Lappeenranta University of Technology
Faculty of Technology
Degree Program in Environmental Technology

Anil Kunwor

Economic and environmental evaluation of renewable energy systems

Examiners: Professor Risto Soukka
Professor Esa Vakkilainen

ABSTRACT

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Keywords: Renewable energy systems, PV systems, wind energy systems, Biomass energy, Economic evaluation, Environmental evaluation, IRR, MIRR.

The main objective of this thesis is to evaluate the economic and environmental effectiveness of three different renewable energy systems: solar PV, wind energy and biomass energy systems. Financial methods such as Internal Rate of Return (IRR) and Modified Internal Rate of Return (MIRR) were used to evaluate economic competitiveness. Seasonal variability in power generation capability of different renewable systems were also taken into consideration. In order to evaluate the environmental effectiveness of different energy systems, default values in GaBi software were taken by defining the functional unit as 1kWh. The results show that solar PV systems are difficult to justify both in economic as well as environmental grounds. Wind energy performs better in both economic and environmental grounds and has the capability to compete with conventional energy systems. Biomass energy systems exhibit environmental and economic performance at the middle level. In each of these systems, results vary depending upon several systems related factors.

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Anil Kunwor
Lappeenranta, 16th of November 2015.

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LIST OF SYMBOLS AND ABBREVIATIONS

AC	Alternating Current
a-Si	Amorphous Silicon
BOS	Balance of Systems
BFB	Bubbling Fluidised Bed
CAPEX	Capital Expenditure
CFB	Circulating Fluidised Bed
CdTe	Cadmium-Telluride
CH_4	Methane
CIS	Copper-Indium-Selendie
CIGS	Copper-Indium-Gallium-Diselenide
CO_2	Carbon Dioxide
CPV	Concentrating Photovoltaic
c-Si	Crystalline Silicon
DC	Direct Current
DCF	Discounted Cash Flow Rate
CML	Centre of Environmental Science, University of Leiden, the Netherlands
GaBi	Ganzheitlichen Bilanzierung (German for holistic balancing)
GWP	Global Warming Potential
HAWT	Horizontal Wind Turbine
HVAC	High Voltage Alternating Current
HVDC	High Voltage Direct current
IRR	Internal Rate of Return
kW	Kilowatt
kWh	Kilowatt Hour
LCA	Life Cycle Assessment
LCOE	Levilised Cost of Electricity
mc-Si	Multi-Crystalline Silicon
MIRR	Modified Internal Rate of Return

m/s	Meters per Second
MW	Megawatt
NPV	Net Present Value
N_2O	Nitrous Oxide
O&M	Operating and Maintenance
OPEX	Operation and Maintenance Expenditure
PR	Performance Ratio
PVS	Photovoltaic Systems
RQ	Research Question
TTLC	Total Life Cycle Cost
USD	United States Dollar
VAWT	Vertical Wind Turbine
W	Watts
WACC	Weighted Average Cost Of Capital

1 INTRODUCTION

1.1 Research objectives

The use of renewable energy systems to mitigate adverse economic effects is almost a taken for granted concept. With this rationale, large amount of investments are made on renewable energy systems. Often the motivating rationale is not only environmental but also economical. In this context, it seems appropriate to explore whether investments in renewable energy systems are supported by both economic and environmental gains. Still further, it would make sense to compare different renewable energy systems in terms of their economic and environmental performance taking into consideration different relevant attributes that can affect economic as well as environmental efficiency. This issue might also be relevant to contemporary policy decisions. For example: Is it worthwhile to invest in renewable energy systems in comparison to non-renewable energy systems? Further, if investment is to be made, which system would likely have the higher economic and environmental returns?

Motivated by these relevant questions, this thesis aims to explore first the current understanding of different factors that affect the environmental and economic performance of various renewable energy systems. The renewable energy systems taken into consideration in this thesis are bioenergy, solar energy and wind energy. Delineating those factors, this thesis aims to evaluate the economic and environmental attractiveness of different energy systems taking both into consideration.

1.2 Research questions

Following from the previous section, the research questions of this thesis could be stated as:
RQ1: In terms of economic returns, which renewable energy system is the most effective?
RQ2: In terms of environmental gains, which renewable energy system is the most effective?
RQ3: How does seasonal variability affect the economic and environmental gains of different energy systems?

In order to answer RQ1, different means of economic or financial evaluation of energy projects will be explored. Thereafter, the cost structures and factors affecting economic evaluation of three different energy systems: solar, wind and biomass energy will be assessed. The appropriate means for financial evaluation will then be used to evaluate these three different energy systems considering different cost related factors.

In order to answer RQ2, emissions in the form of kg CO_2-Equivalent will be determined for different renewable energy systems through LCA analysis. This will then be used to conduct environmental effectiveness of these three renewable energy systems. Since, seasonal variability is also an important component determining the economic performance of renewable energy systems, their relationship is dealt with RQ3.

1.3 Structure of the thesis

Chapter 2 consists of literature review. In this review, first, different system components of PV systems, wind energy systems and biomass systems are identified. It is then followed by cost parameters for each of these systems and the output generated by each of them systems. Then different economic means of evaluating alternative investment decisions are discussed. Since power outputs are variable according to seasonal fluctuations, especially for renewable energy systems like wind and solar energy systems, this is discussed in section 2.4.

Chapter 3 deals with specific case of Finland. First of all, taking into account solar radiation level in Finland, output from PV systems is calculated leading to annual cash flows. This is then used to calculate IRR for economic evaluation. Second, wind speed in the Finnish case is taken into consideration and IRR derived by following the same process. Then feedstock materials in the Finnish case i.e. bulk pellets and wood chips are used to calculate output and cash flows to derive IRR of the biomass plant. At the end, GaBi software is used to evaluate the CO_2 emissions of each of these renewable energy systems and measure their environmental performance.

Chapter 4 presents the results of both environmental and economical effectiveness of each of these renewable energy systems. This chapter discusses the differences in these three systems in terms of IRR and CO_2 emissions. Chapter 5 concludes the study highlighting the major findings, what it suggests for policy decision making, what were the limitations of this study and what could be avenues for further research.

2 LITERATURE REVIEW

2.1 Different renewable energy systems

One of the criteria to differentiate between renewable and non-renewable energy systems is whether the source of energy is exhaustible or inexhaustible. For example, some energy sources such as fusion process are considered inexhaustible. Some sources of energy are fixed in availability and deplete after use such as fossil fuels. There are some natural sources of energy, which can be limited in their flows but are not exhaustible such as solar radiation, wind and biomass. It is this third category of energy sources that has been classified as renewable energy systems.

Similarly, the other source of differentiation is whether the use of energy technologies leads to emission of significant carbon dioxide or other greenhouse gases in the atmosphere. While some energy technologies using fossil fuels can have large negative effects on the environment, other energy technologies using natural sources are considered to have neutral environmental effects and are considered to be "clean" sources of energy (Mishra, et al., 2012). It is this latter type of energy systems that are considered in this thesis and elaborated further in this section.

2.1.1 Photovoltaics (PV) Systems

Solar photovoltaics (PV), which are also sometimes referred to as solar cells or PV, are electronic devices, which help to convert sunlight into electricity. The origination of the term "photovoltaics" refers to the physical process where photons (in light) are converted to voltage, as in electricity; which is also referred sometimes as the "PV effect". This conversion of solar energy to direct-current (DC) electricity takes place in the light sensitive semiconductor device of PV systems called a solar cell, which could be considered as its basic building block (NEED, 2015). The basic principle of solar energy systems is illustrated in figure 1.

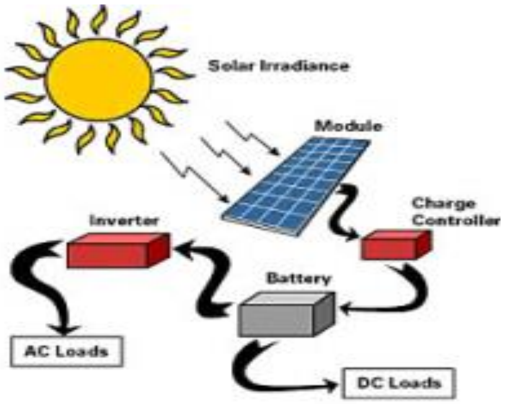

Figure 1. General components of PV solar system (Energy Development Co-operative Limited, 2013).

When these cells are interconnected to each other they form a PV module usually of 50 to 200 W (Watts). Majority of the PV cells are produced using crystalline silicon technology. In addition to cells, a photovoltaic power generation systems also consist of other mountings, mechanical and electrical connection and other means through which the electric output is regulated. Depending upon different types of PV cell technologies used, PV systems are classified into different "generations" based on the type of materials used and readiness to commercialization. Evidence shows that PV systems dominating the market today are the first generation and second generation and third generation PV systems (IRENA, 2012), which are further explored below.

First generation PV systems are characterized by the use of wafer-based crystalline silicon (c-Si) technology, which could be in the form of single crystalline (sc-Si) or multi-crystalline (mc-Si) form. In contrast, second generation PV systems are based on thin-film PV technologies. These thin-film PV technologies then could be further divided into: amorphous (aSi) and micro morph silicon (a-Si or μc-Si); Cadmium-Telluride (cdTe) and finally, Copper-Indium-Selenide (CIS) or Copper-Indium-Gallium-Diselenide (CIGS). Second generation PV systems are referred to as "thin film" systems because the semi-conducting materials used to produce cells are only few micro meters thick. Most of these technologies are actually still at the early stages of development. Third generation PV systems, in turn are characterized by the use of concentrating PV (CPV) or organic PV cells. These third generation technologies are still emerging technologies. (IRENA, 2015)

2.1.2 Wind energy

Wind energy denotes mechanical power or electricity generated by wind. Wind energy is produced through conversion of kinetic energy in the wind into mechanical energy by mounted wind turbines. In principle, the kinetic energy generated by the airflow turns the wind turbine blades, which then via drive shaft powers the turbine generator (Karimirad, 2014). This section describes first the general components used in wind energy systems, and then the differentiation of wind energy systems based on location and axis of the wind turbine.

General components of wind energy systems

The general principle of wind energy systems is illustrated in figure 2. As seen in figure 2, the basic components of wind energy systems are foundation, tower, nacelle, rotor, gearbox, generator, controller and transformer. Each of these components are further elaborated in sections below.

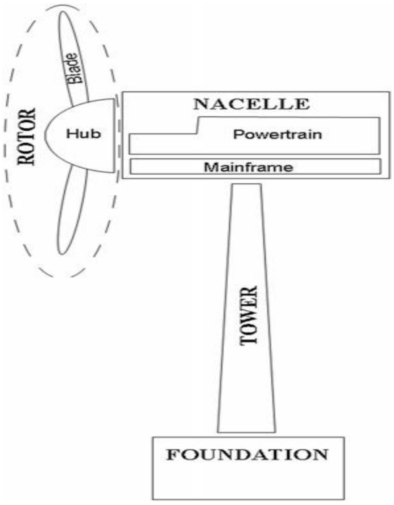

Figure 2. The basic layout of wind energy system (Singh, et al., 2013).

Foundation: The main purpose of the foundation in the wind energy system is to support the weight of the wind turbine. The structure of the foundation highly varies with the consistency of the soil in the construction location and also according to the turbine unit. In a monopole type of foundation, the height could range from 4 to 25 meters and is usually a hollow steep pile where additional grout is injected between the pile and transition piece. Surface level foundations sit on a terrain and is a large base which is made of concrete. (Singh, et al., 2013)

“Jackets” type of foundation can be anywhere between 30 to 35 meters in height and are similar to lattice towers which are in frequent use in offshore oil and gas drilling sites. In contrast, “multipile” foundations can be of height up to 40 meters, with several layers of different construction materials and having a significant footprint than the monopile foundations. In this range, there could also be several different types of foundations adapted from the simple monopile structure. Obviously, the type of foundation is dependent upon the type of location, which could include factors such as height of the sea-bed, whether it is in offshore or onshore location and as mentioned previously, according to the consistency of the soil. (Singh, et al., 2013)

Tower: Much of the design of the tower is dependent upon the weight of the nacelle and rotor; and is built to bear the strain caused by fluctuations in the wind speed. Similarly the weight of the tower is also dependent upon the power of the turbine and the diameter of the rotor blade (Singh, et al., 2013). Table 1 shows this relationship.

Table1. Variation of the height of the tower based on the turbine power and rotor diameter.

Tower height (m)	**Rated power (kW)**	**Rotor diameter (m)**
65	600–1,000	40–60
65–115	1,500–2,000	70–80
120–130	4,500–6,000	112–126

In terms of the structure of the tower, the general types of the tower structures are: tabular steel towers, concrete towers built on site, prefabricated concrete towers, lattice towers and hybrid towers. Tabular steel towers are generally seen in large wind turbines. In such cases, the towers are built in 20-30 meter sections with flanges bolted at both site. In order to efficiently use materials and to increase the strength of the towers, they are usually tapered towards the end. Concrete towers, which are built on site, are usually selected when transportation is difficult or impossible to be installed with the turbine.

However, there might be height restrictions when considering these concrete towers built on site. Prefabricated concrete towers are similar in structures but they are placed on top of another as separate sections. Lattice towers also appear similar in structure, but are made of latticed steel sections. They are used in order to be efficient in use of materials as the volume of the materials to be used are rather low than in other types of structures while being resilient in the same degree. These, however, could be used less widely, for simple aesthetic reasons. For such reasons, latticed towers might be more widely used in emerging nations than on developed nations. However, in cases of large turbines with high-energy production, often the combination of discussed methods can be used simultaneously as hybrid structures. For example, it might be the case that the bottom part of the tower is made of steel whereas the upper part could be fashioned with tabular steel. (Singh, et al., 2013)

Nacelle: Nacelle is a component that encases the parts and components of the wind turbine. Since the wind turbine should be able to rotate according to the direction of the wind, to facilitate this rotation, nacelle is connected to the tower with bearings. The design of the nacelle is highly dependent upon the manufacturer and other components that are attached to the nacelle in the system. (Singh, et al., 2013)

Rotor: Rotor is the main component which helps to convert wind energy to mechanical energy through rotation. Although, the revolutions per minute (rpm) of rotor is dependent upon the size of the turbine and design; generally turbine rotor with hub assembly revolve at a rate of 10-25 revolutions per minute. This hub is connected to low speed shaft, which in turn is connected to turbine gearbox. The hub that is at the center of the rotor is usually made of cast steel or iron. Hub can either be connected to low-speed shaft of the gearbox, if the turbine has gearbox or directly connected to the generator if the turbine has no gearbox.

The most common form of design has rotor with three blades and a horizontal shaft. The length of the rotor blade can be usually anywhere between 40 and 90 meters in diameter.

This conventional design of three blades is thought to distribute weight evenly allowing for more stable rotation and thus, efficiently generate power. The materials used to manufacture rotor blades are usually fiberglass or carbon fiber galvanized with plastic. In many ways, the material used and the principle behind rotor blades is very much similar to the wings used in airplanes. However, the actual look of rotor blades is dependent upon the manufacturer. (Singh, et al., 2013)

Gearbox: Gearbox consists of turbine blades and the hub which connects the blades to main shaft. Usually gearbox connects the revolutions of the rotor to the speed of the generator, and is seen in majority of installed turbines. In other words, it is the gearbox which converts the rotation of the rotor blades, which is low in speed and high in torque, into high speed (usually 1500 rpm) and low torque input ideal for the generator. In this way, the gearbox connects the input of the rotor blades to the generator. It has been suggested that since gearboxes require constant maintenance, large-scale turbines may not have gearbox in order to reduce maintenance costs.

Generator: Generator is situated inside the nacelle and it is the main component which converts the mechanical energy of the rotor to the electrical energy. Generally the voltage level of operation of generators is 690 Volts (V) and operates with three phases of alternating current (AC). This type of doubly-fed induction generators are the norm in wind energy systems design. However permanent magnet and asynchronous generators are also used in direct-drive designs (Singh, et al., 2013).

Controller: This component of the wind energy system controls and monitors the turbine by collecting operational data. This operational data can be rotational speed, hydraulics temperature and pitch of the blade and nacelle yaw angles to wind speed. Mechanism in the controller (yaw) ensures that the turbine is always facing the wind improving energy output and loading of turbine. Increasingly advanced controller design has enabled remote location control of the wind energy system (Singh, et al., 2013).

Transformer: It is a component which converts the voltage output from the generator to the local grid requirement. For example, the medium level of voltage output from generator is converted in the range of 10kV to 35kV, which is the general requirement of the local grid. Transformer is usually placed in the tower of the wind turbine (Singh, et al., 2013).

Different types of wind energy systems

Wind energy systems are differentiated based on two major factors: the axis of the wind turbine and the location of the plant. The axis of the wind turbine can either be vertical (VAWT) or horizontal (HAWT) whereas the location of can be offshore and onshore (IRENA, 2012).

Differentiation based on axis of wind turbine: The main difference between vertical-axis and horizontal-axis turbine is determined by characteristics such as rotor placement (either upwind or downwind), the number of blades, output regulation system of generator, hub connection to the rotor (either rigid or hinged), design of the gearbox (multi stage, single stage or direct drive), rotational speed of the rotor, and the capacity of the wind turbine. The most typical utility scale wind turbine can have three blades, diameter ranging between 80 to100 meters, the capacity of turbine ranging from 0.5 MW to 3 MW, and the number of turbines ranging from 15 to150 connections in a grid (IRENA,2012).

Differentiation based on location: Onshore wind systems are constructed in the mainland whereas offshore wind systems are constructed in bodies of water. The difference between these systems is that in the offshore environment; wind turbines are designed to be more resistant to wind velocity, to withstand corrosion due to water and other challenges in the harsh offshore environment. Offshore systems can also be more costly due to higher installation costs of foundations and other components and to shield the structures from harsh marine environment. The design of the foundations of offshore systems, which can be; single pile, gravity or multi-pile structure is more challenging and costly compared to land based systems (Singh, et al., 2013).

The actual power that can be generated by a wind turbine is variable according to different factors such as wind resource, wind speed, capacity of the turbine either in kW or MW, the diameter of the rotor blade and the height of the turbine tower. Majority of the utility scale wind turbines use horizontal axis technology. Many researchers suggest that vertical axis wind turbine is less common as they are thought to be less efficient aerodynamically. As a result, they do not significantly occupy market share (EPA, 2013).

2.1.3 Biomass energy

Biomass denotes renewable organic matter or stored energy. This includes all materials of biological origin except fossil fuels. This could also include that portion of residues from agricultural, forestry and industrial wastes that are biodegradable. Biomass energy systems deal with the conversion of biomass into electricity. There are currently several forms of technology used for such purposes; some of which are direct combustion in stoker boilers, low percentage co-firing, anaerobic digestion, municipal solid waste incineration, landfill gas, atmospheric biomass gasification, pyrolysis, integrated gasification combined cycle, bio-refineries and bio-hydrogen and so on. The discussion of these different biomass energy systems is beyond the scope of this thesis, but all of these technologies vary according to their readiness to commercialization (IEA, 2007).

To generate power from biomass, the biomass energy systems require three major components namely: biomass feedstock, biomass conversion and energy generation technologies. Each of these are elaborated further in sections below.

Biomass feedstock

The chemical composition and properties affecting power generation are variable according to different regions. Whereas some combustion technologies can accept varying forms of biomass feedstock, some others require specific form of biomass feedstock to operate. Common form of biomass resources are agricultural waste, animal waste, waste from food and paper industries, municipal waste, sewage sludge, short rotation energy crops, coppiced wood, grasses, sugar crops, starch and oil crops. In a sense, all organic wastes can be used as source of biomass feedstock. The amount of moisture and ash; size of the particle, and density of the biomass feedstock determines which residue is more effective as a biomass feedstock (IRENA, 2012).

Conversion of biomass feedstock

Biomass is converted to generate heat and electricity through different processes. The most common processes are either thermal-chemical processes; which includes combustion, gasification and pyrolysis or bio-chemical processes that comprises significantly of anaerobic digestion (IRENA, 2012).

Technologies of generating power

The third component of biomass energy generation is the technology to generate power. There are different kinds of commercial technologies that convert biomass to generate heat and electricity. The essence of majority of combustion based biomass plant technologies has two main elements: biomass fired boiler and steam turbine. Biomass fired boiler produces steam, which drives steam turbine and can be either of the stoker type or fluidized bed type. These combustion-based technologies can either use solely biomass as fuel input or can be used with other solid fuels (IEA-ETSAP and IRENA, 2015).

General components of biomass energy systems

The general principle of biomass energy system is illustrated in figure 3. In a combustion based biomass system, the principle components are biomass-fired boiler and the steam turbine. The biomass-fired boiler produces steam and the steam turbine is used to generate electricity. There can also be different types of boilers of which stoker boilers and fluidized bed boilers are the most common forms. While stoker boilers produce steam by burning fuel from above (overfeed) or under the grate (underfeed); fluidized bed boilers suspend fuels on upward blowing jets of air during combustion (IEA-ETSAP and IRENA, 2015).

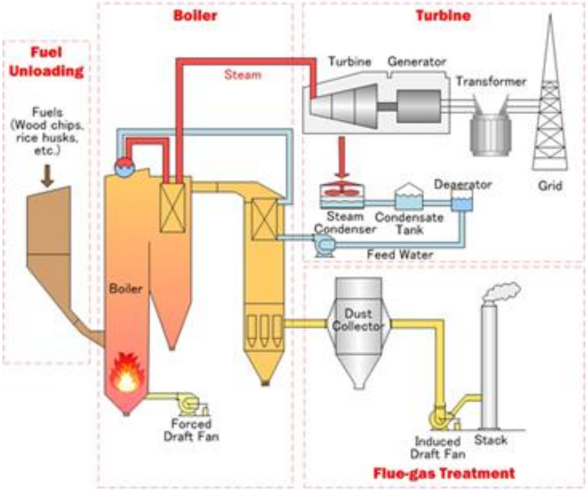

Figure 3. General components of biomass energy systems (Yokogawa electric corporation, 2015).

2.2 Means for economic evaluation

As discussed in previous sections, renewable energy systems denoted plants to generate electricity from renewable energy sources such as solar, wind and bioenergy. The purpose behind economic evaluation is to make decisions based on monetary costs and returns. Therefore in this section, first, different methods of economically evaluating investments in different projects are discussed. After that the cost structure of renewable energy sources of solar, wind and bioenergy are discussed.

2.2.1 Cost structures of different renewable systems

In this section, cost structure of different renewable energy systems including wind, solar and biomass energy will be discussed. The cost structure here include different types of cost incurred during setting up of the system which includes installation, operation and maintenance costs; cost of civil infrastructure and so on for each of these different renewable energy systems.

Wind energy systems

***Installed capital cost*:** The upfront cost of the wind turbines, the cost of building the towers and the additional costs of installation are the major costs of wind energy systems. The cost of the tower and the rotor blades can amount to almost half of the overall cost. Following these, gearbox is the next expensive component. Cost of other components such as generator, power converter, nacelle and transformer also comprises of the total installed cost. Gearbox also comprises major part of the operating and maintenance (O&M) costs. Obviously, this cost is variable according to the location of the project, institutionalization of wind energy systems in that particular country and the specific situation of the project (IRENA, 2012).

Civil works and construction costs: Under this category, the costs incurred are construction costs for the site preparation and the foundations for the towers. The costs of transportation and installation of wind turbine and tower, the construction of the foundation of the tower, access roads and other infrastructure required for the wind farm are all included in the total cost of wind energy system. While laying down the foundations of the wind turbine, more than 45% to 50% of the cost of foundations, especially of the monopole foundations is incurred due to material costs of steel. (IRENA, 2015)

However, the cost of civil works and construction costs also vary according to whether the wind turbine is of the offshore or the onshore type. For example, the nature of foundations and the material used in both of these types of wind energy systems are different. Whereas in the onshore type, foundation is mainly poured concrete, in the offshore location it is usually drilled steel monopoles. Depending upon the type of materials used in the foundation, the civil and construction costs for both types of wind turbine are different. Similarly, in the offshore location, due to requirement of purpose built vessels, the transportation costs of materials required could also be higher (IRENA,2012).

Grid connection costs: When the wind energy system is connected to the grid, this also includes the connection costs to local transmission network, including the costs of transformers and sub stations. The location of the wind farm from the distribution network also affects the grid connection costs. If the distance is too far, instead of the typical high voltage alternating current (HVAC) connection, there might be a need for high voltage direct current (HVDC) connection, which costs more. Further, grid connection costs can also include costs of electrical work, electricity lines and connection point. (IRENA, 2012)

Grid connection costs can also vary according to geographical location of the wind farm and the type of wind energy system (offshore or onshore). In some countries, the operator bares the cost of transmission system upgrade whereas in others it is the wind farm owner. Similarly, whether the wind farm is offshore or onshore also affects the grid connection costs. For example, it has been suggested that whereas for the onshore wind farms, the grid connection costs can range from 11-14% of the total capital costs, for the offshore wind farms it can range from 15-30% of the total capital costs (IRENA, 2012).

Operation and maintenance costs: It has been suggested that operation and maintenance (O&M) costs of wind power systems can account from 20-25% of total LCOE (Levelised Cost of Electricity), which turn out to be typically 2% of the initial investment cost per year. O&M costs of wind power systems are usually divided as fixed and variable costs. When the costs include the costs of insurance, administration, grid access fees and costs of service contracts for scheduled maintenance, these are generally attributed as fixed O&M costs. Variable costs include costs incurred due to unexpected occurrences that are not covered by fixed service contracts. This could be for example, costs of unscheduled maintenance, costs of replacement parts and materials and labor costs required to cover unscheduled maintenance. Maintenance costs can be due to small and frequent activities or due to large and infrequent occurrences such as replacing major components of the system. (IRENA, 2012)

Once again the geographical location of the wind power system and the type (onshore or offshore) affects the degree of O&M costs incurred. For example it has been suggested that O&M costs are higher in European countries when compared to the United States. Similarly, O&M costs of offshore wind farms tend to be higher because of difficulty in accessing and maintaining wind turbines and also due to higher failure rate of components in offshore environment. (IRENA, 2012). Table 2 shows the breakdown of the installed capital cost for wind turbine.

Table 2. Breakdown of capital cost for wind turbine (IRENA, 2012).

Turbine cost	Grid connection costs	Other capital cost
▪ Blades ▪ Tower ▪ Transformer	▪ Construction costs for site preparation ▪ Foundation for the towers	▪ Construction of building ▪ Control systems ▪ Project consultancy costs ▪ O&M costs ▪ Insurance ▪ Contingencies

Similarly, figure 4 shows how different costs can vary according to the type of the wind energy systems.

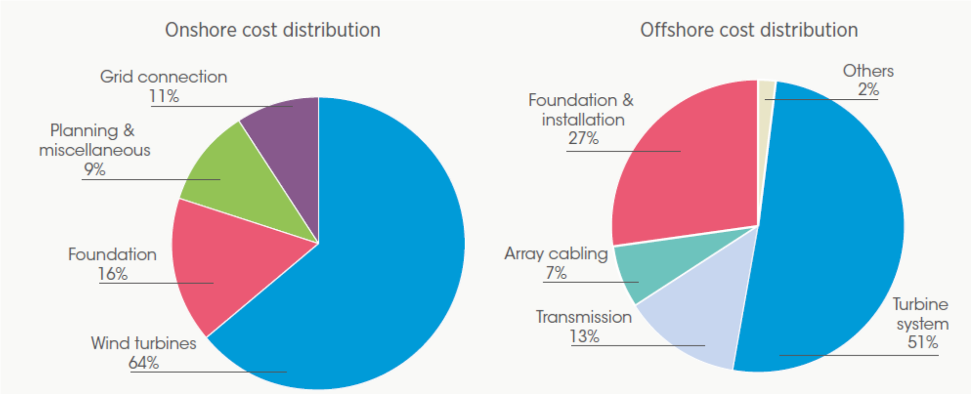

Figure 4. Cost distribution according to wind energy system type (IRENA, 2012).

In any case, the key parameters that determine the economic effectiveness of wind power systems are investment costs, operation and maintenance costs, capacity factor of the system, lifetime of the system and the overall cost of the capital. This section discussed majority of these cost factors.

Cost breakdown of Solar PV systems

Capital cost of PV system is composed of PV module and Balance of system (BOS) cost (Tsekeris, 2013). It has been suggested that the PV module cost can range from 34-50% of the total capital cost of a PV system (IRENA, 2015).

***PV module costs*:** Since the module is composed of interconnected PV cells, the PV module costs is further composed of the costs of raw material of these PV cells and their interconnections. This includes the cost of silicon, cell processing costs and assembly costs. However, the costs of the PV modules obviously vary by the geographical location of the system, the technology used, manufacturer, manufacturer's retail margin and the types of components used. For example, c-Si PV modules are expensive than other systems, whereas CIGS modules are cheaper although the former can be more efficient. Similarly, PV module prices can also vary quite much by geographical locations, which in turn determine the manufacturer and the conventional margin rate acceptable across different locations (IRENA , 2015).

Inverter costs: Inverter is one of the most important components of the PV module system that transforms DC electricity in PV modules to grid compatible AC form. Depending upon the purpose, whether residential or utility-scale, the size of the inverter varies. The number of inverter used in the PV modules also depends upon installed PV capacity and overall system. Inverter can, on average amount to 5% of the overall installed cost of PV systems (IRENA , 2015).

BOS costs: The BOS costs in turn includes the costs of the structural systems, electrical costs, battery and if it is the case of off grid PV module, the cost of storage systems. Electric cost here is used to mean the cost of electrical components such as inverters, transformers, wiring and installation costs. Other costs of hardware that are categorized under BOS costs include the cost of components required to mount and rack PV systems, the cost of combiner box, labor costs for installation and grid connection and site preparation. In sum BOS cost includes all cost components excluding the PV module costs, which includes all hardware and installation costs. (IRENA, 2015)

Obviously, the BOS costs also vary according to geographical locations, most notably due to different sort of incentive schemes and tax subsidies across regimes and the market segment. It has been claimed that the larger the scale of the PV systems, the lower is the BOS cost calculated per kW because of the economics of scale effect and increased purchasing and bargaining power. Therefore, for small scale systems such as residential systems, BOS and installation costs can be up to 55-60% of the total PV system costs whereas for large scale utility PV plants it can be 20% of the total PV system. Even within large scale utility PV plants, costs for simple grid connection systems can be up to 70% of the total PV system when it is of the off-grid type. Whether the PV system is ground or roof mounted can also affect the overall cost of the PV systems in general. In addition to these costs, operation and maintenance costs (O&M costs) of solar PV systems is estimated to be 1% of the total investment cost per year (IRENA, 2015). Table 3 summarizes all major cost components of solar PV systems.

Table 3. Cost breakdown structure of PV systems (IRENA, 2015).

PV module	Inverter	BOS/installation
Semiconductor ▪ Raw materials (Si feedstock, saw slurry) ▪ Utilities, maintenance, labor ▪ Equipment, tooling, building, cost of capital ▪ Manufacturer´s 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 labor costs
Cell ▪ Raw materials (metallization, SiNX, dopants, chemicals) ▪ Utilities, maintenance, labor ▪ Equipment, tooling, building, cost of capital. ▪ Manufacturers' margin		
Module ▪ Raw materials (glass, EVA, metal frame, j-box ▪ Utilities, maintenance, labor ▪ Equipment, tooling, building, cost of capital ▪ Shipping ▪ Manufacturers' margin ▪ Retailers' margin		

Cost breakdown of biomass power generation technologies

The basic costs that should be included in calculating the costs of biomass power generation technologies are the a) prices of the feedstock used such as pellets, wood chips b) costs of technology used and finally c) operation and maintenance costs. Each of these costs are discussed further in this section.

Feedstock prices: Feedstocks are required to produce electricity through biomass energy systems, which is not necessary for wind or solar energy systems. It is necessary to produce, collect, transport and store this feedstock for electricity power generation. For example, pellets and woodchips are the most used sources of feedstock. Obviously, the cost of feedstock is dependent upon their availability and distance to the source, and whether these suppliers are reliable. Similarly the energy content, moisture content, the properties of feedstock affecting the handing and processing of power plant and the efficiency of the fuel source all have an effect on the cost of feedstock. The preparation time required for feedstock and the economies of scale available in processing and handling feedstock materials are also economic factors that can have positive or negative affect on the prices of feedstock. However, it has been estimated that feedstock cost can represent up to 40-50% of the total cost of the electricity produced. It is difficult to obtain the data of feedstock prices that are locally available due to unavailability of data sources (IRENA, 2012).

Biomass power generation technology cost: The total cost related to technology used for generation of electricity by biomass energy systems or the total investment cost (capital expenditure /CAPEX) cost primarily consists of the equipment used (whether prime mover or fuel conversion system), fuel handling and preparation machinery costs, the costs of engineering and construction for the biomass system and other planning costs. The planning costs can include the cost of consultation, design and other working capital. Other costs include costs of grid connection and additional civil works. Obviously, the cost of biomass energy systems is variable dependent on the type of technology used, the region where this is set up, and the type of feedstock used and the amount of time and effort required to prepare and handle feedstock in the site. The choice of type and size of technology is also often dependent upon the local demand for electricity and heat. From this discussion, it is quite clear that the cost of technology will be dependent upon type of technology, the size of the project, requirements of components, feedstock requirement and so on but on average, 62-77% of the total capital costs is determined by the feedstock conversion technology and machinery required for feedstock preparation and handling. (IRENA,2012)

Operation and maintenance expenditure (OPEX): Operation and maintenance costs (O&M) costs for biomass energy systems can be divided into fixed and variable costs. Fixed O&M costs includes the costs of labor, maintenance, replacement of machine components, insurance and other related costs. Fixed O&M costs is expressed as a percentage of capital costs and in general it is assumed to range from 1-6% of the initial CAPEX cost per year.

Due to the effect of economies of scale, the larger the size of the biomass generation project, the lower the fixed O&M costs (such as labor costs) as it is spread over the additional electricity output. Variable O&M costs, as a rule, are calculated as costs per unit of output. The major components of variable O&M costs are costs associated with maintenance that is unplanned, replacement of equipment and parts, servicing costs, ash disposal costs and other costs that are generally categorized as non-biomass fuel costs (IRENA, 2012). Table 4 summarizes different cost components for the biomass energy generation systems.

Table 4. Capital cost breakdown of biomass power generation technologies (IRENA, 2012).

Fuel handling/preparation The pre-treatment and on-site handling/processing of fuels can be a significant proportion of biomass capital costs.
Electrical / Balance of plant These costs covers the equipment necessary to connect plant to the grid but does not include the costs of transmission lines.
Converter system The converter system includes anaerobic digesters, gas collection systems and some other gas treatment systems.
Prime mover The prime mover costs includes costs associated with power generation technologies, converter and any in-line elements such as particulate matter filters.

2.2.2 Electricity generated by different renewable energy systems

Since economic evaluation of different energy systems will have to consider revenue and costs of each, it is important that for comparison, the electricity output of each of these systems be evaluated. After all, it is only after considering energy output of different systems that the cash flows generated from different systems can be calculated. Different factors can affect the power output of different systems, which are discussed briefly in this section.

PV systems

Energy generated from PV systems: The solar energy output (E) of PV systems is a function of total area of the solar panel (A), solar panel yield (r), annual average solar radiation (H) and the performance ratio of the PV systems (PR). This general equation gives the global estimate of energy generated from PV systems. More precisely,

$$E=A*r*H*PR \qquad (1)$$

Where,
E = energy (kWh)
A = total solar panel Area (m^2)
r = solar panel yield (%)
H = annual average solar radiation on tilted panels (shadings not included)
PR = performance ratio

The performance ratio (PR) or the coefficient for losses ranges from 0,5 to 0,9 and the default value is taken to be 0,75. It is one of the most important measures taken to evaluate the quality of PV systems as it indicates the level of performance of PV systems independent of the inclination and orientation of PV systems. “r” or the yield of the solar panel is calculated by considering the relation of electrical power in kW of one solar panel to its area (TOOLS, 2014).

Energy losses of PV systems: In the previous section, the general annual energy outputs of PV systems were discussed. However, if we were to consider the energy output of the PV systems throughout its life cycle, it is also necessary to acknowledge that in its life cycle the system output is reduced by different components and different percentage. It is then necessary to evaluate cash inflows of energy systems by considering this output degradation throughout the useful period. Table 5 shows output losses by different factors and components.

Table 5. Energy losses of PV system components and other loss factors (TOOLS, 2014)

Components or loss factors	**Loss percentage range**
Inverter	4-15%
Temperature	5-18%
DC cable	1-3%
AC cable	1-3%
Shadings by specific site	0-80%
Weak ration	3-7%
Dust and Snow	2%

The annual power degradation of PV systems can amount to 0,5% of the total power generated. It is also necessary to consider the type of PV systems as different types of PV panels can have different degradation rate in power output. For example, researches show that power degradation in thin-film solar panels such as a-Si, CdTe and CIGS is much faster than mono and polycrystalline panels (IRENA, 2012).

Wind systems

Energy generated from wind systems: Energy generated from wind systems (kW) can be calculated by considering the density of air (ρ), the wind speed (v) and the area intercepting the wind. The higher the density of the air (i.e. which is heavier) the power generated by the wind energy is higher compared to lighter air. Air density is measured in kg/m^3 (Mathew, 2006)$^.$ Similarly, the power generated by wind energy also varies with the cube of the wind speed. Wind speed is measured in m/s. In turn, power generated by wind energy is also dependent upon the wind captured; and the higher the captured or intercepted area, the power is higher. The area intercepted or captured by the rotor blade is measured in (m^2). More precisely, if the rotor sweeps in an arc forming a circle, the area intercepted is given as a function of rotor's radius (r) and π. In addition to that, there is an exponential relationship between power generated by wind energy and the area intercepted by the rotor blade;

whether horizontal or vertical (Jorstad, 2009). This relationship between swept area (m^2), the nominal diameter of the rotor (m) and the nominal power rating (kW) is given in table 6.

Table 6. The relationship between intercepted area and rotor diameter to power output (Joskow, 2011).

Swept area (m^2)	**Nominal rotor diameter (m)**	**Nominal power rating (kW)**
1	1.1	0.2
5	2.5	1
10	3.6	2
50	8	10-20
100	11	25-40
1000	36	300-400
5000	80	1500-2500

Therefore, in sum power generated by the wind turbine (P) is the function of density of the air (ρ), cube of wind speed (v^3) and the area intercepting the wind (πr^2).

$$P = \frac{1}{2} * \rho * \pi r^2 * v^3 \qquad (2)$$

Where,

P = power generated by the wind turbine (kW)

ρ = air density (kg/m^3); generally taken as 1,225 kg/m^3 at sea level

A (πr^2) = area intercepted by the rotor blade (m^3)

v = speed of the wind (m/s)

Using equation (i), electrical energy generated in a certain time, (E=P* t) in kWh by wind turbine (P) can be estimated by taking into consideration some other additional factors. To convert the power produced by wind turbine in a day to yearly energy output, the P in equation (i) is multiplied by 24*365=8760. Therefore, energy produced by wind turbine in a year (E) is:

$$E=\frac{1}{2}*\rho*\pi r^2*v^3*8760 \qquad (3)$$

In addition to these, some additional factors also need to be considered to derive more precise measurement of energy output of wind turbine in a year. For example, conversion efficiency of wind turbine and distribution of energy pattern factor, more precisely known as Rayleigh distribution also need to be considered. Rayleigh distribution has been considered as a good approximation of wind speed over a time and since our goal is to estimate energy produced by wind turbine in a year; this distribution functions gives the general approximation of varying wind speed over a year. Overall wind speed over a particular time is assumed to be estimated by Rayleigh distribution.

Given energy systems such as wind energy; and the energy output over a particular period of time, it is also necessary to include the energy conversion efficiency (η). This is the standard ratio of the input energy and the converted output energy. Since, each system has a variable efficiency in terms of output energy generated from input energy, the energy output of wind turbine over a time also requires consideration of energy conversion efficiency.

Therefore the final equation estimating the energy production of wind turbine annually is given by:

$$E=\frac{1}{2}*\rho*\pi r^2*v^3*\eta*8760 \qquad (4)$$

Energy losses of wind energy systems: In the previous section, the general annual energy output of wind energy system was discussed. However, if we were to consider the energy output of the wind energy systems throughout its life cycle, it is also necessary to acknowledge that in its life cycle, the system output degrades by different components and different percentage. The evaluation of the cash inflows of energy systems by considering the energy output throughout the useful period is also an important criteria to assess. Table 7 shows output losses by different factors and components in wind energy systems.

Table 7. Energy losses of wind energy systems (Morthorst & Awerbuch, 2009).

Components or loss factors	Loss percentage range
Array losses/ park effects	5-10%
Rotor blade soiling losses	1-2%
Grid losses	1-3%
Machine downtime	2%
Wind direction hysteresis	1%

Array losses occur because there is a possibility that one wind turbine shadow each other, which can lead to loss of energy in wind turbine. The layout of the wind farm and the intensity of the turbulence also affect the array losses. Rotor blade soiling losses is due to blades becoming dirtier and less efficient after use. Grid losses refer to the losses in energy due to conversion of energy inside the cables and transformers into heat. Machine downtime losses occur due to time spent for maintenance when there are technical failures in the turbine and rotor blades. Since the wind direction is variable, and the yaw mechanism in wind turbine will not be able to effectively follow the exact direction, some amount of energy may be lost due to this misalignment. All in all, when each of these energy losses are considered together, 10-15% of energy might be lower than the theoretical maximum power output of the wind turbine. This might also occur as the operation years of the wind turbine keeps on increasing. The annual output degradation of wind systems can amount to 0,60% annually. (U.S. Energy Information Administration, 2013)

Biomass systems

Energy generated from biomass energy systems: Biomass energy is different from electricity generated from wind energy and solar energy systems. Biomass energy systems produce dispatchable baseload electricity. It is a type of electricity power point that can always produce a baseload demand and the power output can also be variable on will dependent upon the final demand (Joskow, 2011). Biomass energy output (E), therefore is the function of yearly operating hours (h_a) and the capacity of plant in generating electricity output (P_{max}). Plant electric capacity in turn is calculated by taking into consideration both electrical efficiency and annual fuel usage. Or more precisely,

$$E_a = h_a * P_{max} \quad (5)$$

$$P_{max} = \eta * F_a \quad (6)$$

Where,

h_a = annual operating hours

P_{max} = plant electric capacity

Therefore,

$P_{max} = \eta * F_a$

η = electrical efficiency

F_a = annual fuel required

Energy losses of biomass energy systems: In the previous section, the general annual energy output of biomass systems was discussed. However, if we were to consider the energy output of the biomass systems throughout its life cycle, it is also necessary to acknowledge that in its life cycle the system output degrades by certain percentage annually. The evaluation of the cash inflows of energy systems by considering the energy output throughout the useful period is also an important criteria to assess. Overall considering all of the different categories of losses, the annual output degradation of biomass combustion can amount to 0,4% annually in comparison to the total power generated (Navigant Consulting Inc., 2007).Table 8 shows energy losses due to different reasons.

Table 8. Total combustion losses of biomass boilers (Smith, 2006).

	Biomass stoker		**Biomass fluidized bed**	
Characteristics	**Dry**	**As received**	**Dry**	**As received**
Dry flue gas losses (%)	11,63	11,63	11,63	11,63
Moisture in fuel (%)	0,00	5,90	0,00	5,90
Latent heat (%)	5,69	5,69	5,69	5,69
Unburned fuel (%)	3,50	3,50	0,25	0,25
Radiation and miscellaneous	2,03	2,03	2,03	2,03
Total combustion losses (%)	22,85	28,74	19,60	25,49

2.2.3 Revenue generated or cash inflows from different energy systems

In order to evaluate different investment options, it is also necessary to understand the cash flows generated by different systems. There are different types of cash flows considered in finance according to the types of analysis conducted. However, in investments made in some projects, different types of cash flows can be reduced to three types: operating cash flows, investment cash flows and financial cash flows (Short, et al., 1995). For example, revenue is usually operating type of cash flow from which operating and maintenance (O&M), interests and income taxes are deduced. For investment activities, cash flow could be for example, capital expenditures. For financial activity, the general type of cash flow is the repayment of debt principal and dividends. For this thesis, the most important cash flow considered is the revenue. More precisely, it is the end of the period cash flows.

Ultimately, revenue is the money received from goods and services sold. In this case, the revenue for different energy systems will be the money received from the electricity produced by these different systems. In earlier sections, how the electricity output of different systems can be derived has been discussed already. Revenue is derived by multiplying the unit price of the electricity output with the total units of electricity sold. More precisely,

$$\text{Revenue} = \text{quantity sold} * \text{per unit price} \qquad (7)$$

2.2.4 Other additional measures to be considered in economic evaluation

In addition to revenue and cost of different renewable energy systems, it is also necessary to consider some economic measures to make the analysis more precise. While considering investment decisions, the general measures that need to be considered are the inflation rates, discount rates, depreciation costs, present value and net present value (NPV). Each of these are elaborated in brief in this section.

Inflation rate: Future cash flows, including costs and revenue can only be expressed as current value. Current value of the cash can however change over time due to inflation. Current value of the cash therefore represents the cash that would have been required if the cost was paid in the base year, say (n). In that case, the value of cash in current year (m), if referred to as F_m can be converted to cash value in any year n, F_n by considering the effect of inflation (e) (Short, et al., 1995).

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

$$\mathrm{F}_n = \mathrm{F_m}/(1+\mathrm{e})^{\,\mathrm{m-n}} \tag{8}$$

Discounts rates: Money has a time value. Cash in possession today is more valuable than the cash received in the future because current cash can be invested to earn interest. Discount rates consider this time value of money and make it easier to compare current and the future value of the money. Generally discount rates can either be nominal or real, depending upon whether they include the inflation rate (in which case it is real) or not (in which case it is nominal) (Short, et al., 1995).

Discount rates and nominal rates can be converted to each other by the use of following equations:

$$(1+d_n) = (1+\mathrm{d}_r)(1+\mathrm{e}) \tag{9}$$

$$\mathrm{d}_n = [(1+\mathrm{d}_r)(1+\mathrm{e})] - 1 \tag{10}$$

$$\mathrm{d}_r = [(1+\mathrm{d}_n)/(1+\mathrm{e})] - 1 \tag{11}$$

Where,

$\mathrm{d_n}$ = nominal discount rate

$\mathrm{d_r}$ = real discount rate

e = inflation rate

Present value and net present value (NPV): As discussed, there is time value of money. As a result, future cash flows are somewhat different in value compared to their present value. When future cash flows (revenue or costs) are converted to current value it is known as the present value. The present value of future cash flows can be calculated by multiplying future cash flows with the present value discount factors (Short, et al., 1995). More precisely,

$$\mathrm{PV} = \mathrm{PVIF}_n * \mathrm{F_n} \tag{12}$$

$$\mathrm{PVIFn} = 1/(1 + \mathrm{d})^n \tag{13}$$

$$\mathrm{PV} = \mathrm{PVIF}_n * \mathrm{F}_n = \frac{1}{(1+\mathrm{d})^n} * \mathrm{F_n} \tag{14}$$

Where,
PV = present value
$\mathrm{PVIF_n}$ = Present value interest factor
$\mathrm{F_n}$ = Cash flow n years in the future
d = annual discount rate

When cash flows (both revenue and costs) are considered together, NPV analysis is used to evaluate alternate investment decisions. NPV is often defined as:

$$\mathrm{NPV} = \sum_{\mathrm{n=0}}^{\mathrm{N}} \frac{\mathrm{F}_n}{(1+\mathrm{d})^n} = \mathrm{F_0} + \frac{\mathrm{F_1}}{(1+\mathrm{d})^1} + \frac{\mathrm{F_1}}{(1+\mathrm{d})^{\,2}} \dots \dots . + \frac{\mathrm{F}_n}{(1+\mathrm{d})^n} \tag{15}$$

Where,
NPV = net present value
$\mathrm{F_n}$ = net cash flow in year n
N = analysis period
d = annual discount rate

Depreciation costs: Depreciation is the measure of decrease in the value of assets over time. Sometimes it is also used to refer to the cost of assets during periods in which it is used. The time period over which the depreciation rate is assigned is equal to the useful life of an asset (Short, et al., 1995). The rate of depreciation will then be assigned throughout the period of useful life of an asset. There are different types of accounting methods to assign depreciation costs such as the fixed percentage methods, straight line and the declining balance methods.

Depreciation costs can be variable according to the methods used and also according to the types of assets (Short, et al., 1995).

In this thesis, straight-line depreciation method is used, as it is the simplest and common method of calculating depreciation costs. Depreciation in this method is calculated by considering scrap value of an asset, which is the value of an asset when it is sold or disposed of at the end of its useful life. This scrap value will then be charged as depreciation over the useful life of the asset until the original value of the asset is equal to the scrap value (Short, et al., 1995). More precisely:

$$S = P(1 - i)^{Y} \tag{16}$$

Where:
S = salvage value
P = original price
i = nominal depreciation rate
Y = age in years

Therefore,

$$Annual\ \text{depreciation} = \frac{\text{Cost of fixed asset} - \text{Salvage value}}{\text{Useful life (years)}} \tag{17}$$

2.2.5 Means for evaluating alternative investment options

One of the most important criteria for evaluating the cost effectiveness of energy systems is the internal rate of return (IRR). In this thesis also, the main criteria of economic evaluation of different energy systems is internal return of return. In this section, the rationale behind internal rate of return as the measure of economic effectiveness, and how it can be used is further elaborated.

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 series of future flows (F) from an investment in different years (F_0, F_1, F_2…..F_n). It is the principle method through which investment decisions are compared. When the minimum acceptable rate of return or hurdle rate is known, this rate can be used to accept or reject investment decisions through IRR analysis. Hurdle rate also represents the IRR of the next best alternative. Although, IRR is usually used to compare the after tax return on financial instruments such as bonds, this method can also be easily used to compare the investment decisions made on renewable energy systems (Short, et al., 1995).

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

$$0 = \mathrm{NPV} = \sum_{\mathrm{n}=0}^{\mathrm{N}} \left[\mathrm{F}_{n} \div (1 + \mathrm{d})^{n}\right] \tag{18}$$

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 positive and negative cash flows when used as a discount rate

Modified internal rate of return

Modified Internal rate of return is used for economic analysis because of shortcomings of both IRR and NPV methods for economic evaluation. It has been shown that the results from both NPV and IRR analysis can be different because they have different assumptions about reinvestment. For example, in the NPV method it is assumed that reinvestment is made in the discount rate whereas in IRR analysis, it is assumed to be the reinvestment rate. However, in practice, the reinvestment rate can be flexible (Short, et al., 1995). More precisely:

$$\mathrm{MIRR} = \mathrm{r}, \text{where } \sum_{\mathrm{n}=0}^{\mathrm{N}} \frac{\mathrm{Fn}_{n}}{(1+\mathrm{d})^{n}} = \sum_{\mathrm{n}=0}^{\mathrm{N}} \frac{\mathrm{Fp}_{n}(1+\mathrm{d})^{\mathrm{N}-\mathrm{n}}}{(1+\mathrm{r})^{\mathrm{N}}} \tag{19}$$

Where,
MIRR = Modified Internal Rate of Return

Fp_n= net positive cash flows at time
d = rate of return of reinvestment
N = life of investment

Levelised cost of electricity (LCOE)

LCOE is the price of electricity generated from a source in order to break even over the lifetime of the project. Or more simply, LCOE is the price of electricity required in order to make revenues equal to costs, including a return on the capital invested in a project equal to the discount rate. DCF or discounted cash flow rate is commonly used to calculate the cost of different energy systems by discounting financial flows to a common base which considers the time value of the money. At the price of electricity above this rate, the return on capital would be higher whereas at lower than this rate, there will be lower return on capital and perhaps, loss (Short, et al., 1995).

Specially, when the investments in different types of technologies, which are of different scales of operations and operating time are compared, this method gives a much better method of evaluation. This is appropriate in this situation because we are comparing three different types of renewable energy systems. It is not recommended measure when the alternate investment decisions are mutually exclusive (Short, et al., 1995). Still more, this type of method includes not only the initial investment of the project but also the overall cost over the lifetime including operations and maintenance cost, cost of capital and fuel. As the following equations show, if LCOE is assigned to every unit of energy produced or saved by the production system over the period of analysis, it equals to the Total Life Cycle Cost (TLCC) when it is discounted back to the base year using appropriate discounting rate (IRENA, 2012).

LCOE can be calculated by using the following formula:

$$\text{LCOE}=\frac{\sum_{t=1}^{n}\left[\frac{I_t + M_t + F_t}{(1+r)^t}\right]}{\sum_{t=1}^{n}\frac{E_t}{(1+r)^t}} \tag{20}$$

Where,

LCOE = average lifetime levelised cost of electricity generation

l_t = investment expenditures in the year t

M_t = operations and maintenance expenditures in the year t

F_t = fuel expenditures in the year t

E_t = electricity generation in the year t

r = discount rate

n = life of the systems

2.3 Means for environmental evaluation

This thesis also identifies possible environmental effects of three renewable energy sources: bioenergy, solar energy and wind energy. One of the most important criteria to identify the environmental effects of each of these will be the amount of CO_2 emissions measured in kg CO_2 equivalent. The objectives of this thesis is also to assess which of the different energy production systems will perform the best in terms of CO_2 emissions. In order to do so, it is necessary to understand the concept of life cycle analysis.

2.3.1 Life cycle assessment (LCA)

LCA has been defined as the *"compilation and evaluation of the inputs, outputs and potential environmental impacts of a product system throughout its life cycle"* (ISO14040, 2006). In general with LCA, it is possible to find out environmental effects of different processes during a product's life cycle. The assessment can include environmental effects of all process in the supply chain of the product including sourcing resources, production, transportation, storage, disposal, reuse and recycle costs. In the context of this thesis, LCA can be used to find out the environmental effects of each of the renewable energy systems considering all of the different stages of energy production throughout the supply chain

(Singh, et al., 2013). According to ISO (2006), LCA methodology includes four main stages which includes: goal and scope definition, inventory analysis (LCI), imapct assessment (LCIA) and interpretation of results. Different steps in the LCA analysis are illustrated in figure 5.

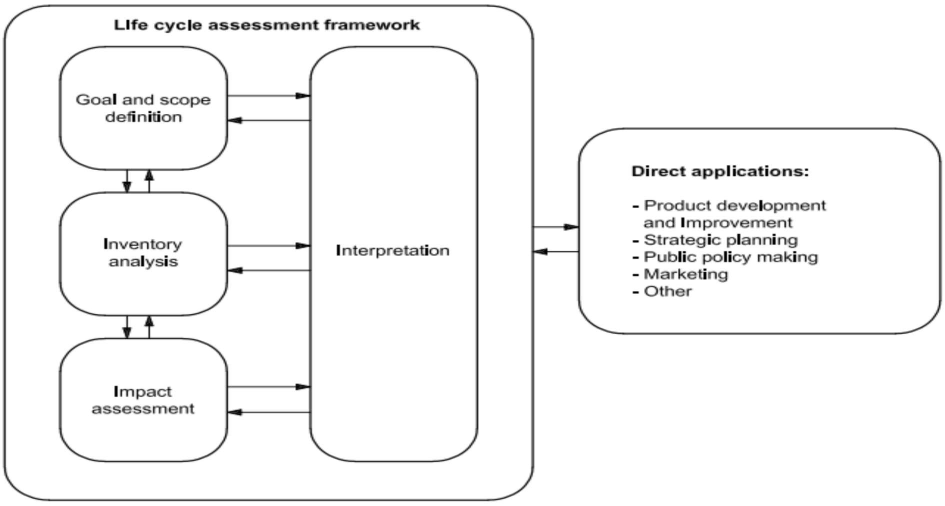

Figure 5. Stages of an LCA (ISO14040, 2006).

While considering the LCA of renewable energy systems, it is necessary to design the goal and scope of the process, choose appropriate functional unit, system boundaries, establish inventory and to allocate emission during production.

2.4 Seasonal variability

Seasonal variability takes into account the natural variability in electricity production of different energy systems, primarily, renewable energy systems due to the variation in seasonal availability of natural inputs. It is much more important for renewable energy systems as they are “intermittent” source of electricity as opposed to “dispatched” source of electricity such as CCGT, coal and nuclear technologies. In such cases, for example, the electricity production is dependent upon availability of natural inputs in different locations and the type of technology rather than the system level operators. (Joskow, 2011)

For example, for PV cells, the energy produced is very much dependent upon the intensity and availability of sunshine and the tilt angle of solar PV cells. As a result, the electricity generated in winter and cloudy weather is reduced whereas in theory, PV cells are capable of producing maximum output during summer and in equator region. Even during the diurnal cycle (dawn till dusk), the electricity produced by PV cells can peak during the middle of the day and decline gradually. One suggested way of reducing this variability in electricity production is to distribute PV production across these variations (IEA, 2005). Figure 6, for example shows the short-term fluctuations of electricity output according to solar irradiation level and the tilt of the solar panels according to different times of the year.

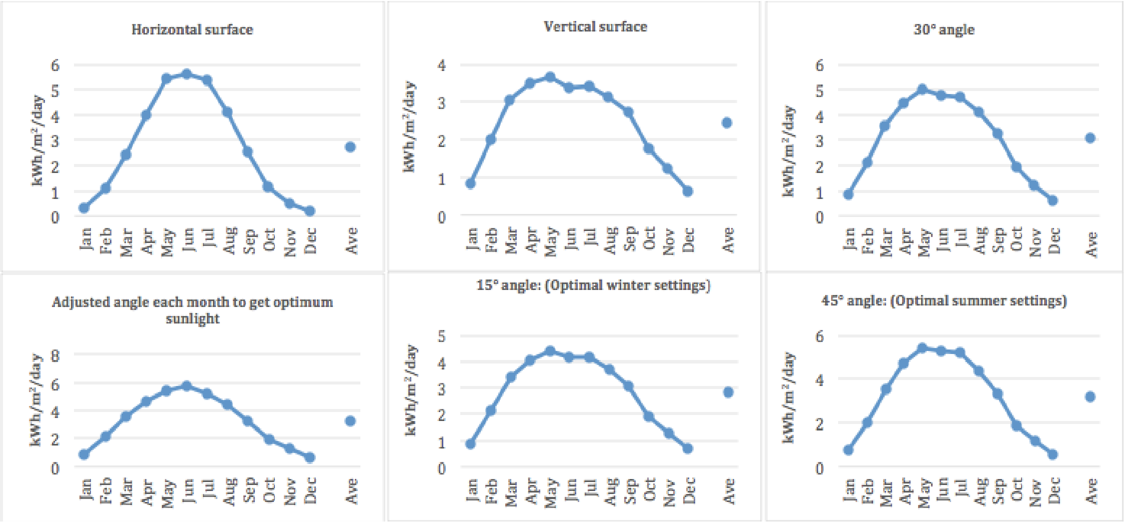

Figure 6. Variations of solar irradiation throughout the year in different angles.

Similarly, the energy produced by wind turbines is also subject to seasonal variability. The level of energy produced is directly related to the cube of wind speed. At lower levels of wind speeds, the electricity generated might be negligible whereas at intense level of wind speeds, the system may have to be shut down to reduce the risk of damage and so again affecting the energy output. The energy generated is optimal at the wind speed range of 2,5 to 25 m/s (Pelaflow Consulting, 2008).

As a result, depending upon the geographical region where the wind energy system is located, generally the level of energy produced will peak during winter or summer as well as during different times during the day. The level of energy produced is also dependent on the type of wind system, whether it is offshore or onshore, as there will be variability in the wind speed of sea breezes as compared to land breezes. However, it is thought that the short term fluctuations in energy production level out in large wind farms and are minute in comparison to the installed capacity of the system (IEA, 2005). For example, figure 7 shows the variation in energy output of energy systems according to different times of the year and also according to the tower height.

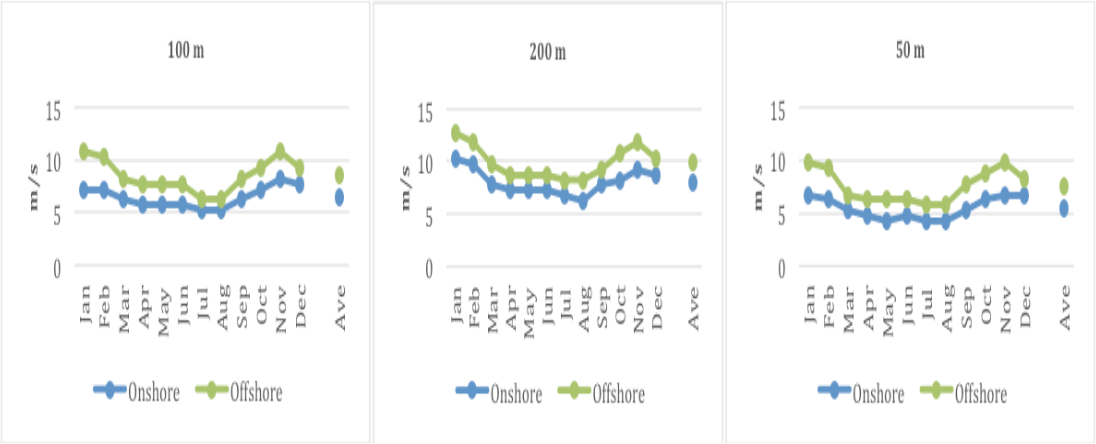

Figure 7.wind variations throughout the year in different heights.

Similarly, for biomass plants the level of energy output will ultimately depend upon the seasonal availability of feedstock. Since, the source of feedstock are generally planted biomass crops, the energy output of biomass system will depend upon the seasonal production of these biomass crops. Yearly as well seasonal variation in the supply of feedstock sources will be dependent upon the variability in production and the market demand for agricultural commodities. It has been suggested that this variability can be reduced by setting up long term contracts; securing the sources of supply; and through installation of storage warehouses to reduce the variability in supply. Since, these factors will depend upon case by case basis it is very difficult to generalize the seasonal variability of feedstock supply and in turn, the variability in energy produced from biomass plants (IEA, 2005).

3 CASE STUDY AND ANALYSIS

3.1 Method used to evaluate IRR for different energy systems

3.1.1 Photovoltaic systems

Previous researches (IEA-ETSAP & IRENA, 2013) have suggested baseline performance of different commercial PV technologies. The basic parameters are listed in table 9.

Table 9. Baseline parameters of different PV technologies.

	Efficiency (%)	**Area/kW (m^2/kW)**	**Life time (yrs.)**
c-Si			
Mono-c-Si	22	7	25
Multi-c-Si	20,3	8	25
TF			
a-Si	7,1	15	25
CdTe	11,2	10	25
CI(G)S	12,1	10	25

Based on table 9, the estimated lifetime in years of all different variants of different technologies is same, which is 25 years. In terms of area, on average, TF technologies have generally higher solar panel area. In terms of cell efficiency, however, c-Si technology perform inefficiently than TF variants of PV technologies (IEA-ETSAP & IRENA, 2013).

After outlining the basic parameters of these different technologies, it is necessary then to outline basic cost parameters because it will eventually be important for economic evaluation. The most recent data that are available from published data in 2014 (IRENA, 2012) indicate different costs by technologies. Total installed cost includes both the initial cost of capital as well as the installation cost before operation. Since total installation costs does not include the yearly operations and maintenance (O&M) costs, these estimations have been included separately. Since, O&M costs are variable costs they are expressed as unit price per kW/yr. In general, as a rule of thumb, it is expressed as 1% of the investment cost per year (IRENA and IEA-ETSAP, 2013).

Similarly, Levelised Cost of Electricity (LCOE) is the *"price of electricity required for a project where revenues would equal costs including making a return on the capital invested equal to the discount rate"* (IRENA, 2012). Regarding different PV technologies, it is expected to be 0,25-0,65 USD per kWh for crystalline Si and 0,20-0,52 for thin film (a-Si, CdTe and Ci(G)s as summarized in table 10. Since, it is important for us to discount the future cash flows from PV technologies in the net present value (NPV) it is also important to state the general inflation rate which indicates the fluctuating value of money. Although, generally the inflation rate in developed countries is slightly lower (0-4%) than developing countries (5-10%), the general global inflation rate is taken to be 4% for the sake of analysis. Since, the future cash flows of PV technologies is also dependent upon the capacity of the system over its lifetime, which tends to degrade at a fixed rate of 0,50% annually, it is also summarized in table 10.

Table 10. Cost parameters of different PV systems.

	Typical current international values and ranges (2012 USD,1 EUR =1.3 USD)			
Cost by technology	**Crystalline Si**	**Thin film**		
	c-Si	**a-Si**	**CdTe**	**Ci(G)S**
Total installed cost USD/kW	3070-5000	3600-5000	2640-4500	
LCOE (USD/kWh)	0,25-0,65	0,20-0,52		
O&M ($/kW-yr.)	Estimated at 1% of the investment cost per year			
Inflation rate :	4% on average			
Output degradation	0,50 %			

After discussing the system parameters (life time, area and efficiency) and the general cost parameters of different PV systems, now it is possible to calculate the power possible to be generated from different PV systems by using equation 1.

Here, from table 10, information related to total solar panel areas (A) according to different technologies are available to us. Solar panel yield is the efficiency of different systems, which was also provided in table 9. For example for TF a-Si technology it is 7,1% (IRENA, 2012). As discussed earlier in the theoretical section, the performance ratio (PR) or the coefficient for losses ranges from 0,5 to 0,9 and the default value is taken to be 0,75. It is one of the most important measures taken to evaluate the quality of PV systems as it indicates the level of performance of PV systems independent of the inclination and orientation of PV systems. For the calculations, in this case the default value 0,75 is taken.

In this case, the information related to A (area of the panel), r (solar panel yield), and PR (performance ratio) of different systems are given. However, the value of H (Annual average solar radiation on tilted panels) is obviously dependent upon the tilt or the angle of the solar panels, the orientation of solar panels (horizontal or vertical) and the geographical area or the location of the solar panels is important. Since this thesis is focused on the case of Finland, the annual average solar irradiation is provided in table 11.

To derive this information, first the location “Finland” was chosen as country from the published Solar Electricity Handbook (Boxwell, 2015). The data are also available in the online edition of the book (Boxwell, 2015).Then, in “town or city”, “Helsinki” was chosen. However, further analysis revealed that the monthly solar irradiation level according to different locations in Finland did not vary that much. To put it in other words, the choice of location was not that relevant as long as it was in Finland. Thereafter, each different combination of horizontal or vertical orientation, tilt of the angle was chosen to derive the solar irradiance level according to different months in different locations in Finland. The data so derived are summarized in table 11.

For the sake of convenience in calculating the annual energy output, the data for each different month were averaged to derive the annual solar irradiation level for different combinations as described earlier. This also gives a good estimate for “H” (solar irradiance) in the energy output calculation. For example, for horizontal surface, kWh/m^2/day for January is 0,32. For each month, these were taken from the Solar Electricity Handbook

(Boxwell, 2015). At the second last column, all of these data for each month were averaged, here to derive 2,73. Since, the data is given as kWh/m^2/day, the annual solar irradiation is derived my multiplying it with 365 here 996,75 kWh/m2/yr. The table shows annual solar irradiation level for different cases.

Table 11. Annual solar irradiation level for different cases in Finland.

kWh/m2/yr.	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec	Avg	Annual solar irradiation
horizontal	0,32	1,10	2,44	3,96	5,41	5,63	5,40	4,09	2,54	1,18	0,50	0,20	2,73	996,75
vertical	0,85	2,02	3,07	3,50	3,64	3,38	3,40	3,13	2,72	1,77	1,22	0,65	2,45	892,73
30° angle	0,85	2,13	3,54	4,48	4,99	4,76	4,72	4,12	3,27	1,94	1,23	0,63	3,05	1115,08
Angle is adjusted	0,88	2,15	3,54	4,7	5,42	5,74	5,19	4,49	3,27	1,94	1,26	0,66	3,27	1193,55
15° angle	0,88	2,13	3,39	4,06	4,40	4,15	4,14	3,7	3,07	1,90	1,26	0,66	2,81	1026,26
45° angle	0,77	2,02	3,51	4,68	5,42	5,27	5,19	4,39	3,32	1,88	1,13	0,56	3,18	1160,09

At this stage, now the data for calculating annual energy output for different PV systems according to different situations are available to us. Plugging different variables in the equation 1, it is now possible to derive the annual energy output of different PV systems in Finland. For example, for horizontal surface, we know from table 9 that the solar panel area for Mono-c-Si is 7, solar panel yield (r) is equal to 22%, annual solar irradiance level (H) in Finland is 996,75 kWh/m2/yr and performance ratio is 0,75.

Therefore annual energy output (E) is equal to: 7 * 0,22 * 997 * 0,75 =1151,535~1152, which can be seen in table 12. Similar procedure was used to calculate the energy output for different orientation, tilt and solar irradiance level in Finland.

Table 12. Calculated annual energy production illustrated with Mono-cSi PV systems.

	Annual Energy production (kWh/Yr.)				
Different angles	**Mono-c-Si**	**Multi-c-Si**	**a-Si**	**CdTe**	**CI(G)S**
horizontal surface	1152	1214	796	823	897
vertical surface	1031	1088	703	737	804
30° angle	1289	1359	879	921	1004
angle is adjusted to get optimum sunlight	1378	1453	939	984	1074
15° angle	1185	1250	808	846	923
45° angle	1340	1413	914	957	1044

Now that it is possible to derive electricity output of different PV systems depending upon different surface orientations, tilt and geographical area (in this case, Finland). With this information, it is now also possible to derive cash flows at different years by using equation 7.

Here, in our case, quantity sold is assumed to be the electrical output in each year. For instance, in the first year of operation, for Mono-cSi as discussed earlier it will be 1152 kWh/yr. However, we also assumed that for different systems, the output will keep on degrading by 0,50% on average for all kinds of PV systems Therefore, for the second year for instance, the electricity output will then degrade by 0,50%.

Now, when we consider per unit price in equation (7), per unit price of electricity here is considered to be levelised cost of electricity (LCOE). As discussed earlier LCOE is the price of electricity generated from a source in order to break even over the lifetime of the project. Or more simply, LCOE is the price of electricity required in order to make revenues equal to costs, including a return on the capital invested in a project equal to the discount rate. LCOE can be derived by using equation 20 and the annual revenue for different PV systems can be derived by using equation 7.

As discussed earlier and summarized in table 10, the LCOE or unit selling price of electrical output from different PV systems or Levelised cost of Electricity (LCOE) in USD/kWh is given in the range of 0,25-0,65 USD/kWh for crystalline and 0,20-0,52 for thin film. In other words, for example the lower price that can be sought from electricity for crystalline is 0,25 USD/kWh; the average as 0,45 USD/kWh [(L+H)/2] and the higher price to be 0,65 USD/kWh.

The output degrades but the real value of the money decrease due to inflation, while the nominal value increases by the inflation rate. Equation 8 indicates the current value of the cash in year (n) when the inflation rate is considered.

For example, in table 12, when we take the case of horizontal surface; in year 1, the electricity output is 1152 kWh/yr., in year 2 the output will degrade by 0,5% (Jordan & Kurtz, 2011),which is 1152-(1152 * 0,005); for third year the output of 2nd year minus (0,5% of output of 2nd year) and so on.

Similarly, if we take the case of lower unit price or LCOE which is 0,25 USD/kWh, in the first year if we take the inflation rate to be 4% (as summarized in table 9, cost parameters); the unit price in the first year will be 0,25+ (0,25 * 0,04); in the second year it will be the price of first year + (0,25 * price of first year and so on.

These then will allow us to calculate the total revenue for each of the case in different years, considering a) the surface type b) tilted angle c) different solar irradiation d) degrading output and e) rate of inflation leading to changes in unit price or LCOE. For example, in the case of Mono-cSi PV systems for the horizontal surface type, the revenue is calculated using equation 7 as explained below.

For year 1: [1152 * [0,25 + (0,25 * 0,04)] =299,52
For year 2: [1152-(1152* 0,005] *[0,26 + (0,26 * 0,04)] = 309,94 and so on considering the rise in unit price due to inflation and degradation in power output due to power loss. Table 13, shows the revenue for each different years, from year 1 to year 5, for different surface types and tilted angle situations for Mono-cSi PV systems. The revenue calculations for different price ranges (LCOE) for other PV systems are reproduced in appendix 1.

Table 13. Annual revenue for Mono-cSi in different years with lower, average and high LCOE illustrated.

	Lower					**Average**					**Higher**				
Year	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
horizontal surface	299,52	309,94	320,73	331,89	343,44	539,14	557,90	577,31	597,40	618,19	778,75	805,85	833,90	862,92	892,95
Vertical surface	268,06	277,39	287,04	297,03	307,37	482,51	499,30	516,67	534,66	553,26	696,96	721,21	746,31	772,28	799,16
30° angle	335,14	346,80	358,87	371,36	384,28	603,25	624,25	645,97	668,45	691,71	871,36	901,69	933,07	965,54	999,14
angle is adjusted to get optimum sunlight	358,28	370,75	383,65	397,00	410,82	644,90	667,35	690,57	714,60	739,47	931,53	963,95	997,49	1032,20	1068,12
15° angle	308,10	318,82	329,92	341,40	353,28	554,58	573,88	593,85	614,52	635,90	801,06	828,94	857,78	887,63	918,52
45° angle	348,40	360,52	373,07	386,05	399,49	627,12	648,94	671,53	694,90	719,08	905,84	937,36	969,98	1003,74	1038,67

Equation 18 is used in order to calculate IRR for other variants of PV technology.

In the previous discussions, how the revenue from different PV systems or the cash flows at different years F_n were discussed for Mono cSi PV system. These data are then already calculated.

Salvage value is calculated using equation 16 and the depreciation cost is derived from equation 17. In this thesis, straight-line depreciation method is used, as it is the simplest and common method of calculating depreciation costs. Depreciation in this method is calculated by considering scrap value of an asset, which is the value of an asset when it is sold or disposed of at the end of its useful life.

The total installed cost of different PV systems is already given (see table 10). Once again the data provided is a range of values. For example, for c-Si PV systems, the range could be from 3070 to 5000 USD/kW. Similarly, it is assumed that O&M costs ($/KW-yr.) is 1% of the total installed cost in a year as in some previous researches (IRENA, 2012). Once again due to inflation, the nominal value money increases while the real value decreases. Here, it is assumed that the average global inflation rate per year is 4%. This will lead to increase of O&M cost price by the same margin.

The calculation of revenue of different PV systems according to surface, tilt angles and solar irradiance level was explained earlier. Salvage value of capital invested, is derived by using equation 16.

This equation has been explained earlier. In this case, for example if the initial price is assumed to be 3070 (P) and the life in years of that investment is 25 years (Y), and the nominal depreciation rate (i) is 4% (100%/ 25 yrs.), then the salvage value is equal to 1106,42. This amount will lead to depreciation cost being 151,04 in the first year, for example.

Similarly, in order to calculate IRR, it is also necessary to have F_n, which basically indicates net cash flow. In order to calculate the net cash flow it is necessary to deduct taxes (such as federal tax) or subsidies. However, in this thesis, since tax and subsidies are so variable across different countries it will only complicate the situation in comparing the IRR of different renewable technologies in a more general manner. Still, before tax cash flow can also provide a baseline for comparing IRR of different renewable technologies. Before tax flow in this study is derived by deducting investment (in the first year), O&M costs and depreciation each year from the gross cash flow or revenue. In this study, the number of years considered is also only 5 and then the IRR is calculated by using the formula. In this case, excel IRR function was used to find out the discount rate for which the NPV is equal to 0 using equation 18.

Table14. Illustration of IRR calculation for Crystalline Si (Mono-c-SI).

Crystalline Si (Mono-c-SI)															
horizontal															
	Lower range					Average range					Higher range				
Year	Investment	O&M	Revenue	Depreciation	Before Tax flow	Investment	O&M	Revenue	Depreciation	Before Tax Flow	Investment	O&M	Revenue	Depreciation	Before tax-cash flow
0	3070	0,0	0,00	0	-3070	4035	0,0	0,00	0	-4035	5000	0,0	0,00	0	-5000
1	0	31,2	299,52	151,04	117,28	0	42,0	539,14	198,52	298,65	0	52,0	778,75	246	480,75
2	0	32,4	309,94	145	132,50	0	43,6	557,90	190,58	323,68	0	54,1	805,85	236,16	515,61
3	0	33,7	320,73	138,96	148,02	0	45,4	577,31	182,64	349,28	0	56,2	833,90	226,32	551,33
4	0	35,1	331,89	132,92	163,87	0	47,2	597,40	174,7	375,50	0	58,5	862,92	216,48	587,94
5	0	36,5	343,44	126,88	180,06	0	49,1	618,19	166,76	402,34	0	60,8	892,95	206,64	625,47
				IRR	**-33%**				**IRR**	**-22%**				**IRR**	**-16%**
				MIRR	**-23%**				**MIRR**	**-13%**				**MIRR**	**-8%**

IRR for other variant of PV systems is provided in appendix 1. Here for instance, for Crystalline Si (Mono-c-SI) with horizontal configuration, in the lower range of LCOE, the IRR is (-33%). In addition to IRR, considering the financial rate of 10% and reinvestment rate of 8%, MIRR was also calculated, which amounts to (-23%). Although, the financial and investment rate were chosen arbitrarily, these are the normally used rates in conventional economic evaluation. The MIRR for other variants of PV systems is also provided in the same tables in appendix 1.

3.1.2 Wind power

The purpose of this section is to implement the theoretical knowledge in economic evaluation (via IRR method) of wind energy systems. In order to do so, the first step would be to evaluate the power generated by wind energy systems in different circumstances, especially focused in the Finnish case.

In order to conduct economic evaluation of wind power systems, it is first necessary to identify known cost parameters. On average the total installed cost for wind power systems generating 1 kW of electricity is given as 1280-2290 USD for onshore type and 2700-5070 USD for offshore type globally (IRENA, 2012). The LCOE for onshore wind energy systems is given as ranging from 0,06- 0,12 USD/kWh, and for the offshore wind energy systems is given as ranging from 0,10-0,20 USD/kWh (IRENA, 2012). The Operations and Maintenance (O&M) costs of wind power energy is generally estimated as being 2% of the investment cost per year in $/kW per year. Most important of these baseline cost parameters are summarized in table 15 (IRENA, 2012).

Table 15. Baseline cost parameters for wind energy systems.

Typical current international values and ranges (2012 USD,1 EUR =1.3 USD)		
Cost by technology	**Onshore**	**offshore**
Total installed cost USD/kW	1280-2290	2700-5070
LCOE (USD/kWh)	0,06- 0,12	0,10-0,20
O&M ($/kW-yr.)	Estimated at 2% of the investment cost per year	
Inflation rate :	4% on average	
Output degrades	1,6%	
Density (kg/m3) ρ	1,225	
Swept Area (m2) A	5	
Max Power Coefficient (Cp max)	0,59	

Now, in our case, since the capacity of the wind energy system taken into consideration is 1 kW, and as explained earlier in table 6, which shows the relationship between intercepted area, rotor diameter and the power output; it has been suggested as “rule of thumb” that for a nominal power rating of 1 kW (which is our focus) the swept area required is generally 5 m^2. This is what will be taken as value in our case as well.

For the efficiency of the wind power system, it is well established that there is an upper limit for the efficiency of wind turbine (Benz limit), which is near to 59%. It has also been suggested that for large wind turbines the coefficients can vary between 40-50% and for smaller wind turbine it is considered to be from 20-30%. In our situation, it is difficult to exactly pinpoint efficiency of turbine which is not already operational, therefore all ranges of efficiency from 20 to 50% has been considered for calculation (Pelaflow Consulting, 2008).

The most variable value in this calculation is the wind speed. Since, our case here is based on Finland, data was collected from finish wind atlas, which states the monthly wind speed (Finish Wind Atlas, 2015). Since, wind speeds are variable not only seasonally but also according to different heights of the tower and whether the wind power system is onshore or offshore, these values should also be considered. Earlier, it has already been discussed that wind speeds tend to be higher in higher towers and onshore wind systems face higher wind speeds than offshore wind systems. The last column of the table shows the average annual value of wind speed in the Finnish case, which accounts for seasonal variation as well. The height of the towers considered are 50, 100 and 200 meters (Finish Wind Atlas, 2015). In the calculation, whether the wind system is onshore or offshore is also considered. Table 16 below summarizes wind speed in different situations in the Finnish case.

Table 16. Measure of seasonal wind speed and annual average in Finland under different circumstances.

Measured in m/s in 50 m:												
Month	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Ave**
Onshore	6,75	6,25	5,25	4,75	4,25	4,75	4,25	4,25	5,25	6,25	6,75	6,75	5,5
Offshore	9,75	9,25	6,75	6,25	6,25	6,25	5,75	5,75	7,75	8,75	9,75	8,25	7,5
Measured in m/s in 100 m:													
Month	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Ave**
Onshore	7,25	7,25	6,25	5,75	5,75	5,75	5,25	5,25	6,25	7,25	8,25	7,75	6,5
Offshore	10,75	10,25	8,25	7,75	7,75	7,75	6,25	6,25	8,25	9,25	10,75	9,25	8,5
Measured in m/s in 200 m:													
Month	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Ave**
Onshore	10,25	9,75	7,75	7,25	7,25	7,25	6,75	6,25	7,75	8,25	9,25	8,75	8,04
Offshore	12,75	11,75	9,75	8,75	8,75	8,75	8,25	8,25	9,25	10,75	11,75	10,25	9,92

The second step in economic evaluation would be to calculate the electricity output. Considering all of these different criteria, especially different annual average wind speed, now it is possible to calculate the electricity output of different wind energy systems under different efficiency parameters, which is shown in table 17. For example, for the tower height of 50 m; for an onshore type of wind power system at 20% efficiency level, the electricity output is 872,55 kWh/year. Equation 4 as discussed earlier has been used to derive the electricity output of different types of wind energy systems.

Table 17. Electricity output of wind energy systems under different circumstances (kWh/year).

Height	Type	20% Efficiency	30% efficiency	40% Efficiency	50% efficiency
50 m	Onshore	872,55	1308,83	1745,10	2181,38
	Offshore	2301,51	3452,26	4603,01	5753,77
100 m	Onshore	1473,50	2210,25	2947,00	3683,75
	Offshore	3343,78	5015,67	6687,57	8359,46
200 m	Onshore	2790,28	4185,43	5580,57	6975,71
	Offshore	5232,48	7848,72	10464,95	8720,80

At this stage, electricity outputs of different wind energy systems depending upon different heights, type and efficiency parameters have been calculated. After this it should be possible to derive cash flows at different years. In order to do so, equation 7 has been used.

Here, the quantity sold is the amount of electricity produced. For the unit price of electricity, LCOE is used as proxy. As discussed earlier LCOE is the price of electricity generated from a source in order to break even over the lifetime of the project. Or more simply, LCOE is the price of electricity required in order to make revenues equal to costs, including a return on the capital invested in a project equal to the discount rate. For wind power systems, this information is already available to us. The LCOE for onshore wind energy systems is given as ranging from 0,06-0,12 USD/kWh, and for the offshore wind energy systems is given as ranging from 0,10-0,20 USD/kWh (IRENA, 2012). To account for the variation, the average value is also considered. For example, the lower price that can be sought from electricity is 0,06 USD/kWh; the average as 0,09 USD/kWh [(L+H)/2] and the higher price to be 0,12 USD/kWh.

Putting these values in equation 12, for example, table 18, the revenue for 5 years for onshore wind energy system for tower height of 200 m is illustrated. For example, in the first year, we know that the lower onshore installed cost is 1280 USD (from table 15). In the second year, the O&M cost is 2% of installed cost, which is 25,6. However, since the global average inflation rate is assumed to be 4%, the real value of O&M costs will be 25,6 + (4% of 25,6) = 26,62. In the second year, once again with the similar process the O&M cost will be 26,62 + (4% of 26,62) which is equal to 27,7 and so on.

Equation 7 has been used to derive revenue for different years. For the first year, as illustrated in table 18, revenue will be equal to the electricity output multiplied by the LCOE of that wind energy type. As illustrated in table 18, for onshore type with 200 m tower height and turbine operating at 50% efficiency, the electricity output in the first year is 6975,71. The lower range of LCOE for this onshore type as illustrated in table 15 was 0,06. However, the real monetary value of this base price here in the first year will be (0,06 + 4% of 0,06), which is equal to 0,062. Multiplying these together we get the revenue for first year as (6975,71 * 0,062) which is 432,5.

For the second year, the output degrades but the real value of the money decrease due to inflation, while the nominal value increases by the inflation rate. In the baseline cost parameters as illustrated in table 15, output degrades by 0,016 or 1,6% (Earthtechling, 2012) Therefore the energy output in the second year for onshore type, 200 m height and operating at 50% efficiency, will be (output in year 1 minus 1,6% of output) or [6975,71- (6975,71 * 0,016)] which is equal to 6864,09 For the third year output will be [6864,09 - (6864,09*0,016)] which is equal to 6754,27 and so on.

Similarly, if we take the case of lower unit price or LCOE which is 0,06 USD/kWh, in the first year if we take the inflation rate to be 4% (as summarized in table 15, cost parameters); the unit price in the first year will be 0,06+ (0,06 *0,04); in the second year it will be the price of first year + (0,15 * price of first year and so on.

These then will let us calculate the total revenue for each of the case in different years by using equation 7.

For year 1: [6975,71 * [0,06 + (0,06 * 0,04)] = 432,5
For year 2: [6975,71- (6975,71 * 0,016] *[0,062 + (0,062 *0,04)] and so on considering the rise in unit price due to inflation and degradation in power output due to power loss. Table 15 shows the revenue for each different years, from year 1 to year 5. The revenue

calculations for different price ranges (LCOE) for other wind systems are reproduced in appendix (2).

The next step would be to calculate IRR of wind energy systems. In this study the number of years considered is only 5. The IRR was calculated by using equation 18 where the NPV is assumed to be 0. Excel IRR function was used to calculate the discount rate when this condition holds true.

In order to calculate IRR, it is also necessary to have F_n, which basically indicates net cash flow. In order to calculate the net cash flow it is necessary to deduct taxes (such as federal tax) or subsidies. However, in this thesis, since tax and subsidies are so variable across different countries it will only complicate the situation in comparing the IRR of different renewable technologies in a more general manner. Still before tax cash flow can also provide a baseline for comparing IRR of different renewable technologies.

Before tax flow in this study is derived by deducting investment (in the first year), O&M costs and depreciation each year from the gross cash flow or revenue. In this thesis, straight-line depreciation method is used, as it is the simplest and common method of calculating depreciation costs. Depreciation in this method is calculated by considering scrap value of an asset which is the value of an asset when it is sold or disposed of at the end of its useful life (Matrixlab-examples.com, 2015). Depreciation value is calculated by using equation 16.

In this case, when the lower installed cost for onshore type is assumed to be 1280 (P) and the life in years of that investment is 25 years (Y), and the nominal depreciation rate (i) is 4% (100%/ 25 yrs.), then the salvage value is equal to 461,31. This amount will lead to depreciation cost being 62,98 in the first year; 60,46 for the second year and so on, for the other years.

Table 18. Illustration of IRR and MIRR calculation for Onshore: Measured in m/s in 200 m.

Onshore-Measured in 200 m															
50% Efficiency															
	Lower range					**Average range**					**Higher range**				
Year	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before Tax flow**	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before Tax Flow**	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before tax-cash flow**
0	1280	0,0	0,00	0	-1280	1785	0,0	0,00	0	-1785	2290	0,0	0,00	0	-2290
1	0	26,6	432,49	62,98	342,89	0	37,0	655,72	87,82	530,87	0	47,0	871,96	112,67	711,66
2	0	27,7	425,57	60,46	337,43	0	38,5	645,23	84,31	522,41	0	49,5	858,01	108,16	700,32
3	0	28,8	418,76	57,94	332,03	0	40,0	634,90	80,8	514,06	0	51,5	844,28	103,65	689,12
4	0	29,9	412,06	55,42	326,70	0	41,6	624,74	77,28	505,82	0	53,6	830,78	99,15	678,05
5	0	31,1	405,47	52,9	321,43	0	43,3	614,75	73,77	497,66	0	55,7	817,48	94,64	667,12
				IRR	**9%**				**IRR**	**14%**				**IRR**	**16%**
				MIRR	**9%**				**MIRR**	**11%**				**MIRR**	**12%**

The process of how revenue is derived for each year for wind power systems has been already described. With this it is now possible to derive IRR for each year for different variant of wind power systems. IRR is calculated by using F_n which is the cash flow of each year and is derived by deducting O&M costs and depreciation costs from revenue of each year which will lead to cash flow before tax deduction. For example, in table 18, it can be seen that for the wind power system with 200 m height and of the onshore type the IRR is 9% when calculating with the lower limit of LCOE operating at 50% efficiency. IRR for other variant of wind power systems is provided in appendix 2.

In addition to IRR, considering the financial rate of 10% and reinvestment rate of 8%, MIRR was also calculated, which amounts to 9 %. Although, the financial and investment rate were chosen arbitrarily, these were the normally used rates in conventional economic evaluation (Short, et al., 1995). The MIRR for other variants of wind energy plants is also provided in the same tables in appendix 2.

3.1.3 Biomass power

Different cost parameters for biomass power systems are summarized in table 19.The most common biomass technologies for electricity generations are boilers and BFB/CFB. These two types are considered in this thesis. For the stoker boilers the total installed cost on average ranges in between 1880-4260 USD/kW and for BFB/CFB technology, in between 1880-4260 USD/kW. Since, this is the only energy systems in which fuel source as a form of feedstock is used to generate electricity, it is also necessary to add the cost of fuel source while evaluating total costs of the biomass energy systems in addition to the total installed cost.

In addition to the installed cost and fuel cost, there are also O&M costs, which is estimated to be 4% of the total installed cost annually. However, in comparison to wind and solar energy systems, the cost of operation of bioenergy plants are divided into variable and fixed O&M costs as discussed earlier. In our case, it is estimated that the fixed cost ranges between 2-7% of the capital cost in a year, and the variable cost ranges from 3,8-4,7 USD/MWh (IRENA, 2012). For comparison, in this thesis the fixed cost is assumed to be 4% of the capital cost and since our plant capacity is assumed to be 1kW, the variable cost is estimated to be 0,005 per kWh (or 5 USD/MWh).

In the case of Finland, the most commonly used feedstock are wood chips and bulk pellets and they cost on average 0,0212 and 0,0374 USD converted from euros respectively (PÖYRY, 2015). The price is for the amount of feedstock that is estimated to be used to generate 1kW of electricity, which is the baseline for comparison. Here again, although the prices of feedstock can vary under different circumstances, the most recent price was taken for the comparison purpose.

Table 19. Cost parameters of biomass energy systems.

Typical current international values and ranges (2012 USD,1 EUR =1,13 USD)		
Cost by technology	**Stoker boilers**	**BFB/CFB**
Total installed cost USD/kW	1880-4260	2170-4500
LCOE (USD/kWh)	0,06-0,21	0,07-0,21
Fixed O&M ($/kW-yr.)	Estimated at 4% of the investment cost per year	
Inflation rate :	4% on average	
Output degrades	0,40 %	
Fuels		
Wood chips /kWh	0,021€ (0,025 $)	
Bulk pellets /kWh	0,037€ (0,042$)	

As already discussed in the theoretical section, biomass energy output (E) is the function of yearly operating hours (h_a) and the capacity of plant in generating electricity output (P_{max}). Plant electric capacity in turn is calculated by taking into consideration both electrical efficiency and annual fuel usage. Equation 5 and equation 6 are used to derive energy output from biomass systems.

Since we are concerned with the biomass plant that has plant electric capacity of 1 kW for comparison purpose, the plant electric capacity here is taken to be 1 kW (P_{max}). Therefore, by using equation ($E_a = h_a * P_{max}$), the electricity generated will be dependent upon the yearly operating hours of the biomass plant. Since, here the plant has the capacity of 1 kW, the efficiency and the fuel usage will be determined accordingly, and the electric output will eventually be determined only by the number of operating hours.

For example, table 20, shows the estimated electricity generated dependent upon the number of operating hours. According to the table, for instance, if the plant is operating for 4500 hours in a year, a plant with 1kW capacity will generate 4500 kWh electricity in a year. Since, the operating hours for biomass plant also can differ in case by case basis, here in this case, operating hours of biomass plant is assumed to be 7800 hours which is less than the full potential hours allowing remaining time for ash removal, scheduled maintenance and other requirements. In addition, it is also important to note that the output degrades by 0,4% annually.

Table 20. Electricity output dependent solely on operating hours.

Operating hours	**Electricity (kWh/year)**
4500	4500
7000	7000
7800	7800
8000	8000

Based on this data, now it is possible to calculate the cash flow for the first five years of operation to calculate the IRR of bio mass plant. Table 20 shows the cash flow for stoker boiler with annual operating hours of 7800 taking into account all of the factors discussed

Table 21. Illustration of IRR calculation for Stoker boilers.

Stoker boilers /wood chips :7800 operating hours																					
	Lower range							Average range							Higher range						
Year	Investment	Fuel cost	Fixed O&M	Variable O&M	Revenue	Depreciation	Before Tax-cash-flow	Investment	Fuel cost	Fixed O&M	Variable O&M	Revenue	Depreciation	Before Tax Flow	Investment	Fuel cost	Fixed O&M	Variable O&M	Revenue	Depreciation	Before tax-cash flow
0	1880	0	0	0	0,00	0	-1880	3070	0	0	0	0,00	0	-3070	4260	0	0	0,00	0	0	-4260
1	0	194,28	78,21	40,56	486,72	92,5	81,17	0	194,28	127,71	40,56	1095,12	151,04	581,53	0	194,28	177,22	40,56	1703,52	209,59	1081,87
2	0	193,51	81,34	40,40	504,16	88,8	100,12	0	193,51	132,82	40,40	1134,37	145,00	622,65	0	193,51	184,30	40,40	1764,57	201,21	1145,16
3	0	192,73	84,59	40,23	522,23	85,1	119,58	0	192,73	138,13	40,23	1175,02	138,96	664,97	0	192,73	191,68	40,23	1827,82	192,83	1210,34
4	0	191,96	87,97	40,07	540,95	81,4	139,54	0	191,96	143,66	40,07	1217,14	132,92	708,53	0	191,96	199,34	40,07	1893,33	184,44	1277,51
5	0	191,19	91,49	39,91	560,34	77,7	160,04	0	191,19	149,40	39,91	1260,76	126,88	753,37	0	191,19	207,32	39,91	1961,18	176,06	1346,70
						IRR	**-27%**						**IRR**	**3%**						**IRR**	**13 %**
						MIRR	**-18%**						**MIRR**	**5%**						**MIRR**	**11%**

In table 21, the case for stoker boilers using wood chips as feedstock material is used as an illustration of calculation of IRR. Here for example, as explained in table 19, the installed cost is assumed to be 1880 USD/kW. In order to produce 7800 kWh of electricity i.e. by operating at 7800 hours the cost associated with wood chips as feedstock at the rate of 0,0212 will amount to 165,36 Euros or with (1 €=1,13 USD), it amounts to 187,63 USD. However, taking into consideration the real value of money it will be (187,63 + 4% of 187,63) which is equal to 194,28. In year 2, considering the output degradation of 0, 4% the output in the second year will be 7800 minus 0,4% of 7800 which is 7768,8 kWh. Accordingly, the price for the fuel will also be 7768,8 * (unit price + 4% of unit price due to inflation) which will be 193,51 and so on for the next 5 years.

Now the fixed O&M cost of biomass plant is assumed to be 4% of the total installed cost. Here the initial investment cost was assumed to be 1880, therefore the fixed O&M cost in the first year is (4% of 1880) which is equal to 75,2 USD and considering the inflation rate of 4%, the real value of the money is 78,21. Now in year 2, the additional inflation rate of 4% will make the value of the money to be 81,34 and so on.

Similarly, the variable cost is assumed to be 0,005 USD/kWh; and since here the assumed output of biomass plant is 7800 kWh/yr, the variable cost will be 39. Taking into considering the inflation rate of 4% the real monetary value will be 39+(0,04 * 39) which is equal to 40,56 USD. However in year 2, the output will degrade by 0,40 %, therefore even with 7800 operating hours the output now will be (7800 kWh/yr minus 0,40% of 7800 kWh/yr.), 7768,8 kWh, for the third year (7768,8 kWh/yr minus 0,40% of 7768,8 kWh/yr), it will be 7737,73 kWh/yr and so on. Correspondingly, for year 2, with 0,005 USD/kWh, the nominal variable cost will be 38,844 and the real value with 4% inflation rate will be (38,844 + 4% of 38,844) which is 40,40; and for year 3 it will be 40,20 and so on for the next 5 years.

The sixth column in table 21 shows the annual revenue generated from the stoker boiler with assumed 7800 operating hours and wood chips as feedstock material. The revenue is derived from the equation 21.

For the first year, as illustrated in table 21, revenue will be equal to the electricity output multiplied by the LCOE of electricity generated by biomass plant. As illustrated in table 21, for stoker boilers, the electricity output in the first year is 7800 kWh. The lower range of LCOE for this biomass table 19 was 0,06 USD. Multiplying these together we get the nominal revenue for first year as (7800 * 0,06) which is 468. If we consider 4% inflation rate the real value will be 486,72.

For the second year, in the baseline cost parameters as illustrated in table 19, the output degradation rate is taken to be 0,4%. Therefore the energy output in the second year will be (output in year 1 minus 0,4 % of output in year 1) or [7800- (7800 * 0,004)] which is equal to 7768,8. For the third year output will be [7768,8- (7768,8 * 0,004)] which is equal to 7737,73 and so on. These then will let us calculate the total revenue for each of the case in different years, by using equation 21.

For year 1: [7800 * [0,06 + (0,06 * 0,04)] = 486,72
For year 2: [7800-(7800 * 0,004] * [0,0624 + (0,0624 * 0,04)] = 504,16
For year 3: [7737,73 * [0,065 + (0,065 * 0,04)] = 522,23

and so on considering the rise in unit price due to inflation and degradation in power output due to power loss. Table 21 shows the revenue for each different years, from year 1 to year 5. The revenue calculations for other type of biomass power systems are reproduced in appendix 3.

Before tax flow in this study is derived by deducting investment (in the first year), O&M costs (both fixed and variable costs) and depreciation each year from the gross cash flow or revenue. In this thesis, straight-line depreciation method is used, as it is the simplest and common method of calculating depreciation costs. Depreciation in this method is calculated by considering scrap value of an asset, which is the value of an asset when it is sold or disposed of at the end of its useful life. Depreciation value is calculated using equation 16.

In this case, the lower installed cost for onshore type is assumed to be 1880 (P) and the life in years of that investment is 25 years (Y), and the nominal depreciation rate (i) is 4% (100%/ 25 yrs), then the salvage value is equal to 677,55. This amount will lead to depreciation cost being 92,5 in the first year, 88,8 for the second year and so on, which is illustrated in table 21.

The process of how revenue is derived for each year for stoker biomass plant has been already described. With this now it is possible to derive IRR for each year for different variant of biomass systems. IRR is calculated by using F_n which is the cash flow of each year which is derived by deducting O&M costs (both fixed and variable) and depreciation costs from revenue of each year which will lead to cash flow before tax deduction. For example, in table 21, it can be seen that for stoker boilers using wood chips and operating hours of 7800; before tax cash flow for first year will be revenue-(fuel costs + fixed costs + variable costs + depreciation) which is 81,17. For the second year F_n will then be 100,12 and so on. Considering all of these before tax flow, now it is possible to calculate the IRR of this particular type of biomass plant which is (-27 %) by using equation 18.

IRR for other variant of biomass power plants is provided in appendix 3.In addition to IRR, considering the financial rate of 10% and reinvestment rate of 8%, MIRR was also calculated, which amounts to (-18%). Although, the financial and investment rate were chosen arbitrarily, these were the normally used rates in conventional economic evaluation (Short, et al., 1995). The MIRR for other variants of biomass power plants is also provided in the same tables in appendix 3.

3.2 Life cycle assessment (LCA)

Life cycle assessment (LCA) is one of the well-established method of evaluating environmental impacts of production and consumption processes. One of the tools used for LCA analysis is GaBi software. In this thesis, in order to evaluate the environmental impact of different renewable energy systems GaBi 6.0 software was used. In this section, LCA analysis of three different renewable sources i.e. emissions from PV systems, wind power systems and biomass systems by using GaBi 6.0 software is elaborated.

In the analysis, different known transport processes including ocean and inland ship as well as land and pipeline transport of commodities were taken into account. Transport processes, for example, deals with transportation of raw materials and other components during the construction and operation of different renewable systems. The analysis also includes emissions from different life cycle stages of energy carriers of different renewable systems in specific supply situations (GaBi databases , 2006).

One of the major criteria for determining the emission level or the impact of particular substance to climate is Global Warming Potential (GWP) as defined by Intergovernmental Panel on Climate Change (IPCC) (IPCC, 2015). The GWP is the ratio of the contribution to the heat radiation absorption from the rapid release of 1 kg of greenhouse gas compare to an equal emission of CO_2 over time. Three GWP methods have been developed, each for a different time span (20, 100 and 500 y). In this thesis, the time span considered is 100 years. Global warming (GWP100) is linked to the effects of greenhouse gas emissions on human health and the environment (PE International, 2001).

Greenhouse gases considered in GWP can be for instance CO_2, CH_4 and N_2O. In this thesis, the assessment method chosen is CML 2001. According to the CML method, methane has a characterization factor of 25, carbon dioxide has 1 and nitrous oxide has 298. This means that CML has determined that methane contributes 25 times more than carbon dioxide to the global warming potential when a time frame of a hundred years is taken into account (PE International, 2001). In the end, the output of GaBi software in terms of GWP in CO_2 equivalent was used to compare the environmental effects of different renewable systems.

3.2.1 Systems description in GaBi

For the photovoltaic model, GaBi simulates mix of different photovoltaic technologies. That is, GaBi takes into account different types of PV systems as discussed earlier in economic evaluation and then shows the combined result. Therefore, this estimation was taken as proxy for all types of PV systems. GaBi models all life cycle stages including manufacturing and operational life cycle but does not include the end of life stage because there is no common technology to recycle it. For different models, the life cycle considered was 20 years. All data used in the calculation of the LCI results refer to net calorific (GaBi Database, 2006).

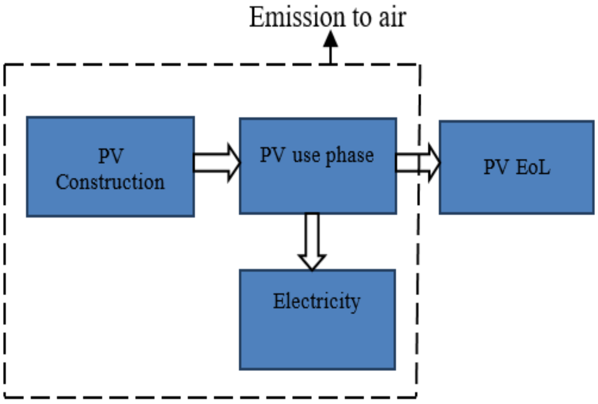

Figure 8. System boundaries of photovoltaic (PV).

For the wind energy system, GaBi takes into consideration electricity generation by both onshore and offshore wind system both individually and mixed with different combinations of national and regional conditions. First a representative LCA model is set up which is then simulated as being operational in different national conditions generating different operational data during its operation (GaBi Database, 2006).

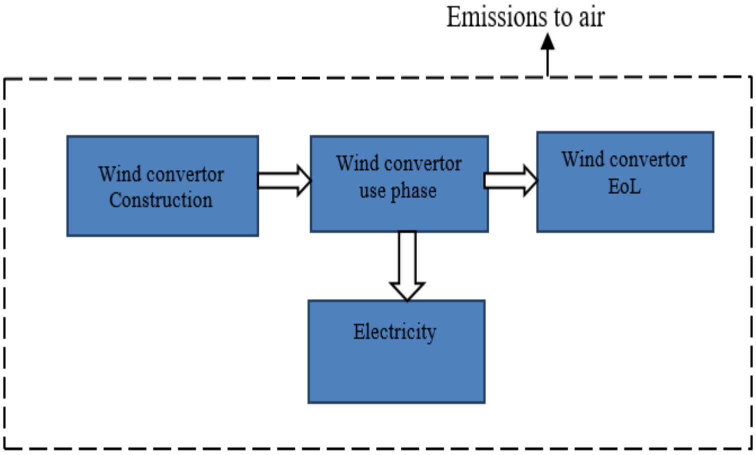

Figure 9. System boundaries of wind power.

For the biomass power plant, GaBi considers both solid specific power plant or CHP plants. In this case also, first, representative LCA model is set up and then assumed to be operational in different national conditions considering technological standards and other efficiency parameters. In this model it is assumed that the residues from combustion of solid fuels such as ash and gypsum are reused such as in construction work. Waste treatment of residuals is not considered in the model. Particularly, in the case of biomass plants, the production, processing and transportation process of fuels is also considered (GaBi Database, 2006).

During analysis, the function of the system was assumed to be electricity production. The functional unit is assumed to be a system producing 1kWh of electricity. In this thesis, instead of constructing own model, electricity generated by already modelled systems (PV, wind and biomass) in GaBi was used as proxy for comparison of environmental effectiveness of these three renewable systems. Considering electricity output of different modelled system in GaBi, the CO_2 emission of each of these systems was taken into consideration for comparison of environmental effectiveness.

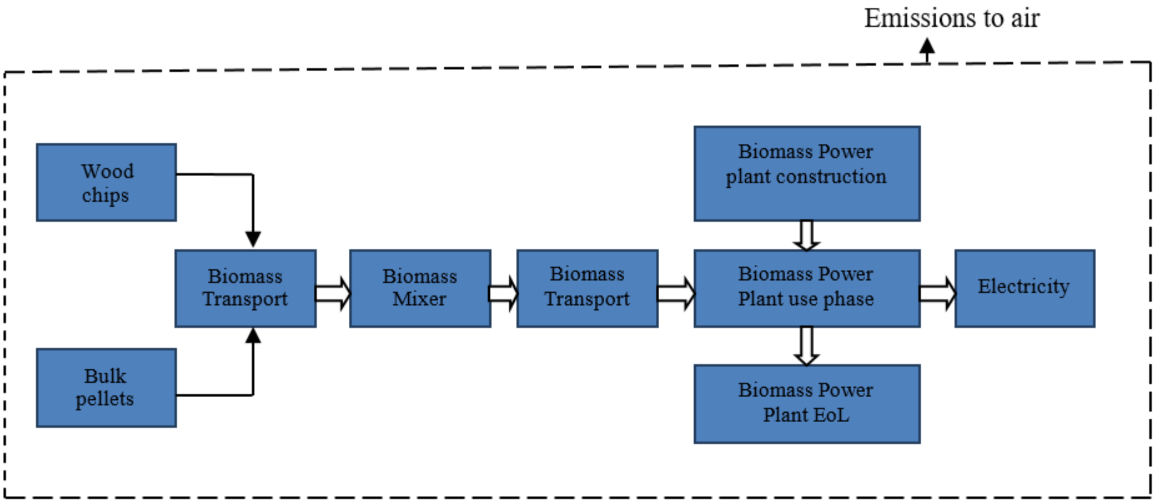

Figure 10. Systems boundaries of biomass.

4 RESULTS AND DISCUSSIONS

4.1 Results from IRR evaluation of PV systems

After the calculation with due process, the results for IRR rates for different variants of PV systems are presented in figure 10. The result clearly shows that IRR rates for all different variants of PV systems are negative. Further, with adjusted reinvestment rate and financial rate in MIRR (figure 11), the results are more negative for majority of the PV systems. However, it should be noted that the result is not in similar scale for all different types of PV systems. For example, for Multi cSi PV system with 15 degree angle, the initial investment is recuperated at a faster rate (better IRR rate) than for instance, aSi and CdTe technologies.

One way of explaining this variation in IRR rates even within PV systems is that those systems that are more efficient will naturally generate more electrical output and thus the cash flow would be better and eventually better IRR rates. With efficiency, in this thesis it includes both cell as well as module efficiency. In comparison to multi cSi technology for instance, both cdTe and aSi are considered to be less efficient. For example, it terms of recorded commercial and lab efficiency; for multi c-Si it is about 20,3 % whereas for cdTe is only about 11,2%. However, it has been claimed that the overall efficiency of PV systems are improving as a general trend (Energy Development Co-operative Limited, 2013). If it is so then it can be expected in the future that PV systems can be in the future commercially viable.

Similarly, this variation in IRR rates of different PV systems can also be reflection of differences in initial capital investment. It could safely be said that higher the initial capital investment required, the longer it would take to recuperate the initial investment. Since, there is a variation in initial capital investment, for example; in 2011, the total initial investment for c-Si was around 3070-5000 whereas for aSi it was in the range of 3600-5000. Although, in this case the total initial cost is quite similar, one could make an argument that higher the initial investment cost, the longer it will take to recuperate the investment. This could have been as a result of differences in LCOE.

However, several researches also show that the initial investment cost for PV systems is gradually declining (IEA-ETSAP & IRENA, 2013). For example, prices for PV modules in 2014 were about 75% less than what they were in 2009. If this trend continues, it can be assumed that the initial investment costs for PV systems in general will decline leading to shorter times for recuperating initial investments and in turn better IRR.

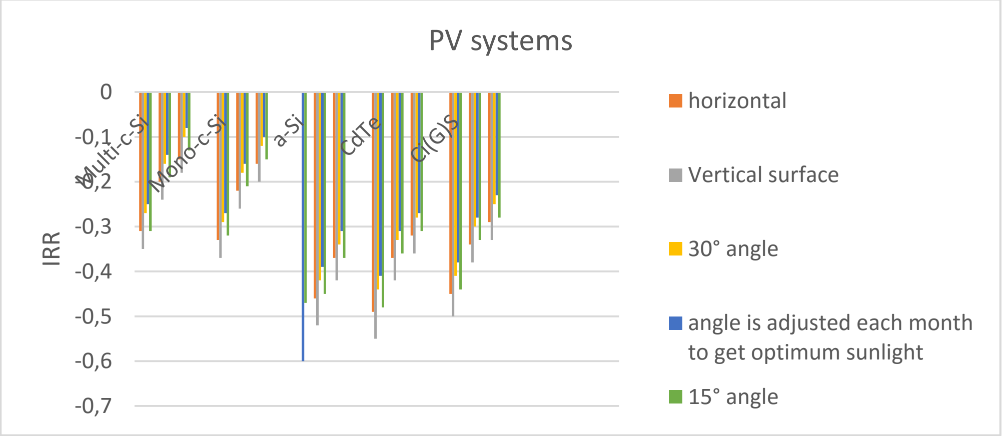

Figure 11. IRR evaluation of different PV systems.

Similarly, since the gross revenue is the result of total output and per unit price of electricity, which is LCOE, the differences in LCOE of different PV systems will also lead to variation in cash flows. As a result, ceteris paribus, the higher the LCOE, the higher will be the revenue. If depreciation costs, O&M costs, electric output degradation and inflation were to be taken into account, higher LCOE would mean higher cash flows and better IRR rate. For example, LCOE for cSi module in 2011 was in the range of 1,04 to 1,34 USD whereas for aSi it was around 0,20 to 0,52 USD. It has been claimed that LCOE in general are also declining (IEA-ETSAP & IRENA, 2013). Ultimately, the economic effectiveness of PV systems will be the dynamics between initial investment amount and the trends in LCOE.

When considering the power equation for PV systems, the electric output of this system is quite highly dependent upon solar irradiance levels or the local solar radiation level. The lower economic competitiveness of PV systems can also be reflection of very low local solar radiation level as we took the data from annual solar irradiance level in Finland (Boxwell, 2015).

Generally, it can be expected that the solar radiation level in Finland, if we consider all months in a year, is quite low and for a very short time (Boxwell, 2015). Instead, if we would have taken a case where the solar radiation level would have been higher, it could have reflected in better economic performance. It also means that just because it seems commercially not viable in the Finnish case, it can be generalized in cases where the solar radiation level is higher and for a longer time in a year.

When the IRR is negative throughout, it means that during the lifecycle of the project, the initial investment cannot be recuperated. It is also quite evident from the results for cash flow in PV systems that for each years (from year 1 to year 5), the before tax generated cash flow in each year is very low which makes it difficult to recuperate the initial investment cost. The MIRR result in figure 12 also shows similar situation. Additionally, in our calculation we also did not consider taxes and subsidies. If taxes were included, the cash flow would further degenerate. Therefore, it can safely be said that during the life cycle of PV systems, without subsidies it would be very difficult to justify initial investment purely on economic grounds. Without external support such as government subsidies at the moment, PV systems do not seem to be commercially viable. This is also the result from several researches in the past (IEA-ETSAP & IRENA, 2013).

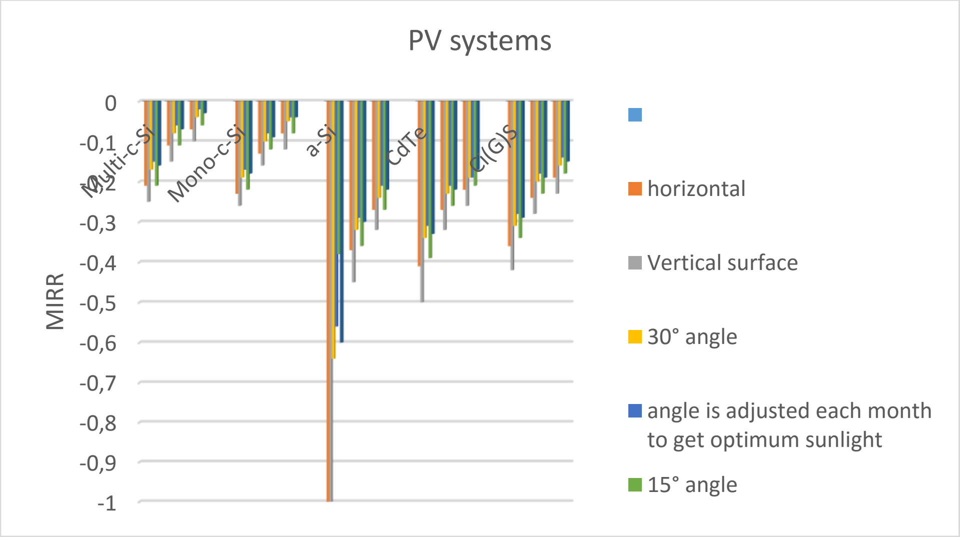

Figure 12. Figure 6 MIRR rates of different PV systems

4.2 Results from IRR evaluation of wind systems

After the due process in IRR calculation, figure 13 shows the results of IRR of onshore and offshore wind energy systems. In the MIRR calculation, as explained earlier 10% financial rate and 8% reinvestment rate were assumed. The results show that from MIRR evaluation, IRR rate has declined but there is no fundamental difference in the overall relationships.

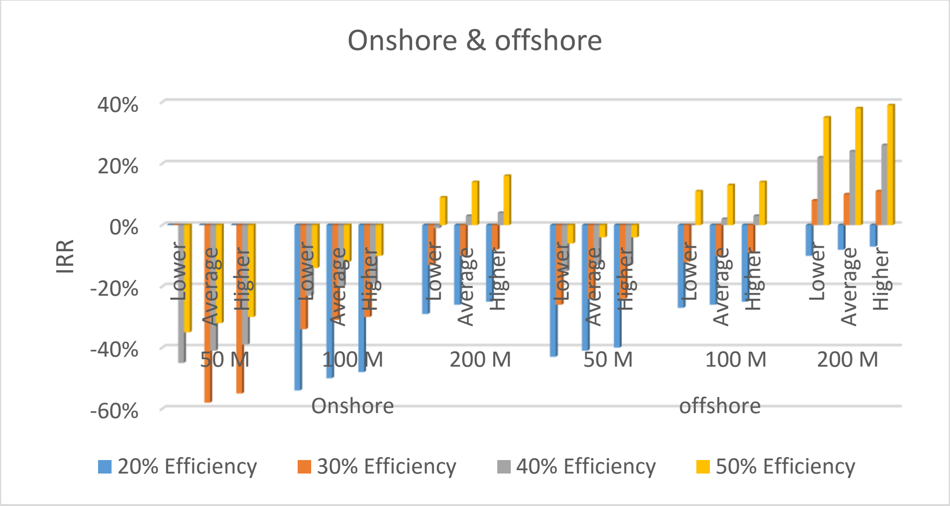

Figure 13. IRR of onshore and offshore wind energy systems.

In sharp contrast to PV systems, it can be seen that several of the results in wind energy systems variants show positive IRR. In this thesis, all different ranges of LCOE were taken into account as is apparent from different LCOE for onshore and offshore systems. The results clearly show that, for onshore wind power systems, with the height of 200m and operating at 40% and 50% efficiency, at all LCOE price ranges, the IRR rate is positive.

Similarly, for offshore type when the height of the tower is 100m, at lower range of LCOE, when the operating efficiency is 50%, the IRR rate is positive. For same height, but for the average LCOE range as well as higher LCOE range, IRR is positive only when the wind power system is operating at both 40% and 50% efficiency. When the height of the tower is 200m, if the system is operating at 30%, 40% and 50%, at all LCOE ranges the IRR rate is positive.

This suggests several outcomes. First, in comparison to PV systems, wind power systems show better commercial potential in that the initial investment can be recuperated faster in many variants of the wind power systems (as suggested by positive and higher IRR rates). Secondly, it also suggests that offshore wind energy systems tend to perform better as can be seen from higher and positive IRR rates at the heights of 100m and 200m. Third, it also suggests that the higher the operating efficiency, the faster the initial investment is recuperated as suggested by higher IRR rates. Fourth, it also suggests that higher the tower height, the better is the economic performance of wind power systems.

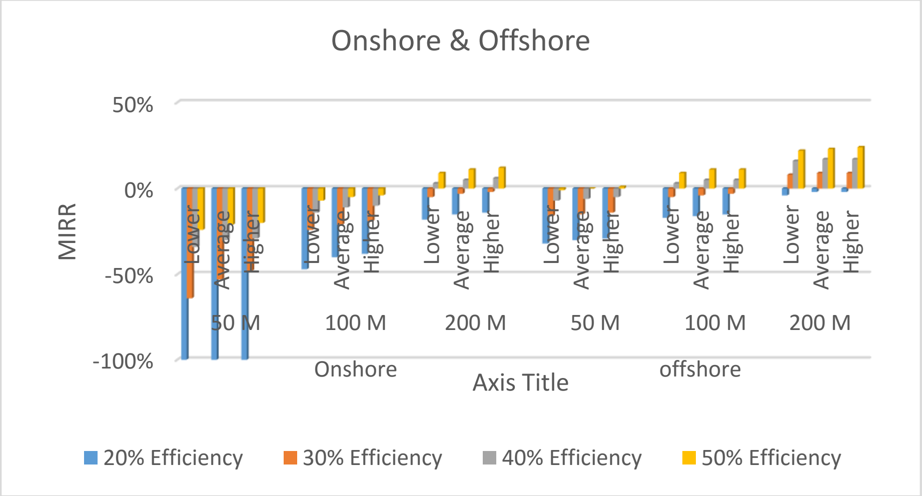

Figure 14. MIRR of onshore and offshore wind energy systems.

These results can be explained by several other factors. For instance, higher efficiency naturally means higher amount of output and the resulting cash flow or revenue would be higher leading to better economic performance. Similarly, result shows that offshore type of wind power system with higher tower performs better economically. This could be because if we consider the power equation for wind power systems, which lead us to calculate the amount of electricity generated, it is quite highly dependent upon the wind speed. It is quite apparent that at higher tower height and if the wind power system is installed offshore, the higher the wind speed that can be expected. This will naturally result in higher electric output as long as the efficiency of the wind power system is acceptable.

In the calculation of IRR, the tax liabilities and subsidy grants were not included. It would mean that if there is higher government subsidies, wind power systems would show better cash outflow resulting in shorter period to recuperate initial investment costs. Also, if the initial investment cost, for example, the construction and civil work and the prices of the components of wind power systems decline in general, the commercial viability of wind power systems will be higher. In any case, results show better economic performance of wind power systems in comparison to PV systems. With further analysis, it could be seen that wind power systems have the capability to compete with conventional energy production systems.

4.3 Results from IRR evaluation of biomass systems

With due process in IRR calculation, now it is possible to present the IRR rates of investment in biomass plants with 1 kW as the capacity of the power plant. In figure 15, with assumed 10% financial rate and 8% reinvestment rate, the results of MIRR are also shown. The results show similar relationships in both the calculations albeit with MIRR calculation, IRR rate tend to decrease.

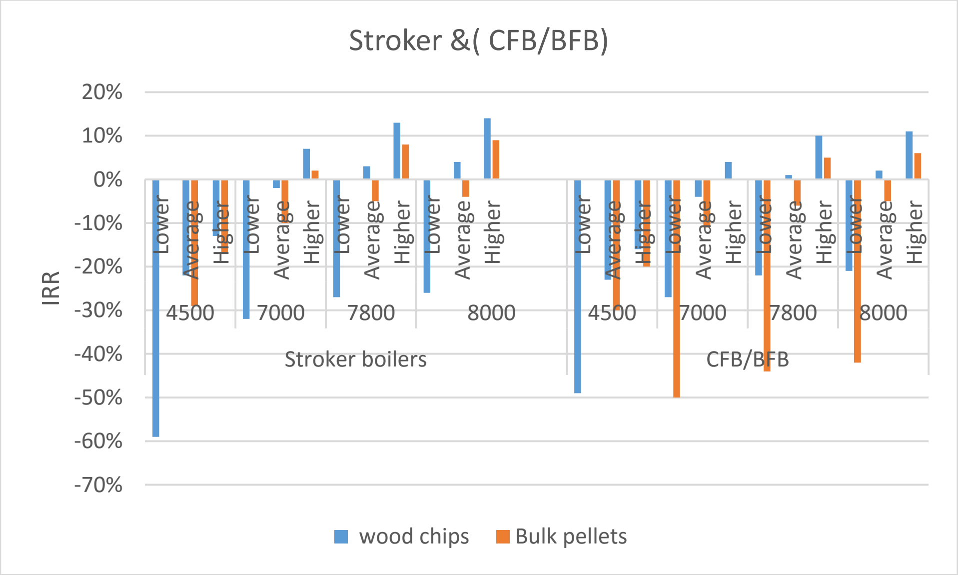

Figure 15. IRR rates of stoker and CFB/BFB biomass plants.

The results show that for stoker boilers, with assumed 7000 operating hours, at the higher LCOE rate, IRR is positive. It shows however, that for woodchips it shows better performance. Similarly, at 7800 operating hours, for the higher LCOE, both woodchips and bulk pellets show positive IRR where woodchips show better performance. For 8000 operating hours, at the higher LCOE, once again the results are similar.

However, with CFB/BFB biomass plant, IRR is positive for wood chips at higher LCOE with 7000 operating hours, at higher LCOE with 7800 operating hours and average and higher LCOE with 8000 operating hours. With bulk pellets for CFB/BFB biomass plants, IRR is positive at higher LCOE with 7800 and 8000 operating hours.

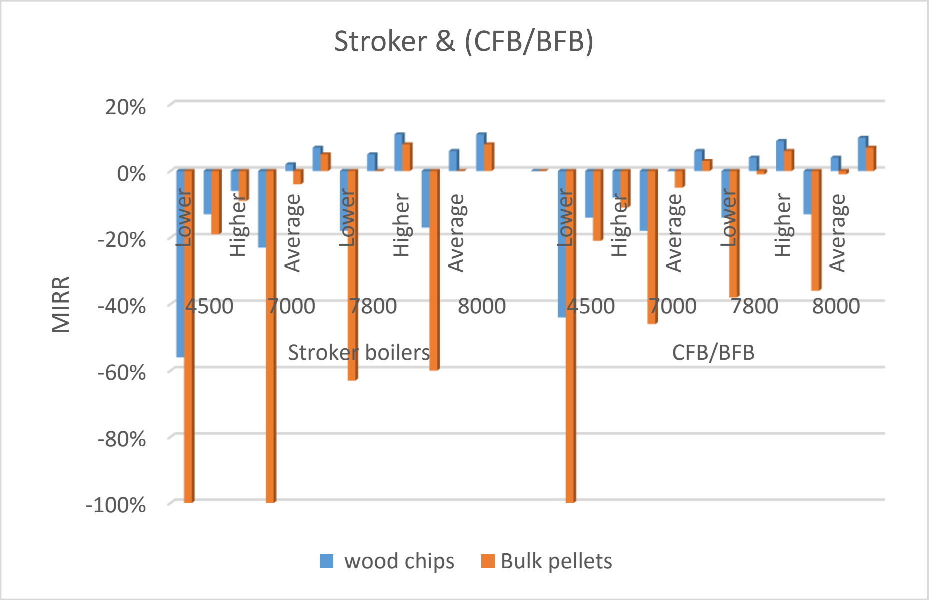

Figure 16. MIRR rates of stoker and CFB/BFB biomass plants.

This has several implications. It shows that the economic performance of biomass plants is a result of operating hours. It seems that higher the operating hours, the better the IRR rate and the possibility to recuperate initial investment. This is also institutive as the machine operates much longer, the more will be the output and more the cash flow. Similarly, if the price that can be charged for the electrical output (LCOE) is higher, the higher is the IRR rate. This is also self-evident because if the unit price is higher it would basically mean higher revenue.

What is interesting is the relationship between the feedstock used. As far as the result shows, use of wood chips is better considering the economic performance in comparison to bulk pellets. This however, could only be the reflection of the fuel prices rather than other factors. For example, the price of wood chips in euro per MWh is 21,2 and for bulk pellets the prices in euro is 37,4 Euro/MWh. It means that lower the fuel costs, the better will be the economic performance. Since, biomass plant in comparison to wind and PV systems, is the only system which requires feedstock, the competitiveness of feedstock prices goes a long way in determining the economic performance of biomass plants in comparison to other renewable energy systems.

4.4 Results from LCA analysis in GaBi

In addition to the economic evaluation of different renewable systems, for the environmental evaluation of these systems, GaBi software was used to evaluate the CO_2 emissions of different renewable systems in kg CO_2 equivalent. Although, the analysis was not detailed in that the default system values were taken into account while changing the functional unit to 1kWh, this still does provide the initial benchmark for comparing environmental performance of these renewable systems. Table 22 shows the CO_2 emissions in kg CO_2 equivalent for three systems and the resulting figure 17 illustrates this.

Table 22.CO_2 emissions of different renewable systems (1 kWh functional unit).

Technologies	**kg CO_2-Equiv.**
Wind energy	0,0082
Photovoltaic systems	0,0549
Biomass power	0,0256

The results clearly show that even while taking default system value in GaBi, in terms of CO_2 emissions, PV systems perform the worst followed by biomass and then wind power systems. If this data were to be taken as truth value, in terms of environmental performance, taking solely into account the CO_2 emissions in kg CO_2 equivalent, wind power performs the best. However, this result could be different if specific local or regional conditions and other operational data were taken into account.

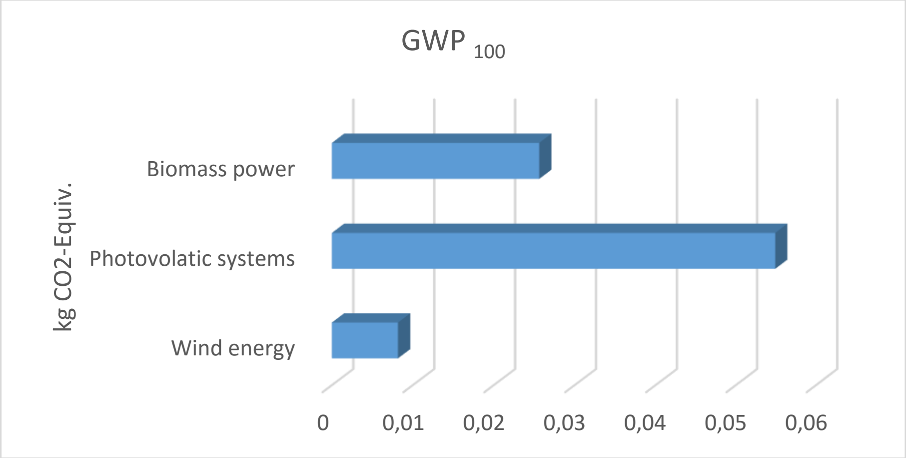

Figure 17. CO_2 emissions of different renewable systems (1 kWh functional unit)

4.5 Overall comparison

Now at this stage it will be possible to concretely determine, given the used conditions, which renewable system performs better economically and environmentally. The results clearly show that in terms of economic performance PV systems rank the lowest, biomass energy systems somewhere in the average region and the wind power systems the best. This is claimed with caution as different parameters than what were used could have led to different results. Similarly, in terms of environmental performance, taking solely CO_2 emissions as the major criteria, once again, PV systems performs the worst followed by biomass systems and then at the end wind energy systems. There is a general alignment between the economic and environmental performance of all of these different renewable systems.

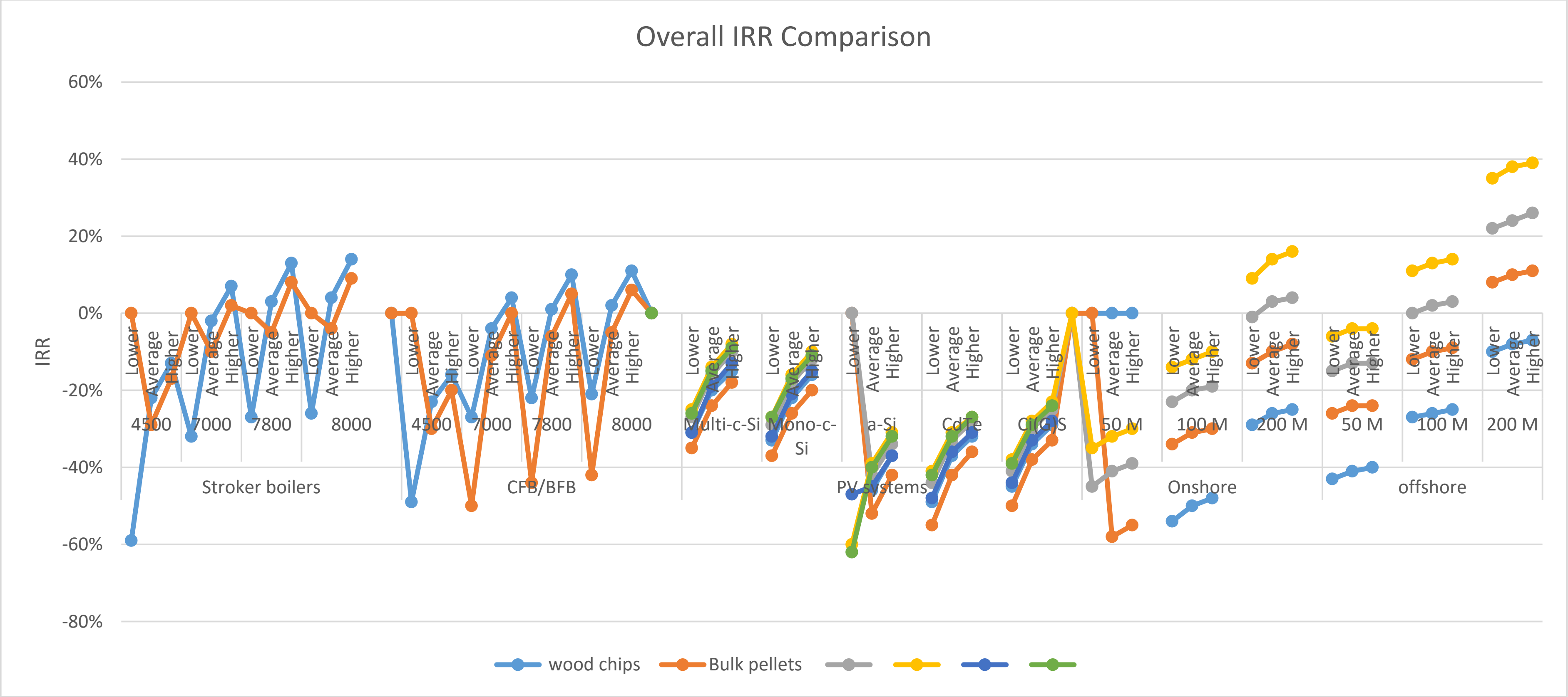

Figure 18. Overall IRR comparison of Biomass, PV solar and wind energy.

5 CONCLUSIONS

This research was conducted with the view to evaluate economic and environmental performance of renewable energy systems; which included wind power, PV and biomass systems. This is increasingly becoming important due to several policy decisions as well as the general discourse regarding renewable energy systems. In order to find out economic competitiveness of these three systems, first basic cost parameters of all of these systems were identified. After that, in order to calculate the revenue generated, Levelised cost of electricity (LCOE) and the output potential of each of these systems were calculated or taken from accepted data sources. Following that, for each of these different energy systems, cash flows were calculated for all of these systems including different parameters. Eventually Internal Rate of Return (IRR) and Modified Internal Rate of Return (MIRR) were used to evaluate the returns from each of these different investment decisions. IRR is quite well accepted financial tool in assessing the profitability or economic viability of investment decisions (Short, et al., 1995).

Similarly, in order to evaluate the environmental performance of these three different systems, with chosen functional unit as 1 kWh and taking other default modeling value in GaBi software, the CO_2 emissions of different renewable energy systems were identified by using life cycle analysis (LCA) methods.

It can be concluded that given the parameters that were considered, in terms of economic performance with IRR rate as a proxy, PV systems generally tend to perform the lowest followed by biomass energy systems and ultimately wind power systems. The environmental evaluation also follows the similar relationship i.e. wind energy systems performs the best in comparison to both PV and biomass systems. Obviously, all due care was taken to identify the cost parameters and accurate data from different sources but use of other parameters might lead to different conclusions.

5.1 Policy Implications

This conclusion also leads to several policy implications. It is counterintuitive that despite low economic and environmental performance of PV systems, that investment in PV systems is growing. Calculations without consideration of taxes and subsidies show the economic performance of PV systems to be considerably negative. If PV systems is to compete with other renewable and conventional energy technologies, at the moment it does seem that government and other subsidies is essential to at least recuperate the initial investment. Similarly, if the efficiency of PV systems and cost of PV modules keep on decreasing, as is seen from the current trends, PV systems might eventually be commercially viable source of renewable technology.

What is surprising is that wind energy systems, as was found from this research, tend to perform better both economically and environmentally. Despite not considering government subsidies, offshore type of wind energy systems with higher tower heights seems to generate higher returns in a short period of time. With government subsidies, this technology has the possibility to compete with regular energy production technologies.

5.2 Limitations of the study

This study was limited in several grounds. First, in many cases, the global average of cost parameters were taken into account for regional variation. This can limit the applicability in the immediate context as local costs of feedstock, system costs, and electricity costs and so on can be variable. Similarly, in order to take into account the seasonal variations of wind speed and solar radiation levels, annual average was taken, which might not be exactly generalizable. For biomass plants, only two feedstocks were considered which were relevant in the Finnish case as they are locally available and commonly used sources of feedstock.

This study also takes into account as recent sources of data as were available. However, since the unit price of electricity (in terms of LCOE e.g.) and the system costs keep on varying, this study might not be relevant for a longer period of time although due process can be applied to derive similar conclusions in the relevant time frame. Additionally, in this study, 1kW was taken for comparison purpose for each of these energy systems although in reality there will be very few power plants with such a limited output. However, depending upon the case, the procedure can be applied to power plants with varying outputs.

It has also been suggested that IRR as a means of evaluating alternative investment decisions is not always the best method as it can lead to ambiguous conclusions specially when the results lead to negative IRR. As was seen in this study, it does lead to final result in negative IRR, which might lead to ambiguous interpretation. To limit this dilemma, MIRR was used as a method for evaluating investment decisions, but fundamentally there were not so much difference in the final result.

Finally, for evaluating the environmental effectiveness, GaBi software was used. The major limitation in this study is that the default value of GaBi software was taken to come up with the CO_2 emissions with 1 kWh chosen as functional unit. Although, the data used in GaBi software is a good approximation of different parameters in varying regional contexts, the conclusions derived in such a way, still remains limited and not generalizable across all contexts. In the end, in all of the renewable energy systems considered, generally heat is also produced as output along with electricity. However, in this study heat output was not considered and not included in the calculation. This can also be considered as one of the limitations of the study.

5.3 Suggestions for further research

This study highlights the due process that is required in environmental and economic performance of different renewable energy systems. This method can be applied in any context by considering the local system requirements and output. For further analysis, it might also be possible to build regression models considering different variables as independent variables and economic or environmental performance as a dependent variable. For example, for wind energy system it might be possible to build a multiple regression model relating IRR as dependent variable and swept area, height of the tower, onshore or offshore type, system cost and so on as independent variables. Due to the scope of this research, this was not considered. Finally, in this study, the monetary value of emissions or avoided emissions, in terms of negative or positive externalities were not considered. The environmental performance was only taken to be reduction in CO_2 emissions. In future researches, it might be possible to monetize these avoided emissions and add it together with the cash flow generated during life cycle of different systems and perform truly economic analysis with monetized environmental performance.

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APPENDIX 1. PV Systems

Calculation of IRR and MIRR of PV systems at different angles

Table 1.IRR, MIRR and revenue of Multi-c-Si in horizontal surface.

(Multi-c-Si)															
Horizontal															
	Lower range					**Average range**					**Higher range**				
Year	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before Tax-cash flow**	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before Tax Flow**	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before tax-cash flow**
0	3070	0,0	0,00	0	-3070	4035	0,0	0,00	0	-4035	5000	0,0	0,00	0	-5000
1	0	31,2	315,64	151,04	133,40	0	42,0	568,15	198,52	327,67	0	52,0	820,66	246	522,66
2	0	32,4	326,62	145	149,18	0	43,6	587,92	190,58	353,70	0	54,1	849,22	236,16	558,98
3	0	33,7	337,99	138,96	165,28	0	45,4	608,38	182,64	380,36	0	56,2	878,78	226,32	596,21
4	0	35,1	349,75	132,92	181,74	0	47,2	629,56	174,7	407,65	0	58,5	909,36	216,48	634,38
5	0	36,5	361,92	126,88	198,54	0	49,1	651,46	166,76	435,61	0	60,8	941,00	206,64	673,53
				IRR	**-31%**				**IRR**	**-20%**				**IRR**	**-15%**
				MIRR	**-21%**				**MIRR**	**-11%**				**MIRR**	**-7%**

Table 2. IRR, MIRR and revenue of Multi-c-Si in vertical surface.

(Multi-c-Si)															
vertical surface															
	Lower range					**Average range**					**Higher range**				
Year	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before Tax-cash flow**	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before Tax Flow**	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before tax-cash flow**
0	3070	0,0	0,00	0	-3070	4035	0,0	0,00	0	-4035	5000	0,0	0,00	0	-5000
1	0	31,2	282,88	151,04	100,64	0	42,0	509,18	198,52	268,70	0	52,0	735,49	246	437,49
2	0	32,4	292,72	145	115,28	0	43,6	526,90	190,58	292,68	0	54,1	761,08	236,16	470,84
3	0	33,7	302,91	138,96	130,21	0	45,4	545,24	182,64	317,21	0	56,2	787,57	226,32	505,01
4	0	35,1	313,45	132,92	145,44	0	47,2	564,21	174,7	342,31	0	58,5	814,98	216,48	540,00
5	0	36,5	324,36	126,88	160,98	0	49,1	583,85	166,76	368,00	0	60,8	843,34	206,64	575,86
				IRR	**-35%**				**IRR**	**-24%**				**IRR**	**-18%**
				MIRR	**-25%**				**MIRR**	**-15%**				**MIRR**	**-10%**

Table 3. IRR, MIRR and revenue of Multi-c-Si in 30° angle.

(Multi-c-Si)															
30° angle															
	Lower range					Average range					Higher range				
Year	Investment	O&M	Revenue	Depreciation	Before Tax-cash flow	Investment	O&M	Revenue	Depreciation	Before Tax Flow	Investment	O&M	Revenue	Depreciation	Before tax-cash flow
0	3070	0,0	0,00	0	-3070	4035	0,0	0,00	0	-4035	5000	0,0	0,00	0	-5000
1	0	31,2	353,34	151,04	171,10	0	42,0	636,01	198,52	395,53	0	52,0	918,68	246	620,68
2	0	32,4	365,64	145	188,19	0	43,6	658,15	190,58	423,92	0	54,1	950,65	236,16	660,41
3	0	33,7	378,36	138,96	205,65	0	45,4	681,05	182,64	453,02	0	56,2	983,74	226,32	701,17
4	0	35,1	391,53	132,92	223,51	0	47,2	704,75	174,7	482,85	0	58,5	1017,97	216,48	743,00
5	0	36,5	405,15	126,88	241,77	0	49,1	729,77	166,76	513,42	0	60,8	1053,40	206,64	785,92
				IRR	**-27%**				**IRR**	**-16%**				**IRR**	**-10%**
				MIRR	**-17%**				**MIRR**	**-8%**				**MIRR**	**-4%**

Table 4. IRR, MIRR and revenue of Multi-c-Si in Angle is adjusted to optimum sunlight.

(Multi-c-Si)															
Angle is adjusted to optimum sunlight															
	Lower range					**Average range**					**Higher range**				
Year	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before Tax-cash flow**	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before Tax Flow**	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before tax-cash flow**
0	3070	0,0	0,00	0	-3070	4035	0,0	0,00	0	-4035	5000	0,0	0,00	0	-5000
1	0	31,2	377,78	151,04	195,54	0	42,0	680,00	198,52	439,52	0	52,0	982,23	246	684,23
2	0	32,4	390,93	145	213,48	0	43,6	703,67	190,58	469,45	0	54,1	1016,41	236,16	726,17
3	0	33,7	404,53	138,96	231,83	0	45,4	728,16	182,64	500,13	0	56,2	1051,78	226,32	769,22
4	0	35,1	418,61	132,92	250,59	0	47,2	753,50	174,7	531,59	0	58,5	1088,38	216,48	813,41
5	0	36,5	433,18	126,88	269,80	0	49,1	779,72	166,76	563,87	0	60,8	1126,26	206,64	858,79
				IRR	**-25%**				**IRR**	**-14%**				**IRR**	**-8%**
				MIRR	**-15%**				**MIRR**	**-6%**				**MIRR**	**-2%**

Table 5. IRR, MIRR and revenue of Multi-c-Si in 15° angle.

(Multi-c-Si)															
15° angle															
	Lower range					**Average range**					**Higher range**				
Year	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before Tax-cash flow**	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before Tax Flow**	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before tax-cash flow**
0	3070	0,0	0,00	0	-3070	4035	0,0	0,00	0	-4035	5000	0,0	0,00	0	-5000
1	0	31,2	325	151,04	142,76	0	42,0	585,00	198,52	344,52	0	52,0	845,00	246	547,00
2	0	32,4	323,38	145	145,93	0	43,6	605,36	190,58	371,14	0	54,1	874,41	236,16	584,17
3	0	33,7	334,63	138,96	161,92	0	45,4	626,42	182,64	398,40	0	56,2	904,84	226,32	622,27
4	0	35,1	346,27	132,92	178,26	0	47,2	648,22	174,7	426,32	0	58,5	936,32	216,48	661,35
5	0	36,5	358,32	126,88	194,94	0	49,1	670,78	166,76	454,93	0	60,8	968,91	206,64	701,44
				IRR	**-31%**				**IRR**	**-19%**				**IRR**	**-13%**
				MIRR	**-21%**				**MIRR**	**-11%**				**MIRR**	**-6%**

Table 6. IRR, MIRR and revenue of Multi-c-Si in 45° angle.

(Multi-c-Si)															
45° angle															
	Lower range					**Average range**					**Higher range**				
Year	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before Tax flow**	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before Tax Flow**	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before tax-cash flow**
0	3070	0,0	0,00	0	-3070	4035	0,0	0,00	0	-4035	5000	0,0	0,00	0	-5000
1	0	31,2	367,38	151,04	185,14	0	42,0	661,28	198,52	420,80	0	52,0	955,19	246	657,19
2	0	32,4	380,16	145	202,72	0	43,6	684,30	190,58	450,07	0	54,1	988,43	236,16	698,19
3	0	33,7	393,39	138,96	220,69	0	45,4	708,11	182,64	480,08	0	56,2	1022,83	226,32	740,26
4	0	35,1	407,08	132,92	239,07	0	47,2	732,75	174,7	510,85	0	58,5	1058,42	216,48	783,45
5	0	36,5	421,25	126,88	257,87	0	49,1	758,25	166,76	542,40	0	60,8	1095,25	206,64	827,78
				IRR	**-26%**				**IRR**	**-15%**				**IRR**	**-9%**
				MIRR	**-16%**				**MIRR**	**-7%**				**MIRR**	**-3%**

Table 7. IRR, MIRR and revenue of Mono-c-SI in horizontal surface.

(Mono-c-SI)															
horizontal															
	Lower range					Average range					Higher range				
Year	Investment	O&M	Revenue	Depreciation	Before Tax flow	Investment	O&M	Revenue	Depreciation	Before Tax Flow	Investment	O&M	Revenue	Depreciation	Before tax-cash flow
0	3070	0,0	0,00	0	-3070	4035	0,0	0,00	0	-4035	5000	0,0	0,00	0	-5000
1	0	31,2	299,52	151,04	117,28	0	42,0	539,14	198,52	298,65	0	52,0	778,75	246	480,75
2	0	32,4	309,94	145	132,50	0	43,6	557,90	190,58	323,68	0	54,1	805,85	236,16	515,61
3	0	33,7	320,73	138,96	148,02	0	45,4	577,31	182,64	349,28	0	56,2	833,90	226,32	551,33
4	0	35,1	331,89	132,92	163,87	0	47,2	597,40	174,7	375,50	0	58,5	862,92	216,48	587,94
5	0	36,5	343,44	126,88	180,06	0	49,1	618,19	166,76	402,34	0	60,8	892,95	206,64	625,47
				IRR	**-33%**				**IRR**	**-22%**				**IRR**	**-16%**
				MIRR	**-23%**				**MIRR**	**-13%**				**MIRR**	**-8%**

Table 8. IRR, MIRR and revenue of Mono-c-SI in Vertical surface.

(Mono-c-SI)															
Vertical surface															
	Lower range					Average range					Higher range				
Year	Investment	O&M	Revenue	Depreciation	Before Tax flow	Investment	O&M	Revenue	Depreciation	Before Tax Flow	Investment	O&M	Revenue	Depreciation	Before tax-cash flow
0	3070	0,0	0,00	0	-3070	4035	0,0	0,00	0	-4035	5000	0,0	0,00	0	-5000
1	0	31,2	268,06	151,04	85,82	0	42,0	482,51	198,52	242,02	0	52,0	696,96	246	398,96
2	0	32,4	277,39	145	99,94	0	43,6	499,30	190,58	265,08	0	54,1	721,21	236,16	430,97
3	0	33,7	287,04	138,96	114,34	0	45,4	516,67	182,64	288,65	0	56,2	746,31	226,32	463,74
4	0	35,1	297,03	132,92	129,01	0	47,2	534,66	174,7	312,75	0	58,5	772,28	216,48	497,31
5	0	36,5	307,37	126,88	143,99	0	49,1	553,26	166,76	337,41	0	60,8	799,16	206,64	531,68
				IRR	**-37%**				**IRR**	**-26%**				**IRR**	**-20%**
				MIRR	**-26%**				**MIRR**	**-16%**				**MIRR**	**-12%**

Table 9. IRR, MIRR and revenue of Mono-c-SI in 30° angle.

(Mono-c-SI)															
30° angle															
	Lower range					Average range					Higher range				
Year	Investment	O&M	Revenue	Depreciation	Before Tax flow	Investment	O&M	Revenue	Depreciation	Before Tax Flow	Investment	O&M	Revenue	Depreciation	Before tax-cash flow
0	3070	0,0	0,00	0	-3070	4035	0,0	0,00	0	-4035	5000	0,0	0,00	0	-5000
1	0	31,2	335,14	151,04	152,90	0	42,0	603,25	198,52	362,77	0	52,0	871,36	246	573,36
2	0	32,4	346,80	145	169,35	0	43,6	624,25	190,58	390,02	0	54,1	901,69,	236,16	611,45
3	0	33,7	358,87	138,96	186,17	0	45,4	645,97	182,64	417,94	0	56,2	933,07	226,32	650,50
4	0	35,1	371,36	132,92	203,34	0	47,2	668,45	174,7	446,54	0	58,5	965,54	216,48	690,56
5	0	36,5	384,28	126,88	220,90	0	49,1	691,71	166,76	475,86	0	60,8	999,14	206,64	731,66
				IRR	**-29%**				**IRR**	**-18%**				**IRR**	**-12%**
				MIRR	**-19%**				**MIRR**	**-10%**				**MIRR**	**-5%**

Table 10. IRR, MIRR and revenue of Mono-c-SI in angle is adjusted each month to get optimum sunlight.

(Mono-c-SI)															
angle is adjusted each month to get optimum sunlight															
	Lower range					**Average range**					**Higher range**				
Year	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before Tax flow**	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before Tax Flow**	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before tax-cash flow**
0	3070	0,0	0,00	0	-3070	4035	0,0	0,00	0	-4035	5000	0,0	0,00	0	-5000
1	0	31,2	358,28	151,04	176,04	0	42,0	644,90	198,52	404,42	0	52,0	931,53	246	633,53
2	0	32,4	370,75	145	193,30	0	43,6	667,35	190,58	433,12	0	54,1	963,95	236,16	673,71
3	0	33,7	383,65	138,96	210,94	0	45,4	690,57	182,64	462,54	0	56,2	997,49	226,32	714,93
4	0	35,1	397,00	132,92	228,99	0	47,2	714,60	174,70	492,70	0	58,5	1032,20	216,48	757,23
5	0	36,5	410,82	126,88	247,44	0	49,1	739,47	166,76	523,62	0	60,8	1068,12	206,64	800,65
				IRR	**-27%**				**IRR**	**-16%**				**IRR**	**-10%**
				MIRR	**-17%**				**MIRR**	**-8%**				**MIRR**	**-4%**

Table 11. IRR, MIRR and revenue of Mono-c-SI in 15° angle.

(Mono-c-SI)															
15° angle															
	Lower range					**Average range**					**Higher range**				
Year	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before Tax flow**	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before Tax Flow**	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before tax-cash flow**
0	3070	0,0	0,00	0	-3070	4035	0,0	0,00	0	-4035	5000	0,0	0,00	0	-5000
1	0	31,2	308,10	151,04	125,86	0	42,0	554,58	198,52	314,10	0	52,0	801,06	246	503,06
2	0	32,4	318,82	145	141,37	0	43,6	573,88	190,58	339,66	0	54,1	828,94	236,16	538,70
3	0	33,7	329,92	138,96	157,21	0	45,4	593,85	182,64	365,82	0	56,2	857,78	226,32	575,22
4	0	35,1	341,40	132,92	173,38	0	47,2	614,52	174,7	392,61	0	58,5	887,63	216,48	612,66
5	0	36,5	353,28	126,88	189,90	0	49,1	635,90	166,76	420,05	0	60,8	918,52	206,64	651,05
				IRR	**-32%**				**IRR**	**-21%**				**IRR**	**-15%**
				MIRR	**-22%**				**MIRR**	**-12%**				**MIRR**	**-8%**

Table 12. IRR, MIRR and revenue of Mono-c-SI in 45° angle.

(Mono-c-SI)															
45° angle															
	Lower range					Average range					Higher range				
Year	Investment	O&M	Revenue	Depreciation	Before Tax flow	Investment	O&M	Revenue	Depreciation	Before Tax Flow	Investment	O&M	Revenue	Depreciation	Before tax-cash flow
0	3070	0,0	0,00	0	-3070	4035	0,0	0,00	0	-4035	5000	0,0	0,00	0	-5000
1	0	31,2	348,40	151,04	166,16	0	42,0	627,12	198,52	386,64	0	52,0	905,84	246	607,84
2	0	32,4	360,52	145	183,08	0	43,6	648,94	190,58	414,72	0	54,1	937,36	236,16	647,12
3	0	33,7	373,07	138,96	200,36	0	45,4	671,53	182,64	443,50	0	56,2	969,98	226,32	687,42
4	0	35,1	386,05	132,92	218,04	0	47,2	694,90	174,7	472,99	0	58,5	1003,74	216,48	728,77
5	0	36,5	399,49	126,88	236,11	0	49,1	719,08	166,76	503,23	0	60,8	1038,67	206,64	771,20
				IRR	**-27%**				**IRR**	**-17%**				**IRR**	**-11%**
				MIRR	**-18%**				**MIRR**	**-9%**				**MIRR**	**-4%**

Table 13. IRR, MIRR and revenue of a-Si in horizontal surface.

a-Si															
Horizontal															
	Lower range					Average range					Higher range				
Year	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before Tax flow**	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before Tax Flow**	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before tax-cash flow**
0	3600	0,0	0,00	0	-3600	4300	0,0	0,00	0	-4300	5000	0,0	0,00	0	-5000
1	0	37,4	165,57	177,12	-48,99	0	44,7	298,02	211,56	41,74	0	52,0	430,48	246	132,48
2	0	38,9	171,33	170,04	-37,65	0	46,5	308,39	203,1	58,78	0	54,1	445,46	236,16	155,22
3	0	40,5	177,29	162,95	-26,15	0	48,4	319,13	194,64	76,12	0	56,2	460,96	226,32	178,40
4	0	42,1	183,46	155,87	-14,52	0	50,3	330,23	186,17	93,76	0	58,5	477,00	216,43	202,08
5	0	43,8	189,85	148,78	-2,73	0	52,3	341,72	177,71	111,70	0	60,8	493,60	206,64	226,13
				IRR	**#NUM!**				**IRR**	**-46%**				**IRR**	**-37%**
				MIRR	**-100%**				**MIRR**	**-37%**				**MIRR**	**-27%**

Table 14. IRR, MIRR and revenue of a-Si in vertical surface.

a-Si															
Vertical															
	Lower range					**Average range**					**Higher range**				
Year	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before Tax flow**	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before Tax Flow**	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before tax-cash flow**
0	3600	0,0	0,00	0	-3600	4300	0,0	0,00	0	-4300	5000	0,0	0,00	0	-5000
1	0	37,4	146,22	177,12	-68,34	0	44,7	263,20	211,56	6,92	0	52,0	380,18	246	82,18
2	0	38,9	151,31	170,04	-57,67	0	46,5	272,36	203,10	22,75	0	54,1	393,41	236,16	103,17
3	0	40,5	156,58	162,95	-46,87	0	48,4	281,84	194,64	38,83	0	56,2	407,10	226,32	124,54
4	0	42,1	162,03	155,87	-35,96	0	50,3	291,65	186,17	55,18	0	58,5	421,27	216,43	146,35
5	0	43,8	167,67	148,78	-24,91	0	52,3	301,80	177,71	71,77	0	60,8	435,93	206,64	168,46
				IRR	**#NUM!**				**IRR**	**-52%**				**IRR**	**-42%**
				MIRR	**-100%**				**MIRR**	**-45%**				**MIRR**	**-32%**

Table 15. IRR, MIRR and revenue of a-Si in 30° angle.

a-Si															
30° angle															
	Lower range					Average range					Higher range				
Year	Investment	O&M	Revenue	Depreciation	Before Tax flow	Investment	O&M	Revenue	Depreciation	Before Tax Flow	Investment	O&M	Revenue	Depreciation	Before tax-cash flow
0	3600	0,0	0,00	0	-3600	4300	0,0	0,00	0	-4300	5000	0,0	0,00	0	-5000
1	0	37,4	182,83	177,12	-31,73	0	44,7	329,10	211,56	72,82	0	52,0	475,36	246	177,36
2	0	38,9	189,19	170,04	-19,78	0	46,5	340,55	203,1	90,94	0	54,1	491,91	236,16	201,67
3	0	40,5	195,78	162,95	-7,67	0	48,4	352,40	194,64	109,39	0	56,2	509,02	226,32	226,46
4	0	42,1	202,59	155,87	4,61	0	50,3	364,66	186,17	128,19	0	58,5	526,74	216,43	251,82
5	0	43,8	209,64	148,78	17,06	0	52,3	377,36	177,71	147,33	0	60,8	545,07	206,64	277,60
				IRR	**#NUM**				**IRR**	**-42%**				**IRR**	**-34%**
				MIRR	**-64%**				**MIRR**	**-32%**				**MIRR**	**-24%**

Table 16. IRR, MIRR and revenue of a-Si in angle is adjusted each month to get optimum sunlight.

a-Si															
angle is adjusted each month to get optimum sunlight															
	Lower range					**Average range**					**Higher range**				
Year	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before Tax flow**	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before Tax Flow**	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before tax-cash flow**
0	3600	0,0	0,00	0	-3600	4300	0,0	0,00	0	-4300	5000	0,0	0,00	0	-5000
1	0	37,4	195,31	177,12	-19,25	0	44,7	351,56	211,56	95,28	0	52,0	507,81	246	209,81
2	0	38,9	202,11	170,04	-6,87	0	46,5	363,80	203,1	114,19	0	54,1	525,48	236,16	235,24
3	0	40,5	209,14	162,95	5,70	0	48,4	376,46	194,64	133,45	0	56,2	543,77	226,32	261,21
4	0	42,1	216,42	155,87	18,44	0	50,3	389,56	186,17	153,08	0	58,5	562,69	216,43	287,77
5	0	43,8	223,95	148,78	31,37	0	52,3	403,11	177,71	173,09	0	60,8	582,27	206,64	314,80
				IRR	**-60%**				**IRR**	**-39%**				**IRR**	**-31%**
				MIRR	**-56%**				**MIRR**	**-29%**				**MIRR**	**-21%**

Table 17. IRR, MIRR and revenue of a-Si in 15° angle.

a-Si															
15° angle															
	Lower range					Average range					Higher range				
Year	Investment	O&M	Revenue	Depreciation	Before Tax flow	Investment	O&M	Revenue	Depreciation	Before Tax Flow	Investment	O&M	Revenue	Depreciation	Before tax-cash flow
0	3600	0,0	0,00	0	-3600	4300	0,0	0,00	0	-4300	5000	0,0	0,00	0	-5000
1	0	37,4	246,,48	177,12	31,92	0	44,7	302,52	211,56	46,24	0	52,0	436,96	246	138,97
2	0	38,9	255,06	170,04	46,08	0	46,5	313,04	203,1	63,43	0	54,1	452,17	236,16	161,93
3	0	40,5	263,93	162,95	60,49	0	48,4	323,94	194,64	80,93	0	56,2	467,91	226,32	185,35
4	0	42,1	273,12	155,87	75,13	0	50,3	335,21	186,17	98,74	0	58,5	484,19	216,43	209,27
5	0	43,8	282,62	148,78	90,04	0	52,3	346,87	177,71	116,85	0	60,8	501,04	206,64	233,57
				IRR	**-47%**				**IRR**	**-45%**				**IRR**	**-37%**
				MIRR	**-38%**				**MIRR**	**-36%**				**MIRR**	**-27%**

Table 18. IRR, MIRR and revenue of a-Si in 45° angle.

a-Si															
45° angle															
	Lower range					**Average range**					**Higher range**				
Year	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before Tax flow**	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before Tax Flow**	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before tax-cash flow**
0	3600	0,0	0,00	0	-3600	4300	0,0	0,00	0	-4300	5000	0,0	0,00	0	-5000
1	0	37,4	190,11	177,12	-24,45	0	44,7	342,20	211,56	85,92	0	52,0	494,29	246	196,29
2	0	38,9	196,73	170,04	-12,25	0	46,5	354,11	203,1	104,50	0	54,1	511,49	236,16	221,25
3	0	40,5	203,57	162,95	0,13	0	48,4	366,43	194,64	123,42	0	56,2	529,29	226,32	246,73
4	0	42,1	210,66	155,87	12,67	0	50,3	379,19	186,17	142,71	0	58,5	547,71	216,43	272,79
5	0	43,8	217,99	148,78	25,441	0	52,3	392,38	177,71	162,35	0	60,8	566,77	206,64	299,30
				IRR	**-62%**				**IRR**	**-40%**				**IRR**	**-32%**
				MIRR	**-60%**				**MIRR**	**-30%**				**MIRR**	**-22%**

Table 19. IRR, MIRR and revenue of CdTe in horizontal surface.

CdTe															
horizontal surface															
	Lower range					**Average range**					**Higher range**				
Year	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before Tax flow**	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before Tax Flow**	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before tax-cash flow**
0	2640	0,0	0,00	0	-2640	3570	0,0	0,00	0	-3570	4500	0,0	0,00	0	-4500
1	0	27,5	171,18	129,89	13,84	0	37,1	308,13	175,64	95,36	0	46,8	445,08	221,4	176,88
2	0	28,6	177,14	124,69	23,90	0	38,6	318,85	168,62	111,62	0	48,7	460,57	212,54	199,36
3	0	29,7	183,31	119,50	34,11	0	40,2	329,95	161,59	128,20	0	50,6	476,59	203,69	222,29
4	0	30,9	1189,68	114,30	44,50	0	41,8	341,43	154,57	145,10	0	52,6	493,18	194,83	245,71
5	0	32,1	196,29	109,11	55,06	0	43,4	353,31	147,54	162,34	0	54,7	510,34	185,98	269,61
				IRR	**-49%**				**IRR**	**-37%**				**IRR**	**-32%**
				MIRR	**-41%**				**MIRR**	**-27%**				**MIRR**	**-22%**

Table 20. IRR, MIRR and revenue of CdTe in vertical surface.

CdTe															
Vertical															
	Lower range					**Average range**					**Higher range**				
Year	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before Tax flow**	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before Tax Flow**	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before tax-cash flow**
0	2640	0,0	0,00	0	-2640	3570	0,0	0,00	0	-3570	4500	0,0	0,00	0	-4500
1	0	27,5	153,30	129,89	-4,05	0	37,1	275,93	175,64	63,16	0	46,8	398,57	221,4	130,37
2	0	28,6	158,63	124,69	5,39	0	38,6	285,54	168,62	78,30	0	48,7	412,44	212,54	151,23
3	0	29,7	164,15	119,50	14,95	0	40,2	295,47	161,59	93,72	0	50,6	426,79	203,69	172,48
4	0	30,9	169,86	114,30	24,68	0	41,8	305,75	154,57	109,42	0	52,6	441,65	194,83	194,17
5	0	32,1	175,77	109,11	34,55	0	43,4	316,39	147,54	125,42	0	54,7	457,01	185,98	216,28
				IRR	**-55%**				**IRR**	**-42%**				**IRR**	**-36%**
				MIRR	**-50%**				**MIRR**	**-32%**				**MIRR**	**-26%**

Table 21. IRR, MIRR and revenue of CdTe in 30° angle.

CdTe															
30° angle															
	Lower range					Average range					Higher range				
Year	Investment	O&M	Revenue	Depreciation	Before Tax flow	Investment	O&M	Revenue	Depreciation	Before Tax Flow	Investment	O&M	Revenue	Depreciation	Before tax-cash flow
0	2640	0,0	0,00	0	-2640	3570	0,0	0,00	0	-3570	4500	0,0	0,00	0	-4500
1	0	27,5	191,57	129,89	34,22	0	37,1	344,82	175,64	132,05	0	46,8	498,08	221,4	229,88
2	0	28,6	198,23	124,69	44,99	0	38,6	356,82	168,62	149,59	0	48,7	515,41	212,54	254,20
3	0	29,7	205,13	119,50	55,94	0	40,2	369,24	161,59	167,49	0	50,6	533,35	203,69	279,04
4	0	30,9	212,27	114,30	67,09	0	41,8	382,09	154,57	185,76	0	52,6	551,91	194,83	304,43
5	0	32,1	219,66	109,11	78,43	0	43,4	395,39	147,54	204,41	0	54,7	571,11	185,98	330,38
				IRR	**-44%**				**IRR**	**-33%**				**IRR**	**-28%**
				MIRR	**-34%**				**MIRR**	**-23%**				**MIRR**	**-19%**

Table 22. IRR, MIRR and revenue of CdTe in angle is adjusted each month to get optimum sunlight.

CdTe															
angle is adjusted each month to get optimum sunlight															
	Lower range					**Average range**					**Higher range**				
Year	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before Tax flow**	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before Tax Flow**	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before tax-cash flow**
0	2640	0,0	0,00	0	-2640	3570	0,0	0,00	0	-3570	4500	0,0	0,00	0	-4500
1	0	27,5	204,67	129,89	47,33	0	37,1	368,41	175,64	155,64	0	46,8	532,15	221,4	263,95
2	0	28,6	211,79	124,69	58,55	0	38,6	381,23	168,62	174,00	0	48,7	381,23	212,54	120,02
3	0	29,7	219,17	119,50	69,97	0	40,2	394,50	161,59	192,75	0	50,6	569,83	203,69	315,52
4	0	30,9	226,79	114,30	81,61	0	41,8	408,23	154,57	211,89	0	52,6	589,66	194,83	342,19
5	0	32,1	234,68	109,11	93,45	0	43,4	422,43	147,54	231,46	0	54,7	610,18	185,98	369,45
				IRR	**-41%**				**IRR**	**-31%**				**IRR**	**-27%**
				MIRR	**-31%**				**MIRR**	**-21%**				**MIRR**	**-19%**

Table 23. IRR, MIRR and revenue of CdTe in 15° angle.

CdTe															
15° angle															
	Lower range					Average range					Higher range				
Year	Investment	O&M	Revenue	Depreciation	Before Tax flow	Investment	O&M	Revenue	Depreciation	Before Tax Flow	Investment	O&M	Revenue	Depreciation	Before tax-cash flow
0	2640	0,0	0,00	0	-2640	3570	0,0	0,00	0	-3570	4500	0,0	0,00	0	-4500
1	0	27,5	175,97	129,89	18,62	0	37,1	316,74	175,64	103,97	0	46,8	457,52	221,4	189,32
2	0	28,6	182,09	124,69	28,85	0	38,6	327,77	168,62	120,53	0	48,7	473,44	212,54	212,23
3	0	29,7	188,43	119,50	39,23	0	40,2	339,17	161,59	137,42	0	50,6	489,91	203,69	235,61
4	0	30,9	194,99	114,30	49,80	0	41,8	350,97	154,57	154,64	0	52,6	506,96	194,83	259,49
5	0	32,1	201,77	109,11	60,54	0	43,4	363,19	147,54	172,21	0	54,7	524,61	185,98	283,88
				IRR	**-48%**				**IRR**	**-36%**				**IRR**	**-31%**
				MIRR	**-39%**				**MIRR**	**-26%**				**MIRR**	**-21%**

Table 24. IRR, MIRR and revenue of CdTe in 45° angle.

CdTe															
45° angle															
	Lower range					**Average range**					**Higher range**				
Year	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before Tax flow**	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before Tax Flow**	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before tax-cash flow**
0	2640	0,0	0,00	0	-2640	3570	0,0	0,00	0	-3570	4500	0,0	0,00	0	-4500
1	0	27,5	199,06	129,89	41,71	0	37,1	358,30	175,64	145,53	0	46,8	517,55	221,40	249,35
2	0	28,6	205,98	124,69	52,74	0	38,6	370,77	168,62	163,54	0	48,7	535,56	212,54	274,34
3	0	29,7	213,15	119,50	63,95	0	40,2	383,67	161,59	181,92	0	50,6	554,19	203,69	299,88
4	0	30,9	220,57	114,30	75,38	0	41,8	397,02	154,57	200,69	0	52,6	573,48	194,83	326,01
5	0	32,1	228,24	109,11	87,02	0	43,4	410,84	147,54	219,87	0	54,7	593,44	185,98	352,71
				IRR	**-42%**				**IRR**	**-32%**				**IRR**	**-27%**
				MIRR	**-33%**				**MIRR**	**-22%**				**MIRR**	**-17%**

Table 25. IRR, MIRR and revenue of Ci(G)S in horizontal surface.

Ci(G)S															
Horizontal															
	Lower range					Average range					Higher range				
Year	Investment	O&M	Revenue	Depreciation	Before Tax flow	Investment	O&M	Revenue	Depreciation	Before Tax Flow	Investment	O&M	Revenue	Depreciation	Before tax-cash flow
0	2640	0,0	0,00	0	-2640	3570	0,0	0,00	0	-3570	4500	0,0	0,00	0	-4500
1	0	27,5	186,58	129,89	29,23	0	37,1	335,84	175,64	123,07	0	46,8	485,10	221,40	216,90
2	0	28,6	193,07	124,69	39,82	0	38,6	347,52	168,62	140,29	0	48,7	501,98	212,54	240,77
3	0	29,7	199,79	119,50	50,59	0	40,2	359,62	161,59	157,87	0	50,6	519,45	203,69	265,14
4	0	30,9	206,74	114,30	61,56	0	41,8	372,13	154,57	175,80	0	52,6	537,52	194,83	209,05
5	0	32,1	213,93	109,11	72,71	0	43,4	385,08	147,54	194,11	0	54,7	556,23	185,98	315,50
				IRR	**-45%**				**IRR**	**-34%**				**IRR**	**-29%**
				MIRR	**-36%**				**MIRR**	**-24%**				**MIRR**	**-19%**

Table 26. IRR, MIRR and revenue of Ci(G)S in vertical surface**.**

Ci(G)S															
vertical surface															
	Lower range					**Average range**					**Higher range**				
Year	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before Tax flow**	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before Tax Flow**	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before tax-cash flow**
0	2640	0,0	0,00	0	-2640	3570	0,0	0,00	0	-3570	4500	0,0	0,00	0	-4500
1	0	27,5	167,23	129,89	9,89	0	37,1	301,02	175,64	88,25	0	46,8	434,80	221,40	166,60
2	0	28,6	173,05	124,69	19,81	0	38,6	311,49	168,62	104,26	0	48,7	449,93	212,54	188,72
3	0	29,7	179,07	119,50	29,88	0	40,2	322,33	161,59	120,59	0	50,6	465,59	203,69	211,28
4	0	30,9	185,31	114,30	40,12	0	41,8	333,55	154,57	137,22	0	52,6	481,79	194,83	234,32
5	0	32,1	191,75	109,11	50,52	0	43,4	345,16	147,54	154,18	0	54,7	498,56	185,98	257,83
				IRR	**-50%**				**IRR**	**-38%**				**IRR**	**-33%**
				MIRR	**-42%**				**MIRR**	**-28%**				**MIRR**	**-23%**

Table 27. IRR, MIRR and revenue of Ci(G)S in 30° angle.

Ci(G)S															
30° angle															
	Lower range					Average range					Higher range				
Year	Investment	O&M	Revenue	Depreciation	Before Tax flow	Investment	O&M	Revenue	Depreciation	Before Tax Flow	Investment	O&M	Revenue	Depreciation	Before tax-cash flow
0	2640	0,0	0,00	0	-2640	3570	0,0	0,00	0	-3570	4500	0,0	0,00	0	-4500
1	0	27,5	208,83	129,89	51,49	0	37,1	375,90	175,64	163,13	0	46,8	542,96	221,4	274,76
2	0	28,6	216,10	124,69	62,86	0	38,6	388,98	168,62	181,75	0	48,7	561,86	212,54	300,65
3	0	29,7	223,62	119,50	74,42	0	40,2	402,52	161,59	200,77	0	50,6	581,41	203,69	327,10
4	0	30,9	231,40	114,30	86,22	0	41,8	416,52	154,57	220,19	0	52,6	601,64	194,83	354,17
5	0	32,1	239,45	109,11	98,22	0	43,4	431,02	147,54	240,04	0	54,7	622,58	185,98	381,85
				IRR	**-41%**				**IRR**	**-30%**				**IRR**	**-25%**
				MIRR	**-31%**				**MIRR**	**-20%**				**MIRR**	**-16%**

Table 28. IRR, MIRR and revenue of Ci(G)S in Angle is adjusted each month to get optimum sunlight.

Ci(G)S															
Angle is adjusted each month to get optimum sunlight															
	Lower range					**Average range**					**Higher range**				
Year	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before Tax flow**	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before Tax Flow**	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before tax-cash flow**
0	2640	0,0	0,00	0	-2640	3570	0,0	0,00	0	-3570	4500	0,0	0,00	0	-4500
1	0	27,5	223,39	129,89	66,05	0	37,1	402,11	175,64	189,34	0	46,8	580,82	221,40	312,62
2	0	28,6	231,17	124,69	77,92	0	38,6	416,10	168,62	208,87	0	48,7	601,03	212,54	339,82
3	0	29,7	239,21	119,50	90,01	0	40,2	430,58	161,59	228,83	0	50,6	621,95	203,69	367,64
4	0	30,9	247,54	114,30	102,35	0	41,8	445,56	154,57	249,23	0	52,6	643,59	194,83	396,12
5	0	32,1	256,15	109,11	114,92	0	43,4	461,07	147,54	270,09	0	54,7	665,99	185,98	425,26
			IRR		**-38%**				**IRR**	**-28%**				**IRR**	**-23%**
			MIRR		**-28%**				**MIRR**	**-18%**				**MIRR**	**-14%**

Table 29. IRR, MIRR and revenue of Ci(G)S in 15° angle.

Ci(G)S															
15° angle															
	Lower range					**Average range**					**Higher range**				
Year	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before Tax flow**	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before Tax Flow**	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before tax-cash flow**
0	2640	0,0	0,00	0	-2640	3570	0,0	0,00	0	-3570	4500	0,0	0,00	0	-4500
1	0	27,5	191,98	129,89	34,64	0	37,1	345,57	175,64	132,80	0	46,8	499,16	221,4	230,96
2	0	28,6	198,67	124,69	45,42	0	38,6	357,60	168,62	150,36	0	48,7	516,53	212,54	255,32
3	0	29,7	205,58	119,50	56,38	0	40,2	370,04	161,59	168,29	0	50,6	534,50	203,69	280,20
4	0	30,9	212,73	114,30	67,55	0	41,8	382,92	154,57	186,58	0	52,6	553,11	194,83	305,63
5	0	32,1	220,14	109,11	78,91	0	43,4	396,24	147,54	205,27	0	54,7	572,35	185,98	331,62
				IRR	**-44%**				**IRR**	**-33%**				**IRR**	**-28%**
				MIRR	**-34%**				**MIRR**	**-23%**				**MIRR**	**-18%**

Table 30. IRR, MIRR and revenue of Ci(G)S in 45° angle.

Ci(G)S															
45° angle															
	Lower range					**Average range**					**Higher range**				
Year	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before Tax flow**	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before Tax Flow**	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before tax-cash flow**
0	2640	0,0	0,00	0	-2640	3570	0,0	0,00	0	-3570	4500	0,0	0,00	0	-4500
1	0	27,5	217,15	129,89	59,81	0	37,1	390,87	175,64	178,13	0	46,8	564,60	221,4	296,40
2	0	28,6	224,71	124,69	71,46	0	38,6	404,48	168,62	197,26	0	48,7	584,24	212,54	323,00
3	0	29,7	232,53	119,50	83,33	0	40,2	418,55	161,59	216,76	0	50,6	604,57	203,69	350,28
4	0	30,9	240,62	114,30	95,44	0	41,8	433,12	154,57	236,75	0	52,6	625,61	194,83	378,18
5	0	32,1	248,99	109,11	107,76	0	43,4	448,19	147,54	257,25	0	54,7	647,39	185,98	406,71
				IRR	**-39%**				**IRR**	**-29%**				**IRR**	**-24%**
				MIRR	**-29%**				**MIRR**	**-19%**				**MIRR**	**-15%**

APPENDIX 2. Wind energy

Calculation of IRR and MIRR of onshore and offshore wind energy systems with varying heights and efficiency

Table 1. IRR, MIRR and revenue of onshore in 50m with 20% efficiency.

0nshore -Measured in 50 m															
20% efficiency															
	Lower range					Average range					Higher range				
Year	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before Tax flow**	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before Tax Flow**	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before tax-cash flow**
0	1280	0,0	0,00	0	-1280	1785	0,0	0,00	0	-1785	2290	0,0	0,00	0	-2290
1	0	26,6	54,45	62,98	-35,16	0	37,0	81,67	87,82	-43,17	0	47,6	108,89	112,67	-51,41
2	0	27,7	55,72	60,46	-32,43	0	38,5	83,58	84,31	-39,24	0	49,5	111,44	108,16	-46,26
3	0	28,8	57,02	57,94	-29,72	0	40,0	85,53	80,80	-35,31	0	51,5	114,04	103,65	-41,13
4	0	29,9	58,35	55,42	-27,02	0	41,6	87,53	77,28	-31,40	0	53,6	116,71	99,15	-36,02
5	0	31,1	59,72	52,90	-24,33	0	43,3	89,57	73,77	-27,51	0	55,7	119,43	94,64	-30,93
				IRR		**#NUM!**			**IRR**		**#NUM!**			**IRR**	**#NUM!**
				MIRR		**-100%**			**MIRR**		**-100%**			**MIRR**	**-100%**

Table 2. IRR, MIRR and revenue of onshore in 50m with 30% efficiency.

Onshore-Measured in 50 m															
30% Efficiency															
	Lower range					**Average range**					**Higher range**				
Year	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before Tax flow**	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before Tax Flow**	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before tax-cash flow**
0	1280	0,0	0,00	0	-1280	1785	0,0	0,00	0	-1785	2290	0,0	0,00	0	-2290
1	0	26,6	81,67	62,98	-7,93	0	37,0	122,51	87,82	-2,34	0	47,6	163,34	112,67	3,04
2	0	27,7	83,58	60,46	-4,57	0	38,5	125,37	84,31	2,55	0	49,5	167,16	108,16	9,46
3	0	28,8	85,53	57,94	-1,21	0	40,0	128,30	80,8	7,45	0	51,5	171,06	103,65	15,89
4	0	29,9	87,53	55,42	2,16	0	41,6	131,29	77,28	12,37	0	53,6	175,06	99,15	22,33
5	0	31,1	89,57	52,9	5,23	0	43,3	134,36	73,77	17,28	0	55,7	179,15	94,64	28,79
				IRR	**#NUM!**				**IRR**	**-58%**				**IRR**	**-55%**
				MIRR	**-64%**				**MIRR**	**-53%**				**MIRR**	**-48%**

Table 3. IRR, MIRR and revenue of onshore in 50m with 40% efficiency.

Onshore-Measured in 50 m															
40% Efficiency															
	Lower range					**Average range**					**Higher range**				
Year	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before Tax flow**	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before Tax Flow**	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before tax-cash flow**
0	1280	0,0	0,00	0	-1280	1785	0,0	0,00	0	-1785	2290	0,0	0,00	0	-2290
1	0	26,6	108,89	62,98	19,29	0	37,0	163,34	87,82	38,50	0	47,6	217,79	112,67	57,49
2	0	27,7	111,44	60,46	23,29	0	38,5	167,16	84,31	44,34	0	49,5	222,88	108,16	65,18
3	0	28,8	114,04	57,94	27,30	0	40,0	171,06	80,80	50,22	0	51,5	228,08	103,65	72,91
4	0	29,9	116,71	55,42	31,34	0	41,6	175,06	77,28	56,13	0	53,6	233,41	99,15	80,68
5	0	31,1	119,43	52,9	35,39	0	43,3	179,15	73,77	62,06	0	55,7	238,86	94,64	88,50
				IRR	**-45%**				**IRR**	**-41%**				**IRR**	**-39%**
				MIRR	**-34%**				**MIRR**	**-30%**				**MIRR**	**-29%**

Table 4. IRR, MIRR and revenue of onshore in 50m with 50% efficiency.

Onshore-Measured in 50 m															
50% Efficiency															
	Lower range					**Average range**					**Higher range**				
Year	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before Tax flow**	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before Tax Flow**	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before tax-cash flow**
0	1280	0,0	0,00	0	-1280	1785	0,0	0,00	0	-1785	2290	0,0	0,00	0	-2290
1	0	26,6	136,12	62,98	46,51	0	37,0	204,18	87,82	79,33	0	47,6	272,24	112,67	111,93
2	0	27,7	139,30	60,46	51,15	0	38,5	208,95	84,31	86,13	0	49,5	278,60	108,16	120,90
3	0	28,8	142,55	57,94	55,82	0	40,0	213,83	80,8	92,98	0	51,5	285,10	103,65	129,93
4	0	29,9	145,88	55,42	60,51	0	41,6	218,82	77,28	99,90	0	53,6	291,76	99,15	139,03
5	0	31,1	149,29	52,9	65,24	0	43,3	223,93	73,77	106,85	0	55,7	298,58	94,64	148,22
				IRR	**-35%**				**IRR**	**-32%**				**IRR**	**-30%**
				MIRR	**-24%**				**MIRR**	**-21%**				**MIRR**	**-20%**

Table 5. IRR, MIRR and revenue of onshore in 100m with 20% efficiency.

Onshore-Measured in 100 m															
20% Efficiency															
	Lower range					**Average range**					**Higher range**				
Year	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before Tax flow**	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before Tax Flow**	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before tax-cash flow**
0	1280	0,0	0,00	0	-1280	1785	0,0	0,00	0	-1785	2290	0,0	0,00	0	-2290
1	0	26,6	91,95	62,98	2,34	0	37,0	137,92	87,82	13,08	0	47,6	183,89	112,67	23,59
2	0	27,7	94,09	60,46	5,95	0	38,5	141,14	84,31	18,33	0	49,5	188,19	108,16	30,49
3	0	28,8	96,29	57,94	9,56	0	40,0	144,44	80,80	23,59	0	51,5	192,58	103,65	37,42
4	0	29,9	98,54	55,42	13,17	0	41,6	147,81	77,28	28,89	0	53,6	197,08	99,15	44,35
5	0	31,1	100,84	52,9	16,80	0	43,3	151,27	73,77	34,18	0	55,7	201,69	94,64	51,32
				IRR	**-54%**				**IRR**	**-50%**				**IRR**	**-48%**
				MIRR	**-47%**				**MIRR**	**-40%**				**MIRR**	**-38%**

Table 6. IRR, MIRR and revenue of onshore in 100m with 30% efficiency.

Onshore-Measured in 100 m															
30% Efficiency															
	Lower range					Average range					Higher range				
Year	Investment	O&M	Revenue	Depreciation	Before Tax flow	Investment	O&M	Revenue	Depreciation	Before Tax Flow	Investment	O&M	Revenue	Depreciation	Before tax-cash flow
0	1280	0,0	0,00	0	-1280	1785	0,0	0,00	0	-1785	2290	0,0	0,00	0	-2290
1	0	26,6	137,92	62,98	48,32	0	37,0	206,88	87,82	82,04	0	47,6	275,84	112,67	115,54
2	0	27,7	141,14	60,46	52,99	0	38,5	211,71	84,31	88,90	0	49,5	282,28	108,16	124,59
3	0	28,8	144,44	57,94	57,70	0	40,0	216,66	80,8	95,81	0	51,5	288,88	103,65	133,71
4	0	29,9	147,81	55,42	62,44	0	41,6	221,72	77,28	102,79	0	53,6	295,63	99,15	142,90
5	0	31,1	151,27	52,9	67,22	0	43,3	226,90	73,77	109,82	0	55,7	302,53	94,64	152,17
				IRR	**-34%**				**IRR**	**-31%**				**IRR**	**-30%**
				MIRR	**-24%**				**MIRR**	**-21%**				**MIRR**	**-19%**

Table 7. IRR, MIRR and revenue of onshore in 100 m with 40% efficiency.

Onshore-Measured in 100 m															
40% Efficiency															
	Lower range					**Average range**					**Higher range**				
Year	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before Tax flow**	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before Tax Flow**	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before tax-cash flow**
0	1280	0,0	0,00	0	-1280	1785	0,0	0,00	0	-1785	2290	0,0	0,00	0	-2290
1	0	26,6	183,89	62,98	94,29	0	37,0	275,84	87,82	151,00	0	47,6	367,79	112,67	207,48
2	0	27,7	188,19	60,46	100,04	0	38,5	282,28	84,31	159,47	0	49,5	376,38	108,16	218,68
3	0	28,8	192,58	57,94	105,85	0	40,0	288,88	80,80	168,03	0	51,5	385,17	103,65	230,00
4	0	29,9	197,08	55,42	111,72	0	41,6	295,63	77,28	176,70	0	53,6	394,17	99,15	241,44
5	0	31,1	201,69	52,9	117,64	0	43,3	302,53	73,77	185,45	0	55,7	403,37	94,64	253,01
				IRR	**-23%**				**IRR**	**-20%**				**IRR**	**-19%**
				MIRR	**-14%**				**MIRR**	**-11%**				**MIRR**	**-10%**

Table 8. IRR, MIRR and revenue of onshore in 100m with 50% efficiency**.**

Onshore-Measured in 100 m															
50% Efficiency															
	Lower range					Average range					Higher range				
Year	Investment	O&M	Revenue	Depreciation	Before Tax flow	Investment	O&M	Revenue	Depreciation	Before Tax Flow	Investment	O&M	Revenue	Depreciation	Before tax-cash flow
0	1280	0,0	0,00	0	-1280	1785	0,0	0,00	0	-1785	2290	0,0	0,00	0,00	-2290
1	0	26,6	229,87	62,98	140,26	0	37,0	344,80	87,82	219,96	0	47,6	459,73	112,67	299,43
2	0	27,7	235,24	60,46	147,09	0	38,5	352,85	84,31	230,04	0	49,5	470,47	108,16	312,77
3	0	28,8	240,73	57,94	153,99	0	40,0	361,10	80,8	240,25	0	51,5	481,46	103,65	326,29
4	0	29,9	246,35	55,42	160,99	0	41,6	369,53	77,28	250,60	0	53,6	492,71	99,15	339,98
5	0	31,1	252,11	52,9	168,06	0	43,3	378,16	73,77	261,08	0	55,7	504,22	94,64	353,86
				IRR	**-14%**				**IRR**	**-12%**				**IRR**	**-10%**
				MIRR	**-7%**				**MIRR**	**-5%**				**MIRR**	**-4%**

Table 9. IRR, MIRR and revenue of onshore in 200m with 20% efficiency.

Onshore-Measured in 200 m															
20% Efficiency															
	Lower range					**Average range**					**Higher range**				
Year	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before Tax flow**	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before Tax Flow**	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before tax-cash flow**
0	1280	0,0	0,00	0	-1280	1785	0,0	0,00	0	-1785	2290	0,0	0,00	0	-2290
1	0	26,6	173,00	62,98	83,39	0	37,0	262,29	87,82	137,44	0	47,6	348,79	112,67	188,48
2	0	27,7	170,23	60,46	82,08	0	38,5	258,09	84,31	135,27	0	49,5	343,20	108,16	185,51
3	0	28,8	167,51	57,94	80,77	0	40,0	253,96	80,8	133,12	0	51,5	337,71	103,65	182,54
4	0	29,9	164,83	55,42	79,46	0	41,6	249,90	77,28	120,97	0	53,6	332,31	99,15	179,58
5	0	31,1	162,19	52,9	78,14	0	43,3	245,90	73,77	128,82	0	55,7	326,99	94,64	176,63
				IRR	**-29%**				**IRR**	**-26%**				**IRR**	**-25%**
				MIRR	**-18%**				**MIRR**	**-15%**				**MIRR**	**-14%**

Table 10. IRR, MIRR and revenue of onshore in 200m with 30% efficiency.

Onshore-Measured in 200 m															
30% Efficiency															
	Lower range					Average range					Higher range				
Year	Investment	O&M	Revenue	Depreciation	Before Tax flow	Investment	O&M	Revenue	Depreciation	Before Tax Flow	Investment	O&M	Revenue	Depreciation	Before tax-cash flow
0	1280	0,0	0,00	0	-1280	1785	0,0	0,00	0	-1785	2290	0,0	0,00	0	-2290
1	0	26,6	259,50	62,98	169,89	0	37,0	393,43	87,82	268,59	0	47,6	523,18	112,67	362,88
2	0	27,7	255,34	60,46	167,20	0	38,5	387,14	84,31	264,32	0	49,5	514,81	108,16	357,11
3	0	28,8	251,26	57,94	164,52	0	40,0,	380,94	80,8	260,10	0	51,5	506,57	103,65	351,40
4	0	29,9	247,24	55,42	161,87	0	41,6	374,85	77,28	255,92	0	53,6	498,47	99,15	345,74
5	0	31,1	243,28	52,9	159,24	0	43,3	368,85	73,77	251,77	0	55,7	490,49	94,64	340,13
				IRR	**-13%**				**IRR**		**-10%**			**IRR**	**-8%**
				MIRR	**-5%**				**MIRR**		**-3%**			**MIRR**	**-2%**

Table 11. IRR, MIRR and revenue of onshore in 200m with 40% efficiency.

Onshore-Measured in 200 m															
40% Efficiency															
	Lower range					**Average range**					**Higher range**				
Year	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before Tax flow**	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before Tax Flow**	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before tax-cash flow**
0	1280	0,0	0,00	0	-1280	1785	0,0	0,00	0	-1785	2290	0,0	0,00	0	-2290
1	0	26,6	346,00	62,98	256,39	0	37,0	524,57	87,82	399,73	0	47,6	697,57	112,67	537,27
2	0	27,7	340,46	60,46	252,31	0	38,5	516,18	84,31	393,37	0	49,5	686,41	108,16	528,71
3	0	28,8	335,01	57,94	248,28	0	40,0	507,92	80,8	387,08	0	51,5	675,43	103,65	520,26
4	0	29,9	329,65	55,42	244,28	0	41,6	499,79	77,28	380,87	0	53,6	664,62	99,15	511,89
5	0	31,1	324,38	52,9	240,33	0	43,3	491,80	73,77	374,72	0	55,7	653,99	94,64	503,62
				IRR	**-1%**				**IRR**	**3%**				**IRR**	**4%**
				MIRR	**3%**				**MIRR**	**5%**				**MIRR**	**6%**

Table 12. IRR, MIRR and revenue of onshore in 200m with 50% efficiency.

Onshore-Measured in 200 m															
50% Efficiency															
	Lower range					**Average range**					**Higher range**				
Year	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before Tax flow**	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before Tax Flow**	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before tax-cash flow**
0	1280	0,0	0,00	0	-1280	1785	0,0	0,00	0	-1785	2290	0,0	0,00	0	-2290
1	0	26,6	432,49	62,98	342,89	0	37,0	655,72	87,82	530,87	0	47,0	871,96	112,67	711,66
2	0	27,7	425,57	60,46	337,43	0	38,5	645,23	84,31	522,41	0	49,5	858,01	108,16	700,32
3	0	28,8	418,76	57,94	332,03	0	40,0	634,90	80,8	514,06	0	51,5	844,28	103,65	689,12
4	0	29,9	412,06	55,42	326,70	0	41,6	624,74	77,28	505,82	0	53,6	830,78	99,15	678,05
5	0	31,1	405,47	52,9	321,43	0	43,3	614,75	73,77	497,66	0	55,7	817,48	94,64	667,12
				IRR	**9%**				**IRR**	**14%**				**IRR**	**16%**
				MIRR	**9%**				**MIRR**	**11%**				**MIRR**	**12%**

Table 13. IRR, MIRR and revenue of offshore in 50m with 20% efficiency.

Offshore-Measured in 50m															
20% Efficiency															
	Lower range					Average range					Higher range				
Year	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before Tax flow**	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before Tax Flow**	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before tax-cash flow**
0	2700	0,0	0,00	0	-2700	3885	0,0	0,00	0	-3885	5070	0,0	0,00	0	-5070
1	0	56,2	239,36	132,84	50,36	0	80,8	359,04	191,14	87,09	0	108,6	478,71	249,45	120,69
2	0	58,4	244,95	127,53	59,01	0	84,0	367,42	183,5	99,88	0	112,9	489,90	239,47	135,51
3	0	60,7	250,67	122,21	67,72	0	87,4	376,01	175,85	112,75	0	117,4	501,34	229,49	154,42
4	0	63,2	256,53	116,9	76,45	0	90,9	384,79	168,21	125,68	0	122,1	513,05	219,51	171,41
5	0	65,7	262,52	111,59	85,23	0	94,5	393,78	160,5	138,74	0	127,0	525,04	209,53	188,49
				IRR	**-43%**				**IRR**	**-41%**				**IRR**	**-40%**
				MIRR	**-32%**				**MIRR**	**-30%**				**MIRR**	**-29%**

Table 14. IRR, MIRR and revenue of offshore in 50m with 30% efficiency**.**

Offshore-Measured in 50m															
30% Efficiency															
	Lower range					**Average range**					**Higher range**				
Year	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before Tax flow**	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before Tax Flow**	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before tax-cash flow**
0	2700	0,0	0,00	0	-2700	3885	0,0	0,00	0	-3885	5070	0,0	0,00	0	-5070
1	0	56,2	359,04	132,84	170,04	0	80,8	538,55	191,14	266,60	0	108,6	718,07	249,45	360,04
2	0	58,4	367,42	127,53	181,49	0	84,0	551,13	183,5	283,59	0	112,9	734,84	239,47	382,46
3	0	60,7	376,01	122,21	193,05	0	87,4	564,01	175,85	300,76	0	117,4	752,01	229,49	405,08
4	0	63,2	384,79	116,9	204,72	0	90,9	577,18	168,21	318,07	0	122,1	769,58	219,51	427,93
5	0	65,7	393,78	111,59	216,49	0	94,5	590,67	160,5	335,63	0	127,0	787,55	209,53	451,01
				IRR	**-26%**				**IRR**	**-24%**				**IRR**	**-24%**
				MIRR	**-16%**				**MIRR**	**-15%**				**MIRR**	**-14%**

Table 15. IRR, MIRR and revenue of offshore in 50m with 40% efficiency.

Offshore-Measured in 50m															
40% Efficiency															
	Lower range					**Average range**					**Higher range**				
Year	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before Tax flow**	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before Tax Flow**	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before tax-cash flow**
0	2700	0,0	0,00	0	-2700	3885	0,0	0,00	0	-3885	5070	0,0	0,00	0	-5070
1	0	56,2	478,71	132,84	289,71	0	80,8	718,07	191,14	446,12	0	108,6	957,43	249,45	599,40
2	0	58,4	489,90	127,53	202,96	0	84,0	734,84	183,5	467,30	0	112,9	979,79	239,47	627,40
3	0	60,7	501,34	122,21	318,39	0	87,4	752,01	175,85	488,76	0	174,4	1002,68	229,49	655,75
4	0	63,2	513,05	116,9	332,98	0	90,9	769,58	168,21	510,47	0	122,1	1026,10	219,51	684,46
5	0	65,7	525,04	111,59	347,75	0	94,5	787,55	160,5	532,52	0	127,0	1050,07	209,53	713,52
				IRR	**-15%**				**IRR**	**-13%**				**IRR**	**-13%**
				MIRR	**-7%**				**MIRR**	**-6%**				**MIRR**	**-5%**

Table 16. IRR, MIRR and revenue of offshore in 50m with 50% efficiency**.**

Offshore-Measured in 50m															
50% Efficiency															
	Lower range					**Average range**					**Higher range**				
Year	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before Tax flow**	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before Tax Flow**	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before tax-cash flow**
0	2700	0,0	0,00	0	-2700	3885	0,0	0,00	0	-3885	5070	0,0	0,00	0	-5070
1	0	56,2	598,39	132,84	409,39	0	80,8	897,59	191,14	625,64	0	108,6	1196,78	249,45	838,76
2	0	58,4	612,37	127,53	426,43	0	84,0	918,56	183,50	651,20	0	112,9	1224,74	239,47	872,35
3	0	60,7	626,68	122,21	443,72	0	87,4	940,01	175,85	676,76	0	117,4	1253,35	229,49	906,43
4	0	63,2	641,31	116,9	461,24	0	90,9	961,97	168,21	702,86	0	122,1	1282,63	219,51	940,99
5	0	65,7	656,30	111,59	479,01	0	94,5	984,44	160,50	729,41	0	127,0	1312,59	209,53	976,04
				IRR	**-6%**				**IRR**	**-4%**				**IRR**	**-4%**
				MIRR	**-1%**				**MIRR**	**0%**				**MIRR**	**1%**

Table 17. IRR, MIRR and revenue of offshore in 100m with 20% efficiency.

Offshore-Measured in 100m															
20% Efficiency															
	Lower range					Average range					Higher range				
Year	Investment	O&M	Revenue	Depreciation	Before Tax flow	Investment	O&M	Revenue	Depreciation	Before Tax Flow	Investment	O&M	Revenue	Depreciation	Before tax-cash flow
0	2700	0,0	0,00	0	-2700	3885	0,0	0,00	0	-3885	5070	0,0	0,00	0	-5070
1	0	56,2	347,75	132,84	158,75	0	80,8	521,63	191,14	249,68	0	108,6	695,51	249,45	337,48
2	0	58,4	355,88	127,53	169,94	0	84,0	533,81	183,5	266,27	0	112,9	711,75	239,47	359,36
3	0	60,7	364,19	122,21	181,24	0	87,4	546,28	175,85	283,03	0	117,4	728,38	229,49	381,45
4	0	63,2	372,70	116,9	192,63	0	90,9	559,05	168,21	299,94	0	122,1	745,39	219,51	403,75
5	0	65,7	381,40	111,59	204,11	0	94,5	572,11	160,5	317,07	0	127,0	762,81	209,53	426,26
				IRR	**-27%**				**IRR**	**-26%**				**IRR**	**-25%**
				MIRR	**-17%**				**MIRR**	**-16%**				**MIRR**	**-15%**

Table 18. IRR, MIRR and revenue of offshore in 100m with 30% efficiency.

Offshore-Measured in 100m															
30% Efficiency															
	Lower range					**Average range**					**Higher range**				
Year	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before Tax flow**	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before Tax Flow**	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before tax-cash flow**
0	2700	0,0	0,00	0	-2700	3885	0,0	0,00	0	-3885	5070	0,0	0,00	0	-5070
1	0	56,2	521,63	132,84	332,63	0	80,8	782,44	191,14	510,50	0	108,6	1043,26	249,45	685,23
2	0	58,4	533,81	127,53	347,88	0	84,0	800,72	183,5	533,18	0	112,9	1067,63	239,47	715,24
3	0	60,7	546,28	122,21	363,33	0	87,4	819,43	175,85	556,18	0	117,4	1092,57	229,49	745,64
4	0	63,2	559,05	116,9	378,97	0	90,9	838,57	168,21	579,46	0	122,1	1118,09	219,51	776,45
5	0	65,7	572,11	111,59	394,82	0	94,5	858,16	160,5	603,12	0	127,0	1144,21	209,53	807,66
				IRR	**-12%**				**IRR**	**-10%**				**IRR**	**-9%**
				MIRR	**-5%**				**MIRR**	**-4%**				**MIRR**	**-3%**

Table 19. IRR, MIRR and revenue of offshore in 100m with 40% efficiency**.**

Offshore-Measured in 100m															
40% Efficiency															
	Lower range					Average range					Higher range				
Year	Investment	O&M	Revenue	Depreciation	Before Tax flow	Investment	O&M	Revenue	Depreciation	Before Tax Flow	Investment	O&M	Revenue	Depreciation	Before tax-cash flow
0	2700	0,0	0,00	0	-2700	3885	0,0	0,00	0	-3885	5070	0,0	0,00	0	-5070
1	0	56,2	695,51	132,84	506,51	0	80,8	1043,26	191,14	771,31	0	108,6	1391,01	249,45	1032,99
2	0	58,4	711,75	127,53	525,82	0	84,0	1067,63	183,5	800,09	0	112,9	1423,51	239,47	1071,12
3	0	60,7	728,38	122,21	545,43	0	87,4	1092,57	175,85	829,32	0	117,4	1456,76	229,49	1109,84
4	0	63,2	745,40	116,9	565,32	0	90,9	1118,09	168,21	6858,99	0	122,1	1490,79	219,51	1149,15
5	0	65,7	762,81	111,59	585,52	0	94,5	1144,21	160,5	889,18	0	127,0	1525,62	209,53	1189,07
				IRR	**0%**				**IRR**	**2%**				**IRR**	**3%**
				MIRR	**3%**				**MIRR**	**5%**				**MIRR**	**5%**

Table 20. IRR, MIRR and revenue of offshore in 100m with 50% efficiency.

Offshore-Measured in 100m															
50% Efficiency															
	Lower range					Average range					Higher range				
Year	Investment	O&M	Revenue	Depreciation	Before Tax flow	Investment	O&M	Revenue	Depreciation	Before Tax Flow	Investment	O&M	Revenue	Depreciation	Before tax-cash flow
0	2700	0,0	0,00	0	-2700	3885	0,0	0,00	0	-3885	5070	0,0	0,00	0	-5070
1	0	56,2	869,38	132,84	680,38	0	80,8	1304,08	191,14	1032,13	0	108,6	1738,77	249,45	1380,74
2	0	58,4	889,69	127,53	703,76	0	84,0	1334,54	183,5	1067,00	0	112,9	1779,39	239,47	1427,00
3	0	60,7	910,48	122,21	727,52	0	87,4	1365,71	175,85	1102,46	0	117,4	1820,95	229,49	1474,03
4	0	63,2	931,74	116,9	751,67	0	90,9	1397,62	168,21	1138,51	0	122,1	1863,49	219,51	1521,85
5	0	65,7	953,51	111,59	776,22	0	94,5	1430,27	160,5	1175,23	0	127,0	1907,02	209,53	1570,47
				IRR	**11%**				**IRR**	**13%**				**IRR**	**14%**
				MIRR	**9%**				**MIRR**	**11%**				**MIRR**	**11%**

Table 21. IRR, MIRR and revenue of offshore in 200m with 20% efficiency**.**

Offshore-Measured in 200m															
20% Efficiency															
	Lower range					**Average range**					**Higher range**				
Year	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before Tax flow**	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before Tax Flow**	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before tax-cash flow**
0	2700	0,0	0,00	0	-2700	3885	0,0	0,00	0	-3885	5070	0,0	0,00	0	-5070
1	0	56,2	544,18	132,84	355,18	0	80,8	816,27	191,14	544,32	0	108,6	1088,36	249,45	730,33
2	0	58,4	556,89	127,53	370,95	0	84,0	835,33	183,5	567,79	0	112,9	1113,78	239,47	761,39
3	0	60,7	569,90	122,21	386,95	0	87,4	854,85	175,85	591,60	0	117,4	1139,80	229,49	792,87
4	0	63,2	583,21	116,9	403,14	0	90,9	874,82	168,21	615,71	0	122,1	1166,42	219,51	824,78
5	0	65,7	596,84	111,59	419,55	0	94,5	895,25	160,5	640,22	0	127,0	1193,67	209,53	857,12
				IRR	**-10 %**				**IRR**	**-8%**				**IRR**	**-7%**
				MIRR	**-4%**				**MIRR**	**-2%**				**MIRR**	**-2%**

Table 22. IRR, MIRR and revenue of offshore in 200m with 30% efficiency.

Offshore-Measured in 200m															
30% Efficiency															
	Lower range					Average range					Higher range				
Year	Investment	O&M	Revenue	Depreciation	Before Tax flow	Investment	O&M	Revenue	Depreciation	Before Tax Flow	Investment	O&M	Revenue	Depreciation	Before tax-cash flow
0	2700	0,0	0,00	0	-2700	3885	0,0	0,00	0	-3885	5070	0,0	0,00	0	-5070
1	0	56,2	816,27	132,84	627,27	0	80,8	1224,40	191,14	952,45	0	108,6	1632,53	249,45	1274,51
2	0	58,4	835,33	127,53	649,40	0	84,0	1253,00	183,5	985,46	0	112,9	1670,67	239,47	1318,28
3	0	60,7	854,85	122,21	671,90	0	87,4	1282,27	175,85	1019,02	0	117,4	1709,70	229,49	1362,77
4	0	63,2	874,82	116,9	694,75	0	90,9	1312,23	168,21	1053,12	0	122,1	1749,64	219,51	1407,99
5	0	65,7	895,25	111,59	717,96	0	94,5	1342,88	160,5	1087,85	0	127,0	1790,51	209,53	1453,96
				IRR	**8%**				**IRR**	**10%**				**IRR**	**11%**
				MIRR	**8%**				**MIRR**	**9%**				**MIRR**	**9%**

Table 23. IRR, MIRR and revenue of offshore in 200m with 40% efficiency**.**

Offshore-Measured in 200m															
40% Efficiency															
	Lower range					**Average range**					**Higher range**				
Year	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before Tax flow**	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before Tax Flow**	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before tax-cash flow**
0	2700	0,0	0,00	0	-2700	3885	0,0	0,00	0	-3885	5070	0,0	0,00	0	-5070
1	0	56,2	1088,35	132,84	899,35	0	80,8	1632,53	191,14	1360,58	0	108,6	2176,71	249,45	1818,68
2	0	58,4	1113,78	127,53	927,84	0	84,0	1670,67	183,5	1403,13	0	112,9	2227,56	239,47	1875,17
3	0	60,7	1139,80	122,21	956,84	0	87,4	1709,69	175,85	1446,44	0	117,4	2279,59	229,49	1932,67
4	0	63,2	1166,42	116,9	986,35	0	90,9	1749,63	168,21	1490,53	0	122,1	2332,84	219,51	1991,20
5	0	65,7	1193,67	111,59	1016,38	0	94,5	1790,50	160,5	1535,47	0	127,0	2387,35	209,53	2050,79
				IRR	**22%**				**IRR**	**24%**				**IRR**	**26%**
				MIRR	**16%**				**MIRR**	**17%**				**MIRR**	**17%**

Table 24. IRR, MIRR and revenue of offshore in 200m with 50% efficiency**.**

Offshore-Measured in 200m															
50% Efficiency															
	Lower range					Average range					Higher range				
Year	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before Tax flow**	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before Tax Flow**	**Investment**	**O&M**	**Revenue**	**Depreciation**	**Before tax-cash flow**
0	2700	0,0	0,00	0	-2700	3885	0,0	0,00	0	-3885	5070	0,0	0,00	0	-5070
1	0	56,2	1358,36	132,84	1169,36	0	80,8	2037,55	191,14	1765,60	0	108,6	2716,73	249,45	2358,70
2	0	58,4	1390,10	127,53	1204,16	0	84,0	2085,14	183,5	1817,60	0	112,9	2780,19	239,47	2427,80
3	0	60,7	1422,57	122,21	1239,62	0	87,4	2133,85	175,85	1870,60	0	117,4	2845,14	229,49	2498,21
4	0	63,2	1455,80	116,9	1275,73	0	90,9	2183,70	168,21	1924,59	0	122,1	2911,60	219,51	2569,95
5	0	65,7	1489,81	111,59	1312,52	0	94,5	2234,71	160,5	1979,68	0	127,0	2979,61	209,53	2643,06
				IRR	**35 %**				**IRR**	**38%**				**IRR**	**39 %**
				MIRR	**22%**				**MIRR**	**23%**				**MIRR**	**24%**

APPENDIX 3.Biomass power

Calculation of IRR and MIRR of biomass energy systems (stroker/BFB) at varying levels of operating hours and feedstock use.

Table 1. IRR, MIRR and revenue of Stoker boilers in 7800 operating hours with wood chips.

Stoker boilers /wood chips :7800 operating hours																					
	Lower range							**Average range**							**Higher range**						
Year	**Investment**	**Fuel cost**	**Fixed O&M**	**Variable O&M**	**Revenue**	**Depreciation**	**Before Tax flow**	**Investment**	**Fuel cost**	**Fixed O&M**	**Variable O&M**	**Revenue**	**Depreciation**	**Before Tax Flow**	**Investment**	**Fuel cost**	**Fixed O&M**	**Variable O&M**	**Revenue**	**Depreciation**	**Before tax-cash flow**
0	1880	0	0	0	0,00	0	-1880	3070	0	0	0	0,00	0	-3070	4260	0	0	0,00	0	0	-4260
1	0	194,28	78,21	40,56	486,72	92,5	81,17	0	194,28	127,71	40,56	1095,12	151,04	581,53	0	194,28	177,22	40,56	1703,52	209,59	1081,87
2	0	193,51	81,34	40,40	504,16	88,8	100,12	0	193,51	132,82	40,40	1134,37	145,00	622,65	0	193,51	184,30	40,40	1764,57	201,21	1145,16
3	0	192,73	84,59	40,23	522,23	85,1	119,58	0	192,73	138,13	40,23	1175,02	138,96	664,97	0	192,73	191,68	40,23	1827,82	192,83	1210,34
4	0	191,96	87,97	40,07	540,95	81,4	139,54	0	191,96	143,66	40,07	1217,14	132,92	708,53	0	191,96	199,34	40,07	1893,33	184,44	1277,51
5	0	191,19	91,49	39,91	560,34	77,7	160,04	0	191,19	149,40	39,91	1260,76	126,88	753,37	0	191,19	207,32	39,91	1961,18	176,06	1346,70
						IRR	**-27%**						**IRR**	**3%**						**IRR**	**13 %**
						MIRR	**-18%**						**MIRR**	**5%**						**MIRR**	**11%**

Table 2. IRR, MIRR and revenue of Stoker boilers in 7800 operating hours with Bulk pellets.

Stoker boilers /Bulk pellets :7800 operating hours																					
	Lower range							**Average range**							**Higher range**						
Year	**Investment**	**Fuel cost**	**Fixed O&M**	**Variable O&M**	**Revenue**	**Depreciation**	**Before Tax flow**	**Investment**	**Fuel cost**	**Fixed O&M**	**Variable O&M**	**Revenue**	**Depreciation**	**Before Tax Flow**	**Investment**	**Fuel cost**	**Fixed O&M**	**Variable O&M**	**Revenue**	**Depreciation**	**Before tax-cash flow**
0	1880	0	0	0	0,00	0	-1880	3070	0	0	0	0,00	0	-3070	4260	0	0	0,00	0	0	-4260
1	0	342,83	78,21	40,56	486,72	92,5	-67,38	0	342,83	127,71	40,56	1095,12	151,04	432,98	0	342,83	177,22	40,56	1703,52	209,59	933,32
2	0	341,46	81,34	40,40	504,16	88,8	-47,83	0	341,46	132,82	40,40	1134,37	145,00	474,69	0	341,46	184,30	40,40	1764,57	201,21	997,20
3	0	340,09	84,59	40,23	522,23	85,1	-27,78	0	340,09	138,13	40,23	1175,02	138,96	517,60	0	340,09	191,68	40,23	1827,82	192,83	1062,98
4	0	338,73	87,97	40,07	540,95	81,4	-7,23	0	338,73	143,66	40,07	1217,14	132,92	561,76	0	338,73	199,34	40,07	1893,33	184,44	1130,74
5	0	337,38	91,49	39,91	560,34	77,7	13,86	0	337,38	149,40	39,91	1260,76	126,88	607,19	0	337,38	207,32	39,91	1961,18	176,06	1200,52
						IRR	**#NUM!**						**IRR**	**-5%**						**IRR**	**8%**
						MIRR	**-63%**						**MIRR**	**0%**						**MIRR**	**8%**

Table 3. IRR, MIRR and revenue of Stoker boilers in 4500 operating hours with wood chips.

Stoker boilers /Woodchips :4500 operating hours																					
	Lower range							**Average range**							**Higher range**						
Year	**Investment**	**Fuel cost**	**Fixed O&M**	**Variable O&M**	**Revenue**	**Depreciation**	**Before Tax flow**	**Investment**	**Fuel cost**	**Fixed O&M**	**Variable O&M**	**Revenue**	**Depreciation**	**Before Tax Flow**	**Investment**	**Fuel cost**	**Fixed O&M**	**Variable O&M**	**Revenue**	**Depreciation**	**Before tax-cash flow**
0	1880	0	0	0	0,00	0	-1880	3070	0	0	0	0,00	0	-3070	4260	0	0	0,00	0	0	-4260
1	0	112,07	78,21	22,50	280,80	92,5	-24,48	0	112,07	127,71	22,50	631,80	151,04	218,48	0	112,07	177,22	22,50	982,80	209,59	461,43
2	0	111,62	81,34	22,41	290,86	88,8	-13,30	0	111,62	132,82	22,41	654,44	145,00	242,60	0	111,62	184,30	22,41	1018,02	201,21	498,48
3	0	111,08	84,59	22,30	300,99	85,1	-2,08	0	111,08	138,13	22,30	677,22	138,96	266,75	0	111,08	191,68	22,30	1053,45	192,83	535,57
4	0	110,52	87,97	22,19	311,46	81,4	9,38	0	110,52	143,66	22,19	700,79	132,92	291,50	0	110,52	199,34	22,19	1090,11	184,44	573,62
5	0	109,97	91,49	22,08	322,30	77,7	21,06	0	109,97	149,40	22,08	725,17	126,88	316,84	0	109,97	207,32	22,08	1128,05	176,06	612,62
						IRR	**-59%**						**IRR**	**-22%**						**IRR**	**-13%**
						MIRR	**-56%**						**MIRR**	**-13%**						**MIRR**	**-6%**

Table 4. IRR, MIRR and revenue of Stoker boilers in 4500 operating hours with Bulk pellets.

Stoker boilers /Bulk pellets :4500 operating hours																					
	Lower range							**Average range**							**Higher range**						
Year	**Investment**	**Fuel cost**	**Fixed O&M**	**Variable O&M**	**Revenue**	**Depreciation**	**Before Tax flow**	**Investment**	**Fuel cost**	**Fixed O&M**	**Variable O&M**	**Revenue**	**Depreciation**	**Before Tax Flow**	**Investment**	**Fuel cost**	**Fixed O&M**	**Variable O&M**	**Revenue**	**Depreciation**	**Before tax-cash flow**
0	1880	0	0	0	0,00	0	-1880	3070	0	0	0	0,00	0	-3070	4260	0	0	0,00	0	0	-4260
1	0	197,79	78,21	22,50	280,80	92,5	-110,19	0	197,79	127,71	22,50	631,80	151,04	132,76	0	197,79	177,22	22,50	982,80	209,59	375,71
2	0	197,00	81,34	22,41	290,86	88,8	-98,68	0	197,00	132,82	22,41	654,44	145,00	157,22	0	197,00	184,30	22,41	1018,02	201,21	413,10
3	0	196,01	84,59	22,30	300,99	85,1	-87,01	0	196,01	138,13	22,30	677,22	138,96	181,82	0	196,01	191,68	22,30	1053,45	192,83	450,64
4	0	195,03	87,97	22,19	311,46	81,4	-75,13	0	195,03	143,66	22,19	700,79	132,92	206,99	0	195,03	199,34	22,19	1090,11	184,44	489,11
5	0	194,05	91,49	22,08	322,30	77,7	-63,02	0	194,05	149,40	22,08	725,17	126,88	232,76	0	194,05	207,32	22,08	1128,05	176,06	528,54
						IRR	**#NUM!**						**IRR**	**-29%**						**IRR**	**-17%**
						MIRR	**-100%**						**MIRR**	**-19%**						**MIRR**	**-9%**

Table 5. IRR, MIRR and revenue of Stoker boilers in 7000 operating hours with wood chips.

Stoker boilers /wood chips :7000 operating hours																					
Lower range								**Average range**							**Higher range**						
Year	**Investment**	**Fuel cost**	**Fixed O&M**	**Variable O&M**	**Revenue**	**Depreciation**	**Before Tax flow**	**Investment**	**Fuel cost**	**Fixed O&M**	**Variable O&M**	**Revenue**	**Depreciation**	**Before Tax Flow**	**Investment**	**Fuel cost**	**Fixed O&M**	**Variable O&M**	**Revenue**	**Depreciation**	**Before tax-cash flow**
0	1880	0	0	0	0,00	0	-1880	3070	0	0	0	0,00	0	-3070	4260	0	0	0,00	0	0	-4260
1	0	174,28	78,21	35,00	436,80	92,5	56,82	0	174,28	127,71	35,00	982,80	151,04	494,77	0	174,28	177,22	35,00	1528,80	209,59	932,72
2	0	173,66	81,34	34,86	452,45	88,8	73,80	0	173,66	132,82	34,86	1018,02	145,00	531,68	0	173,66	184,30	34,86	1583,59	201,21	989,56
3	0	172,79	84,59	34,69	468,20	85,1	91,03	0	172,79	138,13	34,69	1053,45	138,96	568,88	0	172,79	191,68	34,69	1638,70	192,83	1046,72
4	0	171,93	87,97	34,51	484,49	81,4	108,68	0	171,93	143,66	34,51	1090,11	132,92	607,09	0	171,93	199,34	34,51	1695,73	184,44	1105,51
5	0	171,07	91,49	34,34	501,35	77,7	126,76	0	171,07	149,40	34,34	1128,05	126,88	646,36	0	171,07	207,32	34,34	1754,74	176,06	1165,96
						IRR	**-32%**						**IRR**	**-2%**						**IRR**	**7%**
						MIRR	**-23%**						**MIRR**	**2%**						**MIRR**	**7%**

Table 6. IRR, MIRR and revenue of Stoker boilers in 7000 operating hours with Bulk pellets.

Stoker boilers /Bulk pellets :7000 operating hours																					
	Lower range							Average range							Higher range						
Year	**Investment**	**Fuel cost**	**Fixed O&M**	**Variable O&M**	**Revenue**	**Depreciation**	**Before Tax flow**	**Investment**	**Fuel cost**	**Fixed O&M**	**Variable O&M**	**Revenue**	**Depreciation**	**Before Tax Flow**	**Investment**	**Fuel cost**	**Fixed O&M**	**Variable O&M**	**Revenue**	**Depreciation**	**Before tax-cash flow**
0	1880	0	0	0	0,00	0	-1880	3070	0	0	0	0,00	0	-3070	4260	0	0	0,00	0	0	-4260
1	0	307,67	78,21	35,00	436,80	92,5	-76,58	0	307,67	127,71	35,00	982,80	151,04	361,38	0	307,67	177,22	35,00	1528,80	209,59	799,33
2	0	306,44	81,34	34,86	452,45	88,8	-58,98	0	306,44	132,82	34,86	1018,02	145,00	398,91	0	306,44	184,30	34,86	1583,59	201,21	856,78
3	0	304,90	84,59	34,69	468,20	85,1	-41,08	0	304,90	138,13	34,69	1053,45	138,96	436,77	0	304,90	191,68	34,69	1638,70	192,83	914,60
4	0	303,35	87,97	34,51	484,49	81,4	-22,74	0	303,35	143,66	34,51	1090,11	132,92	475,67	0	303,35	199,34	34,51	1695,73	184,44	974,08
5	0	301,86	91,49	34,34	501,35	77,7	-4,04	0	301,86	149,40	34,34	1128,05	126,88	515,56	0	301,86	207,32	34,34	1754,74	176,06	1035,16
						IRR	**#NUM!**						**IRR**	**-10%**						**IRR**	**2%**
						MIRR	**-100%**						**MIRR**	**-4%**						**MIRR**	**5%**

Table 7. IRR, MIRR, revenue of Stoker boilers in 8000 operating hours with wood chips.

Stoker boilers /wood chips :8000 operating hours																					
	Lower range							**Average range**							**Higher range**						
Year	**Investment**	**Fuel cost**	**Fixed O&M**	**Variable O&M**	**Revenue**	**Depreciation**	**Before Tax flow**	**Investment**	**Fuel cost**	**Fixed O&M**	**Variable O&M**	**Revenue**	**Depreciation**	**Before Tax Flow**	**Investment**	**Fuel cost**	**Fixed O&M**	**Variable O&M**	**Revenue**	**Depreciation**	**Before tax-cash flow**
0	1880	0	0	0	0,00	0	-1880	3070	0	0	0	0,00	0	-3070	4260	0	0	0,00	0	0	-4260
1	0	199,26	78,21	40,00	499,20	92,5	89,23	0	199,26	127,71	40,00	1123,20	151,04	605,18	0	199,26	177,22	40,00	1747,20	209,59	1121,13
2	0	198,47	81,34	39,84	517,09	88,8	108,65	0	198,47	132,82	39,84	1163,46	145,00	647,33	0	198,47	184,30	39,84	1809,82	201,21	1186,00
3	0	197,47	84,59	39,64	535,09	85,1	128,28	0	197,47	138,13	39,64	1203,94	138,96	689,74	0	197,47	191,68	39,64	1872,80	192,83	1251,18
4	0	196,49	87,97	39,44	553,71	81,4	148,40	0	196,49	143,66	39,44	1245,84	132,92	733,33	0	196,49	199,34	39,44	1937,97	184,44	1318,26
5	0	195,50	91,49	39,25	572,98	77,7	169,03	0	195,50	149,40	39,25	1289,20	126,88	778,16	0	195,50	207,32	39,25	2005,42	176,06	1387,29
						IRR	**-26%**						**IRR**	**4%**						**IRR**	**14%**
						MIRR	**-17%**						**MIRR**	**6%**						**MIRR**	**11%**

Table 8. IRR, MIRR, and revenue of Stoker boilers in 8000 operating hours with Bulk pellets.

Stoker boilers /Bulk pellets :8000 operating hours																					
Lower range								**Average range**							**Higher range**						
Year	**Investment**	**Fuel cost**	**Fixed O&M**	**Variable O&M**	**Revenue**	**Depreciation**	**Before Tax flow**	**Investment**	**Fuel cost**	**Fixed O&M**	**Variable O&M**	**Revenue**	**Depreciation**	**Before Tax Flow**	**Investment**	**Fuel cost**	**Fixed O&M**	**Variable O&M**	**Revenue**	**Depreciation**	**Before tax-cash flow**
0	1880	0	0	0	0,00	0	-1880	3070	0	0	0	0,00	0	-3070	4260	0	0	0,00	0	0	-4260
1	0	351,62	78,21	40,00	499,20	92,5	-63,13	0	351,62	127,71	40,00	1123,20	151,04	452,83	0	351,62	177,22	40,00	1747,20	209,59	968,77
2	0	350,21	81,34	39,84	517,09	88,8	-43,10	0	350,21	132,82	39,84	1163,46	145,00	495,58	0	350,21	184,30	39,84	1809,82	201,21	1034,25
3	0	348,46	84,59	39,64	535,09	85,1	-22,71	0	348,46	138,13	39,64	1203,94	138,96	538,75	0	348,46	191,68	39,64	1872,80	192,83	1100,19
4	0	346,72	87,97	39,44	553,71	81,4	-1,83	0	346,72	143,66	39,44	1245,84	132,92	583,10	0	346,72	199,34	39,44	1937,97	184,44	1168,03
5	0	344,99	91,49	39,25	572,98	77,7	19,55	0	344,99	149,40	39,25	1289,20	126,88	628,68	0	344,99	207,32	39,25	2005,42	176,06	1237,81
						IRR	**#NUM!**						**IRR**	**-4%**						**IRR**	**9%**
						MIRR	**-60%**						**MIRR**	**0%**						**MIRR**	**8%**

Table 9. IRR, MIRR and revenue of BFB/CFB in 7800 operating hours with wood chips.

BFB/CFB/Woodchips:7800 operating hours																					
	Lower range							**Average range**							**Higher range**						
Year	**Investment**	**Fuel cost**	**Fixed O&M**	**Variable O&M**	**Revenue**	**Depreciation**	**Before Tax flow**	**Investment**	**Fuel cost**	**Fixed O&M**	**Variable O&M**	**Revenue**	**Depreciation**	**Before Tax Flow**	**Investment**	**Fuel cost**	**Fixed O&M**	**Variable O&M**	**Revenue**	**Depreciation**	**Before tax-cash flow**
0	2170	0	0	0	0,00	0	-2170	3335	0	0	0	0,00	0	-3335	4500	0	0	0,00	0	0	-4500
1	0	194,28	90,27	40,56	567,84	106,76	135,97	0	194,28	138,74	40,56	1135,68	164,08	598,02	0	194,28	187,20	40,56	1703,52	221,40	1060,08
2	0	193,51	93,88	40,40	588,19	102,49	157,92	0	193,51	144,29	40,40	1176,38	157,52	640,67	0	193,51	194,69	40,40	1764,57	212,54	1123,44
3	0	192,73	97,64	40,23	609,27	98,22	180,45	0	192,73	150,06	40,23	1218,54	150,96	684,56	0	192,73	202,48	40,23	1827,82	203,69	1188,69
4	0	191,96	101,54	40,07	631,11	93,95	203,58	0	191,96	156,06	40,07	1262,22	144,39	729,74	0	191,96	210,57	40,07	1893,33	194,83	1255,89
5	0	191,19	105,61	39,91	653,73	89,68	227,34	0	191,19	162,30	39,91	1307,45	137,83	776,22	0	191,19	219,00	39,91	1961,18	185,98	1325,10
						IRR	**-22%**						**IRR**	**1%**						**IRR**	**10%**
						MIRR	**-14%**						**MIRR**	**4%**						**MIRR**	**9%**

Table 10. IRR, MIRR, revenue of BFB/CFB in 7800 operating hours with Bulk pellets.

BFB/CFB/Bulk pellets:7800 operating hours																					
	Lower range							Average range							Higher range						
Year	**Investment**	**Fuel cost**	**Fixed O&M**	**Variable O&M**	**Revenue**	**Depreciation**	**Before Tax flow**	**Investment**	**Fuel cost**	**Fixed O&M**	**Variable O&M**	**Revenue**	**Depreciation**	**Before Tax Flow**	**Investment**	**Fuel cost**	**Fixed O&M**	**Variable O&M**	**Revenue**	**Depreciation**	**Before tax-cash flow**
0	2170	0	0	0	0,00	0	-2170	3335	0	0	0	0,00	0	-3335	4500	0	0	0,00	0	0	-4500
1	0	342,83	90,27	40,56	567,84	106,76	-12,58	0	342,83	138,74	40,56	1135,68	164,08	449,47	0	342,83	187,20	40,56	1703,52	221,40	911,53
2	0	341,46	93,88	40,40	588,19	102,49	9,96	0	341,46	144,29	40,40	1176,38	157,52	492,72	0	341,46	194,69	40,40	1764,57	212,54	975,49
3	0	340,09	97,64	40,23	609,27	98,22	33,09	0	340,09	150,06	40,23	1218,54	150,96	537,20	0	340,09	202,48	40,23	1827,82	203,69	1041,32
4	0	338,73	101,54	40,07	631,11	93,95	56,81	0	338,73	156,06	40,07	1262,22	144,39	582,96	0	338,73	210,57	40,07	1893,33	194,83	1109,12
5	0	337,38	105,61	39,91	653,73	89,68	81,15	0	337,38	162,30	39,91	1307,45	137,83	630,04	0	337,38	219,00	39,91	1961,18	185,98	1178,92
						IRR	**-44%**						**IRR**	**-6%**						**IRR**	**5%**
						MIRR	**-38%**						**MIRR**	**-1%**						**MIRR**	**6%**

Table 11. IRR, MIRR and revenue of BFB/CFB in 4500 operating hours with wood chips.

BFB/CFB/Woodchips:4500 operating hours																					
	Lower range							**Average range**							**Higher range**						
Year	**Investment**	**Fuel cost**	**Fixed O&M**	**Variable O&M**	**Revenue**	**Depreciation**	**Before Tax flow**	**Investment**	**Fuel cost**	**Fixed O&M**	**Variable O&M**	**Revenue**	**Depreciation**	**Before Tax Flow**	**Investment**	**Fuel cost**	**Fixed O&M**	**Variable O&M**	**Revenue**	**Depreciation**	**Before tax-cash flow**
0	2170	0	0	0	0,00	0	-2170	3335	0	0	0	0,00	0	-3335	4500	0	0	0,00	0	0	-4500
1	0	112,07	90,27	22,50	327,60	106,76	-4,00	0	112,07	138,74	22,50	655,20	164,08	217,82	0	112,07	187,20	22,50	982,80	221,40	439,63
2	0	111,62	93,88	22,41	339,34	102,49	8,94	0	111,62	144,29	22,41	678,68	157,52	242,85	0	111,62	194,69	22,41	1018,02	212,54	476,77
3	0	111,08	97,64	22,30	351,15	98,22	21,91	0	111,08	150,06	22,30	702,30	150,96	267,91	0	111,08	202,48	22,30	1053,45	203,69	513,91
4	0	110,52	101,54	22,19	363,37	93,95	35,17	0	110,52	156,06	22,19	726,74	144,39	293,58	0	110,52	210,57	22,19	1090,11	194,83	552,00
5	0	109,97	105,61	22,08	376,02	89,68	48,68	0	109,97	162,30	22,08	752,03	137,83	319,85	0	109,97	219,00	22,08	1128,05	185,98	519,02
						IRR	**-49%**						**IRR**	**-23%**						**IRR**	**-16%**
						MIRR	**-44%**						**MIRR**	**-14%**						**MIRR**	**-8%**

Table 12. IRR, MIRR and revenue of BFB/CFB in 4500 operating hours with Bulk pellets.

BFB/CFB/Bulk pellets:4500 operating hours																					
Lower range								**Average range**							**Higher range**						
Year	**Investment**	**Fuel cost**	**Fixed O&M**	**Variable O&M**	**Revenue**	**Depreciation**	**Before Tax flow**	**Investment**	**Fuel cost**	**Fixed O&M**	**Variable O&M**	**Revenue**	**Depreciation**	**Before Tax Flow**	**Investment**	**Fuel cost**	**Fixed O&M**	**Variable O&M**	**Revenue**	**Depreciation**	**Before tax-cash flow**
0	2170	0	0	0	0,00	0	-2170	3335	0	0	0	0,00	0	-3335	4500	0	0	0,00	0	0	-4500
1	0	197,79	90,27	22,50	327,60	106,76	-89,72	0	197,79	138,74	22,50	655,20	164,08	132,10	0	197,79	187,20	22,50	982,80	221,40	353,91
2	0	197,00	93,88	22,41	339,34	102,49	-76,44	0	197,00	144,29	22,41	678,68	157,52	157,47	0	197,00	194,69	22,41	1018,02	212,54	391,39
3	0	196,01	97,64	22,30	351,15	98,22	-63,02	0	196,01	150,06	22,30	702,30	150,96	182,98	0	196,01	202,48	22,30	1053,45	203,69	428,98
4	0	195,03	101,54	22,19	363,37	93,95	-49,34	0	195,03	156,06	22,19	726,74	144,39	209,07	0	195,03	210,57	22,19	1090,11	194,83	467,49
5	0	194,05	105,61	22,08	376,02	89,68	-35,40	0	194,05	162,30	22,08	752,03	137,83	235,77	0	194,05	219,00	22,08	1128,05	185,98	506,94
						IRR	**#NUM!**						**IRR**	**-30%**						**IRR**	**-20%**
						MIRR	**-100%**						**MIRR**	**-21%**						**MIRR**	**-11%**

Table 13. IRR, MIRR and revenue of BFB/CFB in 7000 operating hours with Wood chips.

BFB/CFB/Woodchips:7000 operating hours																					
	Lower range							Average range							Higher range						
Year	Investment	Fuel cost	Fixed O&M	Variable O&M	Revenue	Depreciation	Before Tax flow	Investment	Fuel cost	Fixed O&M	Variable O&M	Revenue	Depreciation	Before Tax Flow	Investment	Fuel cost	Fixed O&M	Variable O&M	Revenue	Depreciation	Before tax-cash flow
0	2170	0	0	0	0,00	0	-2170	3335	0	0	0	0,00	0	-3335	4500	0	0	0,00	0	0	-4500
1	0	174,28	90,27	35,00	509,60	106,76	103,29	0	174,28	138,74	35,00	1019,20	164,08	507,11	0	174,28	187,20	35,00	1528,80	221,40	910,92
2	0	173,66	93,88	34,86	527,86	102,49	122,97	0	173,66	144,29	34,86	1055,73	157,52	545,40	0	173,66	194,69	34,86	1583,59	212,54	967,85
3	0	172,79	97,64	34,69	546,23	98,22	142,90	0	172,79	150,06	34,69	1092,47	150,96	583,97	0	172,79	202,48	34,69	1638,70	203,69	1025,06
4	0	171,93	101,54	34,51	565,24	93,95	163,31	0	171,93	156,06	34,51	1130,49	144,39	623,60	0	171,93	210,57	34,51	1695,73	194,83	1083,89
5	0	171,07	105,61	34,34	584,91	89,68	184,22	0	171,07	162,30	34,34	1169,83	137,83	664,29	0	171,07	219,00	34,34	1754,74	185,98	1144,36
						IRR	**-27%**						**IRR**	**-4%**						**IRR**	**4%**
						MIRR	**-18%**						**MIRR**	**0%**						**MIRR**	**6%**

Table 14. IRR, MIRR, revenue of BFB/CFB in 7000 operating hours with Bulk pellets.

BFB/CFB/Bulk pellets:7000 operating hours																					
	Lower range							**Average range**							**Higher range**						
Year	**Investment**	**Fuel cost**	**Fixed O&M**	**Variable O&M**	**Revenue**	**Depreciation**	**Before Tax flow**	**Investment**	**Fuel cost**	**Fixed O&M**	**Variable O&M**	**Revenue**	**Depreciation**	**Before Tax Flow**	**Investment**	**Fuel cost**	**Fixed O&M**	**Variable O&M**	**Revenue**	**Depreciation**	**Before tax-cash flow**
0	2170	0	0	0	0,00	0	-2170	3335	0	0	0	0,00	0	-3335	4500	0	0	0,00	0	0	-4500
1	0	307,67	90,27	35,00	509,60	106,76	-30,10	0	307,67	138,74	35,00	1019,20	164,08	373,72	0	307,67	187,20	35,00	1528,80	221,40	777,53
2	0	306,44	93,88	34,86	527,86	102,49	-9,81	0	306,44	144,29	34,86	1055,73	157,52	412,63	0	306,44	194,69	34,86	1583,59	212,54	835,07
3	0	304,90	97,64	34,69	546,23	98,22	10,79	0	304,90	150,06	34,69	1092,47	150,96	451,86	0	304,90	202,48	34,69	1638,70	203,69	892,95
4	0	303,35	101,54	34,51	565,24	93,95	31,89	0	303,35	156,06	34,51	1130,49	144,39	492,17	0	303,35	210,57	34,51	1695,73	194,83	952,46
5	0	301,86	105,61	34,34	584,91	89,68	53,42	0	301,86	162,30	34,34	1169,83	137,83	533,49	0	301,86	219,00	34,34	1754,74	185,98	1013,56
						IRR	**-50%**						**IRR**	**-11%**						**IRR**	**0%**
						MIRR	**-46%**						**MIRR**	**-5%**						**MIRR**	**3%**

Table 15. IRR, MIRR and revenue of BFB/CFB in 8000 operating hours with Wood chips.

<table>
<tr><th colspan="22">BFB/CFB/Woodchips:8000 operating hours</th></tr>
<tr><th colspan="8">Lower range</th><th colspan="7">Average range</th><th colspan="7">Higher range</th></tr>
<tr><th>Year</th><th>Investment</th><th>Fuel cost</th><th>Fixed O&M</th><th>Variable O&M</th><th>Revenue</th><th>Depreciation</th><th>Before Tax flow</th><th>Investment</th><th>Fuel cost</th><th>Fixed O&M</th><th>Variable O&M</th><th>Revenue</th><th>Depreciation</th><th>Before Tax Flow</th><th>Investment</th><th>Fuel cost</th><th>Fixed O&M</th><th>Variable O&M</th><th>Revenue</th><th>Depreciation</th><th>Before tax-cash flow</th></tr>
<tr><td>0</td><td>2170</td><td>0</td><td>0</td><td>0</td><td>0,00</td><td>0</td><td>-2170</td><td>3335</td><td>0</td><td>0</td><td>0</td><td>0,00</td><td>0</td><td>-3335</td><td>4500</td><td>0</td><td>0</td><td>0,00</td><td>0</td><td>0</td><td>-4500</td></tr>
<tr><td>1</td><td>0</td><td>199,26</td><td>90,27</td><td>40,00</td><td>582,40</td><td>106,76</td><td>146,10</td><td>0</td><td>199,26</td><td>138,74</td><td>40,00</td><td>1164,80</td><td>164,08</td><td>622,72</td><td>0</td><td>199,26</td><td>187,20</td><td>40,00</td><td>1747,20</td><td>221,40</td><td>1099,34</td></tr>
<tr><td>2</td><td>0</td><td>198,47</td><td>93,88</td><td>39,84</td><td>603,27</td><td>102,49</td><td>168,59</td><td>0</td><td>198,47</td><td>144,29</td><td>39,84</td><td>1206,55</td><td>157,52</td><td>666,43</td><td>0</td><td>198,47</td><td>194,69</td><td>39,84</td><td>1809,82</td><td>212,54</td><td>1164,28</td></tr>
<tr><td>3</td><td>0</td><td>197,47</td><td>97,64</td><td>39,64</td><td>624,27</td><td>98,22</td><td>191,29</td><td>0</td><td>197,47</td><td>150,06</td><td>39,64</td><td>1248,53</td><td>150,96</td><td>710,40</td><td>0</td><td>197,47</td><td>202,48</td><td>39,64</td><td>1872,80</td><td>203,69</td><td>1229,52</td></tr>
<tr><td>4</td><td>0</td><td>196,49</td><td>101,54</td><td>39,44</td><td>645,99</td><td>93,95</td><td>214,57</td><td>0</td><td>196,49</td><td>156,06</td><td>39,44</td><td>1219,98</td><td>144,39</td><td>755,60</td><td>0</td><td>196,49</td><td>210,57</td><td>39,44</td><td>1937,97</td><td>194,83</td><td>1296,64</td></tr>
<tr><td>5</td><td>0</td><td>195,50</td><td>105,61</td><td>39,25</td><td>668,47</td><td>89,68</td><td>238,44</td><td>0</td><td>195,50</td><td>162,30</td><td>39,35</td><td>1336,94</td><td>137,83</td><td>802,06</td><td>0</td><td>195,50</td><td>219,00</td><td>39,35</td><td>2005,42</td><td>185,98</td><td>1365,69</td></tr>
<tr><td colspan="6"></td><td>IRR</td><td>-21%</td><td colspan="5"></td><td>IRR</td><td>2%</td><td colspan="5"></td><td>IRR</td><td>11%</td></tr>
<tr><td colspan="6"></td><td>MIRR</td><td>-13%</td><td colspan="5"></td><td>MIRR</td><td>4%</td><td colspan="5"></td><td>MIRR</td><td>10%</td></tr>
</table>

Table 16. IRR, MIRR, revenue of BFB/CFB in 7000 operating hours with Bulk pellets.

BFB/CFB/Bulk pellets:8000 operating hours																					
	Lower range							**Average range**							**Higher range**						
Year	**Investment**	**Fuel cost**	**Fixed O&M**	**Variable O&M**	**Revenue**	**Depreciation**	**Before Tax flow**	**Investment**	**Fuel cost**	**Fixed O&M**	**Variable O&M**	**Revenue**	**Depreciation**	**Before Tax Flow**	**Investment**	**Fuel cost**	**Fixed O&M**	**Variable O&M**	**Revenue**	**Depreciation**	**Before tax-cash flow**
0	2170	0	0	0	0,00	0	-2170	3335	0	0	0	0,00	0	-3335	4500	0	0	0,00	0	0	-4500
1	0	351,62	90,27	40,00	582,40	106,76	-6,25	0	351,62	138,74	40,00	1164,80	164,08	470,36	0	351,62	187,20	40,00	1747,20	221,40	946,98
2	0	350,21	93,88	39,84	603,27	102,49	16,85	0	350,21	144,29	39,84	1206,55	157,52	540,69	0	350,21	194,69	39,84	1809,82	212,54	1012,54
3	0	348,46	97,64	39,64	624,27	98,22	40,31	0	348,46	150,06	39,64	1248,53	150,96	559,41	0	348,46	202,48	39,64	1872,80	203,69	1078,53
4	0	346,72	101,54	39,44	645,99	93,95	64,34	0	346,72	156,06	39,44	1291,98	144,39	605,37	0	346,72	210,57	39,44	1937,97	194,83	1146,41
5	0	344,99	105,61	39,25	668,47	89,68	88,95	0	344,99	162,30	39,35	1336,94	137,83	652,58	0	344,99	219,00	39,35	2005,42	185,98	1216,21
						IRR	**-42%**						**IRR**	**-5%**						**IRR**	**6%**
						MIRR	**-36%**						**MIRR**	**-1%**						**MIRR**	**7%**