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COMPARATIVE ASSESSMENT OF INVESTMENT OPPORTUNITIES INTO SUBSIDIZED RENEWABLE ENERGY PRODUCTION

Master's thesis
International Business Administration

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ABSTRACT

Climate change has become a fact and its existence can no longer be debated. Therefore, countries are taking real measures to combat climate change in a variety of sectors by limiting their greenhouse gas emissions. This thesis focuses on the overall policy set out by the European Union to combat climate change and the energy sector– the largest producer of greenhouse gases in the Union. The move from non-renewable energy sources to renewable energy sources is a precondition to fulfilling the European Unions climate ambitions by 2030 and achieving carbon neutrality by 2050.

This thesis aims to discover the best alternative for energy production from renewable energy sources in a sustainable way in order to phase out non-renewable sources as a raw material. To complete this aim, the author first analyses historical subsidy data to compare different renewable energy alternatives and their prevalence in Estonia’s energy sector. Secondly, the author compares the different alternatives by technological comparison. And thirdly, the author calculates investment feasibility criteria to find the most suitable option among the alternatives.

The results of the graduation thesis would indicate that with given inputs of subsidy policy data, investment cost data and technological factors, the best opportunity would lie with solar power by investing in solar photovoltaics technology. The recommendation is supported by the low associated costs of the technology, long technical lifetime and constantly improving efficiency and declining costs.

Keywords: renewable energy production, climate change, feasibility, technology, subsidy

INTRODUCTION

Climate change is the predominant issue of the 21st century thus far. The need for change was accepted by 196 countries worldwide during the 21st Conference of Parties at the end of 2015 and signed as the Paris Climate Agreement. The Agreement stipulates that all of the signees have to limit their emissions of greenhouse gases and we, as a population on earth, need to reach a peak for emissions as soon as possible and start on reducing them as time goes on. The aim is to limit global warming to 1,5 degrees Celsius, compared to pre-industrial temperature levels (United Nations Framework Convetion of Climate Change, 2016).

The reality of climate change was first publicly and effectively introduced by James Hansen with his adress to the United States Congress in 1988. Mr. Hansen concluded that the earth was warmer than it had ever been and it had a direct causal relationship with greenhouse gases. He further concluded that the emission effect was large enough to warrant high probability for extreme weather events such as heat waves (Hansen, 1988). Since then, there has been much disagreement and disinformation about the causal relationship between global warming and greenhouse gas emissions. This can be explained by the large business interests involved, which would suffer from an emissions reduction. Such industries are widely believed to be the oil and gas industry, the metallurgical industry and other industries that rely on the extraction and exploitation of natural resources.

The year 2020 was pivotal to the actions required in mitigating the effects of climate change. During 2020, the global pandemic crisis of the novel Corona Virus, Covid-19 got underway. The pandemic forced people and companies to re-evaluate their habits and business practices to adapt to this new reality. At the start of 2021, while the pandemic was still underway, definite actions and their consequences to the global commodity and consumer markets can be observed. The electric vehicle market in the US has began to increase with incresing orders (Khedarian, 2021) and Chinese electric vehicle producers are reporting triple digit mothly delivery increases (Goldstein, 2021). The crude oil prices, which went to zero in 2020, due to lack of demand because of the pandemic, have started to rebound, but are not expected to reach pre-pandemic levels any time soon (Kearney, 2021). The global green energy market has been rising ever since the end of 2020 and a clear re-focusing to sustainable energy can be observed from the worlds largest retailing companies such as Amazon, Walmart and Home Depot (Khandelwal, 2021). All of these new realities are expected to influence the greenhouse gas emissions worldwide.

While other countries are taking a more stand-alone approach to the issue, the European Union plans to fulfill its promise with the adoption of the European Green Deal. The Green Deal is a growth strategy that intends to transform the union and all of its member states into a a new society with a resource efficient and competitive economy. There will be no net-emissions by 2050 and economic growth will be de-coupled from resource use (European Commision, 2019). The holistic approach will tackle different aspects of the turnaround needed, taking into account energy, food supply, circular economy, construction, environmental preservation and financing the change. In order to make the no net-emissions ambition binding to all member states, the European Union will decree it as the European Climate Law (European Commission, 2021).

One of the aspects of the Green Deal is to promote and encourage investment into renewable energy production by private companies. Renewable energy can be defined as energy generated from renewable non-fossil sources such as wind, solar, aerothermal, geothermal, hydrothermal, ocean energy, hydropower, biomass, landfill gas, sewage treatment plant gas (European Commission, 2009). One of the ways that a member state can encourage investment is through support schemes. Support schemes can entail state aid to certain sectors or companies in the form of grants or tax exemptions. Since such support schemes are effectively market manipulation, in order to advance certain industries or companies, they have to be carefully designed as to not create an unfair long-term advantage and market distortions (European Commission, 2013).

In light of the developments in climate change, it is understood that the status quo of producing energy from coal and other non-renewable sources is not sustainable and will have to be phased out. **This thesis aims to discover the best alternative for energy production from renewable energy sources in a sustainable way in order to phase out non-renewable sources as a raw material.**

The research questions that need to be answered are :
RQ1: Which renewable energy production methods have been and will, in all likely hood, continue to recieve governmental support in the form of subsidies?
RQ2: What would be the best investment opportunity into renewable energy production based on technological comparison?
RQ3: What sustainable energy production methods would generate the highest net present value, internal rate of return and the lowest levelized cost of energy?

This paper is divided into three chapters : 1) Literature review, which will aim to discover the background of the European plan to combat climate change. Sub-chapters include the definition of climate change, aim and purpose of the Green Deal, the energy sector in th European Union, definition of net zero emissions, Estonian governmental subsidy allocation thus far, introduction of the different renewable energy production methods and real options theory introduction, 2) Data and Methodology, which will introduce the data used in comparing different methods, how it will be collected and how it will be analysed. What research approach will be used, 3) Data analysis, which will show the results of the analysis of data to compare the different alternatives. The discussion chapter of the thesis will focus on the authors findings and interpretations of the findings. The conclusion of the thesis will be dedicated to summarizing the results, giving a recommendation on which opportunity to pursue further and the author's suggestions for further research.

1. LITERATURE REVIEW

1.1 Climate change

By definition, climate change is the significant and long-lasting change in the earth's climate and weather patterns (Merriam-Webster dictionary, 2021). It has been long debated if humans are the cause for the ongoing climate change, saying that climate change is a natural process, which has occurred many times during earth's history. Nevertheless, an overwhelming majority of scientists have concluded that the ongoing climate change is a direct result of human activity. According to peer-reviewed scientific journals, 97% of scientists agree that humans are causing climate change (NASA, 2009). This is supported by data showing the evolution of global anthropogenic CO_2 emissions from 1850 to 2000 (Global monitoring laboratory, 2021). Atmospheric CO_2 concentrations have risen 48% above pre-industrial levels since 1850. To put that number into context, it is higher than what happened in a 20 000-year period before 1850. The process of global warming, as it has been established, is directly linked to greenhouse gases of which, CO_2 is the biggest contributor. Greenhouse gases, that are released from human activity, stay in the stratosphere of the planet and work as absorbers of energy from the sun. Without greenhouse gases in the stratosphere, the energy emitted by the sun would get reflected from the planet's surface and into space. Now, that the greenhouse gases are catching and absorbing the reflected energy, they radiate it into all directions including back to the surface, which is causing the overall temperature of the planet to rise (NASA, 2021).

It has been estimated by a range of models that the average temperature of the planet will have risen 2-4 degrees Celsius by 2100. This temperature rise will start to translate into regional climate changes such as increased warming in land areas and high northern altitudes, snow area contraction, disappearance of Arctic late-summer sea ice, higher frequency of peak temperatures, heatwaves and heavy rainfall, more intensive tropical cyclones, more rain in high latitudes and less rain in subtropical land regions, increase of sea level by 50-140mm (Reid, 2014).

Climate change will also affect other areas that are not necessarily linked to regional climates. Food security and farming all over the world will also be affected. The World Food Programme has estimated that the number of malnourished people will be 10-20% higher in 2050 than it would without climate change. This will be especially felt in sub-Saharan African regions (World Food Programme, 2010). Next to food security, water crisis is the next imminent factor. It has been estimated that 59% of the world's population could face shortages of water from rivers and irrigation by 2050.

Since the climate is getting warmer faster than mankind can adapt to the new average temperatures and regional climates, we might start seeing impacts on human health as well. Potential problems could arise from heat stress, physical and psychological traumas from increased catastrophic events, air pollution, transmitted diseases, water- or food-borne diseases (Reid, 2014).

Climate change will not only affect the planet, but the repercussions will be felt everywhere in human life. Habitable areas will change, food and water will become more scarce, new risks on health will start emerging.

1.2 Net zero emissions

To define the goal of climate or carbon neutrality, we must first investigate what net zero emissions actually mean. Emissions can be defined as greenhouse gases released into the atmosphere. These gases include carbon dioxide, methane, nitrous oxide, and fluorinated gases (see Figure 1).

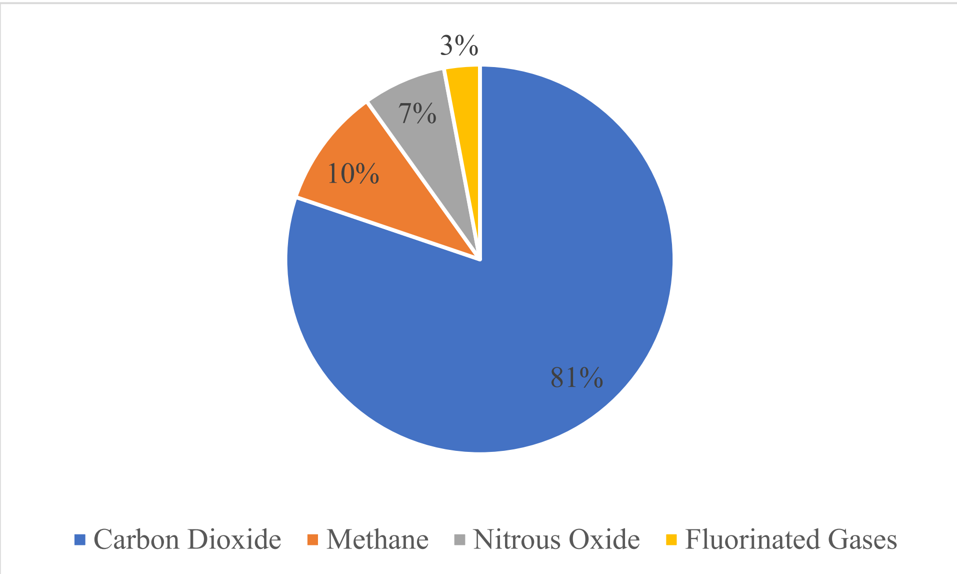

Figure 1. Total emissions in 2018 (United States Environment Protection Agency, 2021)

As seen in the figure above, the biggest contributor in the greenhouse gases mix is carbon dioxide, which, by the EPA estimates, is up to 81% of the whole emission gases. It is followed by methane, nitrous oxide, and fluorinated gases.

While it is true, that by adopting new technologies, it is theoretically possible to reduce the total emissions in some sectors such as energy production, transport, and construction to zero, in other sectors such alternatives are not present. For example, these industries include aviation and agriculture (Energy and Climate Intelligence Unit, 2021). For this reason, it is important to look at the whole picture. This means measuring the quantity of gases we emit and the gases we capture. There are two ways to capture greenhouse gases: 1) Stimulating nature to absorb more with afforestation and reforestation, 2) By using carbon capture technology.

Net zero emissions means that while we are limiting the greenhouse gas emissions into atmosphere is some sectors, we are also taking out more than we are still emitting in sectors where there are no feasible alternatives to do so.

1.3 Energy sector

“Without energy, nothing would ever change, nothing would ever happen. You might say energy is the ultimate agent of change, the mother of all change agents.” (Watson, 2007)

David Watson defines energy as a catalyst for change. It is the thing that drives action, everything that moves, breathes, falls, rises, grows, or thinks, does so, because energy is being transformed. The knowledge on how to harness and use energy has started many high growth periods during human evolution. The latest being the fourth industrial revolution with the start of the Internet and the one before that, which harnessed nuclear energy.

If energy is needed for mankind’s continued evolution, then the answer to stop climate change cannot be the outlawing of energy production. The trade-off with energy production must be with something other than the declining habitability of the planet. The answer must include sustainable energy supply.

The energy supply sector is one of the biggest polluters in terms of greenhouse gas emissions. This is so in every country that operates with low renewable energy sources for their power generation.

Table 1. Greenhouse gas emissions by sector

Sector	kt of CO2 eqvlt	%
Energy supply	1265539	27,39%
Industry	877315	18,99%
Transport	945872	20,47%
Residential/commercial	568900	12,31%
Agriculture	519907	11,25%
Waste	138866	3,01%
International aviation	158268	3,43%
International shipping	145765	3,15%
Sum	4620432	100,00%

Source: (Statista, 2021)

As seen in the table above, the energy sector in the EU accounted for more than 27% of the greenhouse gas emissions in the Union in 2017.

It is by far the largest contributor and efficiency in this regard will have the largest impact on the emission reductions. The energy supply sector must be re-imagined to work with renewable sources and the phasing out of coal and decarbonising gas must be prioritised. Taking all of this into account, the change must be sustainable, secure, and affordable for all users and the preconditions include a fully integrated, interconnected, and digitalised energy market with technological neutrality among member states.

To start this process, every member state had to present a revised energy and climate plan for 2030 by the end of 2019. This plan had to show how each member state plans to fulfil the energy ambitions set out in the Green Deal. The plans and the eventual transition to clean energy must involve and benefit the customers while leaving no one behind and eliminating the risk for energy poverty.

1.4 Green Deal

The European Green Deal has been described as the European "man on the moon" moment by the presiding President Ursula von der Leyen. It is spearheaded by the executive vice president of the European Commission for the Green Deal, Frans Timmermans. The reduction of greenhouse gas emissions, a key factor in the Green Deal, between 1990 and 2018 was 23%, while economic growth was 61% (European Commission, 2019). Extrapolating this figure to 2050, we can see that this is not enough to reach climate neutrality by 2050 – larger measures need to be implemented. It has been calculated that the necessary reduction must be at least 55% from 1990 levels by 2030 to stay on course for 2050.

Table 2. List of Green Deal objectives

Objective
Increasing the EU's Climate ambition for 2030 and 2050
Supplying clean, affordable, and secure energy
Mobilising industry for a clean and circular economy
Building and renovating in an energy and resource efficient way
Zero pollution ambition for a toxic-free environment
Preserving and restoring ecosystems and biodiversity
From "Farm to Fork": a fair, healthy and environmentally friendly food system
Accelerating the shift to sustainable and smart mobility
Financing the transition
Leave no one behind (Just Transition)

Source: (European Commision, 2019)

Among other goals, the need to increase climate ambition for 2030 and 2050 can be seen in the Green Deal's main objectives in the table above. This climate related ambition will be written into the European Climate Law as a target (European Commission, 2019).

1.5 Governmental subsidy allocation

Theoretically, energy production is one of the sectors where greenhouse gas emissions can be brought to zero by using renewable energy sources or nuclear energy. As these options are not as cost-effective in today's energy market, investment into them must be encouraged and supported by governments to meet the climate ambitions set out in the Green Deal. Estonia has submitted its energy and climate plan for 2030 to the European Commission, where it has stated that by 2030, 42% of the summarized energy consumptions must be covered by renewable sources. Furthermore, 50% of the electricity, heat and transport consumption by end-users must be sourced from renewable sources (Ministry of the Environment, 2019). To put it into numbers, 16TWh of the complete energy consumption of 32TWh must come from renewable sources. It is also important to note, that while Estonia's economy is growing, it must keep its energy demand on the level of 32-33TWh. This means that the enactment of efficiency measures needs to be prioritized as well.

These goals need to be supported by the government to achieve them and Estonia has support schemes in place to do just that.

Table 3. Support schemes for increasing renewable energy production quantities.

Support Scheme	Description
EN-1	Subsidy for renewable energy production and efficient cogeneration of heat and electricity
EN-2	Subsidy for investment into wind parks
EN-3	Development of heat generation plants
EN-4	Development of heat generation pipelines
EN-5	Subsidy for renewable energy production through reverse auctions (technology neutral)
EN-6	Subsidy for renewable energy production through reverse auctions (technology specific)
EN-7	Research and developments programs for the energy sector
TR-1	Increasing biofuels proportion in the transport sector
TR-7	Subsidy for electric vehicle purchases
TR-14	Electrification of railways
TR-15	Electrification of ferries
TR-16	Electrification and biomethane use in public transport
PM-7	Investments into diversification of non-agricultural economic activities in rural communities
PM-11	Generation of bioenergy and increase of proportion of use in agricultural sector
PM-22	Research and development into agricultural projects
IP-1	Investment program for green technologies

Source: (Republic of Estonia, 2019)

The list above details all of the various support schemes that Estonia uses or plans to use to fulfil the target of renewable energy production by 2030.

Although, subsidies are needed to encourage investment into renewable energy production, the support schemes must be carefully designed so as to not create unwanted market distortions and unfavourable consequences. Subsidies can cause fiscal imbalances that will leave other public spending priorities unfinanced. Citizens could find it hard to accept that energy subsidies are taking away resources from necessary infrastructure spending, public housing or schools and kindergartens. Lower energy prices can also increase energy consumption and promotion of capital intensive industry resulting in premature depletion of natural resources (B. J. Clements, 2013).

Currently, the Estonian subsidy system for renewable energy production has been running since 1998, when it was first made mandatory for grid operators to buy renewable energy with a fixed price from producers. This scheme was altered in 2007, when the energy law was amended, and subsidies started being paid directly to producers at a price of 53,7 EUR per MWh produced from renewable energy sources. This scheme was largely in place until 2018. At the start of 2019, a new scheme was adopted where subsidies are paid according to auctions held to determine the minimal amount of subsidies needed per project. This system allows any renewable energy producer to participate and apply for subsidies regardless of the technology and source used for energy generation as long as the source is renewable. At the moment, a new bill is being prepared to amend the energy law further, which would allow technology specific auctions to be held in the future. In essence, the system collects money from the consumers to be paid as subsidies to the producers.

1.6 Renewable energy production methods

Wind energy

Wind energy or wind power in generated by the movement of air through the turbine blades. The moving air will start the blades rotating, which will turn around a rotor. The rotor spins the generator thereby creating electricity. Wind energy is a form of solar energy, which is produced by the uneven heating of the atmosphere. The unevenness comes from the position of the globe's poles and equator related to the sun. Each square meter of land on the poles receives less sun than on the equator. This, by the laws of physics, causes equatorial warmer air to rise and colder air on the poles to sink and start flowing from warmer areas to the colder ones to achieve equilibrium in the system (Landberg, 2015). This effect is further supported by the uneven landscape and the rotation of the earth, which will create wind. The wind velocity will vary greatly across different landscapes and is affected by bodies of water and vegetation. Currently, Estonia has only onshore wind parks that generate renewable energy, but it has been noted by the Competition Authority of Estonia, that large untapped opportunities exist in offshore wind parks (Competition Authority of Estonia, 2021), which have yet to be used. Such wind parks would have an advantage over onshore parks as they do not interfere with national defence systems, they have more favourable wind conditions and they are located in unhabitable marine locations, where they do not disturb the consumers sense of aesthetics. Three such wind parks are currently being developed in Estonia.

Table 4. The advantages and challenges of wind energy

Positive aspects	Elaboration
Cost effectiveness	One of the cheapest methods for energy generation.
Job creation	Industry creates jobs in manufacturing, installation, maintenance and supporting services
Industry growth and competitiveness	Investments increasing and scaling decreases costs
Clean fuel source	No emissions of harmful pollutants
Domestic source of energy	Every country has their own inexhaustible wind source
Sustainable	As a form of solar energy, wind is abundant
Abundant locations for wind parks	Low land requirements
Negative aspects	
Competition between conventional generation methods	Projects must be competitive with other conventional energy generation methods.
Best locations in rural areas	Cost of transmissions lines into areas with larger userbase.
Wind parks might not be the best use for land	Wind parks must offer a better return on investment for land-use than other alternative uses for the land
Noise and aesthetics	Turbines might cause noise and be visually unappealing
Impact on local wildlife	Flying animals might fly into the turbine blades

Source: (Office of Energy Efficiency and Renewable Energy, 2021)

The table above compares the positive and negative aspects of wind energy one must keep in mind when deciding on an investment into that particular technology.

Solar energy

Solar energy is created by capturing sunlight and converting it into energy by either photovoltaic panels or mirrors that concentrate solar radiation. There are three types of solar technology systems: 1) photovoltaic, which capture direct sunlight on convert it into energy, 2) concentrating solar power, which use the thermal energy released by the sun to run utility scale turbines for electricity generation, 3) solar heating and cooling systems, which use stored thermal energy for hot water production or air conditioning. The solar photovoltaic system can be regarded as the most widespread solar technology for generating electricity. This also makes it the most researched and advanced type of solar technology. For these reasons, this thesis will focus on solar photovoltaic technology when further elaborating on solar technology.

Table 5. Advantages and challenges of solar energy

Positive aspects	Elaboration
Renewable energy source	Abundant energy source, available everywhere
Reduction in energy bills	As the proportion of solar energy grows in the network, the average price of energy will decrease, because capturing solar energy is more cost efficient than using conventional means to generate energy
Diverse applications	Solar energy can be used to power households in rural areas where transmissions lines are not built. Solar energy can also be used to purify water, create heat and even to create energy in space.
Low maintenance cost	After initial installation, solar panels require very little maintenance to work properly
Technological development	Technological advancement will continue to increase the efficiency of solar panels
Negative aspects	
Weather dependent	Efficiency can drop in cloudy weather conditions
Storage is expensive	As energy can be generated only during the day, batteries must be installed to allow energy consumption during the night.
Uses a lot of space	The higher the demand, the more space one will need for solar panels to satisfy this demand
Associated with pollution	The manufacturing, transport and installation can be associated with pollution

Source: (Greenmatch, 2021)

The table above compares the positive and negative aspects of solar energy.

Biomass

The production of energy from biomass is using human, plant, or animal produced waste in order the generate energy. It relies on the dissolvement and burning of organic materials present in waste and in plant life. While biomass is not the cleanest alternative available for energy generation, it is still regarded as a renewable energy source because of the abundance of raw materials and the very high efficiency factor associated with the technology. The technology, that will be focused on in this thesis, is called cogeneration of heat and power (CHP), which uses biomass as fuel. In regular power plants, electricity is produced from raw materials and the heat, a production by-product, is discarded. Cogeneration plants produce electricity and at the same time, capture the by-product heat and send it to homes or businesses or use it in industry. By doing this, a very high efficiency level of up to 85% can be achieved. The process starts with raw materials being burned in an engine. This engine runs a generator, thereby producing electricity. The hot exhaust gases that are produced by the burning in the engine are directed to a heat recovery unit where water is introduced into the process. This water can remain as the medium for thermal transport, or it can evaporate because of the hot exhaust gases. The hot water or steam is then directed to the end-users.

Table 6. Advantages and challenges of biomass

Positive aspects	Elaboration
Abundance of raw material	If society keeps producing organic waste, there will always be raw materials for biomass
Carbon neutrality	The organic materials involved in generating biomass fuels or energy can only release the same amount of carbon as the carbon they had absorbed during their life cycle
Reduces reliance on fossil fuels	The use of fossil fuels entails large quantities of greenhouse gases being released into the atmosphere. Biomass generation releases less greenhouse gases and can act as a suitable alternative
Cheaper technology	It is less capital intensive to produce energy or fuel from biomass than it is from fossil fuels
Additional revenue stream for organic waste producers	Organic waste producers can add value to the waste they are producing by directing it into biomass generation
Less garbage in landfills	By burning solid waste, the garbage will not get directed into landfills, which will decrease the cost of landfill disposal and land requirements
Negative aspects	
Not as clean as other alternatives	The use of human or animal waste produces methane, which is a greenhouse gas. Also, burning wood or other organic materials produces carbon dioxide which is also a greenhouse gas.
Deforestation	Using wood as raw material reduces forests which act as natural capturers of carbon dioxide
Space requirement	Biomass plants take up more space than conventional alternatives

Source: (European Biomass Industry Association, 2021)

The table above summarizes some of the positive and negative aspects of biomass as a renewable source of energy.

Hydro power

Hydroelectricity is produced by running water through a turbine. The blades of the turbine run around a rotor which in turn spins a generator creating electricity. Production of hydroelectricity, in most cases, uses the drop in elevation between two bodies of water. Due to gravity, water always flows from the higher elevation to the lower elevation. By positioning a turbine in the middle, it is possible to take advantage of the flowing water. The use of water to generate movement or energy has been used for centuries and it has one of the highest efficiency rates among other alternatives.

Unfortunately, Estonia's geographical situation does not allow many opportunities in harnessing the energy from water due to the low elevation differences on the landscape. The maximum elevation in Estonia is 318m, Suur Munamägi and the lowest point is the sea level at 0m. 318m elevation difference is not ideal for hydroelectricity facilities, therefore there are not many such facilities in Estonia and the capacity generated from the whole energy generation is only 0,24% (Elering AS, 2021) with not much room for expansion.

There exist options to still build hydroelectricity facilities by creating artificial elevation drops by digging large water reservoirs underground. These facilities would work by running water down to the reservoirs during the day, when energy demand is high, thereby generating electricity into the grid and storing the overproduction. During the night, when demand is low, the facilities would pump the water back using the stored electricity or grid electricity, which will be cheaper during off-peak periods. This option is however not feasible compared to alternatives considering the much higher investment capacity and the effects on the environment it produces as a by-product.

For these reasons, hydroelectricity, as a renewable energy source, will not be further compared to the other alternatives in the scope of this thesis.

Biogas

Biogas is produced by the decomposition of organic materials found in human, plant, and animal waste products. The waste products are entered into anaerobic digesters in which the bacterial mass will decompose the waste. As a by-product of this process, biogas is released and collected. Biogas has a 50-70% methane composition, which can be utilized for energy production. This gas can further be valorised into biomethane, which is a suitable alternative to natural gas, by filtering out unnecessary by-products and increasing the methane percentage in the gas. Biogas production offers an elimination of greenhouse gas emissions across the whole value chain. Similarly, to biomass, as a raw material, the energy from biogas is produced with cogeneration of heat and power technology.

Table 7. Advantages and challenges of biogas.

Positive aspects	Elaboration
Renewable source	If there exists any kind of production of waste, there will be raw materials for biogas production
Non-polluting	Since anaerobic digestion takes place in an isolated digester, no greenhouse gases are released. Furthermore, by using anaerobic digestion, emissions from natural decomposition in open air are avoided
Alternative uses	Biogas can be used to generate heat, produce electricity, biomethane can be used to produce CNG, which is used in transport
Low capital needs	Smaller biogas facilities can be set up with relatively low capital investments
Digestate use	The digestate from the digesters can be used as a biofertilizer
Negative aspects	
Technological advancement	Little technological advancement has been made to streamlining biogas processes and to encourage investors to invest capital
Biogas impurities	Impurities in biogas can lead to corrosion in engines running on them. Further purification is needed after initial processing by bacteria
Not attractive on a large scale	Large scale biogas applications are not economically viable next to other alternatives. Enhancement of technology is difficult due to biological components involved
Unstable nature of biogas	Biogas becomes flammable if introduced to a oxygen rich environment. This presents the need for explosion resistant safeguards

Source: (Shireen Bhardwaj, 2017)

The table above looks at the positive and negative aspects of using biogas as a renewable energy source.

1.7 Real options theory

This thesis is written based on real options theory. Real options theory is used for investment decisions in case of uncertainties in the future. It can be applied in cases where companies are uncertain of the future and want to look at decision making as exercising an option (Pindyck, 2008). The theory is used for tangible asset options for investment. This means that a company can be weighing options to build a new factory, renovate existing equipment, buy new land and so on. This theory is not applied, when a company is deciding on purchasing or investing in financial instruments such as stock or bonds. The theory utilizes the use of financial indicators to value different investments for decision making, but it goes further than that to address the uncertainties which could alter the calculated financial indicators. It considers the different options companies have when new information becomes available or when the market conditions change favourably or unfavourably. As is in real life, the companies have choices on how to move ahead with projects. They can choose the time, when they will initiate the investment, they can choose the type of capital projects they want to undergo, they can change its size and how they operate their assets. Real option theory can be used to model different alternatives on how a project might turn out. What will happen if the price of land increases, what will happen to the net present value if energy prices fall. This information is crucial for avoiding losses that might occur if a project is continued in unfavourable market conditions. On the other hand, favourable conditions may be cause for accelerating a project for profit maximization.

Real options can be compared to option trading in the financial markets. In the financial markets, one purchases options for a price to receive the opportunity to invest or not invest in the future if the prices are moving in a favourable direction. In this case, the profit would be set, because one knows the price, they can purchase the financial instrument within the future. With real options, the investor does not know the outcome because of the uncertainties involved. The investor has the options to alter its investment timing, size or type as time goes on and the uncertainties become more clearer (Irfanullah, 2021).

In this thesis, the author presents a starting point for an investment decision and looks at ways how the investments feasibility might change in time, considering factors that might alter it. The author has given an overview of the political climate which should benefit any investment made into the sector in the near future.

2. METHODOLOGY

2.1 Research design

The research design chapter will focus on the data used and the methodology for analysing it in the thesis. The investment alternatives will be compared using the discounted cashflow method (DCF). The investments will be targeted to acquire a specific amount of energy (1MWh) and what it will cost in terms on capital expenditures and operational expenditures on a seven-year term. The net present value, internal rate of return and levelized cost of energy for each alternative will be calculated for comparison. The basis for the calculations will lie in numerical secondary data collected with archival research from the databases of International Energy Agency (International Energy Agency, 2015) and International Renewable Energy Agency (International Renewable Energy Agency, 2015).

The author will also introduce factors that might alter the feasibility of the project according to real options theory (Irfanullah, 2021). These factors need to be accounted for when undergoing an investment into renewable energy production in Estonia.

2.2 Data collection

In order to compare different investment scenarios, they have to be reduced to numerical values using secondary data analysis. The secondary data used for the calculation will be acquired from public sources in regard to renewable energy production industry. Such sources will include for example reports from the International Energy Agency and International Renewable Energy Agency. Actual numerical data from private operators will be discarded for the research, because of the reluctance of companies to publish this type of information as they classify it as trade secrets. Paid subsidy information in Estonia will be acquired from the public databases of the Ministry of Finance.

The numerical data collected will primarily involve initial capital expenditures, operating expenses and subsidies received from the government in the timeframe 2016-2020.

2.3 Techniques and procedures of data analysis

2.3.1 Secondary data analysis

Secondary data can be defined as data collected by somebody else for some other purpose (Mark Saunders, 2009). The raw data used in the thesis, will be processed, and fitted into formulas, which will calculate the net present value, internal rate of return and levelized cost of energy for each alternative. The results will be presented in a table comparing the different alternatives.

The raw data, which will be used to calculate the variables needed for comparison, will include the initial investment cost or capex, capacity and efficiency factors, energy prices, subsidy allocations, operations and maintenance costs and various costs. Capacity and efficiency factors will be used to calculate loading and eventual energy production. Energy prices and subsidy allocations will be used to calculate revenues.

Although investment costs can be spread over multiples years and operations and maintenance costs vary from year to year, it is assumed that all the necessary facilities will be built in one year (year 0) and the operations and maintenance costs will remain constant starting from year 1.

Since investment returns depend heavily on energy and thermal prices at which it is possible to market the produced energy, then based on real options theory, multiple scenarios will be modelled to see how key indicators change according to changes in energy prices. For onshore wind and solar photovoltaics, it is possible to only market the electricity generated, whereas Biomass CHP and Biogas CHP also present opportunities to market the generated thermal energy. In the case of biogas CHP, it is assumed that a large portion of the generated thermal energy is consumed to heat the anaerobic digesters necessary to produce biogas. This is a generally accepted principle in biogas CHP technology.

Net present value

Net present value is a metric that is derived from the processing of costs of a project and considering the time-value of money and opportunity cost. It compares the value of money in the present and the value of money in the future. Net present value can be expressed as present value minus required investment:

$$NPV = PV - \text{required investment} \tag{1}$$

Or

$$NPV = \sum \frac{\text{year n cash flow}}{(1-i)^{\wedge}n} - \text{required investment} \tag{2}$$

where
i – interest rate
n - year

As a rule, investors want to know how much value a project will generate less the initial investment. The higher the net present value, the higher the return investors will be getting.

The interest rate adopted for the calculations will be 10%, which is considered as the opportunity cost. It is assumed that the investor would be able to generate a 10% return by investing in the stock market.

Internal rate of return

Internal rate of return is another metric that can be used to describe a projects profitability. Instead of asking how much value will be generated, as with net present value, internal rate of return asks if the projected rate of return will be higher than the opportunity cost of capital and how much, considering that the net present value is 0. The higher the percentage, the higher the rate the investors can expect. Internal rate of return can be expressed in a formula as thus:

$$0 = NPV = \sum \frac{\text{year n cash flow}}{(1-IRR)^{\wedge}n} - \text{required investment} \tag{3}$$

where

IRR – internal rate of return

n – year

Limitations of internal rate of return

When using the internal rate of return, one has to be cautious of its limitations. Using only the internal rate of return for investment decisions can lead to misuse of capital and more profitable projects can be left ignored.

Table 8. Limitations of internal rate of return

Limitation	Elaboration
Multiple IRR's	In the case of positive and negative cashflows during the project's lifetime, IRR can have different outcomes
Does not distinguish between size of project	A project with a smaller initial outlay of capital can generate a higher IRR than a larger project. Regardless of the larger cashflows generated by the larger project during its lifetime
Ignores future costs	IRR is usually calculated by the projected cashflows, but some cash outflows cannot be precisely projected. Such as cost of fuel or cost for maintenance.
Ignores reinvestment rates	IRR assumes that future cash flows can be reinvested at the same rate as IRR. In some cases, IRR can be very high and projects that can generate the same IRR are very few.

Source: (Borad, 2021)

The limitations that need to be considered are presented in the table above.

Levelized cost of energy

If one is choosing between different alternatives to produce renewable energy, than the end-product is the still the same. Profitability between alternatives is determined by the lowest average cost per MWh over the plant's lifetime. This can be summarized with the formula seen below:

$$\text{LCOE} = \frac{\text{sum of costs over lifetime}}{\text{sum of electricity produced over lifetime}} \quad (4)$$

or

$$\text{LCOE} = \frac{\Sigma\frac{\mathbf{In+Mn+Fn}}{(\mathbf{1-r})\mathbf{^\wedge n}}}{\Sigma\frac{\mathbf{En}}{(\mathbf{1-r})\mathbf{^\wedge n}}} \quad (5)$$

where

In – investment expenditures in year n

Mn – operations and maintenance expenditures in year n

Fn – fuel expenditures in year n

En – electricity production in year n

r – discount rate

n – lifetime of the system

Any investment project must be financially viable for investors for capital allocation. The project must show reasonable potential to generate returns for the investor and the returns must be higher than other similar opportunities available for the investor. Financial feasibility metrics, such as net present value, internal rate of return and levelized cost of energy, are analytical tools that evaluate the economic potential of an investment. The metrics analyse the present and future conditions of the projects and can give possible scenarios dependent on the pre-conditions, such as cashflows, of the calculations (Fabozzi, 1999)

3. DATA ANALYSIS

3.1 Subsidy allocation in Estonia 2016-2020

The author will be focusing on support scheme EN-1, which enables the government appointed company, Elering AS, to pay subsidies to companies generating energy from renewable sources. This thesis will focus on the timeframe 2016-2020, which will be most relevant in terms of generating investment proposals for the near future.

Table 9. Summarized subsidy data among 20 receivers of government aid

Alternative	2016	2017	2018	2019	2020
Biomass CHP	55 625 880	76 355 998	86 997 537	68 778 907	49 384 520
Onshore wind	16 194 989	16 965 723	14 984 145	24 581 531	30 809 313
Biogas CHP	1 542 812	1026971	601 393	623806	1 232 972
Hydro	567 377	509032	0	0	478 632
Solar PV	0	0	0	535350	589 564

Source: Authors own work.

The author has compiled the table above to show summarized allocations of subsidies by renewable energy source. This table is summarized from the top 20 subsidy receiving companies in Estonia during the timeframe. The companies are listed in appendix 1.

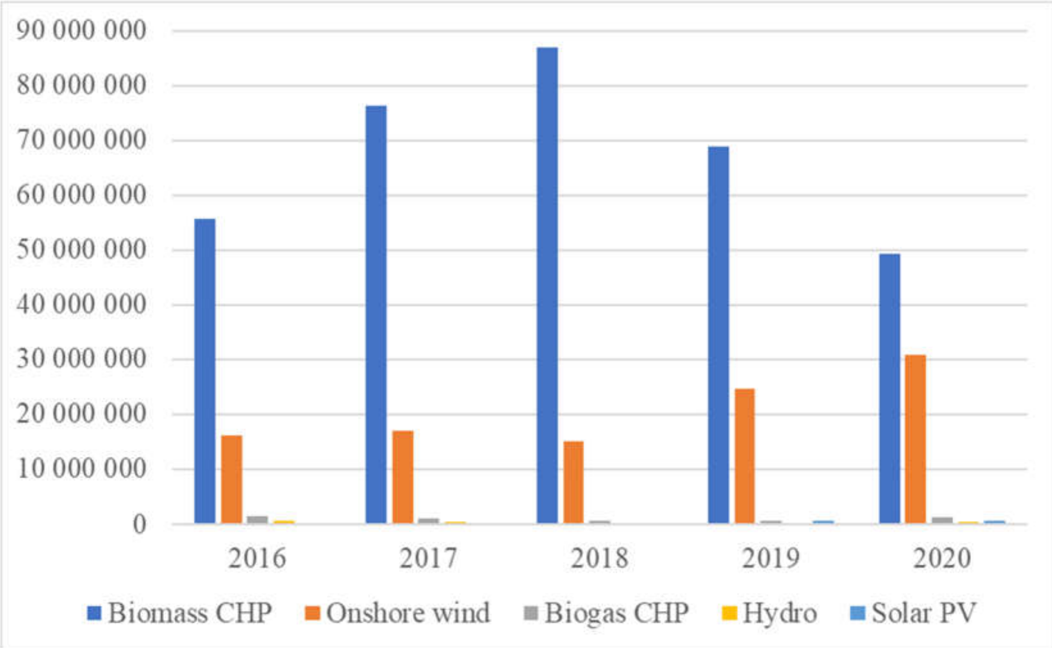

Figure 2. Summarized subsidies for renewable energy production from 2016 until 2020 (Ministry of Finance, 2021)

To visualize the data, the author has compiled the figure above to better understand the subsidy allocation.

3.2 Technological comparison

Presence in Estonia

Research indicates that the transition from coal to renewable energy sources is imperative in Estonia's energy sector. This has been acknowledged by the government in the energy and climate plan for 2030 with the goal of supplying at least 42% of the summarized energy consumption with renewable energy sources. In 2018, this number was 30% (Eurostat, 2021), which is 11% better than the average in the European Union.

From the numerical secondary data analysis, we can see, that in Estonia, biomass and wind energy are the most utilized renewable energy sources. In 2019, 1247GWh of energy was produced in biomass CHP plats using waste products from wood processing. For wind energy, this number was 687GWh. All the other alternatives made up 9,2% of the whole renewable energy production capacity (Statistics Estonia, 2021).

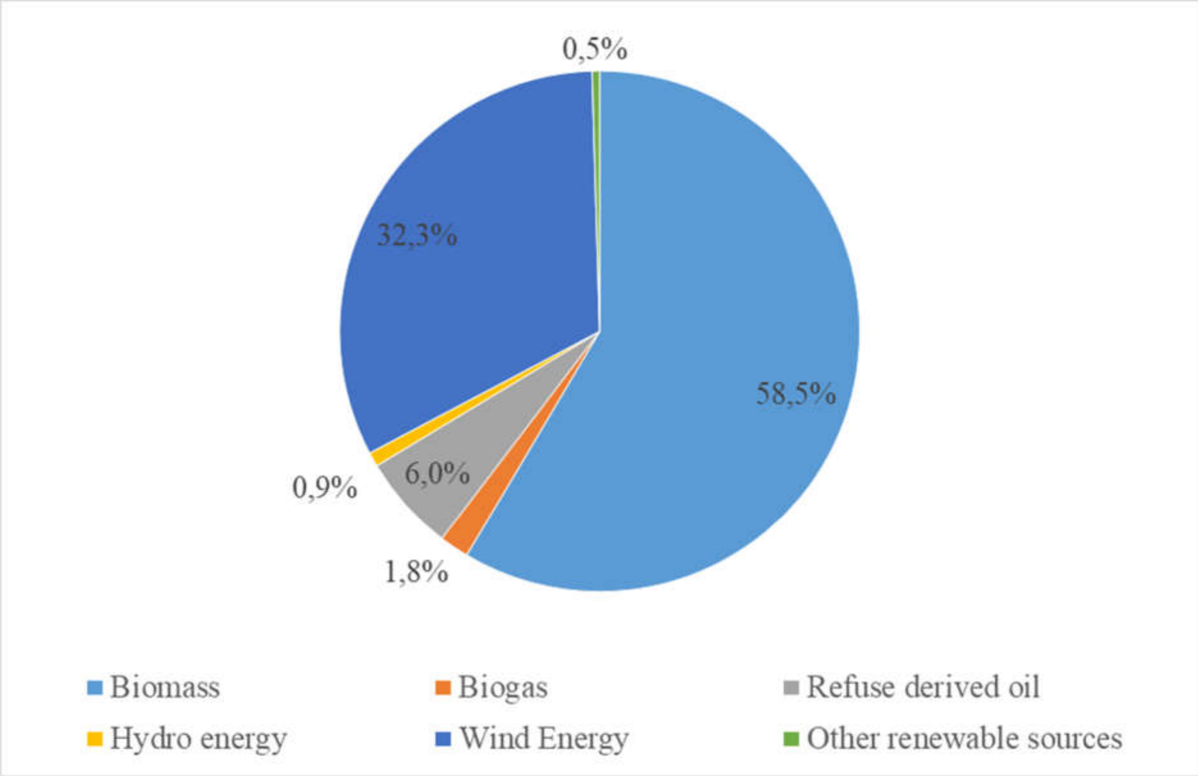

Figure 3. Contributions of renewable energy sources in 2019 in Estonia. Source: (Statistics Estonia, 2021)

The figure above indicates the renewable energy source contributions to the entire sum of renewable sources used in Estonia.

Efficiency

When undertaking any investment project, the investors look at efficiency of the process. This is to ensure that the investment is aimed to the most reliable and feasible project. In the case of renewable energy sources, the processes of generating energy from them have different efficiency levels. This is because the renewable sources themselves are not always constant. In terms of wind and solar activity, the energy generation is highly dependent on the weather. If there is no wind, then the energy generation with wind turbines cannot continue. In the case of solar sources, when the intensity of the sun is being blocked by clouds the efficiency falls dramatically. For biomass and biogas, the efficiency is dependent on the feed-in raw materials and their calorific values. All these affecting factors can be somewhat negated by choosing and maintaining appropriate conditions for production. For example, wind turbines are built into the sea or next to shores without forestation for larger wind exposure, biomass and biogas plants regulate feed-in sludge for optimal calorific value, solar panels move with the sun to always have the best exposure, when the sun is shining.

Renewable energy production efficiency can also be a problem for the grid operator, because of the unstable nature of output. In fact, the inconsistency of renewable energy production has been named as one of the biggest downsides for the industry. The power grids are designed and built with large controllable electric generators in mind. This means the grids are meant supply energy from stable sources which can be momentarily adjusted to the current demand. The problem starts when the grid is being supplied with energy by unstable generators since the grid itself does not have storage capacity. This can result in blackouts or other failures within the grid.

The efficiency levels of renewable energy production methods are improving from year to year because of advancements in generation technology and storage technology due to the high interest in them. From the related literature, one can find different efficiency levels for every renewable energy generation technology. For example, (Xin-long Xu, 2018) have found that wind and solar energy generation efficiencies are at 78,1% and 54,3% respectively. These numbers are average efficiency levels calculated from the World Energy Database data from 2007-2016. The total efficiency for biomass combined heat and power (CHP) generation and biogas combined heat and power generation can be even higher. For these alternatives, one has to take into account two different efficiencies: one only for electricity generation and the other for heat generation. By combining them, one gets the total efficiency of the CHP. The International Renewable Energy Agency has found that the total efficiencies for both biomass CHP and biogas CHP can vary from 40-85%. The electrical efficiency for biomass CHP is usually between 16-36% and for biogas CHP it is 26-32% (International Renewable Energy Agency, 2015).

Table 10. Efficiency levels among renewable energy generation alternatives

Alternative	Efficiency %
Wind	78,1
Solar	54,3
Biomass CHP	40-85
Biogas CHP	40-85

Source: Referenced in the text.

The table above presents the efficiency levels found during research.

Costs

When looking at the costs of investment projects, one must consider at least two different cost types. These are the initial investment or capital expenditure cost (CAPEX) and the operational and maintenance cost (OPEX) for running the facilities. For our alternatives, we can differentiate between two groups: projects where the operator can influence the power generation intensity and ones where the operator cannot. Influencing generation means that the operator supplies the raw material necessary for generation, as is the case for biomass CHP and biogas CHP. For wind and solar energy generation, the generation is dependent on the weather over which the operator has no control. For obvious reasons, this shows in the cost structures. The OPEX costs for projects without operator provided raw material are much lower than they are for the ones where the operator does provide raw material. The CAPEX costs for wind, biomass CHP and biogas CHP are similar, whereas for solar, the costs are much lower.

Table 11. Cost structures for alternatives for 1MWh capacity

Alternative	CAPEX for 1MWh, EUR/MWh	OPEX for 1MWh, EUR/MWh
Wind	1263000	32320
Solar PV	410000	7000
Biomass CHP	1170000	412485
Biogas CHP	1200000	428002

Source: (International Energy Agency, 2015)

The table above presents the cost structures for the alternatives, which were also used for the calculations for the net present value, internal rate of return and the levelized cost of energy.

At these cost levels, for example, investing in an utility scale solar photovoltaic plant would be more efficient then operating an existing coal-fired plant, making the option both environmentally and economically more attractive (International Renewable Energy Agency, 2020). The investment proposal into renewable energy generation is further supported by economies of scale, meaning that the higher the capacity installed the lower the cost per MWh.

Since renewable energy generation technology is constantly improving, one can also see the constant decline of prices associated with the technology. For example, the levelized cost of energy for solar photovoltaic technology declined by 82% between 2010 and 2019 (International Renewable Energy Agency, 2020).

Land requirements

When initiating any energy project, the use and cost of land must be considered, because renewable energy projects differ in the land requirements for the facilities. One should try to minimize the footprint of the facility, but still be able to achieve the largest capacity possible.

Table 12. Average land requirement for alternatives

Alternative	Land requirement, m^2/MWh
Wind	0,7
Solar PV	8,7
Biomass CHP	450
Biogas CHP	300

Source: (International Renewable Energy Agency, 2017)

The author has added the table above, to indicate land use by m^2 for every MWh produced.

Technical lifetime

By technical lifetime or service time, engineers usually mean the time, which the asset will be in use with only regular operational and maintenance activities being performed on it. The longer the assets technical lifetime, the longer it is possible to generate returns from it. Although, in investment project proposals, the complete technical lifetime is seldom used for profitability calculations, because it is difficult to accurately estimate costs in a very long timeframe. Therefore, shorter periods are used, in this case, calculations were performed for 7 years. The technical lifetime for each alternative is considerably longer.

Table 13. Technical lifetime for alternatives

Alternative	years
Wind	25
Solar PV	35
Biomass CHP	40
Biogas CHP	20

Source: (International Renewable Energy Agency, 2015)

The table with the estimated technical lifetimes found from literature are presented above.

3.3 Investment criteria

Secondary data analysis was conducted based on information from various public sources. References for data sources can be found from appendix's 2-21. Four different alternatives were compared with sensitivity analysis for energy prices. Three different variables (net present value, internal rate of return, levelized cost of energy) were calculated for each alternative and compared. Among the alternatives, 3-7 different alternatives were modelled to show sensitivity to energy prices.

Table 14. Scenario list

Scenario	Energy prices modelled EUR/MWh
Onshore wind alt 1	Electricity 50
Onshore wind alt 2	Electricity 60
Onshore wind alt 3	Electricity 70
Biomass alt 1	Electricity 50, Thermal 50
Biomass alt 2	Electricity 60, Thermal 50
Biomass alt 3	Electricity 70, Thermal 50
Biomass alt 4	Electricity 50, Thermal 60
Biomass alt 5	Electricity 50, Thermal 70
Biomass alt 6	Electricity 60, Thermal 60
Biomass alt 7	Electricity 70, Thermal 70
Biogas alt 1	Electricity 50, Thermal 50
Biogas alt 2	Electricity 60, Thermal 50
Biogas alt 3	Electricity 70, Thermal 50
Biogas alt 4	Electricity 50, Thermal 60
Biogas alt 5	Electricity 50, Thermal 70
Biogas alt 6	Electricity 60, Thermal 60
Biogas alt 7	Electricity 70, Thermal 70
Solar PV alt 1	Electricity 50
Solar PV alt 2	Electricity 60
Solar PV alt 3	Electricity 70

Source: Authors own work

The table above lists all of the modelled scenarios that were calculated in this thesis and how they differ from each other.

To differentiate between the different scenarios of alternatives, a grading system was used. The grading system gave the maximum points (20) to the best result and least points (1) to the worst.

Table 15. Results of comparison between scenario alternatives.

Nr	Scenarios	NPV EUR	Points	Scenarios	IRR	Points	Scenarios	LCOE	Points	Sum
1	Biomass alt 7	565402,96	19	Biomass alt 7	25%	19	Biomass alt 7	49	4	42
2	Biogas alt 7	612993,24	20	Biogas alt 7	26%	20	Biogas alt 7	71	2	42
3	Biomass alt 5	439930,53	17	Biomass alt 5	22%	16	Biomass alt 5	49	4	37
4	Biogas alt 3	473756,46	18	Biogas alt 3	22%	17	Biogas alt 3	71	2	37
5	Solar PV alt 3	185231,50	12	Solar PV alt 3	24%	18	Solar PV alt 3	61	3	33
6	Biomass alt 6	240436,00	15	Biomass alt 6	17%	13	Biomass alt 6	49	4	32
7	Onshore wind alt 3	378562,00	16	Onshore wind alt 3	19%	14	Onshore wind alt 3	72	1	31
8	Biogas alt 6	238390,54	13	Biogas alt 6	16%	12	Biogas alt 6	71	2	27
9	Solar PV alt 2	137621,18	9	Solar PV alt 2	21%	15	Solar PV alt 2	61	3	27
10	Onshore wind alt 2	239052,70	14	Onshore wind alt 2	16%	11	Onshore wind alt 2	72	1	26
11	Biomass alt 4	177699,79	11	Biomass alt 4	15%	9	Biomass alt 4	49	4	24
12	Biogas alt 2	168772,15	10	Biogas alt 2	15%	8	Biogas alt 2	71	2	20
13	Solar PV alt 1	90010,87	7	Solar PV alt 1	17%	10	Solar PV alt 1	61	3	20
14	Onshore wind alt 1	99543,40	8	Onshore wind alt 1	13%	7	Onshore wind alt 1	72	1	16
15	Biomass alt 3	40941,48	6	Biomass alt 3	11%	6	Biomass alt 3	49	4	16
16	Biomass alt 2	-21794,74	4	Biomass alt 2	9%	4	Biomass alt 2	49	4	12
17	Biogas alt 5	3024,62	5	Biogas alt 5	10%	5	Biogas alt 5	71	2	12
18	Biomass alt 1	-84530,95	2	Biomass alt 1	8%	2	Biomass alt 1	49	4	8
19	Biogas alt 4	-66593,77	3	Biogas alt 4	8%	3	Biogas alt 4	71	2	8
20	Biogas alt 1	-136212,16	1	Biogas alt 1	6%	1	Biogas alt 1	71	2	4

Source: Authors own work.

The table above lists the results of the scenarios that were modelled and graded with the grading system in this thesis.

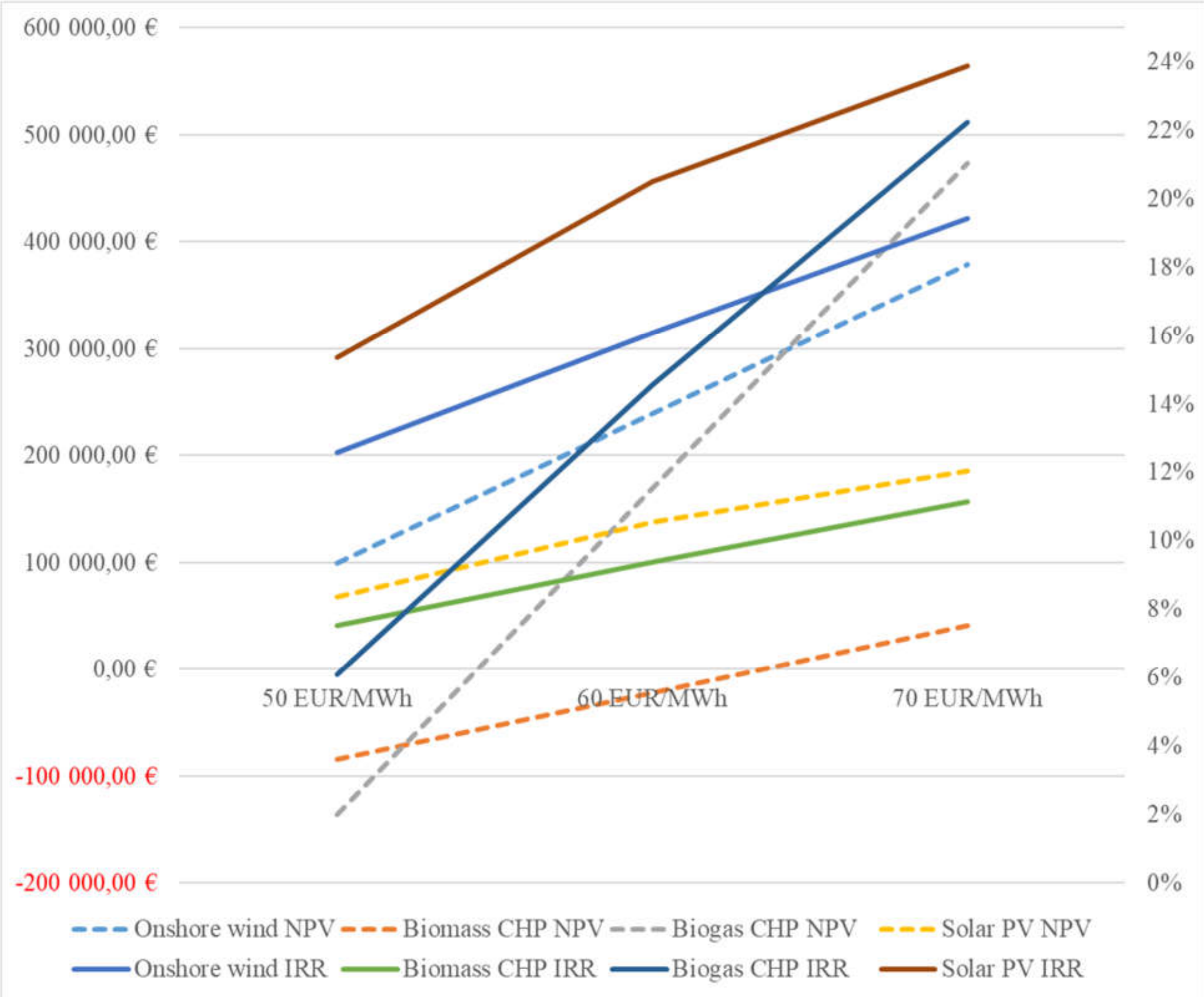

Figure 4. Sensitivity to energy prices between alternatives. Source: Authors own work.

The figure above graphs the results of the calculations to visualize the sensitivity of the net present value and internal rate of return with fluctuating energy prices.

4. DISCUSSION

The research questions the author proposed to find the best alternative with, were as following: 1) Which renewable energy production methods have been and will, in all likely hood, continue to receive governmental support in the form of subsidies? 2) What would be the best investment opportunity into renewable energy production based on technological comparison? 3) What sustainable energy production methods would generate the highest net present value, internal rate of return and the lowest levelized cost of energy?

To answer these questions, the data analysis chapter of the thesis looked at numerical data to produce investment criteria for decision making and documentary data for evaluating aspects that need to be considered as well, when making the final decision.

For the first question, the author provided an overview with Figure 3 of the subsidy allocation by renewable energy source to show which sources are already heavily subsidized and ones where there could be room for new market entrants. The results show that biomass CHP and wind energy technologies are the prevalent technologies in the sector in Estonia. From the last two years observed, it is possible to conclude that the solar energy technologies are becoming more active. This is because of the drastic drops in prices for the technology, making them more and more competitive (International Energy Agency, 2015). The prevalence of biomass usage for energy generation in Estonia is to be expected, considering the abundance of forests in Estonia.

The second research question, which aims to compare the alternatives from a technological point of view needs to be answered by considering various factors concerning the different technologies. The author has researched the outputs of different alternatives in Estonia, the efficiency factors, the costs involved with them, the land requirements, and the technical lifetimes. The largest contributors in the sector in Estonia are wind energy and biomass CHP technologies as shown in Figure 4 (Statistics Estonia, 2021). Biogas CHP and solar photovoltaics present a significantly lower output. For biogas CHP, this can be explained by the more difficult process of anaerobic digestions, which is used to produce biogas. The bacteria cultivation needed for the production is a much more complex process compared to the other alternatives. Also, the digesters themselves present a high investment cost in the project. Solar photovoltaics output is rising because of the declining prices associated with the technology. The technology implementation will take time as the projects are multi-year projects. Nevertheless, it can be deduced, that the technology is starting to gain more traction looking at the subsidy allocation for the years 2019 and 2020 in Table 11.

The efficiency factors are the highest for biomass and biogas CHP, because two types of energy are being produced with these technologies – electricity and heat. The electrical efficiency alone, would be lower than for the other alternatives. The highest electrical efficiency is apparent for wind energy and solar would be second (Xin-long Xu, 2018).

In terms of costs, solar photovoltaics is the clear frontrunner with the lowest initial investment cost and operational and maintenance costs. For wind energy, biomass and biogas, the initial investments are on similar levels, but the operational and maintenance costs are much higher for biomass and biogas, because of the need for steady stream of raw materials which need to be brought into the process (International Energy Agency, 2015).

The land requirements are the highest for biomass and biogas CHP, because of the need to cultivate and gather raw materials. Solar photovoltaics need a lot less land to produce energy and wind energy even less so (International Renewable Energy Agency, 2017).

The technical lifetimes are the longest for biomass CHP and solar photovoltaics. Wind and biogas options have shorter lifetimes and will need reconstruction faster (International Energy Agency, 2015).

Taking all these factors into account, the author would recommend solar photovoltaic technology for investment. This is because of the current low spread of this technology in Estonia, the low costs involved and relatively long technical lifetime. According to the World bank data, Estonia's population density is 30 humans per km^2, which is 148^{th} in the world. This would indicate that there is enough land in Estonia to justify an investment with a relatively higher land requirement. Also, given the historical declines of costs of solar energy it would be reasonable to expect further declines, making the technology even more viable.

For the third research question, the numerical data gathered, produced 20 different scenarios for outlooks dependent on the energy prices at which it would be possible to market the produced energy. From the 20 scenarios, as would be expected, the most profitable scenarios were the ones which favored higher energy prices. Nevertheless, it would be irrational to make the decision based only on the hope that energy prices will rise. Therefore, the author is interested in the scenarios where the energy prices are at current levels – alternative 1's. In that case, Solar photovoltaics will have the best combined grade at position 13. Figure 2 shows that the net present value of solar photovoltaics is in the middle of the class, however the internal rate of return is the highest owing to low initial investment costs and low operational and maintenance costs. Solar photovoltaics technology also produced a positive net present value in all its scenarios similarly to onshore wind energy. One should still prefer solar photovoltaics technology because of the higher internal rate of return and the fact that wind energy subsidies are capped at 600GWh every year in Estonia

(Elering AS, 2021). In 2020, the allowed amount of energy to be subsidized was fulfilled by the 27th of November. This means, that the market is saturated and not enough room for new market entrants exists. The same cannot be said about solar technology.

The Competition Authority of Estonia has compiled a report detailing the subsidy system in place and some rudimentary feasibility calculations for solar technologies. In the report, the Competition Authority has determined that the highest potential for growth in the renewable energy generation sector in Estonia is with wind associated technologies and solar technologies (Competition Authority of Estonia, 2021). However, as the subsidies for wind energy are capped at 600GWh, solar technologies are becoming more attractive, especially industrial scale solar plants. The report compares solar photovoltaics plants with differing capacity and comes to a similar conclusion as this thesis, that solar technologies would be feasible in today's energy environment. It is also important to note, that the report found that the larger the capacity of the solar plant, the more feasible it would become even without subsidies. It was calculated that without subsidies, a 1MWh plant would become feasible with an energy price of 68,2 EUR/MWh. The needed energy price would become smaller as the scale becomes larger. The subsidy system in Estonia only enables subsidy payment for renewable energy generation plants with capacity up to 1MWh. This would mean, that to fully capitalize on the subsidy system, the plants must be built as separate units, which can be segregated from each other forming a cluster plant. Each cluster would have to apply for subsidies separately. The payback period for such a plant, with capacity of 1MWh would be 10-13 years.

The Competition Authority of Estonia has stressed multiple times, that the current system creates market distortions and creates an unfair advantage for certain energy producers. It is also worth noting that the Competition Authority finds that the subsidy system causes unreasonable financial strain for the consumers as it is directly reflected in the cost of energy for the consumer (Competition Authority of Estonia, 2021). Therefore, it can be reasonable to expect further changes in the system and the amount of subsidies paid to decrease. Until concrete measures are enacted however, the current system will stay in place and promises made to producers will have to be upheld. One such promise, according to the current scheme, is that subsidies will be paid at least 12 years after the project in commissioned. This means that any new producer that enters the market, applies for subsidies in the energy auction, and if successful, will be guaranteed a set price of subsidies for at least 12 years. For larger plants, that need a lower energy price to be feasible, this is very reassuring. However, there still exists a political risk, that in the future, the subsidy system might change, and one has to keep this in mind when evaluating opportunities for investment in the sector.

CONCLUSION

Climate change is a new reality, which cannot be denied any longer in today's world. Instead of fighting it with misinformation and prolonging the inevitable, countries and companies are beginning to take steps to mitigate it. Be it the Green Deal and the European Climate Law by the European Union or commitments made by the United States and China - change is coming. This change will envelope all industries and sectors, but the largest contributions can be made in sectors, which are the largest producers of greenhouse gases. An example could be made from the energy sector. The energy sector will have to transform from using non-renewable energy sources into using only renewable energy sources in the future. This statement is supported by the fact that non-renewable resources are finite and will cease to exist at one point in the future. At this moment in time, oil and gas reserves are getting harder to find and harder to extract. Meaning, as the process of extraction becomes more difficult, the costs associated with it, will start going up, making other alternatives more cost-effective in this respect. The question of non-renewable resource depletion has never been a question of "if", but rather a question of "when". An the "when" is approaching faster than ever.

This thesis set out to discover the most feasible investment opportunity into renewable energy production, taking into account numerical investment criteria and differences between realistic investment opportunities in Estonia, which are subsidized by the government.

Based on the different data gathered and the calculations performed, the author would advise one to proceed with the investment into solar photovoltaics technology to generate renewable energy from the sun. The author has found that the chosen alternative has the most promise in Estonia's renewable energy sector with low costs, constantly improving technology and efficiency and sound investment criteria. Given the 35-year technical lifetime, the project would be long-lived and would generate returns on a long timescale in an economic environment favoring renewable energy use.

Before embarking on an investment project, the author would recommend ascertaining the validity of the data used in this thesis from government official and private operators. At the start of 2021, the Competition Authority of Estonia has expressed views, that the subsidization of renewable energy should be phased out and the sector should become market based. This would have adverse effect on the calculations performed in this thesis as revenues from subsidies would be neglected. Nevertheless, until the subsidy system is actually changed, the risks involved are minimal, because they will influence future projects, not existing projects that have already applied for subsidies. For existing projects, the subsidies will be paid according to the current system for as long as they were promised, in most cases at least 12 years after commissioning. The risk of the government neglecting its obligations can be deemed as non-existent as Estonia is regarded as a country with a strong democracy and the promises given will be met.

The initial investment costs in this thesis do not consider the investments that need to go into the grid for connecting the facilities and the price of land. They were left out, because it is impossible to say what the costs would be, as they are affected by the chosen location. On the one hand, the cost of land would be higher near cities, but the cost for grid connection would be cheaper. The opposite would apply in rural areas, where the cost of land would be cheaper, but the cost of connecting to the grid would be higher, because of lack operator grid.

The validity of the initial investment costs for the electricity generation should be confirmed by private operators who have undergone such investments in the past. Such information is unfortunately regarded as trade secret and private operators can be unwilling to relinquish this data. Nondisclosure agreements could be made to keep the data from falling into foreign hands but is unreasonable to assume that the private operators would still be willing to disclose the data to a potential new competitor. Initial investment costs could also be confirmed by nonbinding quotations from original equipment manufacturers who would be inclined to release the data in hopes of generating new business for themselves.

In case of going forward with an investment, the investor should build real options into the project that would enable one to alter the projects timing, scope, or type during the implementation. Projects should be benchmarked and evaluated periodically on how the market conditions have changed and if the feasibility of the investment is still intact or even enhanced.

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APPENDICES

APPENDIX 1 – Top 20 subsidy receivers in Estonia 2016-2020

2016

	Nimi	Toetused	Liik
1	Utilitas Tallinna Elektrijaam OÜ Total	17867816,06	Biomass CHP
2	Anne Soojus AS Total	14152347,89	Biomass CHP
3	Fortum Eesti AS Total	9034861,97	Biomass CHP
4	Enefit Green AS Total	8783814,39	Biomass CHP
5	Pakri Tuulepargid OÜ Total	4388081,74	Tuul
6	Hanila Tuulepargid OÜ Total	3739439,77	Tuul
7	VV Tuulepargid OÜ Total	2777116,23	Tuul
8	Helme Energia OÜ Total	2633810,76	Biomass CHP
9	Aseriaru Tuulepark OÜ Total	2607080,26	Tuul
10	Tuuleenergia OÜ Total	1705542,39	Tuul
11	Adven Eesti AS Total	984790,22	Biomass CHP
12	Eesti Elekter AS Total	940343,76	Biomass CHP
13	Imavere Energia OÜ Total	730534,43	Biomass CHP
14	Jägala Energy OÜ Total	567 377	Hüdro
15	Grüne Fee Eesti AS Total	553 169	Biogaas CHP
16	Five Wind Energy OÜ Total	531 546	Tuul
17	Vinni Biogaas OÜ Total	506 846	Biogaas CHP
18	Kuressaare Soojus AS Total	497 561	Biomass CHP
19	Oisu Biogaas OÜ Total	482 797	Biogaas CHP
20	Tooma Tuulepark OÜ Total	446183	Tuul

2017

	Nimi	Toetused	Liik
1	Utilitas Tallinna Elektrijaam OÜ Total	22602731,54	Biomass CHP
2	Enefit Green AS Total	19592413,03	Biomass CHP
3	Anne Soojus AS Total	13687009,17	Biomass CHP
4	Fortum Eesti AS Total	10457666,19	Biomass CHP
5	Hanila Tuulepargid OÜ Total	5091681,1	Tuul
6	Imavere Energia OÜ Total	3992656,18	Biomass CHP
7	VV Tuulepargid OÜ Total	3234832,97	Tuul
8	Pakri Tuulepargid OÜ Total	2880711,11	Tuul
9	Aseriaru Tuulepark OÜ Total	2446287,42	Tuul
10	Helme Energia OÜ Total	2337215,87	Biomass CHP
11	Tuuleenergia OÜ Total	1782359,21	Tuul
12	Osula Energia OÜ Total	1162756,80	Biomass CHP
13	Eesti Elekter AS Total	1020529,62	Biomass CHP
14	Adven Eesti AS Total	1014047,12	Biomass CHP
15	Skinest Energia AS Total	871808,97	Tuul
16	Five Wind Energy OÜ Total	658042,00	Tuul
17	Grüne Fee Eesti AS Total	529616,76	Biogaas CHP
18	Jägala Energy OÜ Total	509032,29	Hüdro
19	Vinni Biogaas OÜ Total	497354,47	Biogaas CHP
20	Kuressaare Soojus AS Total	488972,32	Biomass CHP

2018

	Nimi	Toetused	Liik
1	Utilitas Tallinna Elektrijaam OÜ Total	25587670,41	Biomass CHP
2	Enefit Green AS Total	22141127,6	Biomass CHP
3	Fortum Eesti AS Total	13033934,25	Biomass CHP
4	Anne Soojus AS Total	11073403,95	Biomass CHP
5	Hanila Tuulepargid OÜ Total	4059337,28	Tuul
6	Osula Energia OÜ Total	4056580,41	Biomass CHP
7	Imavere Energia OÜ Total	4027590,49	Biomass CHP
8	Pakri Tuulepargid OÜ Total	2716906,71	Tuul
9	VV Tuulepargid OÜ Total	2662614,77	Tuul
10	Helme Energia OÜ Total	2563516,97	Biomass CHP
11	Aseriaru Tuulepark OÜ Total	2287217,79	Tuul
12	Anne Soojus AS Total	1637742,26	Biomass CHP
13	Tuuleenergia OÜ Total	1571850,33	Tuul
14	Horizon Tselluloosi Ja Paberi AS Total	1246712,35	Biomass CHP
15	Skinest Energia AS Total	1 043 471	Tuul
16	Eesti Elekter AS Total	686 137	Biomass CHP
17	Five Wind Energy OÜ Total	642 747	Tuul
18	Vinni Biogaas OÜ Total	601 393	Biogaas CHP
19	Adven Eesti AS Total	476 565	Biomass CHP
20	Kuressaare Soojus AS Total	466 557	Biomass CHP

2019

	Nimi	Toetused	Liik
1	Utilitas Tallinna Elektrijaam OÜ Total	20082629,25	Biomass CHP
2	Enefit Wind OÜ Total	15143410,96	Tuul
3	Enefit Green AS Total	13328849,35	Biomass CHP
4	Fortum Eesti AS Total	11068143,69	Biomass CHP
5	Anne Soojus AS Total	9502020,42	Biomass CHP
6	Osula Energia OÜ Total	4138321,61	Biomass CHP
7	Imavere Energia OÜ Total	4101410,09	Biomass CHP
8	Helme Energia OÜ Total	2635610,42	Biomass CHP
9	Hanila Tuulepargid OÜ Total	1873567,93	Tuul
10	Tuuleenergia OÜ Total	1852010,05	Tuul
11	Anne Soojus AS Total	1636784,2	Biomass CHP
12	Horizon Tselluloosi Ja Paberi AS Total	1578258,89	Biomass CHP
13	Aseriaru Tuulepark OÜ Total	1262562,71	Tuul
14	Pakri Tuulepargid OÜ Total	1211692,98	Tuul
15	VV Tuulepargid OÜ Total	1210795,81	Tuul
16	Skinest Energia AS Total	1146476,78	Tuul
17	Five Wind Energy OÜ Total	881014,16	Tuul
18	Eesti Elekter AS Total	706879,42	Biomass CHP
19	Vinni Biogaas OÜ Total	623805,98	Biogaas CHP
20	Solar Light OÜ Total	535350,46	Päike

2020

	Nimi	Toetused	Liik
1	Enefit Wind OÜ Total	26757397,34	Tuul
2	Utilitas Tallinna Elektrijaam OÜ Total	11722592,19	Biomass CHP
3	Fortum Eesti AS Total	9473318,5	Biomass CHP
4	Anne Soojus AS Total	7265288,52	Biomass CHP
5	Enefit Green AS Total	4457221,87	Biomass CHP
6	Osula Energia OÜ Total	4189191,87	Biomass CHP
7	Imavere Energia OÜ Total	3954116,97	Biomass CHP
8	Utilitas Tallinn AS Total	3059627,29	Biomass CHP
9	Helme Energia OÜ Total	2646780,32	Biomass CHP
10	Tuuleenergia OÜ Total	1958650,05	Tuul
11	Horizon Tselluloosi Ja Paberi AS Total	1492521,26	Biomass CHP
12	Skinest Energia AS Total	1298476,37	Tuul
13	Five Wind Energy OÜ Total	794789,57	Tuul
14	Eesti Elekter AS Total	638165,69	Biomass CHP
15	Solar Light OÜ Total	589 564	Päike
16	Aravete Biogaas OÜ Total	556 163	Biogaas CHP
17	Kuressaare Soojus AS Total	485 695	Biomass CHP
18	Jägala Energy OÜ Total	478 632	Hüdro
19	Vinni Biogaas OÜ Total	343 709	Biogaas CHP
20	Oisu Biogaas OÜ Total	333 100	Biogaas CHP

APPENDIX 2 – Onshore wind alt 1 calculations and references

Alt 1 (price 50eur/MWh)

		Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Reference
CAPEX	EUR/MW	-1 263 000								(International Energy Agency, 2015)
Capacity	MW		1	1	1	1	1	1	1	
Power production theoretical load	H/y		8760	8760	8760	8760	8760	8760	8760	
Power production actual load	H/y		3 150	3 150	3 150	3 150	3 150	3 150	3 150	(International Energy Agency, 2015)
Capacity factor	%		0,36	0,36	0,36	0,36	0,36	0,36	0,36	
Energy produced	MWh		3 152	3 152	3 152	3 152	3 152	3 152	3 152	
SALES										
Electricity price (fixed)	EUR/MWh		50	50	50	50	50	50	50	
Subsidy for renewable production	EUR/MWh		53,7	53,7	53,7	53,7	53,7	53,7	53,7	(Elering AS, 2021)
Revenue	EUR/y		326 879	326 879	326 879	326 879	326 879	326 879	326 879	
OPEX										
O&M cost	EUR/y		32 320	32 320	32 320	32 320	32 320	32 320	32 320	(International Energy Agency, 2015)
Various O&M cost	EUR/MWh		4,01	4,01	4,01	4,01	4,01	4,01	4,01	(International Energy Agency, 2015)
Various O&M cost year	EUR/y		12640	12640	12640	12640	12640	12640	12640	
Cash flow	EUR	-1 263 000	281 919	281 919	281 919	281 919	281 919	281 919	281 919	

NPV	99 543,40 €
IRR	13%
LCOE	72

APPENDIX 3 – Onshore wind alt 2 calculations and references

Alt 2 (price 60eur/MWh)

		Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Reference
CAPEX	EUR/MW	-1 263 000								(International Energy Agency, 2015)
Capacity	MW		1	1	1	1	1	1	1	
Power production theoretical load	H/y		8760	8760	8760	8760	8760	8760	8760	
Power production actual load	H/y		3 150	3 150	3 150	3 150	3 150	3 150	3 150	(International Energy Agency, 2015)
Capacity factor	%		0,36	0,36	0,36	0,36	0,36	0,36	0,36	
Energy produced	MWh		3 152	3 152	3 152	3 152	3 152	3 152	3 152	
SALES										
Electricity price (fixed)	EUR/MWh		60	60	60	60	60	60	60	
Subsidy for renewable production	EUR/MWh		53,7	53,7	53,7	53,7	53,7	53,7	53,7	(Elering AS, 2021)
Revenue	EUR/y		358 400	358 400	358 400	358 400	358 400	358 400	358 400	
OPEX										
O&M cost	EUR/y		32 320	32 320	32 320	32 320	32 320	32 320	32 320	(International Energy Agency, 2015)
Various O&M cost	EUR/MWh		4,01	4,01	4,01	4,01	4,01	4,01	4,01	(International Energy Agency, 2015)
Various O&M cost year	EUR/y		12640	12640	12640	12640	12640	12640	12640	
Cash flow	EUR	-1 263 000	313 440	313 440	313 440	313 440	313 440	313 440	313 440	
NPV	239 052,70 €									
IRR	16%									
LCOE	72									

APPENDIX 4 – Onshore wind alt 3 calculations and references

Alt 3 (price 70eur/MWh)

		Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Reference
CAPEX	EUR/MW	-1 263 000								(International Energy Agency, 2015)
Capacity	MW		1	1	1	1	1	1	1	
Power production theoretical load	H/y		8760	8760	8760	8760	8760	8760	8760	
Power production actual load	H/y		3 150	3 150	3 150	3 150	3 150	3 150	3 150	(International Energy Agency, 2015)
Capacity factor	%		0,36	0,36	0,36	0,36	0,36	0,36	0,36	
Energy produced	MWh		3 152	3 152	3 152	3 152	3 152	3 152	3 152	
SALES										
Electricity price (fixed)	EUR/MWh		70	70	70	70	70	70	70	
Subsidy for renewable production	EUR/MWh		53,7	53,7	53,7	53,7	53,7	53,7	53,7	(Elering AS, 2021)
Revenue			389 922	389 922	389 922	389 922	389 922	389 922	389 922	
OPEX										
Fixed O&M cost	EUR/y		32 320	32 320	32 320	32 320	32 320	32 320	32 320	(International Energy Agency, 2015)
Various O&M cost	EUR/MWh		4,01	4,01	4,01	4,01	4,01	4,01	4,01	(International Energy Agency, 2015)
Various O&M cost year	EUR/y		12640	12640	12640	12640	12640	12640	12640	
Cash flow	EUR	-1 263 000	344 962	344 962	344 962	344 962	344 962	344 962	344 962	

NPV	378 562,00 €
IRR %	19%
LCOE EUR/MWh	72

APPENDIX 5 – Biomass CHP alt 1 calculations and references

Alt 1 (el price 50eur/MWh, thermal 50eur/MWh)

		Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Reference
CAPEX	EUR/MW	-1 170 000								(Antonio Marco Pantaleo, 2015)
Boiler capacity	MW		1	1	1	1	1	1	1	
Electrical output	MW		0,189	0,189	0,189	0,189	0,189	0,189	0,189	(Antonio Marco Pantaleo, 2015)
Thermal output	MW		0,79	0,79	0,79	0,79	0,79	0,79	0,79	(Antonio Marco Pantaleo, 2015)
Power production theoretical load	H/y		8760	8760	8760	8760	8760	8760	8760	
Power production actual load	H/y		7 500	7 500	7 500	7 500	7 500	7 500	7 500	(Antonio Marco Pantaleo, 2015)
Capacity factor	%		0,86	0,86	0,86	0,86	0,86	0,86	0,86	
Energy produced	MWh		1 418	1 418	1 418	1 418	1 418	1 418	1 418	
Heat produced	MWh		5 925	5 925	5 925	5 925	5 925	5 925	5 925	
SALES										
Electricity price(fixed)	EUR/MWh		50	50	50	50	50	50	50	
Heat price (fixed)	EUR/MWh		50	50	50	50	50	50	50	(Konkurentsiamet, 2021)
Subsidy for renewable production	EUR/MWh		32	32	32	32	32	32	32	(Elering AS, 2021)
Revenue			412 485	412 485	412 485	412 485	412 485	412 485	412 485	
OPEX										
O&M cost	EUR/y		191 260	191 260	191 260	191 260	191 260	191 260	191 260	(Antonio Marco Pantaleo, 2015)
Cash flow	EUR	-1 170 000	221 225	221 225	221 225	221 225	221 225	221 225	221 225	

NPV EUR	-84 530,95 €
IRR %	8%
LCOE EUR/MWh	49

APPENDIX 6 – Biomass CHP alt 2 calculations and references

Alt 2 (el price 60eur/MWh, thermal 50eur/MWh)

		Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Reference
CAPEX	EUR/MW	-1 170 000								(Antonio Marco Pantaleo, 2015)
Boiler capacity	MW		1	1	1	1	1	1	1	
Electrical output	MW		0,189	0,189	0,189	0,189	0,189	0,189	0,189	(Antonio Marco Pantaleo, 2015)
Thermal output	MW		0,79	0,79	0,79	0,79	0,79	0,79	0,79	(Antonio Marco Pantaleo, 2015)
Power production theoretical load	H/y		8760	8760	8760	8760	8760	8760	8760	
Power production actual load	H/y		7 500	7 500	7 500	7 500	7 500	7 500	7 500	(Antonio Marco Pantaleo, 2015)
Capacity factor	%		0,86	0,86	0,86	0,86	0,86	0,86	0,86	
Energy produced	MWh		1 418	1 418	1 418	1 418	1 418	1 418	1 418	
Heat produced	MWh		5 925	5 925	5 925	5 925	5 925	5 925	5 925	
SALES										
Electricity price(fixed)	EUR/MWh		60	60	60	60	60	60	60	
Heat price (fixed)	EUR/MWh		50	50	50	50	50	50	50	(Konkurentsiamet, 2021)
Subsidy for renewable production	EUR/MWh		32	32	32	32	32	32	32	(Elering AS, 2021)
Revenue			426 660	426 660	426 660	426 660	426 660	426 660	426 660	
OPEX										
O&M cost	EUR/y		191 260	191 260	191 260	191 260	191 260	191 260	191 260	(Antonio Marco Pantaleo, 2015)
Cash flow	EUR	-1 170 000	235 400	235 400	235 400	235 400	235 400	235 400	235 400	

NPV EUR	-21 794,74 €
IRR %	9%
LCOE EUR/MWh	49

APPENDIX 7 – Biomass CHP alt 3 calculations and references

Alt 3 (el price 70eur/MWh, thermal 50eur/MWh)

		Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Reference
CAPEX	EUR/MW	-1 170 000								(Antonio Marco Pantaleo, 2015)
Boiler capacity	MW		1	1	1	1	1	1	1	
Electrical output	MW		0,189	0,189	0,189	0,189	0,189	0,189	0,189	(Antonio Marco Pantaleo, 2015)
Thermal output	MW		0,79	0,79	0,79	0,79	0,79	0,79	0,79	(Antonio Marco Pantaleo, 2015)
Power production theoretical load	H/y		8760	8760	8760	8760	8760	8760	8760	
Power production actual load	H/y		7 500	7 500	7 500	7 500	7 500	7 500	7 500	(Antonio Marco Pantaleo, 2015)
Capacity factor	%		0,86	0,86	0,86	0,86	0,86	0,86	0,86	
Energy produced	MWh		1 418	1 418	1 418	1 418	1 418	1 418	1 418	
Heat produced	MWh		5 925	5 925	5 925	5 925	5 925	5 925	5 925	
SALES										
Electricity price(fixed)	EUR/MWh		70	70	70	70	70	70	70	
Heat price (fixed)	EUR/MWh		50	50	50	50	50	50	50	(Konkurentsiamet, 2021)
Subsidy for renewable production	EUR/MWh		32	32	32	32	32	32	32	(Elering AS, 2021)
Revenue	EUR/y		440 835	440 835	440 835	440 835	440 835	440 835	440 835	
OPEX										
O&M cost	EUR/y		191 260	191 260	191 260	191 260	191 260	191 260	191 260	(Antonio Marco Pantaleo, 2015)
Cash flow	EUR/y	-1 170 000	249 575	249 575	249 575	249 575	249 575	249 575	249 575	

NPV EUR	40 941,48 €
IRR %	11%
LCOE EUR/MWh	49

APPENDIX 8 – Biomass CHP alt 4 calculations and references

Alt 4 (el price 50eur/MWh, thermal 60eur/MWh)

		Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Reference
CAPEX	EUR/MW	-1 170 000								(Antonio Marco Pantaleo, 2015)
Boiler capacity	MW		1	1	1	1	1	1	1	
Electrical output	MW		0,189	0,189	0,189	0,189	0,189	0,189	0,189	(Antonio Marco Pantaleo, 2015)
Thermal output	MW		0,79	0,79	0,79	0,79	0,79	0,79	0,79	(Antonio Marco Pantaleo, 2015)
Power production theoretical load	H/y		8760	8760	8760	8760	8760	8760	8760	
Power production actual load	H/y		7 500	7 500	7 500	7 500	7 500	7 500	7 500	(Antonio Marco Pantaleo, 2015)
Capacity factor	%		0,86	0,86	0,86	0,86	0,86	0,86	0,86	
Energy produced	MWh		1 418	1 418	1 418	1 418	1 418	1 418	1 418	
Heat produced	MWh		5 925	5 925	5 925	5 925	5 925	5 925	5 925	
SALES										
Electricity price(fixed)	EUR/MWh		50	50	50	50	50	50	50	
Heat price (fixed)	EUR/MWh		60	60	60	60	60	60	60	(Konkurentsiamet, 2021)
Subsidy for renewable production	EUR/MWh		32	32	32	32	32	32	32	(Elering AS, 2021)
Revenue	EUR/y		471 735	471 735	471 735	471 735	471 735	471 735	471 735	
OPEX										
O&M cost	EUR/y		191 260	191 260	191 260	191 260	191 260	191 260	191 260	(Antonio Marco Pantaleo, 2015)
Cash flow	EUR/y	-1 170 000	280 475	280 475	280 475	280 475	280 475	280 475	280 475	

NPV EUR	177 699,79 €
IRR %	15%
LCOE EUR/MWh	49

APPENDIX 9 – Biomass CHP alt 5 calculations and references

Alt 5 (el price 50eur/MWh, thermal 70eur/MWh)

		Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Reference
CAPEX	EUR/MW	-1 170 000								(Antonio Marco Pantaleo, 2015)
Boiler capacity	MW		1	1	1	1	1	1	1	
Electrical output	MW		0,189	0,189	0,189	0,189	0,189	0,189	0,189	(Antonio Marco Pantaleo, 2015)
Thermal output	MW		0,79	0,79	0,79	0,79	0,79	0,79	0,79	(Antonio Marco Pantaleo, 2015)
Power production theoretical load	H/y		8760	8760	8760	8760	8760	8760	8760	
Power production actual load	H/y		7 500	7 500	7 500	7 500	7 500	7 500	7 500	(Antonio Marco Pantaleo, 2015)
Capacity factor	%		0,86	0,86	0,86	0,86	0,86	0,86	0,86	
Energy produced	MWh		1 418	1 418	1 418	1 418	1 418	1 418	1 418	
Heat produced	MWh		5 925	5 925	5 925	5 925	5 925	5 925	5 925	
SALES										
Electricity price(fixed)	EUR/MWh		50	50	50	50	50	50	50	
Heat price (fixed)	EUR/MWh		70	70	70	70	70	70	70	(Konkurentsiamet, 2021)
Subsidy for renewable production	EUR/MWh		32	32	32	32	32	32	32	(Elering AS, 2021)
Revenue	EUR/y		530 985	530 985	530 985	530 985	530 985	530 985	530 985	
OPEX										
O&M cost	EUR/y		191 260	191 260	191 260	191 260	191 260	191 260	191 260	(Antonio Marco Pantaleo, 2015)
Cash flow	EUR/y	-1 170 000	339 725	339 725	339 725	339 725	339 725	339 725	339 725	

NPV EUR	439 930,53 €
IRR %	22%
LCOE EUR/MWh	49

APPENDIX 10 – Biomass CHP alt 6 calculations and references

Alt 6 (el price 60eur/MWh, thermal 60eur/MWh)

		Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Reference
CAPEX	EUR/MW	-1 170 000								(Antonio Marco Pantaleo, 2015)
Boiler capacity	MW		1	1	1	1	1	1	1	
Electrical output	MW		0,189	0,189	0,189	0,189	0,189	0,189	0,189	(Antonio Marco Pantaleo, 2015)
Thermal output	MW		0,79	0,79	0,79	0,79	0,79	0,79	0,79	(Antonio Marco Pantaleo, 2015)
Power production theoretical load	H/y		8760	8760	8760	8760	8760	8760	8760	
Power production actual load	H/y		7 500	7 500	7 500	7 500	7 500	7 500	7 500	(Antonio Marco Pantaleo, 2015)
Capacity factor	%		0,86	0,86	0,86	0,86	0,86	0,86	0,86	
Energy produced	MWh		1 418	1 418	1 418	1 418	1 418	1 418	1 418	
Heat produced	MWh		5 925	5 925	5 925	5 925	5 925	5 925	5 925	
SALES										
Electricity price(fixed)	EUR/MWh		60	60	60	60	60	60	60	
Heat price (fixed)	EUR/MWh		60	60	60	60	60	60	60	(Konkurentsiamet, 2021)
Subsidy for renewable production	EUR/MWh		32	32	32	32	32	32	32	(Elering AS, 2021)
Revenue	EUR/y		485 910	485 910	485 910	485 910	485 910	485 910	485 910	
OPEX										
O&M cost	EUR/y		191 260	191 260	191 260	191 260	191 260	191 260	191 260	(Antonio Marco Pantaleo, 2015)
Cash flow	EUR/y	-1 170 000	294 650	294 650	294 650	294 650	294 650	294 650	294 650	

NPV EUR	240 436,00 €
IRR %	17%
LCOE EUR/MWh	49

APPENDIX 11 – Biomass CHP alt 7 calculations and references

Alt 7 (el price 70eur/MWh, thermal 70eur/MWh)

		Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Reference
CAPEX	EUR/MW	-1 170 000								(Antonio Marco Pantaleo, 2015)
Boiler capacity	MW		1	1	1	1	1	1	1	
Electrical output	MW		0,189	0,189	0,189	0,189	0,189	0,189	0,189	(Antonio Marco Pantaleo, 2015)
Thermal output	MW		0,79	0,79	0,79	0,79	0,79	0,79	0,79	(Antonio Marco Pantaleo, 2015)
Power production theoretical load	H/y		8760	8760	8760	8760	8760	8760	8760	
Power production actual load	H/y		7 500	7 500	7 500	7 500	7 500	7 500	7 500	(Antonio Marco Pantaleo, 2015)
Capacity factor	%		0,86	0,86	0,86	0,86	0,86	0,86	0,86	
Energy produced	MWh		1 418	1 418	1 418	1 418	1 418	1 418	1 418	
Heat produced	MWh		5 925	5 925	5 925	5 925	5 925	5 925	5 925	
SALES										
Electricity price(fixed)	EUR/MWh		70	70	70	70	70	70	70	
Heat price (fixed)	EUR/MWh		70	70	70	70	70	70	70	(Konkurentsiamet, 2021)
Subsidy for renewable production	EUR/MWh		32	32	32	32	32	32	32	(Elering AS, 2021)
Revenue	EUR/y		559 335	559 335	559 335	559 335	559 335	559 335	559 335	
OPEX										
O&M cost	EUR/y		191 260	191 260	191 260	191 260	191 260	191 260	191 260	(Antonio Marco Pantaleo, 2015)
Cash flow	EUR/y	-1 170 000	368 075	368 075	368 075	368 075	368 075	368 075	368 075	

NPV EUR	565 402,96 €
IRR %	25%
LCOE EUR/MWh	49

APPENDIX 12 – Biogas CHP alt 1 calculations and references

Alt 1 (el price 50eur/MWh, thermal 50eur/MWh)		Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Reference
CAPEX	EUR/MW	-1 200 000								(Kannan, 2007)
Electrical capacity	MW		1,2	1,2	1,2	1,2	1,2	1,2	1,2	(Oisu Biogas OÜ, 2020)
Thermal capacity	MW		1,2	1,2	1,2	1,2	1,2	1,2	1,2	(Oisu Biogas OÜ, 2020)
Energy produced	MWh		6 891	6 891	6 891	6 891	6 891	6 891	6 891	(Oisu Biogas OÜ, 2020)
Heat produced	MWh		1 573	1 573	1 573	1 573	1 573	1 573	1 573	(Oisu Biogas OÜ, 2020)
SALES										
Electricity price (fixed)	EUR/MWh		50	50	50	50	50	50	50	
Heat price (fixed)	EUR/MWh		50	50	50	50	50	50	50	(Konkurentsiamet, 2021)
Subsidy for renewable production	EUR/MWh		32	32	32	32	32	32	32	(Elering AS, 2021)
Revenue			643 712	643 712	643 712	643 712	643 712	643 712	643 712	
OPEX										
O&M cost	EUR/y		428 002	428 002	428 002	428 002	428 002	428 002	428 002	(Oisu Biogas OÜ, 2020)
Cash flow	EUR	-1 200 000	215 710	215 710	215 710	215 710	215 710	215 710	215 710	

NPV EUR	-136 212,16 €
IRR %	6%
LCOE EUR/MWh	71

APPENDIX 13 – Biogas CHP alt 2 calculations and references

Alt 2 (el price 60eur/MWh, thermal 50eur/MWh)		Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Reference
CAPEX	EUR/MW	-1 200 000								(Kannan, 2007)
Electrical capacity	MW		1,2	1,2	1,2	1,2	1,2	1,2	1,2	(Oisu Biogas OÜ, 2020)
Thermal capacity	MW		1,2	1,2	1,2	1,2	1,2	1,2	1,2	(Oisu Biogas OÜ, 2020)
Energy produced	MWh		6 891	6 891	6 891	6 891	6 891	6 891	6 891	(Oisu Biogas OÜ, 2020)
Heat produced	MWh		1 573	1 573	1 573	1 573	1 573	1 573	1 573	(Oisu Biogas OÜ, 2020)
SALES										
Electricity price (fixed)	EUR/MWh		60	60	60	60	60	60	60	
Heat price (fixed)	EUR/MWh		50	50	50	50	50	50	50	(Konkurentsiamet, 2021)
Subsidy for renewable production	EUR/MWh		32	32	32	32	32	32	32	(Elering AS, 2021)
Revenue			712 622	712 622	712 622	712 622	712 622	712 622	712 622	
OPEX										
O&M cost	EUR/y		428 002	428 002	428 002	428 002	428 002	428 002	428 002	(Oisu Biogas OÜ, 2020)
Cash flow	EUR	-1 200 000	284 620	284 620	284 620	284 620	284 620	284 620	284 620	

NPV EUR	168 772,15 €
IRR %	15%
LCOE EUR/MWh	71

APPENDIX 14 – Biogas CHP alt 3 calculations and references

Alt 3 (el price 70eur/MWh, thermal 50eur/MWh)		Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Reference
CAPEX	EUR/MW	-1 200 000								(Kannan, 2007)
Electrical capacity	MW		1,2	1,2	1,2	1,2	1,2	1,2	1,2	(Oisu Biogas OÜ, 2020)
Thermal capacity	MW		1,2	1,2	1,2	1,2	1,2	1,2	1,2	(Oisu Biogas OÜ, 2020)
Energy produced	MWh		6 891	6 891	6 891	6 891	6 891	6 891	6 891	(Oisu Biogas OÜ, 2020)
Heat produced	MWh		1 573	1 573	1 573	1 573	1 573	1 573	1 573	(Oisu Biogas OÜ, 2020)
SALES										
Electricity price (fixed)	EUR/MWh		70	70	70	70	70	70	70	
Heat price (fixed)	EUR/MWh		50	50	50	50	50	50	50	(Konkurentsiamet, 2021)
Subsidy for renewable production	EUR/MWh		32	32	32	32	32	32	32	(Elering AS, 2021)
Revenue			781 532	781 532	781 532	781 532	781 532	781 532	781 532	
OPEX										
O&M cost	EUR/y		428 002	428 002	428 002	428 002	428 002	428 002	428 002	(Oisu Biogas OÜ, 2020)
Cash flow	EUR	-1 200 000	353 530	353 530	353 530	353 530	353 530	353 530	353 530	
NPV EUR	473 756,46 €									
IRR %	22%									
LCOE EUR/MWh	71									

APPENDIX 15 – Biogas CHP alt 4 calculations and references

Alt 4 (el price 50eur/MWh, thermal 60eur/MWh)		Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Reference
CAPEX	EUR/MW	-1 200 000								(Kannan, 2007)
Electrical capacity	MW		1,2	1,2	1,2	1,2	1,2	1,2	1,2	(Oisu Biogas OÜ, 2020)
Thermal capacity	MW		1,2	1,2	1,2	1,2	1,2	1,2	1,2	(Oisu Biogas OÜ, 2020)
Energy produced	MWh		6 891	6 891	6 891	6 891	6 891	6 891	6 891	(Oisu Biogas OÜ, 2020)
Heat produced	MWh		1 573	1 573	1 573	1 573	1 573	1 573	1 573	(Oisu Biogas OÜ, 2020)
SALES										
Electricity price (fixed)	EUR/MWh		50	50	50	50	50	50	50	
Heat price (fixed)	EUR/MWh		60	60	60	60	60	60	60	(Konkurentsiamet, 2021)
Subsidy for renewable production	EUR/MWh		32	32	32	32	32	32	32	(Elering AS, 2021)
Revenue			659 442	659 442	659 442	659 442	659 442	659 442	659 442	
OPEX										
O&M cost	EUR/y		428 002	428 002	428 002	428 002	428 002	428 002	428 002	(Oisu Biogas OÜ, 2020)
Cash flow	EUR	-1 200 000	231 440	231 440	231 440	231 440	231 440	231 440	231 440	

NPV EUR	-66 593,77 €
IRR %	8%
LCOE EUR/MWh	71

APPENDIX 16 – Biogas CHP alt 5 calculations and references

Alt 5 (el price 50eur/MWh, thermal 70eur/MWh)		Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Reference
CAPEX	EUR/MW	-1 200 000								(Kannan, 2007)
Electrical capacity	MW		1,2	1,2	1,2	1,2	1,2	1,2	1,2	(Oisu Biogas OÜ, 2020)
Thermal capacity	MW		1,2	1,2	1,2	1,2	1,2	1,2	1,2	(Oisu Biogas OÜ, 2020)
Energy produced	MWh		6 891	6 891	6 891	6 891	6 891	6 891	6 891	(Oisu Biogas OÜ, 2020)
Heat produced	MWh		1 573	1 573	1 573	1 573	1 573	1 573	1 573	(Oisu Biogas OÜ, 2020)
SALES										
Electricity price (fixed)	EUR/MWh		50	50	50	50	50	50	50	
Heat price (fixed)	EUR/MWh		70	70	70	70	70	70	70	(Konkurentsiamet, 2021)
Subsidy for renewable production	EUR/MWh		32	32	32	32	32	32	32	(Elering AS, 2021)
Revenue			675 172	675 172	675 172	675 172	675 172	675 172	675 172	
OPEX										
O&M cost	EUR/y		428 002	428 002	428 002	428 002	428 002	428 002	428 002	(Oisu Biogas OÜ, 2020)
Cash flow	EUR	-1 200 000	247 170	247 170	247 170	247 170	247 170	247 170	247 170	

NPV EUR	3 024,62 €
IRR %	10%
LCOE EUR/MWh	71

APPENDIX 17 – Biogas CHP alt 6 calculations and references

Alt 6 (el price 60eur/MWh, thermal 60eur/MWh)		Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Reference
CAPEX	EUR/MW	-1 200 000								(Kannan, 2007)
Electrical capacity	MW		1,2	1,2	1,2	1,2	1,2	1,2	1,2	(Oisu Biogas OÜ, 2020)
Thermal capacity	MW		1,2	1,2	1,2	1,2	1,2	1,2	1,2	(Oisu Biogas OÜ, 2020)
Energy produced	MWh		6 891	6 891	6 891	6 891	6 891	6 891	6 891	(Oisu Biogas OÜ, 2020)
Heat produced	MWh		1 573	1 573	1 573	1 573	1 573	1 573	1 573	(Oisu Biogas OÜ, 2020)
SALES										
Electricity price (fixed)	EUR/MWh		60	60	60	60	60	60	60	
Heat price (fixed)	EUR/MWh		60	60	60	60	60	60	60	(Konkurentsiamet, 2021)
Subsidy for renewable production	EUR/MWh		32	32	32	32	32	32	32	(Elering AS, 2021)
Revenue			728 352	728 352	728 352	728 352	728 352	728 352	728 352	
OPEX										
O&M cost	EUR/y		428 002	428 002	428 002	428 002	428 002	428 002	428 002	(Oisu Biogas OÜ, 2020)
Cash flow	EUR	-1 200 000	300 350	300 350	300 350	300 350	300 350	300 350	300 350	

NPV EUR	238 390,54 €
IRR %	16%
LCOE EUR/MWh	71

APPENDIX 18 – Biogas CHP alt 7 calculations and references

Alt 7 (el price 70eur/MWh, thermal 70eur/MWh)		Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Reference
CAPEX	EUR/MW	-1 200 000								(Kannan, 2007)
Electrical capacity	MW		1,2	1,2	1,2	1,2	1,2	1,2	1,2	(Oisu Biogas OÜ, 2020)
Thermal capacity	MW		1,2	1,2	1,2	1,2	1,2	1,2	1,2	(Oisu Biogas OÜ, 2020)
Energy produced	MWh		6 891	6 891	6 891	6 891	6 891	6 891	6 891	(Oisu Biogas OÜ, 2020)
Heat produced	MWh		1 573	1 573	1 573	1 573	1 573	1 573	1 573	(Oisu Biogas OÜ, 2020)
SALES										
Electricity price (fixed)	EUR/MWh		70	70	70	70	70	70	70	
Heat price (fixed)	EUR/MWh		70	70	70	70	70	70	70	(Konkurentsiamet, 2021)
Subsidy for renewable production	EUR/MWh		32	32	32	32	32	32	32	(Elering AS, 2021)
Revenue			812 992	812 992	812 992	812 992	812 992	812 992	812 992	
OPEX										
O&M cost	EUR/y		428 002	428 002	428 002	428 002	428 002	428 002	428 002	(Oisu Biogas OÜ, 2020)
Cash flow	EUR	-1 200 000	384 990	384 990	384 990	384 990	384 990	384 990	384 990	
NPV EUR	612 993,24 €									
IRR %	26%									
LCOE EUR/MWh	71									

APPENDIX 19 – Solar PV alt 1 calculations and references

Alt 1 (price 50eur/MWh)

		Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Reference
CAPEX	EUR/MW	-410 000								(International Energy Agency, 2015)
Capacity	MW		1	1	1	1	1	1	1	
Power production theoretical load	H/y		8760	8760	8760	8760	8760	8760	8760	
Power production actual load	H/y		1 075	1 075	1 075	1 075	1 075	1 075	1 075	I (International Energy Agency, 2015)
Capacity factor	%		0,12	0,12	0,12	0,12	0,12	0,12	0,12	
Energy produced	MWh		1 076	1 076	1 076	1 076	1 076	1 076	1 076	
SALES										
Electricity price (fixed)	EUR/MWh		50	50	50	50	50	50	50	
Subsidy for renewable production	EUR/MWh		53,7	53,7	53,7	53,7	53,7	53,7	53,7	(Elering AS, 2021)
Revenue	EUR/y		111 554	111 554	111 554	111 554	111 554	111 554	111 554	
OPEX										
O&M cost	EUR/y		7 000	7 000	7 000	7 000	7 000	7 000	7 000	(International Energy Agency, 2015)
Cash flow	EUR	-410 000	104 554	104 554	104 554	104 554	104 554	104 554	104 554	

NPV	90 010,87 €
IRR	17%
LCOE	61

APPENDIX 20 – Solar PV alt 2 calculations and references

Alt 2 (price 60eur/MWh)

		Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Reference
CAPEX	EUR/MW	-410 000								(International Energy Agency, 2015)
Capacity	MW		1	1	1	1	1	1	1	
Power production theoretical load	H/y		8760	8760	8760	8760	8760	8760	8760	
Power production actual load	H/y		1 075	1 075	1 075	1 075	1 075	1 075	1 075	I (International Energy Agency, 2015)
Capacity factor	%		0,12	0,12	0,12	0,12	0,12	0,12	0,12	
Energy produced	MWh		1 076	1 076	1 076	1 076	1 076	1 076	1 076	
SALES										
Electricity price (fixed)	EUR/MWh		60	60	60	60	60	60	60	
Subsidy for renewable production	EUR/MWh		53,7	53,7	53,7	53,7	53,7	53,7	53,7	(Elering AS, 2021)
Revenue	EUR/y		122 311	122 311	122 311	122 311	122 311	122 311	122 311	
OPEX										
O&M cost	EUR/y		7 000	7 000	7 000	7 000	7 000	7 000	7 000	(International Energy Agency, 2015)
Cash flow	EUR/y	-410 000	115 311	115 311	115 311	115 311	115 311	115 311	115 311	

NPV	137 621,18 €
IRR	21%
LCOE	61

APPENDIX 21 – Solar PV alt 3 calculations and references

Alt 3 (price 70eur/MWh)

		Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Reference
CAPEX	EUR/MW	-410 000								(International Energy Agency, 2015)
Capacity	MW		1	1	1	1	1	1	1	
Power production theoretical load	H/y		8760	8760	8760	8760	8760	8760	8760	
Power production actual load	H/y		1 075	1 075	1 075	1 075	1 075	1 075	1 075	I (International Energy Agency, 2015)
Capacity factor	%		0,12	0,12	0,12	0,12	0,12	0,12	0,12	
Energy produced	MWh		1 076	1 076	1 076	1 076	1 076	1 076	1 076	
SALES										
Electricity price (fixed)	EUR/MWh		70	70	70	70	70	70	70	
Subsidy for renewable production	EUR/MWh		53,7	53,7	53,7	53,7	53,7	53,7	53,7	(Elering AS, 2021)
Revenue			133 069	133 069	133 069	133 069	133 069	133 069	133 069	
OPEX										
O&M cost	EUR/y		7 000	7 000	7 000	7 000	7 000	7 000	7 000	(International Energy Agency, 2015)
Cash flow	EUR	-410 000	126 069	126 069	126 069	126 069	126 069	126 069	126 069	

NPV	185 231,50 €
IRR %	24%
LCOE EUR/MWh	61