are still relatively new, hence their costs have gone down. Tenders and auctions in recent years display to a greater extent that despite financial support these technologies can be still be competitive with fossil fuels if right policies and strategies are put in place.

The energy sector especially renewables hence has history of conveying on reductions in the cost structure. This can be attained by improving the efficiencies in the technologies, by utilization of developed technology that reduces financing costs and greatly reduces supply chain costs and by increasing the scale of production.

Moreover, public discussions about renewables generally persists to deteriorate from the view that renewables are not cutthroat. This thesis illustrates that hypothesis that renewable energy production is costly is outdated given that renewable energy production is high, and production is at competitive costs much lower than fossil fuel fired power production costs (IRENA, 2017).

2.2.1 Cost methods for renewable energy production

Power production costs can be calculated in various ways and each method of calculation carries its own awareness. In this thesis we are going to focus on evaluating the impact of technology and market growth (development) on the LCOE. To comprehend these variations, it requires the analysis of overall installed costs, performance capacity, equipment costs, operation, weighted average cost of capital and operation and maintenance costs as shown below. Furthermore, review of developments in technology, their market shares, supply chain capacities, manufacturing innovations are also evaluated.

LCOE is a sign of the cost of electricity needed for a task where revenues would amount to costs, consisting of obtaining a return on the capital invested equivalent to the discounted rate or WACC. An electricity cost higher than this exerts a bigger return on capital, whereas a cost beneath it exerts a small return on capital or even loss. The calculation of LCOE of clean (renewable) energy differs by nation, project and technology according to the operation costs, capital, energy resource and the performance of the technology. (IRENA 2017).

2.2.2 The levelised cost of electricity

The LCOE is a tool used in comparison of costs of various technologies over their operational period. The procedure of LCOE mirrors the risks of universal technology and not specifically risks in projects in specific markets. Because of these risks, there is a difference amidst financial costs and the LCOE for owners in the actual electricity markets facing particular uncertainties. In addition, LCOE is equivalent to the actual cost investments in generation of electricity in electricity markets with controlled prices relatively to the actual costs of generators with different prices in competitive markets.

Because of these factors (structural and technical) for example; no storage of electricity, differences in daily demand of electricity or the occasional fluctuations in both demand and supply, electricity prices for example spot prices are granted to change due to different factors.) Furthermore, the LCOE procedure was developed in an era of controlled markets. As electricity markets deviate from this traditional era, the LCOE must be evaluated by several factors when selecting between different electricity production technologies.

Discounting Discussion

Despite these deficiencies, LCOE continues to be a trusted tool used in the evaluation of generating costs and it's a largely utilized tool in comparison the costs of various power generation systems in policy and modelling research. The theory of LCOE is based on the correlation of the current price of the summation of discounted costs and the current price of the summation of discounted revenues. In addition, LCOE is the tariff where an investor can specifically break even on a project after repaying equity and debt, after auditing for appropriate rate of return to these investors. These tariffs for electricity and LCOE depend on two important factors:

- Electricity tariff, $P_{MWH,}$ is constant and assumed not to alternate during the economic lifetime of the project. All output, at the appropriate capacity factor, is sold with this tariff. (It is not certainly the price at which electricity shall be sold when generation begins)
- The real discount rate r utilized for discounting benefits and costs is stable and doesn't change during the lifecycle of the project under review.

The real equations should simplify these relationships. With discounting annually, the LCOE calculation begins with equation (1) indicating the coordination between the current value of the sum of discounted costs and current value of the sum of discounted revenues, consisting of payments to capital providers. The index t stands for the year in which the sale of production or the cost expenditure takes place. The addition expands from the beginning of preparation of the construction to the finish of disassembling, which comprises of the discounted value at the moment of future waste management costs. All variables are actual, i.e. net of inflation. On the left side, one discovers the discounted sum of benefits and on the right side the discounted sum of costs:

$\sum P_{MWh} * MWh * (1+r)^{-t} = \sum(Capital_t + O\&M_t + Fuel_t + Carbon_t + D_t) * (1+r)^{-t}$

Where the different variables show:

P_{MWh} = The constant lifetime payment of the provider/supplier for electricity;

MWh. = Electricity produced in MWh, assumed constant;

$(1+r)^{-t}$ = Discount factor for year t (reflecting payments to capital);

$Capital_t$ = Total capital construction costs in year t;

$O\&M_t$ = Operation and maintenance costs in year t;

$Fuel_t$ = Fuel costs in year t;

$Carbon_t$ = Carbon costs in year t;

D_t = Decommissioning and waste management costs in year t;

Because P_{MWh} is a constant over time, it can be brought out of the addition, and equation (1) can be converted into

$LCOE = P_{MWh} = \Sigma(Capital_t + O\&M_t + Fuel_t + Carbon_t + D_t) * (1+r)^{-t} / \sum MWh (1+r)^{-t}$

Where this constant, P_{MWh}, is defined as the levelised cost of electricity (LCOE).

The equation above is the formula utilised here to calculate the average lifetime levelized costs on the basis of operation and maintenance, fuel, investment costs, carbon emissions and decommissioning and disassembling.

2.2.3 Power production cost trends in renewable energy.

While the installation of renewable energy technologies increases, a growing improvement in their competitiveness has been sustained throughout 2016 and 2017. This has resulted generally in every area of the world, hydro energy, bio-energy and onshore wind structures commissioned in 2016 and 2017 mostly fell between the territory of non-renewable electricity production costs.

With the fast decline in solar PV module and balance of system costs, solar PV utility scaling has currently developing and is in competition aggressively with alternatives- without any financial support. CSP and offshore wind, although possessing importantly lower installation volume in comparison to other renewable systems, have also observed their costs reductions, with auction outcome in years (2016 and 2017) illustrating that they too are on the path to attain cost competitiveness for projects commissioned over the past decade (IRENA,2017)

The main factors behind these cost reductions are:

- Optimisation of O&M practises and the utilization of current data to grant revised predictive maintenance, reduction in generation loss and O&M costs from planned and unplanned output/outages.
- Decreasing costs of capital, compelled by supportive policy laws, project analysing tools through de-risking and the technical growth of green energy production technology.
- Decrease of waste especially in material and labour usage in the manufacturing process and also optimization of capital.
- Raising the cost advantage in manufacturing, consolidation and vertical integration among manufacturers.
- Less entry limitations and a profusion of experienced developers across the scale (small to large) battling to develop projects, globally.
- Accomplished project developers that gain standardised approaches to show growth and who have reduced project development risks.
- Technology development that are increasing capacity factors and/or lowering installed costs.
- More competitive, global supply chains that are progressively optimised to supply tailored products that perfectly suits local market and resource conditions.

All of this has been occurring contrary to the growing competitive nature in the innovative environment of renewable energy sector. With the advanced wind and solar systems developing from supportive policies, there has been a constant- and occasionally striking- development in their establishment in the last decade. This has led to the development in the solar and wind markets. Hence solar PV structures by 2017 have been 73% lower than 2010 due to the reduction in solar prices in 2009 (IRENA,2017)

Balance of system costs have also dropped, but not very big, showing that the total installed costs globally of recently commissioned projects dropped 68% in the past decade. The duration between 2010 and 2017 shows that the cost of electricity from onshore wind drop by 23%. Certainly, wind energy has undergone a somewhat unrecognized revolution in the years 2008 and 2009 as wind turbine costs have fallen. Between 2008 and 2015, a wholesome cycle of upgraded turbine system, as well as longer blades with wider swept areas, higher hub heights have expanded capacity factors for a given wind resource.

Due to this, the average capacity factors for current projects has risen globally. The reduction in installed costs in wind turbines dropped by 39-58% in regard to particular markets. The balance of systems costs for onshore wind has also reduced hence the low LCOE and increased construction of wind projects. Electricity generated from biomass can also be very cutthroat especially onsite for agricultural, industrial or forestry power plants. Due to this, biomass can produce electricity with a low LCOE for example USD 0.03/kWh and the heat produced can be utilized for CHP power plants (IRENA,2017)

Reasons for Further Cost Reductions

The energy sector is presently experiencing development that shows the introduction of the evolution to a renewables-monopolized, absolutely sustainable energy sector. This is needed in order to avert the serious of climate change. The power production sector dominating this development, with clean energy predicted to have supplemented largely of the global added capacity needed every year. Over the past decade, by 2016 the global installation of solar PV has increased from 1GW to 291GW and by the lattermost part of 2017, it would have increased to 386 GW. Likewise, wind energy at the lattermost of 2001 was 24 GW, but at the lattermost of 2016 had attained 467 GW. At the same time, annual current capacity inclusions of cleaner power production systems raised from 16 GW to 167 GW by the end 2016, a ten-fold raise, with absolute current capacity increases in 2017 expected to exceed this story (IRENA,2017).

The noble cycle of lasting support actions advancing the establishment of renewables thus leading to technology developments and cost reductions (figure) has led to the raised scale and aggressiveness of markets for clean energy systems. The revolution of the energy production sector is thus an effective one, where the policy action for renewables to attain countries lasting targets for sustainable both environmental and to the population, reliable and affordable power is producing results (IRENA,2017)

As costs for wind and solar power equipment has dropped, particularly for onshore wind turbines and solar PV modules, a shift in significance in cost reduction factors is also developing. As costs drop, the concern of dealing with balance of system costs, developing the work of the systems, lowering O&M costs and reducing the capital costs all begin to take on better importance. Likewise, business models and markets are still not standing. Currently, as the fascinating case for clean power production's market has developed, so has establishment. Yet it has not just developed, but also accomplished an astonishing expansion in different regions worldwide. In a few circumstances, this has led to diminishing markets for current ventures in developed markets (particularly Europe), emanating in a large capacity of very skilled technicians now immensely searching global opportunities (IRENA,2017).

This assemblage of elements has been urging current cost reduction trends for renewables, with results that shall only advance in significance in 2018 and beyond. The three important factors that are surfacing to progressively lead to reduction in costs are:

- Increase in global competition for ventures;

  Increased development in renewable energy production establishment, a huge capacity of very skilled project planners has developed worldwide. A lot have observed their initial markets progress slowly and have considered brand new markets to preserve a pipeline of ventures and develop their businesses. This has granted brand-new to gain from previous, arduous business sensitivity in the field of renewable project development. In partnership with local partners, in several cases, to help manoeuvre the local governing and business scenery; these project planners are premising even brand-new markets to attain very vying pricing, where the policy structure and regulatory is favourable to clean energy.

- Competitive acquisition of renewable energy;

  With advanced development of renewable energy, the reduction in costs have surpassed possibilities, hence there is a thriving transition in auctions and other cutthroat procurement measures. In developed businesses, with restricted quantities in bid, this has led to great competition for ventures and has proceeded in dropping costs. Correspondingly decreased support measures have also compelled developers to enforce good tactics in regard to project development, use innovative solutions, and usually decrease margins.

- Extended technology modernization

  Due to the unlocking in the economies of scale in materials efficiency and in manufacturing in current years, endless reductions in costs are starting to become greatly influenced by developments in technology. Specifically, accurate for wind, where large turbines with big or wide diameters are producing more electricity. Bigger/larger turbines also permit the amortising of project improvement costs over better capacities and permit better costs in O&M. Also, wind turbine makers are contributing a growing catalogue of products to permit development for personal wind farms, while the usage of current information to reinforce anticipating maintenance in order to decrease O&M cost and lost energy from downtime which is very fundamental. In regard to solar PV modules, the endless measures to advertise cell structures with better efficiency are aiding to decrease module installed and balance of system costs. These are but a few cases of the continuous modernization that is aiding to minimize costs.

This tendency is not current, but its significance has developed naturally in current years. They influence greatly across the power production category because of the fact in various areas of the globe, renewable power production technologies often provide the minimum cost source of brand-new power production. The game is hence swiftly changing. In ancient years, particularly, there was a structure providing direct financial support, usually directed to personal systems (e.g., solar PV) and even parts (e.g., fluctuating support for commercial, residential and utility-scale parts, frequently separated by alternative factors for example even if they are constructing-integrated or not). Today, this is being reinstated by a positive institutional and administrative scheme that prepares the platform for competitive acquisition of renewable power production to conform countries energy, development and environmental policy goals.

In various areas of the world, industry players, utilities, project developers and asset owners have promptly grasped this current trend and are discovering means to effectively operate this current scene. Without financial support directly, project developers are also utilizing advanced business layouts to develop. Communities are establishing plans that shall permit subsidy-free plans to be effective/profitable in various markets. Illustrations of this range from using utility or corporate power purchasing agreements' (PPAs) to produce revenue certainty, or commercial solar PV structures being constructed in particular areas where extensive market estimates back their finance. More examples comprise of searching for new opportunities, for example storage to improved access peak prices and possibly attain new earnings flows by producing additional benefits to the network. (IRENA 2018).

2.2.4 Future intuitions for Renewable Energy Costs to 2020

The dimension of costs for renewables globally is high and this varies according to the project and location of the project. Hence particular projects have different factors which can lead to cost reductions in their own way. It is surprising, that basically all renewable production systems currently not only comprise of many of projects which provide competitive electricity costs, but that renewable generation systems are also progressively developing because of the decline of the fossil fuel-powered electricity cost structure. This is because fossil fuels are exempted from paying for the damages done to the environment globally, and the

health impacts suffered globally. Adding these costs would unquestionably boost the economics of clean power production costs, in contrast with the data outlined in this thesis. As previously discovered, the instability of wind power and solar PV should be thoroughly considered in system construction to obtain the minimum-cost solution of these technologies. Nonetheless, ancient IRENA data research has shown, the supplementary environmental costs of fossil fuels and estimations of the supplementary costs of variability of wind and solar can largely balance each other. Nonetheless, assessments of both these cost categories is nation explicit and advancing after some time as a better perceptive of the different effects of each is accomplished through experiences in the operations of these technologies and extra studies (research). This area explores further in deep research some of the important factors that are behind study of LCOE, for authorized projects in the past and for upcoming projects in 2020 (IRENA, 2017). The five factors that influences the cost trends;

- Renewable energy systems are progressively not just aggressive without financial assistance, but out-compete fossil fuels.
- Cost discounts for wind and solar are progressing at a constant trend and between the years 2010 - 2020 show exceptional estimates of reduction of costs, automatically thrashing long-term forecasts.
- Electricity costs from solar PV and onshore wind is extending to terribly small levels, only accomplished in the past years by the very good hydropower projects.
- By 2017, a compelling range of newly authorized onshore wind, bioenergy and solar PV activities contended tightly with non- renewable energy without financial help.
- A noticeable merging in the global cost of electricity from each technology has been communicated to 2020 by current auction outcomes. Equipped cost differences between nations continue for solar PV and onshore wind especially, nevertheless displaying cost reduction events.

In 2017, weighted average electricity costs for onshore wind, solar PV and bioenergy all dropped within the scope of fossil fuel-fired electricity and are generally the low-priced source of modern generation needs. The fossil fuel-fired electricity production cost dimension for G20 countries stretches the dimension USD 0.05 to USD 0.17/kWh (IRENA, 2017).

2.2.5 Cost breakdown of Wind energy systems

Total investment in green energy has increased by 3% but still less than the recorded investment in 2015. Conferring to BNEF, globally the total investment in wind energy has grown with China at 40% and Asia Pacific 57% of the total. The investment in total rounds up to about 107 billion US$. Regarding costs for both offshore and onshore wind maintain to astound. At the same time, offshore wind obtained its first no subsidized bids in a tender last year in Germany, with 1 GW new tenders (offshore) acquiring no more than wholesale price of electricity, Generally, offshore costs for schemes/projects to be finished in the following 5 years or so are a fraction of what they were five years ago;

and this tendency is possible to continue. The reasons behind this include: the development of the technology, the expanding industry, management, developing investor trust and the injection of installation of modern of turbines with large diameter and big yield/output. (GWEC, 2017).

Total Offshore Investment Costs.

Wind energy investment costs especially offshore wind are expensive. The real investment costs take up approximately 75% of the absolute lifetime cos of offshore wind energy, which is exceedingly high in connection to other electricity production technologies – generally investment costs are around 40% of the energy cost from a conventional power plant. From the investment per MW perspective off shore wind is about 50% more costly than onshore wind. The biggest capital costs of offshore are because of big structures and complicated logistics in the installation of the towers. Offshore foundations, installations, construction and the grid linkages/connections costs are unquestionably greater than for onshore wind. Generally, offshore turbines are 20% more pricey, and foundations and towers value more than 2.5 times the cost for a project of identical size onshore. (P.E Morthost et al, 2016).

Installed capital costs: Construction of towers and additional installation costs are the biggest costs of wind power systems. Rotor blades and tower costs can sum up to half of the total cost. After this, the other costly segment is the gearbox. The price of additional segments like power converter, generator, nacelle and transformer also consists of the installed costs. Certainly, these costs differ in relation to the region of the project, arrangement of wind energy systems in that specific country and the particular position of the work. For instance, it is known that the installed costs of offshore wind are greater than onshore wind. The high costs come from the installation of wind energy systems in the harsh sea conditions. The preparation, planning and development of the project normally result in high costs. Other factors leading high costs include logistics and environmental permits. Nonetheless, offshore wind has its own merits in regard to the economies of scale because they are not extremely high as onshore wind.

Finally, the total installed costs for onshore wind have declined by 72% over the past decade (5179 USD to 1473 USD). This because of the reduced prices in wind turbines and balance of plant (IRENA, 2019)

Grid connection costs: These costs consist of connection/linkage costs to local transmission network, inclusive of the substations and transformers costs. The position of the wind project from the distribution system also impacts the grid line costs. If the area is too far, rather than the traditional high voltage alternating current (HVAC) linkage, there might be an urgency for high voltage direct current (HVDC) linkage, which is expensive. Furthermore, grid line costs also comprise electrical works, transmission lines and contact point. (Anil, 2015)

These costs can differ in regard to geographical region of the project and category of the wind power system (onshore or offshore). In a few nations, the overseer incurs the upgrade transmission network costs although in others it is the project owner. Equivalently, even if the wind project is onshore or offshore this impacts the grid system costs. For instance, it's been discovered that the offshore wind projects can vary from 15-30% of the overall capital costs and onshore wind projects can vary from 11-14% of the total/overall capital costs (Anil, 2015)

Operation and maintenance costs: It has been reviewed that operation and maintenance (O&M) costs of wind energy systems can account from 30% of total Levelized Cost of Electricity (LCOE), and the outcome is normally 2% of the original investment cost per year. O&M costs are normally divided as fixed and variable costs. When the costs comprise of costs of insurance, grid access fees, administration and the service contracts for scheduled maintenance costs are normally known as fixed O&M costs.

Variable costs are costs obtained due to unexpected circumstances that are not covered by the fixed service contracts. For example, replacement of parts and products, unscheduled maintenance, and the labour costs needed to cover unscheduled maintenance. The costs can be little and frequent actions or because of large and rare occurrences like replacement of major components of the system (IRENA, 2015).

Again, the geographical location of the wind project (offshore or onshore) affects the degree of O&M costs acquired. For instance, it has been said that O&M costs are greater in European countries than United States. Also, offshore costs are more expensive due to the challenges in maintaining and accessing the wind turbines and finally considering the failure rate of segments in offshore environment (IRENA, 2019). The table illustrates the breakdown of the installed capital costs for wind turbines.

Turbine cost	Grid constriction cost	Other costs
• Blades • Tower • Transfer	• Constriction costs for site preparation • Foundation for the towers	• Construction of building • Insurance • O&M costs • Control systems • Contingencies • Project consultancy costs

Table 3: Illustration of capital costs for wind turbines (Anil, 2015)

2.2.6 Cost breakdown of Solar PV systems

Module Costs: The solar PV costs in Europe have declined by 83% from the end of 2010 to the end of 2017. Module costs decreased 80% from the end of 2010 to the end of 2016 hence the 86% cumulative global PV installations at the end of 2016. The module prices decreased rapidly up to 2013 but have accomplished more reliable cost reductions in the recent years as the manufacturers have tried to return profit margins to more sensible levels and several trade disputes impacted minimum costs in several markets. (IRENA,2017).

The module comprises of interlinked PV cells, the raw materials used for these cells and their interlinkages. This comprises of cell processing costs, silicon, and assembly costs. Nonetheless, the module costs differ by the geographical location of the project, manufacturer, technology, retail margin and the types of materials utilized. For illustration, c-Si PV modules are more costly than other systems, while CIGS modules are cheaper even if the c-Si are more effective. Certainly, geographical location is considered when it comes to costing of PV modules hence influence the manufacturer and traditional margin rate acceptable across several locations (Anil,2015).

Inverter costs: The inverter is the integral unit of PV module system that converts DC electricity to from solar PV to grid AC form. The size of the inverter differs due the its purpose whether residential or utility-scale. The number of inverters utilized in the solar modules depend on the installed capacity and overall system. It accounts to 5% of the general installed cost of PV systems. (Anil, 2015).

Balance of System Costs (BOS): These costs contribute greatly to total system cost reductions, adopting policies that can decrease soft costs carters the chance to improve the cost structures towards good practice levels. Such policies include administrative challenges linked to obtaining permits or incentives that slow down application processes. Nations with competitive installed cost levels show, on average BOS (without the inverter) make up about half of the total installed cost. Soft cost criteria of these countries take up a third of these costs and about 17% on average of the total installed costs. Hence, which leads me to say that BOS costs vary according to geographical locations. (IRENA,2017)

Operation and Maintenance Costs: Traditionally, solar PV O&M costs have never been regarded a main constraint to their economics. But the fast decline in PV module and installed costs over the years, the share of O&M costs in the LCOE of solar PV in particular areas has increased greatly. The geographical locations of these solar projects affect the O&M costs greatly. The factors taken into consideration include; land lease, taxes, insurance, site security, maintenance and administration costs. Land lease costs are dependent on site and market. They can be very greatly low in areas where land values are low such deserts or can also be zero when no land fees are charged as an incentive for the project developer to reduce costs. This is different to areas where land constraints are a big challenge, for example on highly populated areas where land costs can be very important. The table below illustrates the cost breakdown of the solar PV system. (IRENA, 2017)

PV module	Inverter	BOS/installation
Semiconductor • Raw materials (Si feedstock, saw slurry) • Utilities, maintenance, labour • Equipment, tooling, building, cost of capital • Manufacturer' margin	• Magnetics • Manufacture • Board and electronics (capacitors) • Enclosure • Power electronics	• Mounting and racking hardware • Wiring • Others • Permits • Systems design, management and marketing • Installer overhead and other costs • Installation labour costs
Cell • Raw materials (metallization, SiNX, dopants, chemicals) • Utilities, maintenance, labour • Equipment, tooling, building, cost of capital • Manufacturer 'margin		
Module • Raw materials (glass, EVA, metal frame, j-box) • Utilities, maintenance, labour • Equipment, tooling, building, cost of capital • Shipping • Manufacturer's margin • Retailer's' margin		

Table 4: Solar PV cost breakdown (Anil,2015)

2.2.7 Cost breakdown of bioenergy energy systems

To analyse the utilization of biomass power production, the following three factors should be examined; Firstly, biomass feedstocks which come in various forms and different properties. Secondly, biomass conversion- the process by which biomass resources are converted into energy then electricity and finally power generation technologies which include a range of proven power generation technologies that can utilized biomass as a fuel input. (IRENA,2017).

Biomass feedstocks: Feedstocks are needed to generate electricity by the biomass technologies, which is not needed for solar or wind power systems. It is required to produce, collect, transport and store the feedstock for electricity production. The cost of feedstock is reliant on the availability and distance to the source and also if the suppliers are dependable. In addition, density, energy content, moisture content and other properties of the feedstock impact the handling and processing of the power plant and the efficiency of the fuel have an impact on the cost of feedstock. The preparation time needed for the feedstock also contribute positively or negatively to the cost of feedstock. Feedstock normally account for 20-50% of the final cost electricity from biomass energy systems. (IRENA, 2017).

Total Installed Costs: Biomass power production differs in different regions in the world in regard to the technology used and the local cost of the total project. Developing countries tend have low investment costs compared to countries with stable economies. The reason behind their low investment costs is because cheap labour, cheap commodities but also no strict environment hence the low emissions control costs unlike in other countries where it is high (IRENA, 2019)

The total investment costs of biomass consist of EPC costs, fuel preparation (handling), equipment and others important units like prime mover and the fuel convert system. Other costs are obtained from infrastructure and the grid linkages (roads). The total installed costs are monopolized by equipment costs, but particular projects possess high costs in infrastructure and grid connections especially obscure regions.

Biomass structures in CHP (Combined heat and power) possess high investment costs, but their high efficiency (80% to 90%) enables possible improvement in economics (IRENA, 2019).

Operation and Maintenance Costs: The fixed O&M costs for bioenergy plants normally vary from 2-6% of total installed costs per year whereas the variable costs are normally low around 0.005/KWh. Fixed O&M costs comprise of scheduled maintenance, labour, routine segment/equipment replacement (for gasifiers, boilers, etc), and insurance etc. Large power plants have low fixed O&M costs because of economies of scale such as labour. Variable O&M costs are dependent on the output of the system and normally displayed as USD/kWh. Non-biomass fuel costs like, unplanned maintenance, ash disposal, replacement of equipment and increasing service costs are the major segments of variable O&M costs. Sadly, the present data always merges the variable and fixed O&M costs into one number hence challenging the breakdown between fixed and variable O&M costs. (IRENA, 2017). The table below illustrates the information selected for the overall O&M costs.

	Fixed O&M (% of CAPEX/YEAR)	**Variable O&M (2016 USD/MWh)**
Stoker/BFB/CFB boilers	3.2	4.08-5.03
Gasifier	3-6	4.08
Anaerobic digester	2.1-3.2	4.49
	2.3-7	
Landfill gas	11-20	n.a

Table 5: Fixed and variable O&M costs for bioenergy power (IRENA,2017)

Biomass power generation technology cost:

The total cost linked to technology utilized for production of electricity by biomass power systems or the total investment cost mainly consists of the equipment utilised (fuel conversion system), fuel handling and preparation machinery costs, engineering costs and the construction for the power system and other planning costs. The planning costs consist of consultation cost, design and other working capital. Other costs comprise of grid connection and civil works.

Certainly, the biomass power systems cost is fickly dependent on the type of technology utilized, the location where it is set up, the type of feedstock utilized, and the amount of time and effort needed to prepare/organize and handle feedstock in the location. The decision of the type and size of technology is also always dependent on the demand of electricity and heat from the locals. For this research, it is evident that the cost of technology will be reliant upon the size of the project, components requirements, feedstock requirements and the type of technology. Finally, 62-77% of the total capital costs is decided by the feedstock conversion technology and equipment needed for feedstock preparation and handling. (Anil,2015).

Cash flows or revenue generated from different energy systems

To evaluate different investment options, it is needed to comprehend the cash flows generated by the different energy systems. There are several cash flows studied in finance in regard to the types of analysis carried out. Nonetheless, different types of cash flows are utilized according to investments made in some projects for example; operating cash flows, financial cash flows and investment cash flows (Anil, 2015). For instance, revenue is normally operating form of cash flow from where operating and maintenance (O&M), income taxes and interests are deducted. For investment actions, cash flow can be for instance, capital expenditures. For financial activity, the typical type of cash flow is the repayment of debt principal and dividends. For this research, the main cash flow studied is the revenue. More importantly, it is the end of the period cash flows.

Basically, revenue is the money obtained from goods and services sold. In this study, the money received from the sale of electricity produced by these different systems. Revenue is calculated by multiplying the unit price of the electricity output with the total units of electricity sold.

$$\text{Revenue} = \text{quantity sold} * \text{per unit price}$$

2.2.8 Additional methods utilized in economic evaluation

It is necessary to study other economic methods to make the analysis more accurate. While making investment decisions, the main measures that must be taken into consideration are the discount rates, depreciation costs, inflation rates, taxes, present and net present value (NPV). Each are briefly described below.

Inflation rate

Future cash flows, comprising revenue and costs can only be illustrated as current value. Current value of the cash certainly changes over time because of inflation. Current value of the cash elaborates the cash that would have been needed if the cost was paid in the base year (n). In that situation, the value of cash in current year (m), if attributed to as F_m can be transformed to cash value in any year n, F_n by considering the effect of inflation (e) (Anil,2015).

If the inflation rate between the years m and n were assumed to be constant,

$$F_n = F_m/(1 + e)^{m-n}$$

Discounts rates

Money has time value. There is appreciation of money over a duration of time that is to say money/cash possessed today will be more valuable than cash got in the future because it can earn interest once it is invested. Discount rates favour this time value of money and allows it to contrast present and the future value of the money. Normally discount rates can either be real or nominal, depending upon whether they incorporate the inflation rate (hence it is real) or not (hence it is nominal) (Anil,2015)

Nominal and discount rates can be transformed to each other by the utilization of the following equations:

$$(1 + d_n) = (1 + d_r)\,(1 + e)$$

$$d_n = [(1 + d_r)\,(1 + e)] - 1$$

$$d_r = [(1 + d_n)/\,(1+ e)] - 1$$

Where,

d_n = nominal discount rate

d_r = real discount rate

e = inflation rate

Present value and net present value (NPV):

Money has time value. Due to this fact, future cash flows differ in value in contrast to their present value. When future cash flows (revenue) are transformed to current value it is described as the present value. The present value of future cash flows can be determined by multiplying cash flows (future) with the discount factors of the present value (Anil, 2015). As shown below;

$$PV = PVIF_n + F_n$$

$$PVIF_n = 1/(1 + d)^n$$

$$PV = PVIF_n + F_n = \frac{1}{(1+d)} * F_n$$

Where,

PV = present value

$PVIF_n$ = Present value interest factor

F_n = Cash flow n years in the future

d = annual discount rate

When cash flows (both revenue and costs) are taken into account in a large sum, NPV analysis is utilized to assess other investment choices. NPV is often described as:

$$NPV = \sum_{n=0}^{N} \frac{Fn}{(1+d)^{\wedge}n} = F_0 + \frac{F1}{(1+d)^{\wedge}1} + \frac{F1}{(1+d)^{\wedge}2} + \ldots\ldots\ldots + \frac{Fn}{(1+d)^{\wedge}n}$$

Where,

NPV = net present value

F_n = net cash flow in year n

N = analysis period

d = annual discount rate

Depreciation costs

It is the compute of decrease in the value of assets over time. Occasionally, it is also utilized to specify the cost of assets during times/periods in which it is used. The duration over which the depreciation rate is allocated is equal to the useful life of an asset (Anil,2015). The depreciation rate shall then be allocated throughout the duration of the lifecycle of an asset. There are several methods of accounting ways to allocate depreciation costs for example fixed percentage mechanisms, straight line and the declining balance mechanisms.

Depreciation costs can fluctuate according to the mechanisms utilized and also according to the categories of assets (Anil, 2015).

In this research, straight-line depreciation mechanism is utilized, because it is the easiest and traditional method of evaluating depreciation costs. Depreciation in this mechanism is calculated by evaluating scrap value of an asset, which is the value of an asset when it is discarded off at the end of useful life. The scrap value shall then be debited as depreciation over the lifecycle of the asset until the initial value of the asset is equivalent to the scrap value (Anil, 2015). As shown below;

$$S = P(1 - i)^y$$

Where;

S = salvage value

P = original price

i = nominal depreciation rate

Y = age in years

Hence;

$$\text{Annual depreciation} = \frac{Cost\ of\ fixed\ asset - Salvage\ value}{Useful\ life\ (years)}$$

Mechanisms to evaluate alternative investment options.

When evaluating the cost structure of projects, the internal rate of return (IRR) is taken into consideration. In this thesis, it will be the main focus as we are reviewing the IRR of different renewable projects. A brief description of internal rate of return (IRR) is illustrated below;

Internal rate of return (IRR)

Internal rate of return (IRR) is the rate at which the Net Present Value (NPV) of an investment equals to zero considering the sequences of future flows (F) from an investment in several years (F_0, F_1, F_2……F_n). It is main mechanism through which investment choices are distinguished.

When the minimal fair rate of return is known, this rate can be utilized to agree and disagree on investment choice through IRR analysis. Even though, IRR is normally utilized to contrast the after-tax return on financial instruments like, bonds. This mechanism can also be utilized to contrast investment choices made on renewable energy systems (Anil,2015)

IRR is the rate at which Net Present Value (NPV) of a particular project is 0; or

$$0 = \text{NPV} = \sum_{n=0}^{N} [Fn/ (1+d)^n]$$

Where,

NPV = net present value of the capital investment

F_n = cash flows received at time n

d = rate that equates the present value of negative and positive cash flows when utilized as a discount rate

3 CASE STUDY AND ANALYSIS

3.1 Method used to evaluate IRR for different energy systems.

These projects are located in Kenya and were chosen at random and analysed/reviewed. One project for each energy system was chosen. Their cost structures were observed and studied and hence the review on each of these different energy systems.

3.1.1 Solar PV Energy

In this sector I reviewed and analysed the Garissa Solar PV project. This project is located on an 85ha site in Barki village, Garissa Kenya. The project is supposed to generate 76, 470MWh/yr and it is operated and maintained by KenGen. The project consists of the construction of a 6km 132kV transmission line supplying the Garissa substation. The installed capacity is 54.7MW and it is connected to the grid. China Jiangxi Corporation for International Economic and Technical Cooperation (CJIC) were the EPC contractor. The initial PPA had a price of Ksh 10/kWh but it was denied by the regulator in Kenya because a concessional government loan had been used to construct the project. The price was later decreased to Ksh5/KWh, approximately US$ 0.05/kWh. The total (investment cost) – KES 13600m which is approximately 122.4m€. (Africa Energy Live Data, 2019).

SOLAR PV KENYA				BUDGET (MEUR)					
Installed capacity		54.7	MW	EPC cost fixed	80.00	Equity	30.00	32.6%	
Derating		1%	pa	A&G	1.02	Debt	62.03		
Plant factor		30%		O&M mob	4.06		92.03		
A&G	construction	1.00	MEUR/a	IDC	1.95				
	operation	0.50	MEUR/a	Contingency	5.00	5.4%			
O&M	mobilisation	4.00	MEUR	Total	92.03				
	operation	4.00	MEUR/a						
Construction period		1	years	OUTPUT					
PPA		20	years	Capacity cost	1.68	MEUR/MW			
Take or pay		80%		Energy cost	0.64	MEUR/GWh			
Tariff		55	EUR/MWh	LCOE	120	USD/MWh			
Non-PPA revenue		190	EUR/MWh	FCFF	8.1%				
CER		5	EUR/MWh	FCFE	9.8%				
Tariff escalation		3.0%	pa	Trapped cash	30.00	MEUR			Govt
Interest on debt		6.5%	pa	DSCR min	1.06				Bank
Repayment		15	years	E&OBS	0.00				
Inflation		1.5%	pa	E&OCF	0.00				
Tax		15%							
Discount rate		10%							

Figure 9: Illustration of the assumptions utilized in the Solar Project

3.1.2 Biomass Energy

The Gorge farm is developed by Tropical Power, with ownership by Biojoule Kenya. The project utilizes Anaerobic digestion plant constructed by Snow Leopard and a gas boiler by General Electric (GE). The Anaerobic digestor operates 50,000t/y organic farm waste and produces 35,000 tonnes fertiliser as a by-product. The plant utilizes two Jeanbacher J420 biogas engines. The biogas is then combusted in a combined heat and power engine to generate electricity and heat. The plant needs 150 tonnes of fresh organic waste every day from the 800-ha vegetable farm. The Farm is the First African electricity producer utilizing biogas to sell electricity to the national grid in Kenya. The remainder shall be sold to Gorge Farm, owned by VP Group for approximately 0.8c/kWh. i.e. 10% discount in relation to Kenya Power. The installed capacity at the farm is 2.8MW. The total cost (investment) is USD6.5m with a PPA of twenty years and the base tariff 0.8c/kWh. (Biomass Magazine 2015).

BIO GAS KENYA				BUDGET (MEUR)				
Installed capacity		2.8	MW	EPC cost fixed	6.00	Equity	2.00	29.4%
Derating		1%	pa	A&G	0.10	Debt	4.79	
Plant factor		60%		O&M mob	0.05		6.79	
A&G	construction	0.10	MEUR/a	IDC	0.14			
	operation	0.05	MEUR/a	Contingency	0.50	7.4%		
O&M	mobilisation	0.05	MEUR	Total	6.79			
	operation	0.50	MEUR/a					
Construction period		1	years	OUTPUT				
PPA		20	years	Capacity cost	2.43	MEUR/MW		
Take or pay		80%		Energy cost	0.46	MEUR/GWh		
Tariff		120	EUR/MWh	LCOE	168	USD/MWh		
Non-PPA revenue		50	EUR/MWh	FCFF	12.2%			
CER		5	EUR/MWh	FCFE	19.2%			
Tariff escalation		1.5%	pa	Trapped cash	2.00	MEUR		
Interest on debt		6.0%	pa	DSCR min	1.43			
Repayment		12	years	E&OBS	0.00			
Inflation		1.5%	pa	E&OCF	0.00			
Tax		28%						
Discount rate		10%						

Figure 10: Illustration of the assumptions utilized in the Biomass Project

3.1.3 Wind Energy

The Lake Turkana Wind Power Project is located in Kenya. The project uses 44-metre high 850kW 365Vestas turbines because they are effective and simplified remote monitoring. Each of the turbines has a capacity of 850kW. The Project is connected to the national grid by a transmission line of 43km which was built by the Kenya Government. (KETRACO). The farm is suppling low cost energy to the national grid. 17% of the installed capacity shall be bought at a particular (fixed) price by the Kenyan Power and Lighting Company (KPLC). This is a Power Purchase Agreement (PPA) over a duration of 20 years (Lake Turkana Wind Power, 2019).

There have been some delays in the project due to the construction of the 428km 400kV transmission line in Lolyangalani – Suswa and its substation. The grid was not completed in time and it was supervised by KETRACO. Otherwise there have been some many challenges in regard to this project. They have been court auctions, and some are still ongoing. The total cost of the project is 498 million euros with a basic tariff of around Ksh 9/KWh and installed capacity of 300MW (Africa Energy Live Data, 2019)

WIND KENYA				BUDGET (MEUR)				
Installed capacity		300.0	MW	EPC cost fixed	500.00	Equity	160.00	30.4%
Derating		1%	pa	A&G	1.02	Debt	365.73	
Plant factor		35%		O&M mob	4.06		525.73	
A&G	construction	1.00	MEUR/a	IDC	10.65			
	operation	0.50	MEUR/a	Contingency	10.00	1.9%		
O&M	mobilisation	4.00	MEUR	Total	525.73			
	operation	5.00	MEUR/a					
Construction period		1	years	OUTPUT				
PPA		20	years	Capacity cost	1.75	MEUR/MW		
Take or pay		80%		Energy cost	0.57	MEUR/GWh		
Tariff		75	EUR/MWh	LCOE	80	USD/MWh		
Non-PPA revenue		50	EUR/MWh	FCFF	9.0%			
CER		5	EUR/MWh	FCFE	12.1%			
Tariff escalation		1.5%	pa	Trapped cash	160.00	MEUR		
Interest on debt		6.0%	pa	DSCR min	1.16			
Repayment		12	years	E&OBS	0.00			
Inflation		1.5%	pa	E&OCF	0.00			
Tax		28%						
Discount rate		10%						

Figure 11: Illustration of the assumptions utilized in the Wind Project

4 RESULTS AND DISCUSSIONS

In this chapter a sensitivity analysis was carried out for all the three different projects. Different parameters were changed to see how the affect the IRR performance of each of the project.

4.1 Results from the review of the Solar Project

After the evaluation and review of the solar project. The results are presented in the figure below. In the first attempt, the inputs are used without any adjusting. The data got about from the project was inputted and other assumptions were considered. The output was then analysed. The IRR of the project will be around 5.10%. The analysis was done with a scale range from 0.80 to 1.20 and at each level, the IRR was evaluated. Three parameters were taken into consideration; Construction Cost (A&G), Revenue, Operation and Maintenance and Interest. These were observed and how the IRR varied at each scale level.

Construction Cost (A&G)		Revenue		O&M		Interest	
FCFF(IRR)	5.10%		5.10%		5.10%		5.10%
0.80	5.12%	0.80	4.27%	0.80	5.45%	0.80	3.11%
0.85	5.11%	0.85	4.28%	0.85	5.45%	0.85	2.97%
0.90	5.11%	0.90	4.29%	0.90	5.44%	0.90	2.84%
0.95	5.10%	0.95	4.30%	0.95	5.44%	0.95	2.71%
1.00	5.10%	1.00	4.31%	1.00	5.43%	1.00	2.58%
1.05	5.09%	1.05	4.32%	1.05	5.42%	1.05	2.45%
1.10	5.09%	1.10	4.33%	1.10	5.42%	1.10	2.33%
1.15	5.08%	1.15	4.34%	1.15	5.41%	1.15	2.21%
1.20	5.07%	1.20	4.35%	1.20	5.41%	1.20	2.09%

Table 6: IRR Results from the solar Project.

In addition, a graph to illustrate further was done.

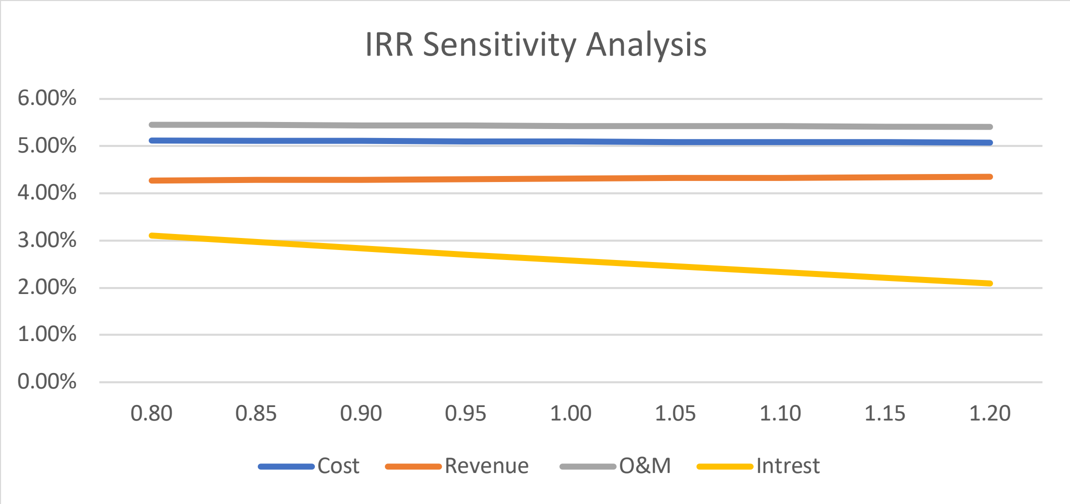

Figure 12: IRR Sensitivity Analysis for Solar PV

In the analysis, several parameters in the assumptions were varied to observe their effect on the IRR of the project. The parameters taken into consideration were; tax, repayment period, tariff escalation and inflation.

Tax: When the tax percentage is reduced while keeping other factors constant, the internal rate of return of the project will increase. When the tax percentage of the project is increased this affects the rate of return negatively (the IRR reduced). The original tax percentage was 28% and then reduced to 10% and increased to 35%. These can be illustrated in the table below.

Construction Cost (A&G)		Revenue		O&M		Interest	
FCFF(IRR)	5.62%		5.62%		5.62%		5.62%
0.80	5.64%	0.80	4.67%	0.80	6.05%	0.80	3.27%
0.85	5.64%	0.85	4.68%	0.85	6.04%	0.85	3.13%
0.90	5.63%	0.90	4.69%	0.90	6.03%	0.90	2.99%
0.95	5.62%	0.95	4.70%	0.95	6.02%	0.95	2.86%
1.00	5.62%	1.00	4.71%	1.00	6.02%	1.00	2.72%
1.05	5.61%	1.05	4.73%	1.05	6.01%	1.05	2.59%
1.10	5.60%	1.10	4.74%	1.10	6.00%	1.10	2.46%
1.15	5.60%	1.15	4.75%	1.15	6.00%	1.15	2.34%
1.20	5.59%	1.20	4.76%	1.20	5.99%	1.20	2.21%

Table 7: IRR results with reduced tax percentage for Solar PV.

The table above illustrates the impact on the IRR with a reduced tax rate and several other parameters being constant. The table below illustrates the impact on the IRR with an increased tax rate and several other parameters being constant.

Construction Cost (A&G)		Revenue		O&M		Interest	
FCFF(IRR)	4.89%		4.89%		4.89%		4.89%
0.80	4.91%	0.80	4.11%	0.80	5.21%	0.80	3.04%
0.85	4.90%	0.85	4.12%	0.85	5.21%	0.85	2.91%
0.90	4.90%	0.90	4.13%	0.90	5.20%	0.90	2.77%
0.95	4.89%	0.95	4.14%	0.95	5.20%	0.95	2.65%
1.00	4.89%	1.00	4.15%	1.00	5.19%	1.00	2.52%
1.05	4.88%	1.05	4.16%	1.05	5.19%	1.05	2.40%
1.10	4.87%	1.10	4.17%	1.10	5.18%	1.10	2.28%
1.15	4.87%	1.15	4.18%	1.15	5.18%	1.15	2.16%
1.20	4.86%	1.20	4.19%	1.20	5.17%	1.20	2.04%

Table 8: IRR results with increased tax rate for Solar PV.

Tariff escalation: A tariff escalation is a situation where the tariff will rise during the processing chains. The tariff escalation rate was increased to 3% and reduced 0.5%. When the tariff escalation was increased, the internal rate of return increased and when it was reduced, the internal rate of return was reduced. This can be illustrated in the tables below.

Construction Cost (A&G)		Revenue		O&M		Interest	
FCFF(IRR)	7.37%		7.37%		7.37%		7.37%
0.80	7.39%	0.80	6.59%	0.80	7.73%	0.80	5.52%
0.85	7.38%	0.85	6.59%	0.85	7.73%	0.85	5.38%
0.90	7.38%	0.90	6.60%	0.90	7.72%	0.90	5.25%
0.95	7.37%	0.95	6.61%	0.95	7.72%	0.95	5.11%
1.00	7.37%	1.00	6.62%	1.00	7.71%	1.00	4.98%
1.05	7.36%	1.05	6.63%	1.05	7.70%	1.05	4.85%
1.10	7.35%	1.10	6.64%	1.10	7.70%	1.10	4.72%
1.15	7.35%	1.15	6.65%	1.15	7.69%	1.15	4.60%
1.20	7.34%	1.20	6.66%	1.20	7.69%	1.20	4.47%

Table 9: IRR results with increased tariff escalation for solar PV.

The table above illustrates the effect on the internal rate of return when the tariff escalation was increased by 3%.

Construction Cost (A&G)			Revenue		O&M		Interest
FCFF(IRR)	3.48%		3.48%		3.48%		3.48%
0.80	3.50%	0.80	2.58%	0.80	3.84%	0.80	1.33%
0.85	3.50%	0.85	2.59%	0.85	3.83%	0.85	1.19%
0.90	3.49%	0.90	2.61%	0.90	3.82%	0.90	1.05%
0.95	3.49%	0.95	2.62%	0.95	3.82%	0.95	0.92%
1.00	3.48%	1.00	2.63%	1.00	3.81%	1.00	0.79%
1.05	3.47%	1.05	2.64%	1.05	3.81%	1.05	0.66%
1.10	3.47%	1.10	2.65%	1.10	3.80%	1.10	0.53%
1.15	3.46%	1.15	2.66%	1.15	3.80%	1.15	0.40%
1.20	3.46%	1.20	2.67%	1.20	3.79%	1.20	0.28%

Table 10: IRR results with reduced tariff escalation for solar PV.

The table above illustrates the impact on the internal rate of return with a reduced tariff escalation.

Repayment period: The repayment period, the period with which the customer can repay back the debt. The repayment period was increased from 12 years to 15 years and reduced from 12 years to 7 years. It can be seen that when the repayment period is reduced, the internal rate of return reduced and when the repayment period was increased the internal rate of return was increased. This can be illustrated in the tables below;

Construction Cost (A&G)			Revenue		O&M		Interest
FCFF(IRR)	4.83%		4.83%		4.83%		4.83%
0.80	4.85%	0.80	4.02%	0.80	5.19%	0.80	2.88%
0.85	4.85%	0.85	4.03%	0.85	5.18%	0.85	2.75%
0.90	4.84%	0.90	4.04%	0.90	5.18%	0.90	2.63%
0.95	4.83%	0.95	4.05%	0.95	5.17%	0.95	2.50%
1.00	4.83%	1.00	4.06%	1.00	5.16%	1.00	2.38%
1.05	4.82%	1.05	4.07%	1.05	5.16%	1.05	2.27%
1.10	4.82%	1.10	4.08%	1.10	5.15%	1.10	2.15%
1.15	4.81%	1.15	4.09%	1.15	5.15%	1.15	2.04%
1.20	4.81%	1.20	4.10%	1.20	5.14%	1.20	1.93%

Table 11: IRR results with reduced repayment period for solar PV

The table above illustrates the effect on the internal rate of return when the repayment period of the debt of the project is reduced.

Construction Cost (A&G)		Revenue		O&M		Interest	
FCFF(IRR)	5.23%		5.23%		5.23%		5.23%
0.80	5.26%	0.80	4.40%	0.80	5.59%	0.80	3.22%
0.85	5.25%	0.85	4.41%	0.85	5.59%	0.85	3.08%
0.90	5.25%	0.90	4.42%	0.90	5.58%	0.90	2.94%
0.95	5.24%	0.95	4.43%	0.95	5.57%	0.95	2.81%
1.00	5.23%	1.00	4.44%	1.00	5.57%	1.00	2.67%
1.05	5.23%	1.05	4.45%	1.05	5.56%	1.05	2.55%
1.10	5.22%	1.10	4.46%	1.10	5.56%	1.10	2.42%
1.15	5.22%	1.15	4.47%	1.15	5.55%	1.15	2.29%
1.20	5.21%	1.20	4.48%	1.20	5.55%	1.20	2.17%

Table 12: IRR results with increased repayment period for solar PV

The table above illustrates the effect on the internal rate of return with an increased repayment period.

Inflation: It is when the common level of prices of goods and services is increasing and otherwise the buying power of currency is decreasing. In this study we can point out the effect of inflation of the internal rate of return of this project. The inflation rate was varied i.e., it was increased and decreased in order to observe its effect. The rate was increased from 1.5% to 3% and reduced from 1.5% to 0.5%. The results of this is illustrated in the tables below;

Construction Cost (A&G)		Revenue		O&M		Interest	
FCFF(IRR)	3.95%		3.95%		3.95%		3.95%
0.80	3.98%	0.80	3.02%	0.80	4.31%	0.80	1.87%
0.85	3.97%	0.85	3.03%	0.85	4.31%	0.85	1.73%
0.90	3.97%	0.90	3.04%	0.90	4.30%	0.90	1.60%
0.95	3.96%	0.95	3.06%	0.95	4.30%	0.95	1.46%
1.00	3.95%	1.00	3.07%	1.00	4.29%	1.00	1.33%
1.05	3.95%	1.05	3.08%	1.05	4.28%	1.05	1.21%
1.10	3.94%	1.10	3.09%	1.10	4.28%	1.10	1.08%
1.15	3.94%	1.15	3.10%	1.15	4.27%	1.15	0.95%
1.20	3.93%	1.20	3.11%	1.20	4.27%	1.20	0.83%

Table 13: IRR results with increased inflation rate for solar PV.

The table above illustrated that when the inflation rate is increased, the internal rate of return will greatly reduce.

Construction Cost (A&G)		Revenue		O&M		Interest	
FCFF(IRR)	5.69%		5.69%		5.69%		5.69%
0.80	5.71%	0.80	4.91%	0.80	6.04%	0.80	3.74%
0.85	5.70%	0.85	4.92%	0.85	6.04%	0.85	3.61%
0.90	5.70%	0.90	4.93%	0.90	6.03%	0.90	3.47%
0.95	5.69%	0.95	4.93%	0.95	6.02%	0.95	3.34%
1.00	5.69%	1.00	4.94%	1.00	6.02%	1.00	3.21%
1.05	5.68%	1.05	4.95%	1.05	6.01%	1.05	3.08%
1.10	5.68%	1.10	4.96%	1.10	6.01%	1.10	2.96%
1.15	5.67%	1.15	4.97%	1.15	6.00%	1.15	2.83%
1.20	5.66%	1.20	4.98%	1.20	6.00%	1.20	2.71%

Table 14: IRR results with reduced inflation rate for solar PV

The table above illustrates the impact on the internal rate of return with a reduced inflation rate. The internal rate of return will increase once the inflation rate is reduced.

4.2 Results from the review of the Wind Project.

After the evaluation and review of the wind project. The results are presented in the figure below. In the first attempt, the inputs are utilized without any adjusting. The data got about the project was inputted and other assumptions were considered. The output was then analysed. The IRR of the project will be around 9.0%. The analysis was done with a scale range from 0.80 to 1.20 and at each level, the IRR was evaluated. Three parameters were taken into consideration; Construction Cost (A&G), Revenue, Operation and Maintenance and Interest.

Construction Cost (A&G)		Revenue		O&M		Interest	
	9.0%		9.0%		9.0%		9.0%
0.80	9.0%	0.80	8.3%	0.80	9.1%	0.80	7.3%
0.85	9.0%	0.85	8.3%	0.85	9.1%	0.85	7.2%
0.90	9.0%	0.90	8.3%	0.90	9.1%	0.90	7.0%
0.95	9.0%	0.95	8.3%	0.95	9.1%	0.95	6.8%
1.00	9.0%	1.00	8.3%	1.00	9.1%	1.00	6.7%
1.05	9.0%	1.05	8.4%	1.05	9.1%	1.05	6.5%
1.10	9.0%	1.10	8.4%	1.10	9.1%	1.10	6.4%
1.15	9.0%	1.15	8.4%	1.15	9.1%	1.15	6.2%
1.20	9.0%	1.20	8.4%	1.20	9.1%	1.20	6.1%

Table 15: IRR results of IRR of the wind project.

The above illustrates the IRR results from the project after their analysis. The graph below shows the sensitivity analysis of the project.

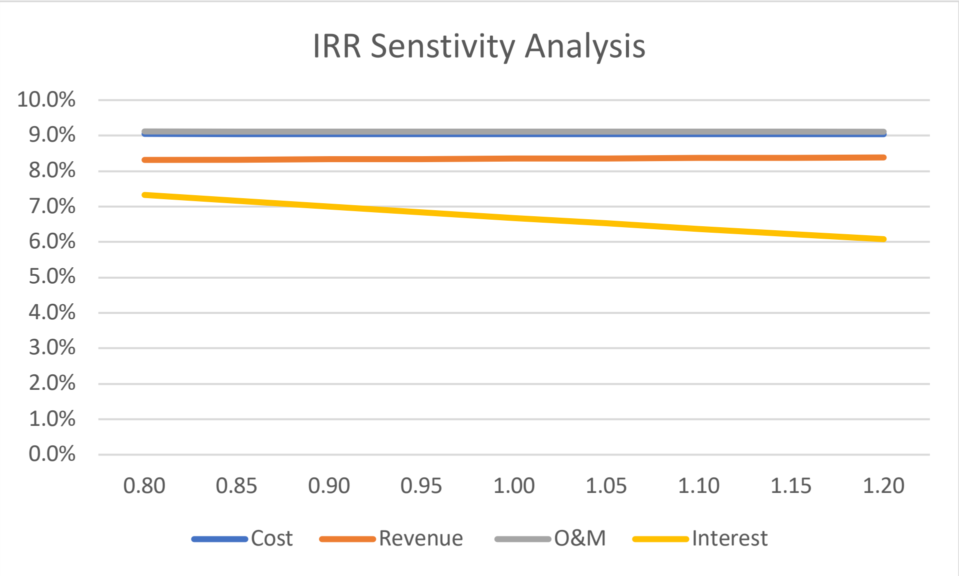

Figure 13: IRR Sensitivity Analysis Wind

The figure above illustrates, the interest on debt is affected more as the internal rate of return keeps reducing. While the rest parameters are still in the same range as the original internal rate of return or have a slight or little change.

Furthermore, other parameters were varied and see their effect on the internal rate of return. The parameters taken into consideration were; tax, repayment period, tariff escalation and inflation.

Tax: When the tax percentage is reduced while keeping other factors constant, the internal rate of return of the project will increase. When the tax percentage of the project is increased this affects the rate of return negatively (the IRR reduced). The original tax percentage was 28% and then reduced to 10% and increased to 35%. These can be illustrated in the table below.

Construction Cost (A&G)		**Revenue**		**O&M**		**Interest**	
FCFF(IRR)	10.3%		10.3%		10.3%		10.3%
0.80	10.3%	0.80	9.5%	0.80	10.4%	0.80	7.7%
0.85	10.3%	0.85	9.5%	0.85	10.4%	0.85	7.5%
0.90	10.3%	0.90	9.5%	0.90	10.4%	0.90	7.3%
0.95	10.3%	0.95	9.5%	0.95	10.4%	0.95	7.2%
1.00	10.3%	1.00	9.5%	1.00	10.4%	1.00	7.0%
1.05	10.3%	1.05	9.5%	1.05	10.4%	1.05	6.8%
1.10	10.3%	1.10	9.5%	1.10	10.4%	1.10	6.7%
1.15	10.3%	1.15	9.5%	1.15	10.4%	1.15	6.5%
1.20	10.3%	1.20	9.5%	1.20	10.4%	1.20	6.4%

Table 16: IRR results reduced tax rate for wind

The table illustrates when the tax rate was reduced from 28% to 10%. The internal rate of return increased.

Construction Cost (A&G)		**Revenue**		**O&M**		**Interest**	
FCFF(IRR)	8.5%		8.5%		8.5%		8.5%
0.80	8.5%	0.80	7.8%	0.80	8.6%	0.80	7.2%
0.85	8.5%	0.85	7.9%	0.85	8.6%	0.85	7.0%
0.90	8.5%	0.90	7.9%	0.90	8.6%	0.90	6.9%
0.95	8.5%	0.95	7.9%	0.95	8.6%	0.95	6.7%
1.00	8.5%	1.00	7.9%	1.00	8.6%	1.00	6.5%
1.05	8.5%	1.05	7.9%	1.05	8.6%	1.05	6.4%
1.10	8.5%	1.10	7.9%	1.10	8.6%	1.10	6.2%
1.15	8.5%	1.15	7.9%	1.15	8.6%	1.15	6.1%
1.20	8.5%	1.20	7.9%	1.20	8.6%	1.20	6.0%

Table 17: IRR results with increased tax rate for wind

The table above illustrates the effect on the internal rate of return with an increased tax rate.

Repayment period: The repayment period, the period with which the customer can repay back the debt. The repayment period was increased from 12 years to 15 years and reduced from 12 years to 7 years. It can be seen that when the repayment period is reduced, the internal rate of return reduced and when the repayment period was increased the internal rate of return was increased. This can be illustrated in the tables below;

Construction Cost (A&G)		Revenue		O&M		Interest	
FCFF(IRR)	8.8%		8.8%		8.8%		8.8%
0.80	8.8%	0.80	8.1%	0.80	8.9%	0.80	6.9%
0.85	8.8%	0.85	8.1%	0.85	8.9%	0.85	6.7%
0.90	8.8%	0.90	8.1%	0.90	8.9%	0.90	6.6%
0.95	8.8%	0.95	8.1%	0.95	8.9%	0.95	6.4%
1.00	8.8%	1.00	8.1%	1.00	8.9%	1.00	6.3%
1.05	8.8%	1.05	8.1%	1.05	8.9%	1.05	6.1%
1.10	8.8%	1.10	8.1%	1.10	8.9%	1.10	6.0%
1.15	8.8%	1.15	8.1%	1.15	8.9%	1.15	5.8%
1.20	8.8%	1.20	8.1%	1.20	8.9%	1.20	5.7%

Table 18: IRR results with reduced repayment period for wind

The table above illustrates the effect on the internal rate of return with a reduced repayment period in debt.

Construction Cost (A&G)		Revenue		O&M		Interest	
FCFF(IRR)	9.2%		9.2%		9.2%		9.2%
0.80	9.2%	0.80	8.4%	0.80	9.2%	0.80	7.5%
0.85	9.2%	0.85	8.4%	0.85	9.2%	0.85	7.4%
0.90	9.2%	0.90	8.4%	0.90	9.2%	0.90	7.2%
0.95	9.2%	0.95	8.5%	0.95	9.2%	0.95	7.0%
1.00	9.2%	1.00	8.5%	1.00	9.2%	1.00	6.9%
1.05	9.2%	1.05	8.5%	1.05	9.2%	1.05	6.7%
1.10	9.2%	1.10	8.5%	1.10	9.2%	1.10	6.6%
1.15	9.2%	1.15	8.5%	1.15	9.2%	1.15	6.4%
1.20	9.2%	1.20	8.5%	1.20	9.2%	1.20	6.3%

Table 19: IRR results with an increased repayment period for wind.

The table above illustrates the impact on the internal rate of return with an increased debt repayment period.

Inflation: It is when the common level of prices of goods and services is increasing and otherwise the buying power of currency is decreasing. In this study we can point out the effect of inflation of the internal rate of return of this project. The inflation rate was varied i.e., it was increased and decreased in order to observe its effect. The rate was increased from 1.5% to 3% and reduced from 1.5% to 0.5%. The results of this is illustrated in the tables below;

Construction Cost (A&G)		**Revenue**		**O&M**		**Interest**	
FCFF(IRR)	8.9%		8.9%		8.9%		8.9%
0.80	8.9%	0.80	8.1%	0.80	8.9%	0.80	7.1%
0.85	8.9%	0.85	8.1%	0.85	8.9%	0.85	7.0%
0.90	8.9%	0.90	8.2%	0.90	8.9%	0.90	6.8%
0.95	8.9%	0.95	8.2%	0.95	8.9%	0.95	6.7%
1.00	8.9%	1.00	8.2%	1.00	8.9%	1.00	6.5%
1.05	8.9%	1.05	8.2%	1.05	8.9%	1.05	6.3%
1.10	8.9%	1.10	8.2%	1.10	8.9%	1.10	6.2%
1.15	8.9%	1.15	8.2%	1.15	8.9%	1.15	6.0%
1.20	8.9%	1.20	8.2%	1.20	8.9%	1.20	5.9%

Table 20: IRR results with increased inflation rate for wind

The table above shows the impact of the internal rate of return with an inflation rate thus the IRR reduces.

Construction Cost (A&G)		**Revenue**		**O&M**		**Interest**	
FCFF(IRR)	9.1%		9.1%		9.1%		9.1%
0.80	9.1%	0.80	8.4%	0.80	9.2%	0.80	7.4%
0.85	9.1%	0.85	8.4%	0.85	9.2%	0.85	7.3%
0.90	9.1%	0.90	8.4%	0.90	9.2%	0.90	7.1%
0.95	9.1%	0.95	8.4%	0.95	9.2%	0.95	6.9%
1.00	9.1%	1.00	8.4%	1.00	9.2%	1.00	6.8%
1.05	9.1%	1.05	8.5%	1.05	9.2%	1.05	6.6%
1.10	9.1%	1.10	8.5%	1.10	9.2%	1.10	6.5%
1.15	9.1%	1.15	8.5%	1.15	9.2%	1.15	6.3%
1.20	9.1%	1.20	8.5%	1.20	9.2%	1.20	6.2%

Table 21: IRR results with a reduced inflation rate for wind

The table above illustrates the impact on the internal rate of return with a reduced inflation rate. It is seen that the internal rate of return increases slightly.

Tariff escalation: A tariff escalation is a situation where the tariff will rise during the processing chains. The tariff escalation rate was increased to 3% and reduced 0.5%. When the tariff escalation was increased, the internal rate of return increased and when it was reduced, the internal rate of return was reduced. This can be illustrated in the tables below.

Construction Cost (A&G)		Revenue		O&M		Interest	
FCFF(IRR)	10.7%		10.7%		10.7%		10.7%
0.80	10.7%	0.80	10.0%	0.80	10.8%	0.80	9.1%
0.85	10.7%	0.85	10.0%	0.85	10.8%	0.85	9.0%
0.90	10.7%	0.90	10.0%	0.90	10.8%	0.90	8.8%
0.95	10.7%	0.95	10.0%	0.95	10.8%	0.95	8.6%
1.00	10.7%	1.00	10.0%	1.00	10.8%	1.00	8.5%
1.05	10.7%	1.05	10.0%	1.05	10.8%	1.05	8.3%
1.10	10.7%	1.10	10.0%	1.10	10.8%	1.10	8.1%
1.15	10.7%	1.15	10.1%	1.15	10.8%	1.15	8.0%
1.20	10.7%	1.20	10.1%	1.20	10.8%	1.20	7.8%

Table 22: IRR results with an increased tariff escalation for wind

The table above illustrates the effect on the internal rate of return with an increased tariff escalation.

Construction Cost (A&G)		Revenue		O&M		Interest	
FCFF(IRR)	7.9%		7.9%		7.9%		7.9%
0.80	7.9%	0.80	7.2%	0.80	8.0%	0.80	6.1%
0.85	7.9%	0.85	7.2%	0.85	8.0%	0.85	6.0%
0.90	7.9%	0.90	7.2%	0.90	8.0%	0.90	5.8%
0.95	7.9%	0.95	7.2%	0.95	8.0%	0.95	5.6%
1.00	7.9%	1.00	7.2%	1.00	8.0%	1.00	5.5%
1.05	7.9%	1.05	7.2%	1.05	8.0%	1.05	5.3%
1.10	7.9%	1.10	7.3%	1.10	8.0%	1.10	5.2%
1.15	7.9%	1.15	7.3%	1.15	8.0%	1.15	5.0%
1.20	7.9%	1.20	7.3%	1.20	8.0%	1.20	4.9%

Table 23: IRR results with a reduced tariff escalation for wind

The table above illustrates the effect on the internal rate of return with a reduced tariff escalation.

4.3 Results from the review of the Biomass Project

After the evaluation and review of the biomass project. The results are presented in the figure below. In the first attempt, the inputs are utilized without any adjusting. The data got about the project was inputted and other assumptions were considered. The output was then analysed. The IRR of the project will be around 9.0%. The analysis was done with a scale range from 0.80 to 1.20 and at each level, the IRR was evaluated. Three parameters were taken into consideration; Construction Cost (A&G), Revenue, Operation and Maintenance and Interest.

Construction Cost (A&G)		Revenue		O&M		Interest	
FCFF (IRR)	12.17%		12.17%		12.17%		12.17%
0.80	10.81%	0.80	11.33%	0.80	10.72%	0.80	10.71%
0.85	10.72%	0.85	11.34%	0.85	10.63%	0.85	10.50%
0.90	10.63%	0.90	11.35%	0.90	10.55%	0.90	10.30%
0.95	10.55%	0.95	11.36%	0.95	10.46%	0.95	10.10%
1.00	10.46%	1.00	11.37%	1.00	10.37%	1.00	9.91%
1.05	10.37%	1.05	11.38%	1.05	10.29%	1.05	9.72%
1.10	10.29%	1.10	11.39%	1.10	10.21%	1.10	9.54%
1.15	10.21%	1.15	11.40%	1.15	10.13%	1.15	9.36%
1.20	10.13%	1.20	11.41%	1.20	10.04%	1.20	9.19%

Table 24: IRR results of IRR of the biomass project.

The above illustrates the IRR results from the project after their analysis.
The graph below shows the sensitivity analysis of the project.

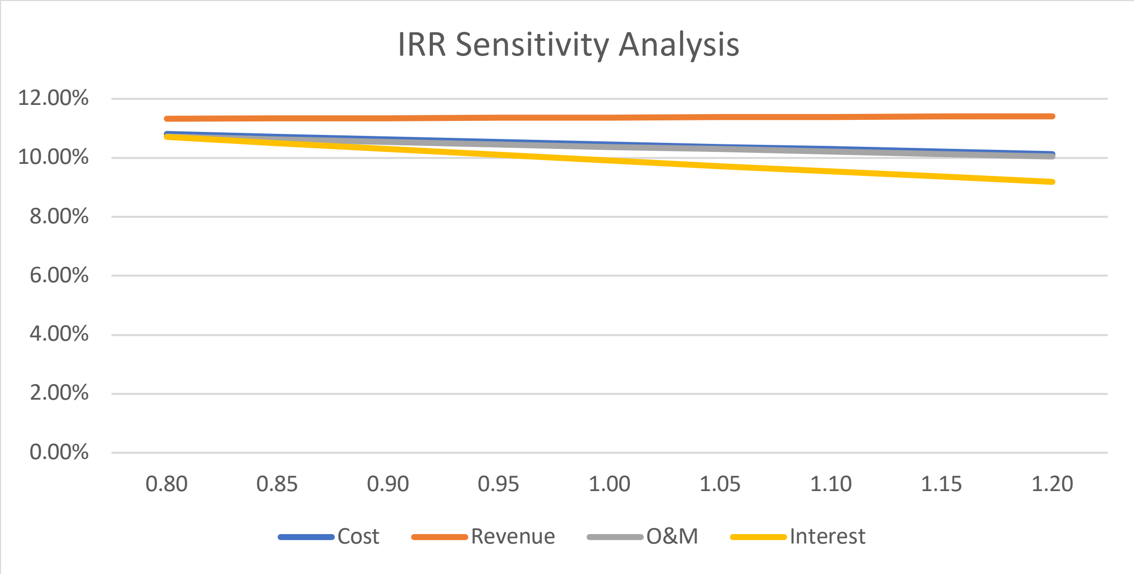

Figure 14: IRR Sensitivity Analysis Biomass

The figure above illustrates, the interest on debt is affected more as the internal rate of return keeps reducing. While the rest parameters are still in the same range as the original internal rate of return or have a slight or little change.

Furthermore, other parameters were varied and see their effect on the internal rate of return. The parameters taken into consideration were; tax, repayment period, tariff escalation and inflation.

Tax: When the tax percentage is reduced while keeping other factors constant, the internal rate of return of the project will increase. When the tax percentage of the project is increased this affects the rate of return negatively (the IRR reduced). The original tax percentage was 28% and then reduced to 10% and increased to 35%. These can be illustrated in the table below.

Construction Cost (A&G)			Revenue		O&M		Interest
FCFF (IRR)	14.07%		14.07%		14.07%		14.07%
0.80	12.42%	0.80	13.06%	0.80	12.31%	0.80	11.07%
0.85	12.31%	0.85	13.07%	0.85	12.20%	0.85	10.86%
0.90	12.20%	0.90	13.08%	0.90	12.10%	0.90	10.65%
0.95	12.10%	0.95	13.09%	0.95	11.99%	0.95	10.45%
1.00	11.99%	1.00	13.11%	1.00	11.89%	1.00	10.26%
1.05	11.89%	1.05	13.12%	1.05	11.79%	1.05	10.07%
1.10	11.79%	1.10	13.13%	1.10	11.69%	1.10	9.88%
1.15	11.69%	1.15	13.14%	1.15	11.59%	1.15	9.70%
1.20	11.59%	1.20	13.16%	1.20	11.49%	1.20	9.52%

Table 25: IRR results with reduced tax rate for biomass

The table illustrates when the tax rate was reduced from 28% to 10%. The internal rate of return increased.

Construction Cost (A&G)		Revenue		O&M		Interest	
FCFF (IRR)	11.95%		11.95%		11.95%		11.95%
0.80	10.62%	0.80	11.13%	0.80	10.54%	0.80	10.67%
0.85	10.54%	0.85	11.14%	0.85	10.45%	0.85	10.46%
0.90	10.45%	0.90	11.15%	0.90	10.37%	0.90	10.26%
0.95	10.37%	0.95	11.16%	0.95	10.28%	0.95	10.06%
1.00	10.28%	1.00	11.17%	1.00	10.20%	1.00	9.87%
1.05	10.20%	1.05	11.18%	1.05	10.12%	1.05	9.69%
1.10	10.12%	1.10	11.19%	1.10	10.04%	1.10	9.50%
1.15	10.04%	1.15	11.20%	1.15	9.96%	1.15	9.32%
1.20	9.96%	1.20	11.21%	1.20	9.88%	1.20	9.15%

Table 26: IRR results with increased tax rate for biomass

The table above illustrates the effect on the internal rate of return with an increased tax rate.

Repayment period: The repayment period, the period with which the customer can repay back the debt. The repayment period was increased from 12 years to 15 years and reduced from 12 years to 7 years. It can be seen that when the repayment period is reduced, the internal rate of return reduced and when the repayment period was increased the internal rate of return was increased. This can be illustrated in the tables below;

Construction Cost (A&G)		Revenue		O&M		Interest	
FCFF (IRR)	12.28%		12.28%		12.28%		12.28%
0.80	10.92%	0.80	11.43%	0.80	10.84%	0.80	10.95%
0.85	10.84%	0.85	11.44%	0.85	10.75%	0.85	10.74%
0.90	10.75%	0.90	11.45%	0.90	10.66%	0.90	10.55%
0.95	10.66%	0.95	11.46%	0.95	10.58%	0.95	10.35%
1.00	10.58%	1.00	11.47%	1.00	10.49%	1.00	10.15%
1.05	10.49%	1.05	11.49%	1.05	10.41%	1.05	9.96%
1.10	10.41%	1.10	11.50%	1.10	10.33%	1.10	9.78%
1.15	10.33%	1.15	11.51%	1.15	10.25%	1.15	9.59%
1.20	10.25%	1.20	11.52%	1.20	10.17%	1.20	9.41%

Table 27: IRR results an increased repayment period for biomass

The table above illustrates the effect on the internal rate of return with an increased repayment period in debt.

Construction Cost (A&G)		Revenue		O&M		Interest	
FCFF (IRR)	11.94%		11.94%		11.94%		11.94%
0.80	10.56%	0.80	11.09%	0.80	10.47%	0.80	10.06%
0.85	10.47%	0.85	11.10%	0.85	10.38%	0.85	9.87%
0.90	10.38%	0.90	11.11%	0.90	10.29%	0.90	9.68%
0.95	10.29%	0.95	11.12%	0.95	10.21%	0.95	9.50%
1.00	10.21%	1.00	11.13%	1.00	10.12%	1.00	9.32%
1.05	10.12%	1.05	11.14%	1.05	10.04%	1.05	9.15%
1.10	10.04%	1.10	11.15%	1.10	9.95%	1.10	8.98%
1.15	9.95%	1.15	11.16%	1.15	9.87%	1.15	8.81%
1.20	9.87%	1.20	11.17%	1.20	9.79%	1.20	8.65%

Table 28: IRR results with reduced repayment period for biomass

The table above illustrates the effect on the internal rate of return with a reduced repayment period in debt.

Inflation: It is when the common level of prices of goods and services is increasing and otherwise the buying power of currency is decreasing. In this study we can point out the effect of inflation of the internal rate of return of this project. The inflation rate was varied i.e., it was increased and decreased in order to observe its effect. The rate was increased from 1.5% to 3% and reduced from 1.5% to 0.5%. The results of this is illustrated in the tables below;

Construction Cost (A&G)		Revenue		O&M		Interest	
FCFF (IRR)	11.03%		11.03%		11.03%		11.03%
0.80	9.67%	0.80	10.12%	0.80	9.58%	0.80	9.50%
0.85	9.58%	0.85	10.13%	0.85	9.50%	0.85	9.29%
0.90	9.50%	0.90	10.14%	0.90	9.41%	0.90	9.09%
0.95	9.41%	0.95	10.15%	0.95	9.32%	0.95	8.90%
1.00	9.32%	1.00	10.16%	1.00	9.24%	1.00	8.71%
1.05	9.24%	1.05	10.17%	1.05	9.16%	1.05	8.53%
1.10	9.16%	1.10	10.18%	1.10	9.07%	1.10	8.35%
1.15	9.07%	1.15	10.19%	1.15	8.99%	1.15	8.17%
1.20	8.99%	1.20	10.20%	1.20	8.91%	1.20	8.00%

Table 29: IRR results with increased inflation rate for biomass

The table above illustrates the effect on the internal rate of return with an increased inflation rate.

Construction Cost (A&G)		Revenue		O&M		Interest	
FCFF (IRR)	12.79%		12.79%		12.79%		12.79%
0.80	11.42%	0.80	11.97%	0.80	11.33%	0.80	11.36%
0.85	11.33%	0.85	11.98%	0.85	11.25%	0.85	11.16%
0.90	11.25%	0.90	11.99%	0.90	11.16%	0.90	10.96%
0.95	11.16%	0.95	12.00%	0.95	11.07%	0.95	10.76%
1.00	11.07%	1.00	12.01%	1.00	10.99%	1.00	10.56%
1.05	10.99%	1.05	12.02%	1.05	10.90%	1.05	10.37%
1.10	10.90%	1.10	12.03%	1.10	10.82%	1.10	10.19%
1.15	10.82%	1.15	12.04%	1.15	10.74%	1.15	10.00%
1.20	10.74%	1.20	12.05%	1.20	10.65%	1.20	9.83%

Table 30: IRR results with reduced inflation rate for biomass

The table above illustrates the effect on the internal rate of return with a reduced inflation rate. It is seen the internal rate of return increases slightly.

Tariff escalation: A tariff escalation is a situation where the tariff will rise during the processing chains. The tariff escalation rate was increased to 3% and reduced 0.5%. When the tariff escalation was increased, the internal rate of return increased and when it was reduced, the internal rate of return was reduced. This can be illustrated in the tables below.

Construction Cost (A&G)		Revenue		O&M		Interest	
FCFF (IRR)	14.75%		14.75%		14.75%		14.75%
0.80	13.31%	0.80	13.91%	0.80	13.22%	0.80	13.41%
0.85	13.22%	0.85	13.92%	0.85	13.12%	0.85	13.20%
0.90	13.12%	0.90	13.93%	0.90	13.03%	0.90	13.00%
0.95	13.03%	0.95	13.94%	0.95	12.94%	0.95	12.80%
1.00	12.94%	1.00	13.95%	1.00	12.85%	1.00	12.60%
1.05	12.85%	1.05	13.96%	1.05	12.76%	1.05	12.41%
1.10	12.76%	1.10	13.97%	1.10	12.67%	1.10	12.22%
1.15	12.67%	1.15	13.98%	1.15	12.59%	1.15	12.03%
1.20	12.59%	1.20	13.99%	1.20	12.50%	1.20	11.85%

Table 31: IRR results with an increased tariff escalation for biomass

The table above illustrates the effect on the internal rate of return with an increased tariff escalation.

Construction Cost (A&G)		Revenue		O&M		Interest	
FCFF (IRR)	10.37%		10.37%		10.37%		10.37%
0.80	9.05%	0.80	9.50%	0.80	8.97%	0.80	8.78%
0.85	8.97%	0.85	9.51%	0.85	8.88%	0.85	8.58%
0.90	8.88%	0.90	9.52%	0.90	8.80%	0.90	8.39%
0.95	8.80%	0.95	9.53%	0.95	8.72%	0.95	8.20%
1.00	8.72%	1.00	9.54%	1.00	8.64%	1.00	8.01%
1.05	8.64%	1.05	9.55%	1.05	8.56%	1.05	7.83%
1.10	8.56%	1.10	9.56%	1.10	8.48%	1.10	7.65%
1.15	8.48%	1.15	9.57%	1.15	8.40%	1.15	7.48%
1.20	8.40%	1.20	9.58%	1.20	8.32%	1.20	7.31%

Table 32: IRR results with a reduced tariff escalation for biomass

The table above illustrates the effect on the internal rate of return with a reduced tariff escalation.

5 CONCLUSION

The main purpose of this thesis is to review the internal rate of return of renewable energy projects. Three renewable energy projects were chosen and analysed, and their cost structure was studied and reviewed. Different assumptions were taken into consideration to see how they affect the internal rate of return of the project. The main aim was to find out how much money is made when investments are made in the renewable sector.

The results for each project were quite fascinating as it shows how the different factors affect the outcome of the results. We got to see how tax, inflation rate, repayment tariff and tariff escalation affects the results. When each factor was altered in different percentages and over a range of scale different outcome of the results were got.

The important recommendations for investors who want to invest in renewable energy projects is to for projects in regions where they are offered subsidizes. With this they will able to gain profit from their investment and also their initial capital costs will not be that high due to the subsidizes that are offered in different parts of the world.

In addition, when taxes are reduced, this works in favour for renewable energy projects. But with high taxes, people are not able to make money from their initial investments that they are made.

Policy Significance

With this research, it can be seen that policies have an impact on the profitability of renewable energy projects worldwide. After decades we can see that the prices of solar projects have greatly reduced. Solar PV used to be so expensive but currently the capex of solar projects is around 750 – 850 USD/kW. Finally, solar PV systems have now become commercially applicable source of renewable energy.

To my surprise, the wind energy technologies seem to perform well both environmentally and economically. Even without government subsides, from this study, their rate of return is high. And if subsidies, wind energy systems have potential to compete with common energy generation technologies.

Limitations of the study

This research was limited to a few areas of study. Firstly, the general study of the renewable energy systems and their trends. In addition, the three renewable cases were chosen and analysed. With this taken into consideration, there will be limitation in applicability in the actual background of the project for example the fuel costs, electricity costs, capital costs vary in several regions. Also, the seasonality of wind and solar, the annual average capacity factors were taken into consideration which might be absolutely observed globally. For biomass, only the plant waste in the Kenya were considered as it the normally utilized source of feedstock.

This research took into consideration the data available, past reports were reviewed, recent renewable projects were analysed. In addition, since the LCOE varies in several regions, this review might not be significant for longer time frame due the methodology can be utilized to obtain akin results in a short time period.

Finally, it is said that IRR as a way of calculating several investment outcomes is not regularly the best method because sometimes the IRR can be a negative value. And during this study in some projects, it led to a negative IRR which makes interpretation difficult. To overcome this issue, several parameters especially the range of scale was adjusted but the final result was not greatly affected.

Suggestions for further research

This research illustrates the process needed for the economic evaluation of different renewable energy systems. This study can utilize in any way by considering the local area regulations and results. Different policies in several areas should be looked into as it has been seen that they greatly impact on the result of IRR of the renewable energy projects. Finally, in this research, the value of emissions (monetary) was not taken into account. In the near future, the emissions in the life cycle of the renewable energy projects can be monetized especially in the Africa.

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Appendix 1 Solar PV Financial Model

SOLAR PV KENYA

Installed capacity		54.7	MW
Derating		1%	pa
Plant factor		30%	
A&G	construction	1.00	MEUR/a
	operation	0.50	MEUR/a
O&M	mobilisation	4.00	MEUR
	operation	4.00	MEUR/a
Construction period		1	years
PPA		20	years
Take or pay		80%	
Tariff		55	EUR/MWh
Non-PPA revenue		190	EUR/MWh
CER		5	EUR/MWh
Tariff escalation		1.5%	pa
Interest on debt		6.5%	pa
Repayment		12	years
Inflation		1.5%	pa
Tax		28%	
Discount rate		10%	

BUDGET (MEUR)

EPC cost fixed	80.00	Equity	30.00	32.6%
A&G	1.02	Debt	62.03	
O&M mob	4.06		92.03	
IDC	1.95			
Contingency	5.00	5.4%		
Total	92.03			

OUTPUT

Capacity cost	1.68	MEUR/MW
Energy cost	0.64	MEUR/GWh
LCOE	120	EUR/MWh
FCFF	5.1%	
FCFE	4.4%	
Trapped cash	30.00	MEUR
DSCR min	0.90	
E&OBS	0.00	
E&OCF	0.00	

O&M	Operation and maintenance
A&G	Administrative and general
E&OBS	Errors and omissions in Balance Sheet
E&OCF	Errors and omissions in Cash Flow statement

100% front equity

Analysis period equal to duration of PPA

Construction Cost (A&G		Revenue		O&M		Interest	
	5.10%		5.10%		5.10%		5.10%
0.80	5.12%	0.80	4.27%	0.80	5.45%	0.80	3.11%
0.85	5.11%	0.85	4.28%	0.85	5.45%	0.85	2.97%
0.90	5.11%	0.90	4.29%	0.90	5.44%	0.90	2.84%
0.95	5.10%	0.95	4.30%	0.95	5.44%	0.95	2.71%
1.00	5.10%	1.00	4.31%	1.00	5.43%	1.00	2.58%
1.05	5.09%	1.05	4.32%	1.05	5.42%	1.05	2.45%
1.10	5.09%	1.10	4.33%	1.10	5.42%	1.10	2.33%
1.15	5.08%	1.15	4.34%	1.15	5.41%	1.15	2.21%
1.20	5.07%	1.20	4.35%	1.20	5.41%	1.20	2.09%

Year		1	2	3	4	5	6	7	8	9	10	11	12
Cost index		1.015	1.030	1.046	1.061	1.077	1.093	1.110	1.126	1.143	1.161	1.178	1.196
Tariff index		1.015	1.030	1.046	1.061	1.077	1.093	1.110	1.126	1.143	1.161	1.178	1.196
EPC disbursements		100%	0%	0%	0%	0%							
Derating		0%	1%	2%	3%	4%	5%	6%	7%	8%	9%	10%	11%
Actual capacity, MW		0.0	54.2	53.6	53.1	52.5	52.0	51.4	50.9	50.3	49.8	49.2	48.7
Generation, GWh	1029.05	0.0	142.3	140.9	139.4	138.0	136.6	135.1	133.7	132.3	130.8	129.4	127.9
PPA sales, GWh		0.0	113.9	112.7	111.6	110.4	109.3	108.1	107.0	105.8	104.7	103.5	102.4
EPC disbursements		80.00	0.00	0.00	0.00	0.00							
A&G		1.02	0.00	0.00	0.00	0.00							
O&M mobilisation		4.06	0.00	0.00	0.00	0.00							
Contingency		5.00	0.00	0.00	0.00	0.00							
Total		90.08	0.00	0.00	0.00	0.00							
Cum		90.08	90.08	90.08	90.08	90.08							
Equity injection		30.00	0.00	0.00	0.00	0.00							
Cum equity		30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00
Debt													
draw		60.08	0.00	0.00	0.00	0.00							
interest added		1.95	0.00	0.00	0.00	0.00							
balance		62.03	56.86	51.69	46.52	41.35	36.18	31.01	25.84	20.68	15.51	10.34	5.17
principal repayment		0.00	5.17	5.17	5.17	5.17	5.17	5.17	5.17	5.17	5.17	5.17	5.17
interest payment		0.00	3.86	3.53	3.19	2.86	2.52	2.18	1.85	1.51	1.18	0.84	0.50
debt service		0.00	9.03	8.70	8.36	8.02	7.69	7.35	7.02	6.68	6.34	6.01	5.67
Revenue													
PPA		0.00	6.45	6.48	6.51	6.54	6.57	6.60	6.63	6.65	6.68	6.71	6.73
Non-PPA		0.00	5.57	5.60	5.62	5.65	5.67	5.70	5.72	5.75	5.77	5.79	5.81
CER		0.00	0.73	0.74	0.74	0.74	0.75	0.75	0.75	0.76	0.76	0.76	0.76
O&M		0.00	4.12	4.18	4.25	4.31	4.37	4.44	4.51	4.57	4.64	4.71	4.78
A&G		0.00	0.52	0.52	0.53	0.54	0.55	0.55	0.56	0.57	0.58	0.59	0.60
Fixed assets													
Addition		92.03	0.00	0.00	0.00	0.00							
Depreciation		0.00	4.60	4.60	4.60	4.60	4.60	4.60	4.60	4.60	4.60	4.60	4.60
Gross		92.03	92.03	92.03	92.03	92.03	92.03	92.03	92.03	92.03	92.03	92.03	92.03
Net		92.03	87.43	82.82	78.22	73.62	69.02	64.42	59.82	55.22	50.62	46.01	41.41
Cash waterfall													
Revenue		0.00	12.76	12.82	12.88	12.93	12.99	13.05	13.10	13.16	13.21	13.26	13.31
O&M, A&G		0.00	-4.64	-4.71	-4.78	-4.85	-4.92	-4.99	-5.07	-5.15	-5.22	-5.30	-5.38
Interest		0.00	-3.86	-3.53	-3.19	-2.86	-2.52	-2.18	-1.85	-1.51	-1.18	-0.84	-0.50
Principal		0.00	-5.17	-5.17	-5.17	-5.17	-5.17	-5.17	-5.17	-5.17	-5.17	-5.17	-5.17
Tax		0.00	0.00	0.00	-0.09	-0.18	-0.27	-0.35	-0.44	-0.53	-0.62	-0.70	-0.79
Cash before dividend		0.00	-0.91	-0.59	-0.35	-0.11	0.12	0.35	0.57	0.80	1.02	1.24	1.46
Available profit		0.00	-0.35	0.55	1.36	2.16	2.95	3.75	4.55	5.34	6.13	6.92	7.71
Dividend		0.00	-0.91	-0.59	-0.35	-0.11	0.12	0.35	0.57	0.80	1.02	1.24	1.46
Closing balance		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Year	13	14	15	16	17	18	19	20	21	22	23	24	25
Cost index	1.214	1.232	1.250	1.269	1.288	1.307	1.327	1.347	1.367	1.388	1.408	1.430	1.451
Tariff index	1.214	1.232	1.250	1.269	1.288	1.307	1.327	1.347	1.367	1.388	1.408	1.430	1.451
EPC disbursements													
Derating	12%	13%	14%	15%	16%	17%	18%	19%	20%	21%	22%	23%	24%
Actual capacity, MW	48.1	47.6	47.0	46.5	45.9	45.4	44.9	44.3	43.8	43.2	42.7	42.1	41.6
Generation, GWh	126.5	125.1	123.6	122.2	120.8	119.3	117.9	116.4	115.0	0.0	0.0	0.0	0.0
PPA sales, GWh	101.2	100.1	98.9	97.8	96.6	95.5	94.3	93.2	92.0	0.0	0.0	0.0	0.0
Cum equity	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00
Debt balance	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
principal repayment	5.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
interest payment	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
debt service	5.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Revenue PPA	6.75	6.78	6.80	6.82	6.84	6.86	6.88	6.90	6.92	0.00	0.00	0.00	0.00
Non-PPA	5.83	5.85	5.87	5.89	5.91	5.93	5.94	5.96	5.97	0.00	0.00	0.00	0.00
CER	0.77	0.77	0.77	0.78	0.78	0.78	0.78	0.78	0.79	0.00	0.00	0.00	0.00
O&M	4.85	4.93	5.00	5.08	5.15	5.23	5.31	5.39	5.47	0.00	0.00	0.00	0.00
A&G	0.61	0.62	0.63	0.63	0.64	0.65	0.66	0.67	0.68	0.00	0.00	0.00	0.00
Depreciation	4.60	4.60	4.60	4.60	4.60	4.60	4.60	4.60	4.60	0.00	0.00	0.00	0.00
Gross	92.03	92.03	92.03	92.03	92.03	92.03	92.03	92.03	92.03	92.03	92.03	92.03	92.03
Net	36.81	32.21	27.61	23.01	18.41	13.80	9.20	4.60	0.00	0.00	0.00	0.00	0.00
Cash waterfall Revenue	13.36	13.40	13.45	13.49	13.53	13.57	13.61	13.64	13.68	0.00	0.00	0.00	0.00
O&M, A&G	-5.46	-5.54	-5.63	-5.71	-5.80	-5.88	-5.97	-6.06	-6.15	0.00	0.00	0.00	0.00
Interest	-0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Principal	-5.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tax	-0.88	-0.91	-0.90	-0.89	-0.88	-0.86	-0.85	-0.83	-0.82	0.00	0.00	0.00	0.00
Cash before dividend	1.68	6.95	6.92	6.89	6.86	6.82	6.79	6.75	6.71	0.00	0.00	0.00	0.00
Available profit	8.49	9.16	4.53	2.29	2.26	2.22	2.19	2.15	2.11	0.00	0.00	0.00	0.00
Dividend	1.68	6.95	4.53	2.29	2.26	2.22	2.19	2.15	2.11	0.00	0.00	0.00	0.00
Closing balance	0.00	0.00	2.39	6.99	11.59	16.20	20.80	25.40	30.00	30.00	30.00	30.00	30.00

Income Statement (MEUR)																											
Year			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Revenue			0.00	12.76	12.82	12.88	12.93	12.99	13.05	13.10	13.16	13.21	13.26	13.31	13.36	13.40	13.45	13.49	13.53	13.57	13.61	13.64	13.68	0.00	0.00	0.00	0.00
O&M, A&G			0.00	-4.64	-4.71	-4.78	-4.85	-4.92	-4.99	-5.07	-5.15	-5.22	-5.30	-5.38	-5.46	-5.54	-5.63	-5.71	-5.80	-5.88	-5.97	-6.06	-6.15	0.00	0.00	0.00	0.00
EBITDA			0.00	8.12	8.11	8.10	8.09	8.07	8.05	8.03	8.01	7.99	7.96	7.93	7.89	7.86	7.82	7.78	7.74	7.69	7.64	7.58	7.53	0.00	0.00	0.00	0.00
Depreciation			0.00	-4.60	-4.60	-4.60	-4.60	-4.60	-4.60	-4.60	-4.60	-4.60	-4.60	-4.60	-4.60	-4.60	-4.60	-4.60	-4.60	-4.60	-4.60	-4.60	-4.60	0.00	0.00	0.00	0.00
Interest			0.00	-3.86	-3.53	-3.19	-2.86	-2.52	-2.18	-1.85	-1.51	-1.18	-0.84	-0.50	-0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EBT			0.00	-0.35	-0.02	0.31	0.63	0.95	1.27	1.58	1.90	2.21	2.52	2.82	3.13	3.26	3.22	3.18	3.13	3.09	3.04	2.98	2.92	0.00	0.00	0.00	0.00
Tax			0.00	0.00	0.00	-0.09	-0.18	-0.27	-0.35	-0.44	-0.53	-0.62	-0.70	-0.79	-0.88	-0.91	-0.90	-0.89	-0.88	-0.86	-0.85	-0.83	-0.82	0.00	0.00	0.00	0.00
Net Income			0.00	-0.35	-0.02	0.22	0.45	0.68	0.91	1.14	1.37	1.59	1.81	2.03	2.25	2.35	2.32	2.29	2.26	2.22	2.19	2.15	2.11	0.00	0.00	0.00	0.00
Balance Sheet (MEUR)																											
Fixed Assets			92.03	87.43	82.82	78.22	73.62	69.02	64.42	59.82	55.22	50.62	46.01	41.41	36.81	32.21	27.61	23.01	18.41	13.80	9.20	4.60	0.00	0.00	0.00	0.00	0.00
Cash			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.39	6.99	11.59	16.20	20.80	25.40	30.00	0.00	0.00	0.00	0.00
Total Assets			92.03	87.43	82.82	78.22	73.62	69.02	64.42	59.82	55.22	50.62	46.01	41.41	36.81	32.21	30.00	30.00	30.00	30.00	30.00	30.00	30.00	0.00	0.00	0.00	0.00
Equity			30.00	30.57	31.14	31.70	32.27	32.84	33.41	33.97	34.54	35.11	35.68	36.24	36.81	32.21	30.00	30.00	30.00	30.00	30.00	30.00	30.00	0.00	0.00	0.00	0.00
Capital			30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	0.00	0.00	0.00	0.00
Accumulated Profit			0.00	0.57	1.14	1.70	2.27	2.84	3.41	3.97	4.54	5.11	5.68	6.24	6.81	2.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Term Liability			56.86	51.69	46.52	41.35	36.18	31.01	25.84	20.68	15.51	10.34	5.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Current Liabilities			5.17	5.17	5.17	5.17	5.17	5.17	5.17	5.17	5.17	5.17	5.17	5.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Equity and Liabilities			92.03	87.43	82.82	78.22	73.62	69.02	64.42	59.82	55.22	50.62	46.01	41.41	36.81	32.21	30.00	30.00	30.00	30.00	30.00	30.00	30.00	0.00	0.00	0.00	0.00
Cash Flow (MEUR)																											
Operating			**0.00**	**4.26**	**4.58**	**4.82**	**5.05**	**5.29**	**5.51**	**5.74**	**5.97**	**6.19**	**6.41**	**6.63**	**6.85**	**6.95**	**6.92**	**6.89**	**6.86**	**6.82**	**6.79**	**6.75**	**6.71**	**0.00**	**0.00**	**0.00**	**0.00**
Revenues			0.00	12.76	12.82	12.88	12.93	12.99	13.05	13.10	13.16	13.21	13.26	13.31	13.36	13.40	13.45	13.49	13.53	13.57	13.61	13.64	13.68	0.00	0.00	0.00	0.00
Operating Costs			0.00	-4.64	-4.71	-4.78	-4.85	-4.92	-4.99	-5.07	-5.15	-5.22	-5.30	-5.38	-5.46	-5.54	-5.63	-5.71	-5.80	-5.88	-5.97	-6.06	-6.15	0.00	0.00	0.00	0.00
Interest			0.00	-3.86	-3.53	-3.19	-2.86	-2.52	-2.18	-1.85	-1.51	-1.18	-0.84	-0.50	-0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tax			0.00	0.00	0.00	-0.09	-0.18	-0.27	-0.35	-0.44	-0.53	-0.62	-0.70	-0.79	-0.88	-0.91	-0.90	-0.89	-0.88	-0.86	-0.85	-0.83	-0.82	0.00	0.00	0.00	0.00
Investing			**-92.03**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Financing			**92.03**	**-4.26**	**-4.58**	**-4.82**	**-5.05**	**-5.29**	**-5.51**	**-5.74**	**-5.97**	**-6.19**	**-6.41**	**-6.63**	**-6.85**	**-6.95**	**-4.53**	**-2.29**	**-2.26**	**-2.22**	**-2.19**	**-2.15**	**-2.11**	**0.00**	**0.00**	**0.00**	**0.00**
Equity			30.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dividend			0.00	0.91	0.59	0.35	0.11	-0.12	-0.35	-0.57	-0.80	-1.02	-1.24	-1.46	-1.68	-6.95	-4.53	-2.29	-2.26	-2.22	-2.19	-2.15	-2.11	0.00	0.00	0.00	0.00
Net Borrowing			62.03	-5.17	-5.17	-5.17	-5.17	-5.17	-5.17	-5.17	-5.17	-5.17	-5.17	-5.17	-5.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Increase in Cash			**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**2.39**	**4.60**	**4.60**	**4.60**	**4.60**	**4.60**	**4.60**	**0.00**	**0.00**	**0.00**	**0.00**
Closing Balance			**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**2.39**	**6.99**	**11.59**	**16.20**	**20.80**	**25.40**	**30.00**	**30.00**	**30.00**	**30.00**	**30.00**
E&OBS	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E&OCF	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FCFF	5.1%		-92.03	8.12	8.11	8.01	7.91	7.80	7.70	7.59	7.48	7.37	7.25	7.14	7.02	6.95	6.92	6.89	6.86	6.82	6.79	6.75	6.71	0.00	0.00	0.00	0.00
FCFE	4.4%		-30.00	-0.91	-0.59	-0.35	-0.11	0.12	0.35	0.57	0.80	1.02	1.24	1.46	1.68	6.95	6.92	6.89	6.86	6.82	6.79	6.75	6.71	0.00	0.00	0.00	0.00
DSCR				0.90	0.93	0.96	0.99	1.02	1.05	1.08	1.12	1.16	1.21	1.26	1.32												
Levellised cost of Energy																											
Investment			-92.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Operation			0.00	-4.64	-4.71	-4.78	-4.85	-4.92	-4.99	-5.07	-5.15	-5.22	-5.30	-5.38	-5.46	-5.54	-5.63	-5.71	-5.80	-5.88	-5.97	-6.06	-6.15	0.00	0.00	0.00	0.00
Sum		123.32	-92.03	-4.64	-4.71	-4.78	-4.85	-4.92	-4.99	-5.07	-5.15	-5.22	-5.30	-5.38	-5.46	-5.54	-5.63	-5.71	-5.80	-5.88	-5.97	-6.06	-6.15	0.00	0.00	0.00	0.00

Appendix 2 Wind Energy Financial Model

WIND KENYA				BUDGET (MEUR)				
Installed capacity		300.0	MW	EPC cost fixed	500.00	Equity	160.00	30.4%
Derating		1%	pa	A&G	1.02	Debt	365.73	
Plant factor		35%		O&M mob	4.06		525.73	
A&G	construction	1.00	MEUR/a	IDC	10.65			
	operation	0.50	MEUR/a	Contingency	10.00	1.9%		
O&M	mobilisation	4.00	MEUR	Total	525.73			
	operation	5.00	MEUR/a					
Construction period		1	years	OUTPUT				
PPA		20	years	Capacity cost	1.75	MEUR/MW		
Take or pay		80%		Energy cost	0.57	MEUR/GWh		
Tariff		75	EUR/MWh	LCOE	80	EUR/MWh		
Non-PPA revenue		50	EUR/MWh	FCFF	9.0%			
CER		5	EUR/MWh	FCFE	12.1%			
Tariff escalation		1.5%	pa	Trapped cash	160.00	MEUR		
Interest on debt		6.0%	pa	DSCR min	1.16			
Repayment		12	years	E&OBS	0.00			
Inflation		1.5%	pa	E&OCF	0.00			
Tax		28%						
Discount rate		10%						

O&M	Operation and maintenance
A&G	Administrative and general
E&OBS	Errors and omissions in Balance Sheet
E&OCF	Errors and omissions in Cash Flow statement

100% front equity

Analysis period equal to duration of PPA

Construction Cost (A&G)		Revenue		O&M		Interest	
FCFF(IRR)	9.0%		9.0%		9.0%		9.0%
0.80	9.0%	0.80	8.3%	0.80	9.1%	0.80	7.3%
0.85	9.0%	0.85	8.3%	0.85	9.1%	0.85	7.2%
0.90	9.0%	0.90	8.3%	0.90	9.1%	0.90	7.0%
0.95	9.0%	0.95	8.3%	0.95	9.1%	0.95	6.8%
1.00	9.0%	1.00	8.3%	1.00	9.1%	1.00	6.7%
1.05	9.0%	1.05	8.4%	1.05	9.1%	1.05	6.5%
1.10	9.0%	1.10	8.4%	1.10	9.1%	1.10	6.4%
1.15	9.0%	1.15	8.4%	1.15	9.1%	1.15	6.2%
1.20	9.0%	1.20	8.4%	1.20	9.1%	1.20	6.1%

Year		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Cost index		1.015	1.030	1.046	1.061	1.077	1.093	1.110	1.126	1.143	1.161	1.178	1.196	1.214	1.232	1.250	1.269	1.288	1.307	1.327	1.347	1.367	1.388	1.408	1.430	1.451
Tariff index		1.015	1.030	1.046	1.061	1.077	1.093	1.110	1.126	1.143	1.161	1.178	1.196	1.214	1.232	1.250	1.269	1.288	1.307	1.327	1.347	1.367	1.388	1.408	1.430	1.451
EPC disbursements		100%	0%	0%	0%	0%																				
Derating		0%	1%	2%	3%	4%	5%	6%	7%	8%	9%	10%	11%	12%	13%	14%	15%	16%	17%	18%	19%	20%	21%	22%	23%	24%
Actual capacity, MW		0.0	297.0	294.0	291.0	288.0	285.0	282.0	279.0	276.0	273.0	270.0	267.0	264.0	261.0	258.0	255.0	252.0	249.0	246.0	243.0	240.0	237.0	234.0	231.0	228.0
Generation, GWh	6,584	0.0	910.6	901.4	892.2	883.0	873.8	864.6	855.4	846.2	837.0	827.8	818.6	809.4	800.2	791.0	781.8	772.6	763.4	754.2	745.0	735.8	0.0	0.0	0.0	0.0
PPA sales, GWh		0.0	728.5	721.1	713.8	706.4	699.0	691.7	684.3	677.0	669.6	662.3	654.9	647.5	640.2	632.8	625.5	618.1	610.7	603.4	596.0	588.7	0.0	0.0	0.0	0.0
EPC disbursements		500.00	0.00	0.00	0.00	0.00																				
A&G		1.02	0.00	0.00	0.00	0.00																				
O&M mobilisation		4.06	0.00	0.00	0.00	0.00																				
Contingency		10.00	0.00	0.00	0.00	0.00																				
Total		515.08	0.00	0.00	0.00	0.00																				
Cum		515.08	515.08	515.08	515.08	515.08																				
Equity injection		160.00	0.00	0.00	0.00	0.00																				
Cum equity		160.00	160.00	160.00	160.00	160.00	160.00	160.00	160.00	160.00	160.00	160.00	160.00	160.00	160.00	160.00	160.00	160.00	160.00	160.00	160.00	160.00	160.00	160.00	160.00	160.00
Debt																										
draw		355.08	0.00	0.00	0.00	0.00																				
interest added		10.65	0.00	0.00	0.00	0.00																				
balance		365.73	335.25	304.77	274.30	243.82	213.34	182.86	152.39	121.91	91.43	60.95	30.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
principal repayment		0.00	30.48	30.48	30.48	30.48	30.48	30.48	30.48	30.48	30.48	30.48	30.48	30.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
interest payment		0.00	21.03	19.20	17.37	15.54	13.71	11.89	10.06	8.23	6.40	4.57	2.74	0.91	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
debt service		0.00	51.51	49.68	47.85	46.02	44.19	42.36	40.53	38.71	36.88	35.05	33.22	31.39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Revenue																										
PPA		0.00	56.29	56.55	56.82	57.08	57.33	57.58	57.82	58.05	58.28	58.51	58.73	58.94	59.14	59.34	59.53	59.71	59.88	60.05	60.21	60.36	0.00	0.00	0.00	0.00
Non-PPA		0.00	9.38	9.43	9.47	9.51	9.55	9.60	9.64	9.68	9.71	9.75	9.79	9.82	9.86	9.89	9.92	9.95	9.98	10.01	10.03	10.06	0.00	0.00	0.00	0.00
CER		0.00	4.69	4.71	4.73	4.76	4.78	4.80	4.82	4.84	4.86	4.88	4.89	4.91	4.93	4.94	4.96	4.98	4.99	5.00	5.02	5.03	0.00	0.00	0.00	0.00
O&M		0.00	5.15	5.23	5.31	5.39	5.47	5.55	5.63	5.72	5.80	5.89	5.98	6.07	6.16	6.25	6.34	6.44	6.54	6.63	6.73	6.84	0.00	0.00	0.00	0.00
A&G		0.00	0.52	0.52	0.53	0.54	0.55	0.55	0.56	0.57	0.58	0.59	0.60	0.61	0.62	0.63	0.63	0.64	0.65	0.66	0.67	0.68	0.00	0.00	0.00	0.00
Fixed assets																										
Addition		525.73	0.00	0.00	0.00	0.00																				
Depreciation		0.00	26.29	26.29	26.29	26.29	26.29	26.29	26.29	26.29	26.29	26.29	26.29	26.29	26.29	26.29	26.29	26.29	26.29	26.29	26.29	26.29	0.00	0.00	0.00	0.00
Gross		525.73	525.73	525.73	525.73	525.73	525.73	525.73	525.73	525.73	525.73	525.73	525.73	525.73	525.73	525.73	525.73	525.73	525.73	525.73	525.73	525.73	525.73	525.73	525.73	525.73
Net		525.73	499.44	473.15	446.87	420.58	394.30	368.01	341.72	315.44	289.15	262.86	236.58	210.29	184.00	157.72	131.43	105.15	78.86	52.57	26.29	0.00	0.00	0.00	0.00	0.00
Cash waterfall																										
Revenue		0.00	70.36	70.69	71.02	71.34	71.66	71.97	72.27	72.57	72.85	73.13	73.41	73.67	73.93	74.17	74.41	74.64	74.86	75.06	75.26	75.45	0.00	0.00	0.00	0.00
O&M, A&G		0.00	-5.67	-5.75	-5.84	-5.93	-6.01	-6.10	-6.20	-6.29	-6.38	-6.48	-6.58	-6.67	-6.77	-6.88	-6.98	-7.08	-7.19	-7.30	-7.41	-7.52	0.00	0.00	0.00	0.00
Interest		0.00	-21.03	-19.20	-17.37	-15.54	-13.71	-11.89	-10.06	-8.23	-6.40	-4.57	-2.74	-0.91	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Principal		0.00	-30.48	-30.48	-30.48	-30.48	-30.48	-30.48	-30.48	-30.48	-30.48	-30.48	-30.48	-30.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tax		0.00	-4.87	-5.45	-6.03	-6.60	-7.18	-7.75	-8.32	-8.89	-9.46	-10.02	-10.58	-11.14	-11.44	-11.48	-11.52	-11.55	-11.59	-11.61	-11.64	-11.66	0.00	0.00	0.00	0.00
Cash before dividend		0.00	8.32	9.82	11.31	12.79	14.27	15.75	17.22	18.68	20.13	21.58	23.03	24.46	55.71	55.81	55.91	56.00	56.08	56.15	56.21	56.27	0.00	0.00	0.00	0.00
Available profit		0.00	12.51	18.20	23.88	29.56	35.23	40.89	46.55	52.21	57.85	63.49	69.13	74.75	79.71	53.53	29.62	29.71	29.79	29.86	29.93	29.98	0.00	0.00	0.00	0.00
Dividend		0.00	8.32	9.82	11.31	12.79	14.27	15.75	17.22	18.68	20.13	21.58	23.03	24.46	55.71	53.53	29.62	29.71	29.79	29.86	29.93	29.98	0.00	0.00	0.00	0.00
Closing balance		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.28	28.57	54.85	81.14	107.43	133.71	160.00	160.00	160.00	160.00	160.00

Income Statement (MEUR)																											
Year			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Revenue			0.00	70.36	70.69	71.02	71.34	71.66	71.97	72.27	72.57	72.85	73.13	73.41	73.67	73.93	74.17	74.41	74.64	74.86	75.06	75.26	75.45	0.00	0.00	0.00	0.00
O&M, A&G			0.00	-5.67	-5.75	-5.84	-5.93	-6.01	-6.10	-6.20	-6.29	-6.38	-6.48	-6.58	-6.67	-6.77	-6.88	-6.98	-7.08	-7.19	-7.30	-7.41	-7.52	0.00	0.00	0.00	0.00
EBITDA			0.00	64.69	64.94	65.18	65.42	65.65	65.86	66.08	66.28	66.47	66.66	66.83	67.00	67.15	67.30	67.43	67.55	67.66	67.76	67.85	67.93	0.00	0.00	0.00	0.00
Depreciation			0.00	-26.29	-26.29	-26.29	-26.29	-26.29	-26.29	-26.29	-26.29	-26.29	-26.29	-26.29	-26.29	-26.29	-26.29	-26.29	-26.29	-26.29	-26.29	-26.29	-26.29	0.00	0.00	0.00	0.00
Interest			0.00	-21.03	-19.20	-17.37	-15.54	-13.71	-11.89	-10.06	-8.23	-6.40	-4.57	-2.74	-0.91	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EBT			0.00	17.38	19.46	21.53	23.59	25.64	27.69	29.73	31.76	33.78	35.80	37.80	39.80	40.87	41.01	41.14	41.27	41.38	41.48	41.57	41.64	0.00	0.00	0.00	0.00
Tax			0.00	-4.87	-5.45	-6.03	-6.60	-7.18	-7.75	-8.32	-8.89	-9.46	-10.02	-10.58	-11.14	-11.44	-11.48	-11.52	-11.55	-11.59	-11.61	-11.64	-11.66	0.00	0.00	0.00	0.00
Net Income			0.00	12.51	14.01	15.50	16.98	18.46	19.94	21.41	22.87	24.33	25.77	27.22	28.65	29.42	29.53	29.62	29.71	29.79	29.86	29.93	29.98	0.00	0.00	0.00	0.00
Balance Sheet (MEUR)																											
Fixed Assets			525.73	499.44	473.15	446.87	420.58	394.30	368.01	341.72	315.44	289.15	262.86	236.58	210.29	184.00	157.72	131.43	105.15	78.86	52.57	26.29	0.00	0.00	0.00	0.00	0.00
Cash			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.28	28.57	54.85	81.14	107.43	133.71	160.00	0.00	0.00	0.00	0.00
Total Assets			525.73	499.44	473.15	446.87	420.58	394.30	368.01	341.72	315.44	289.15	262.86	236.58	210.29	184.00	160.00	160.00	160.00	160.00	160.00	160.00	160.00	0.00	0.00	0.00	0.00
Equity			160.00	164.19	168.38	172.57	176.76	180.95	185.15	189.34	193.53	197.72	201.91	206.10	210.29	184.00	160.00	160.00	160.00	160.00	160.00	160.00	160.00	0.00	0.00	0.00	0.00
Capital			160.00	160.00	160.00	160.00	160.00	160.00	160.00	160.00	160.00	160.00	160.00	160.00	160.00	160.00	160.00	160.00	160.00	160.00	160.00	160.00	160.00	0.00	0.00	0.00	0.00
Accumulated Profit			0.00	4.19	8.38	12.57	16.76	20.95	25.15	29.34	33.53	37.72	41.91	46.10	50.29	24.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Term Liability			335.25	304.77	274.30	243.82	213.34	182.86	152.39	121.91	91.43	60.95	30.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Current Liabilities			30.48	30.48	30.48	30.48	30.48	30.48	30.48	30.48	30.48	30.48	30.48	30.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Equity and Liabilities			525.73	499.44	473.15	446.87	420.58	394.30	368.01	341.72	315.44	289.15	262.86	236.58	210.29	184.00	160.00	160.00	160.00	160.00	160.00	160.00	160.00	0.00	0.00	0.00	0.00
Cash Flow (MEUR)																											
Operating			**0.00**	**38.80**	**40.29**	**41.78**	**43.27**	**44.75**	**46.22**	**47.69**	**49.16**	**50.61**	**52.06**	**53.50**	**54.94**	**55.71**	**55.81**	**55.91**	**56.00**	**56.08**	**56.15**	**56.21**	**56.27**	**0.00**	**0.00**	**0.00**	**0.00**
Revenues			0.00	70.36	70.69	71.02	71.34	71.66	71.97	72.27	72.57	72.85	73.13	73.41	73.67	73.93	74.17	74.41	74.64	74.86	75.06	75.26	75.45	0.00	0.00	0.00	0.00
Operating Costs			0.00	-5.67	-5.75	-5.84	-5.93	-6.01	-6.10	-6.20	-6.29	-6.38	-6.48	-6.58	-6.67	-6.77	-6.88	-6.98	-7.08	-7.19	-7.30	-7.41	-7.52	0.00	0.00	0.00	0.00
Interest			0.00	-21.03	-19.20	-17.37	-15.54	-13.71	-11.89	-10.06	-8.23	-6.40	-4.57	-2.74	-0.91	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tax			0.00	-4.87	-5.45	-6.03	-6.60	-7.18	-7.75	-8.32	-8.89	-9.46	-10.02	-10.58	-11.14	-11.44	-11.48	-11.52	-11.55	-11.59	-11.61	-11.64	-11.66	0.00	0.00	0.00	0.00
Investing			**-525.73**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Financing			**525.73**	**-38.80**	**-40.29**	**-41.78**	**-43.27**	**-44.75**	**-46.22**	**-47.69**	**-49.16**	**-50.61**	**-52.06**	**-53.50**	**-54.94**	**-55.71**	**-53.53**	**-29.62**	**-29.71**	**-29.79**	**-29.86**	**-29.93**	**-29.98**	**0.00**	**0.00**	**0.00**	**0.00**
Equity			160.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dividend			0.00	-8.32	-9.82	-11.31	-12.79	-14.27	-15.75	-17.22	-18.68	-20.13	-21.58	-23.03	-24.46	-55.71	-53.53	-29.62	-29.71	-29.79	-29.86	-29.93	-29.98	0.00	0.00	0.00	0.00
Net Borrowing			365.73	-30.48	-30.48	-30.48	-30.48	-30.48	-30.48	-30.48	-30.48	-30.48	-30.48	-30.48	-30.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Increase in Cash			**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**2.28**	**26.29**	**26.29**	**26.29**	**26.29**	**26.29**	**26.29**	**0.00**	**0.00**	**0.00**	**0.00**
Closing Balance			**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**2.28**	**28.57**	**54.85**	**81.14**	**107.43**	**133.71**	**160.00**	**160.00**	**160.00**	**160.00**	**160.00**
E&OBS	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E&OCF	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FCFF	9.0%		-525.73	59.83	59.49	59.16	58.81	58.47	58.11	57.75	57.38	57.01	56.63	56.25	55.85	55.71	55.81	55.91	56.00	56.08	56.15	56.21	56.27	0.00	0.00	0.00	0.00
FCFE	12.1%		-160.00	8.32	9.82	11.31	12.79	14.27	15.75	17.22	18.68	20.13	21.58	23.03	24.46	55.71	55.81	55.91	56.00	56.08	56.15	56.21	56.27	0.00	0.00	0.00	0.00
DSCR				1.16	1.20	1.24	1.28	1.32	1.37	1.42	1.48	1.55	1.62	1.69	1.78												
Levellised cost of Energy																											
Investment			-525.73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Operation			0.00	-5.67	-5.75	-5.84	-5.93	-6.01	-6.10	-6.20	-6.29	-6.38	-6.48	-6.58	-6.67	-6.77	-6.88	-6.98	-7.08	-7.19	-7.30	-7.41	-7.52	0.00	0.00	0.00	0.00
Sum		526.40	-525.73	-5.67	-5.75	-5.84	-5.93	-6.01	-6.10	-6.20	-6.29	-6.38	-6.48	-6.58	-6.67	-6.77	-6.88	-6.98	-7.08	-7.19	-7.30	-7.41	-7.52	0.00	0.00	0.00	0.00

Appendix 3 Biomass Energy Financial Model

BIO GAS KENYA

Installed capacity		2.8	MW
Derating		1%	pa
Plant factor		60%	
A&G	construction	0.10	MEUR/a
	operation	0.05	MEUR/a
O&M	mobilisation	0.05	MEUR
	operation	0.50	MEUR/a
Construction period		1	years
PPA		20	years
Take or pay		80%	
Tariff		120	EUR/MWh
Non-PPA revenue		50	EUR/MWh
CER		5	EUR/MWh
Tariff escalation		1.5%	pa
Interest on debt		6.0%	pa
Repayment		12	years
Inflation		1.5%	pa
Tax		28%	
Discount rate		10%	

BUDGET (MEUR)

EPC cost fixed	6.00	Equity	2.00	29.4%
A&G	0.10	Debt	4.79	
O&M mob	0.05		6.79	
IDC	0.14			
Contingency	0.50	7.4%		
Total	6.79			

OUTPUT

Capacity cost	2.43	MEUR/MW
Energy cost	0.46	MEUR/GWh
LCOE	168	USD/MWh
FCFF	12.2%	
FCFE	19.2%	
Trapped cash	2.00	MEUR
DSCR min	1.43	
E&OBS	0.00	
E&OCF	0.00	

O&M	Operation and maintenance
A&G	Administrative and general
E&OBS	Errors and omissions in Balance Sheet
E&OCF	Errors and omissions in Cash Flow statement

100% front equity

Analysis period equal to duration of PPA

Assumptions

1 Installed Capacity - 2.8MW
2 Fuel - Biomass
3 Technology - Biogas
4 Total Cost - 6.5MUSD
5 PPA duration - 20yrs
6 Tariff (KWh) - 0.8 cents USD
7 Product - 50000t/y from organic farm waste & 35000 tonnes fertilizer as a by-product
Uses 150 tonnes of fresh organic waste
8 Fuel Cost -

Construction Cost (A&G)	12.20%	Revenue	12.20%	O&M	12.20%	Interest	12.20%
0.80		0.80		0.80		0.80	
0.85		0.85		0.85		0.85	
0.90		0.90		0.90		0.90	
0.95		0.95		0.95		0.95	
1.00		1.00		1.00		1.00	
1.05		1.05		1.05		1.05	
1.10		1.10		1.10		1.10	
1.15		1.15		1.15		1.15	
1.20		1.20		1.20		1.20	

Year		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Cost index		1.015	1.030	1.046	1.061	1.077	1.093	1.110	1.126	1.143	1.161	1.178	1.196	1.214	1.232	1.250	1.269	1.288	1.307	1.327	1.347	1.367	1.388	1.408	1.430	1.451
Tariff index		1.015	1.030	1.046	1.061	1.077	1.093	1.110	1.126	1.143	1.161	1.178	1.196	1.214	1.232	1.250	1.269	1.288	1.307	1.327	1.347	1.367	1.388	1.408	1.430	1.451
EPC disbursements		100%	0%	0%	0%	0%																				
Derating		0%	1%	2%	3%	4%	5%	6%	7%	8%	9%	10%	11%	12%	13%	14%	15%	16%	17%	18%	19%	20%	21%	22%	23%	24%
Actual capacity, MW		0.0	2.8	2.7	2.7	2.7	2.7	2.6	2.6	2.6	2.5	2.5	2.5	2.5	2.4	2.4	2.4	2.4	2.3	2.3	2.3	2.2	2.2	2.2	2.2	2.1
Generation, GWh	105.35	0.0	14.6	14.4	14.3	14.1	14.0	13.8	13.7	13.5	13.4	13.2	13.1	13.0	12.8	12.7	12.5	12.4	12.2	12.1	11.9	11.8	0.0	0.0	0.0	0.0
PPA sales, GWh		0.0	11.7	11.5	11.4	11.3	11.2	11.1	10.9	10.8	10.7	10.6	10.5	10.4	10.2	10.1	10.0	9.9	9.8	9.7	9.5	9.4	0.0	0.0	0.0	0.0
EPC disbursements		6.00	0.00	0.00	0.00	0.00																				
A&G		0.10	0.00	0.00	0.00	0.00																				
O&M mobilisation		0.05	0.00	0.00	0.00	0.00																				
Contingency		0.50	0.00	0.00	0.00	0.00																				
Total		6.65	0.00	0.00	0.00	0.00																				
Cum		6.65	6.65	6.65	6.65	6.65																				
Equity injection		2.00	0.00	0.00	0.00	0.00																				
Cum equity		2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Debt																										
draw		4.65	0.00	0.00	0.00	0.00																				
interest added		0.14	0.00	0.00	0.00	0.00																				
balance		4.79	4.39	3.99	3.59	3.19	2.80	2.40	2.00	1.60	1.20	0.80	0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
principal repayment		0.00	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
interest payment		0.00	0.28	0.25	0.23	0.20	0.18	0.16	0.13	0.11	0.08	0.06	0.04	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
debt service		0.00	0.67	0.65	0.63	0.60	0.58	0.56	0.53	0.51	0.48	0.46	0.44	0.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Revenue																										
PPA		0.00	1.44	1.45	1.45	1.46	1.47	1.47	1.48	1.49	1.49	1.50	1.50	1.51	1.51	1.52	1.52	1.53	1.53	1.54	1.54	1.55	0.00	0.00	0.00	0.00
Non-PPA		0.00	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.00	0.00	0.00	0.00
CER		0.00	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.00	0.00	0.00	0.00
O&M		0.00	0.52	0.52	0.53	0.54	0.55	0.55	0.56	0.57	0.58	0.59	0.60	0.61	0.62	0.63	0.63	0.64	0.65	0.66	0.67	0.68	0.00	0.00	0.00	0.00
A&G		0.00	0.05	0.05	0.05	0.05	0.05	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.07	0.07	0.07	0.07	0.00	0.00	0.00	0.00
Fixed assets																										
Addition		6.79	0.00	0.00	0.00	0.00																				
Depreciation		0.00	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.00	0.00	0.00	0.00
Gross		6.79	6.79	6.79	6.79	6.79	6.79	6.79	6.79	6.79	6.79	6.79	6.79	6.79	6.79	6.79	6.79	6.79	6.79	6.79	6.79	6.79	6.79	6.79	6.79	6.79
Net		6.79	6.45	6.11	5.77	5.43	5.09	4.75	4.41	4.08	3.74	3.40	3.06	2.72	2.38	2.04	1.70	1.36	1.02	0.68	0.34	0.00	0.00	0.00	0.00	0.00
Cash waterfall																										
Revenue		0.00	1.67	1.67	1.68	1.69	1.70	1.70	1.71	1.72	1.73	1.73	1.74	1.74	1.75	1.76	1.76	1.77	1.77	1.78	1.78	1.79	0.00	0.00	0.00	0.00
O&M, A&G		0.00	-0.57	-0.58	-0.58	-0.59	-0.60	-0.61	-0.62	-0.63	-0.64	-0.65	-0.66	-0.67	-0.68	-0.69	-0.70	-0.71	-0.72	-0.73	-0.74	-0.75	0.00	0.00	0.00	0.00
Interest		0.00	-0.28	-0.25	-0.23	-0.20	-0.18	-0.16	-0.13	-0.11	-0.08	-0.06	-0.04	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Principal		0.00	-0.40	-0.40	-0.40	-0.40	-0.40	-0.40	-0.40	-0.40	-0.40	-0.40	-0.40	-0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tax		0.00	-0.14	-0.14	-0.15	-0.16	-0.16	-0.17	-0.17	-0.18	-0.19	-0.19	-0.20	-0.20	-0.21	-0.20	-0.20	-0.20	-0.20	-0.20	-0.20	-0.19	0.00	0.00	0.00	0.00
Cash before dividend		0.00	0.29	0.31	0.32	0.34	0.36	0.37	0.39	0.40	0.42	0.43	0.45	0.46	0.87	0.86	0.86	0.86	0.85	0.85	0.84	0.84	0.00	0.00	0.00	0.00
Available profit		0.00	0.35	0.43	0.50	0.58	0.65	0.73	0.81	0.88	0.96	1.03	1.10	1.18	1.24	0.90	0.56	0.52	0.51	0.51	0.51	0.50	0.00	0.00	0.00	0.00
Dividend		0.00	0.29	0.31	0.32	0.34	0.36	0.37	0.39	0.40	0.42	0.43	0.45	0.46	0.87	0.86	0.56	0.52	0.51	0.51	0.51	0.50	0.00	0.00	0.00	0.00
Closing balance		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.64	0.98	1.32	1.66	2.00	2.00	2.00	2.00	2.00

Income Statement (MEUR)																											
Year			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Revenue			0.00	1.67	1.67	1.68	1.69	1.70	1.70	1.71	1.72	1.73	1.73	1.74	1.74	1.75	1.76	1.76	1.77	1.77	1.78	1.78	1.79	0.00	0.00	0.00	0.00
O&M, A&G			0.00	-0.57	-0.58	-0.58	-0.59	-0.60	-0.61	-0.62	-0.63	-0.64	-0.65	-0.66	-0.67	-0.68	-0.69	-0.70	-0.71	-0.72	-0.73	-0.74	-0.75	0.00	0.00	0.00	0.00
EBITDA			0.00	1.10	1.10	1.10	1.10	1.10	1.09	1.09	1.09	1.09	1.08	1.08	1.08	1.07	1.07	1.06	1.06	1.05	1.05	1.04	1.03	0.00	0.00	0.00	0.00
Depreciation			0.00	-0.34	-0.34	-0.34	-0.34	-0.34	-0.34	-0.34	-0.34	-0.34	-0.34	-0.34	-0.34	-0.34	-0.34	-0.34	-0.34	-0.34	-0.34	-0.34	-0.34	0.00	0.00	0.00	0.00
Interest			0.00	-0.28	-0.25	-0.23	-0.20	-0.18	-0.16	-0.13	-0.11	-0.08	-0.06	-0.04	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EBT			0.00	0.48	0.51	0.53	0.55	0.58	0.60	0.62	0.64	0.66	0.68	0.71	0.73	0.73	0.73	0.72	0.72	0.71	0.71	0.70	0.70	0.00	0.00	0.00	0.00
Tax			0.00	-0.14	-0.14	-0.15	-0.16	-0.16	-0.17	-0.17	-0.18	-0.19	-0.19	-0.20	-0.20	-0.21	-0.20	-0.20	-0.20	-0.20	-0.20	-0.20	-0.19	0.00	0.00	0.00	0.00
Net Income			0.00	0.35	0.37	0.38	0.40	0.41	0.43	0.45	0.46	0.48	0.49	0.51	0.52	0.53	0.53	0.52	0.52	0.51	0.51	0.51	0.50	0.00	0.00	0.00	0.00
Balance Sheet (MEUR)																											
Fixed Assets			6.79	6.45	6.11	5.77	5.43	5.09	4.75	4.41	4.08	3.74	3.40	3.06	2.72	2.38	2.04	1.70	1.36	1.02	0.68	0.34	0.00	0.00	0.00	0.00	0.00
Cash			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.64	0.98	1.32	1.66	2.00	0.00	0.00	0.00	0.00
Total Assets			6.79	6.45	6.11	5.77	5.43	5.09	4.75	4.41	4.08	3.74	3.40	3.06	2.72	2.38	2.04	2.00	2.00	2.00	2.00	2.00	2.00	0.00	0.00	0.00	0.00
Equity			2.00	2.06	2.12	2.18	2.24	2.30	2.36	2.42	2.48	2.54	2.60	2.66	2.72	2.38	2.04	2.00	2.00	2.00	2.00	2.00	2.00	0.00	0.00	0.00	0.00
Capital			2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	0.00	0.00	0.00	0.00
Accumulated Profit			0.00	0.06	0.12	0.18	0.24	0.30	0.36	0.42	0.48	0.54	0.60	0.66	0.72	0.38	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Term Liability			4.39	3.99	3.59	3.19	2.80	2.40	2.00	1.60	1.20	0.80	0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Current Liabilities			0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Equity and Liabilities			6.79	6.45	6.11	5.77	5.43	5.09	4.75	4.41	4.08	3.74	3.40	3.06	2.72	2.38	2.04	2.00	2.00	2.00	2.00	2.00	2.00	0.00	0.00	0.00	0.00
Cash Flow (MEUR)																											
Operating			**0.00**	**0.69**	**0.71**	**0.72**	**0.74**	**0.75**	**0.77**	**0.79**	**0.80**	**0.82**	**0.83**	**0.85**	**0.86**	**0.87**	**0.86**	**0.86**	**0.86**	**0.85**	**0.85**	**0.84**	**0.84**	**0.00**	**0.00**	**0.00**	**0.00**
Revenues			0.00	1.67	1.67	1.68	1.69	1.70	1.70	1.71	1.72	1.73	1.73	1.74	1.74	1.75	1.76	1.76	1.77	1.77	1.78	1.78	1.79	0.00	0.00	0.00	0.00
Operating Costs			0.00	-0.57	-0.58	-0.58	-0.59	-0.60	-0.61	-0.62	-0.63	-0.64	-0.65	-0.66	-0.67	-0.68	-0.69	-0.70	-0.71	-0.72	-0.73	-0.74	-0.75	0.00	0.00	0.00	0.00
Interest			0.00	-0.28	-0.25	-0.23	-0.20	-0.18	-0.16	-0.13	-0.11	-0.08	-0.06	-0.04	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tax			0.00	-0.14	-0.14	-0.15	-0.16	-0.16	-0.17	-0.17	-0.18	-0.19	-0.19	-0.20	-0.20	-0.21	-0.20	-0.20	-0.20	-0.20	-0.20	-0.20	-0.19	0.00	0.00	0.00	0.00
Investing			**-6.79**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Financing			**6.79**	**-0.69**	**-0.71**	**-0.72**	**-0.74**	**-0.75**	**-0.77**	**-0.79**	**-0.80**	**-0.82**	**-0.83**	**-0.85**	**-0.86**	**-0.87**	**-0.86**	**-0.56**	**-0.52**	**-0.51**	**-0.51**	**-0.51**	**-0.50**	**0.00**	**0.00**	**0.00**	**0.00**
Equity			2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dividend			0.00	-0.29	-0.31	-0.32	-0.34	-0.36	-0.37	-0.39	-0.40	-0.42	-0.43	-0.45	-0.46	-0.87	-0.86	-0.56	-0.52	-0.51	-0.51	-0.51	-0.50	0.00	0.00	0.00	0.00
Net Borrowing			4.79	-0.40	-0.40	-0.40	-0.40	-0.40	-0.40	-0.40	-0.40	-0.40	-0.40	-0.40	-0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Increase in Cash			**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.30**	**0.34**	**0.34**	**0.34**	**0.34**	**0.34**	**0.00**	**0.00**	**0.00**	**0.00**
Closing Balance			**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.30**	**0.64**	**0.98**	**1.32**	**1.66**	**2.00**	**2.00**	**2.00**	**2.00**	**2.00**
E&OBS	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E&OCF	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FCFF	12.2%		-6.79	0.96	0.96	0.95	0.94	0.93	0.93	0.92	0.91	0.90	0.89	0.88	0.87	0.87	0.86	0.86	0.86	0.85	0.85	0.84	0.84	0.00	0.00	0.00	0.00
FCFE	19.2%		-2.00	0.29	0.31	0.32	0.34	0.36	0.37	0.39	0.40	0.42	0.43	0.45	0.46	0.87	0.86	0.86	0.86	0.85	0.85	0.84	0.84	0.00	0.00	0.00	0.00
DSCR				1.43	1.47	1.51	1.56	1.61	1.67	1.73	1.79	1.87	1.94	2.03	2.12												
Levellised cost of Energy																											
Investment			-6.79	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Operation			0.00	-0.57	-0.58	-0.58	-0.59	-0.60	-0.61	-0.62	-0.63	-0.64	-0.65	-0.66	-0.67	-0.68	-0.69	-0.70	-0.71	-0.72	-0.73	-0.74	-0.75	0.00	0.00	0.00	0.00
Sum		17.69	-6.79	-0.57	-0.58	-0.58	-0.59	-0.60	-0.61	-0.62	-0.63	-0.64	-0.65	-0.66	-0.67	-0.68	-0.69	-0.70	-0.71	-0.72	-0.73	-0.74	-0.75	0.00	0.00	0.00	0.00