Bioenergy in Rural Poland

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What are the obstacles and opportunities for Dutch companies in the bioenergy sector in rural Poland?

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Preface and Acknowledgments

As a part of my graduation phase of the program International Food Business at Aeres University of Applied Sciences and Dalhousie University, I was tasked to write a thesis. The first stage in writing this thesis was the research proposal. After the research proposal was approved, I started my research into the obstacles and opportunities for Dutch companies in the Polish bioenergy sector.

As I am currently doing an internship at The Embassy of the Kingdom of the Netherlands in Warsaw, the embassy came with the question of whether there were any opportunities for Dutch companies in the (rural) Polish bioenergy sector. After doing preliminary research, I found a knowledge gap in the sector and also several Dutch companies interested in the Polish bioenergy market. I would like to thank my colleagues at the embassy and the Dutch companies operating in the bioenergy sector for assistance and information on the sector.

Several points from the research proposal feedback were incorporated into the final thesis. These changes include in-text citations, sourcing, a connection to the survey questions, the incorporation of the rural context in the sub-questions, a specification and justification of the questioned companies.

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Summary

Poland still has a lot of changes ahead that are necessary, especially in rural areas, if Poland wants to reach the climate goals set by the European Union. Bioenergy could be a great option for Poland as it would tackle Poland's problems with greenhouse gas emissions, air pollution and power interruptions. The Netherlands is one of the main exporters of technology and a leader in innovation within the bioenergy sector but has a relatively low biomass potential. Poland has a high biomass potential and has a lot of room to grow in the bioenergy sector, making the Polish bioenergy market a possible opportunity for Dutch companies. However, many Dutch companies operating in the bioenergy sector are still hesitant about entering the Polish market.

This resulted in the main research question: "What are the obstacles and opportunities for Dutch companies in the bioenergy sector in rural Poland?". To answer the main research question, research was done into rural Poland's energy sector, bioenergy legislation, development costs, support systems, obstacles, and opportunities. The main objective of the research was to review previous research findings and by gaining a broader understanding of the subject and sector, be able to identify where the opportunities and obstacles occur in the Polish bioenergy sector, especially in the rural context. The research is aimed at the interested Dutch companies, to help these companies enter and better position themselves on the Polish bioenergy market.

The main obstacles that were found are Poland's support schemes, bureaucracy, unstable energy market and a lack of biomethane legislation. The main opportunities that were found are Poland's high biomass potential, a high number of biomass incentives, governmental support for prosumers, the European Green Deal, rising energy prices, many available international funds and growing trust of banks.

The recommendations are to create specific guidelines for companies wanting to enter the market, for installations to locate themselves in the central-eastern parts of Poland, to organize training courses for administrative bodies and stakeholders, to launch educational campaigns that could change the national opinion towards bioenergy, to use straw as biomass input, to compare tender and market prices, and to check which funds might be available.

Chapter 1. Introduction

1.1 Air pollution in Poland

Poland, together with Bulgaria, has the highest air pollution in the European Union (Wdowiak, Wdowiak, Sadowska, & Bojar, 2018). Air pollution is the world's single largest environmental health risk (Lowicki, 2019). The Organization for Economic Cooperation and Development recently stated that by 2050, the major cause of death in cities worldwide will be because of air pollution (OECD, 2014). Additionally, six out of ten of the most polluted cities in Europe are found in Poland (Wdowiak, Wdowiak, Sadowska, & Bojar, 2018). In 2010, it is estimated that Poland had 45,000 premature deaths a year due to air pollution (Wdowiak, Wdowiak, Sadowska, & Bojar, 2018). These health problems have an economic cost of over 100 billion US dollars (Vasev, 2017). Polish health care costs from air pollution are estimated to be 20% of the country's GDP (Vasev, 2017).

Air pollution refers to the release of pollutants into the air that are detrimental to the planet as a whole and to human health in particular (Mackenzie, 2016). There are different types of air polluters (Mackenzie, 2016). Pollution in the form of carbon dioxide, methane, and other greenhouse gases is raising the earth's temperature (Mackenzie, 2016). Other pollutants such as smog and particulate matter directly impact human health and these pollutants are worsened by the increase of the earth's temperature (Mackenzie, 2016). According to the Natural Resources Defense Council (Mackenzie, 2016), particulate matter can be defined as:

Particulate matter is made up of tiny particles of chemicals, soil, smoke, dust, or allergens, in the form of gas or solids that are carried in the air. Both particulate matter and smog come from cars and trucks, factories, power plants, incinerators, engines—anything that combusts fossil fuels such as coal, gas, or natural gas. The tiniest airborne particles in particulate matter—whether they're in the form of gas or solids—are especially dangerous because they can penetrate the lungs and bloodstream and worsen bronchitis, lead to heart attacks, and even hasten death (Mackenzie, 2016).

One of the main contributors to air pollution is Poland's energy industry (Vasev, 2017). According to the Polish National Center for Emissions Balancing and Management (Vasev, 2017), coal power plants play a major role in air pollution. Coal power plants in Poland are responsible for 11% of the primary particulate matter (PM2.5), 51% of Sulphur dioxide (SO2) and 31% of nitrogen oxides (NOx) emissions as well as dust (Vasev, 2017). However, coal power plants are not the sole contributor to Poland's air pollution, as the household sector also plays a big part (Kobza, Geremek, & Dul, 2018). The main cause of Poland's unacceptable PM concentrations is household heating systems, boilers, chimneys, and furnaces burnt with coal or wood (Kobza, Geremek, & Dul, 2018). The household sector is said to be the biggest source of particulate matter in most areas in Poland (Chambers & Podstawczynska, 2019). Despite the fact that 40% of Poland's population resides in rural areas, air quality in these areas is poorly monitored (Kaya, Klepacka, & Florkowski, 2019). In 2015, 78% of Polish households in rural areas burned coal, often in inefficient stoves (Kaya, Klepacka, & Florkowski, 2019). These stoves emit large amounts of greenhouse gases and particulate matter (PM2.5, PM10, and benzo(a)preen), resulting in bad air quality, especially during peak heating months (Awe, et al., 2019). Figure 1 shows the levels of particulate matter in large urban residential areas (Lowicki, 2019). The levels of particulate matter experience high seasonal

variability due to household heating (Lowicki, 2019). The distribution shows the importance of the household sector as a source of particulate matter (Lowicki, 2019).

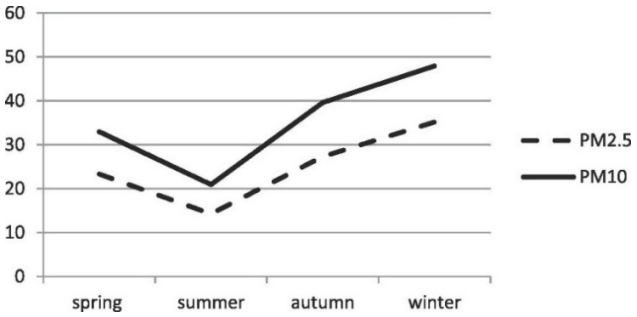

Figure 1, Seasonal variability of PM concentrations in large urban zones (Lowicki, 2019).

1.2 Poland's Energy Production and Consumption

Poland is Europe's biggest hard coal producer and second-biggest lignite (brown coal) producer, making coal their main energy source (Vasev, 2017). Coal-fired power plants create roughly 90% of Poland's total electricity (Vasev, 2017). Coal is also Poland's dominant heat source, as it accounts for 71% of total heat consumption (Awe, et al., 2019). In 2018, Poland produced 63.4 million tonnes of hard coal, which is 86% of the total EU production of 73.7 million tonnes (Eurostat, 2019). Poland (32%), together with Germany (20%) accounted for more than half of the EU's total hard coal consumption in 2017 (Eurostat, 2019). As can be seen in Figure 2, compared to the years 1980-1990, the consumption of hard coal in Poland has considerably decreased (Kuchler & Bridge, 2018). However, in recent years the consumption of hard coal has remained relatively stable, whereas most member states have decreased their consumption of hard coal significantly (Kuchler & Bridge, 2018). The production of lignite is quite similar to that of hard coal and is mainly produced in the countries of consumption (Eurostat, 2019). Poland is the second-biggest producer and consumer of lignite, after Germany (Eurostat, 2019). Poland's consumption of lignite is quite stable and is currently near an all-time high (Kuchler & Bridge, 2018).

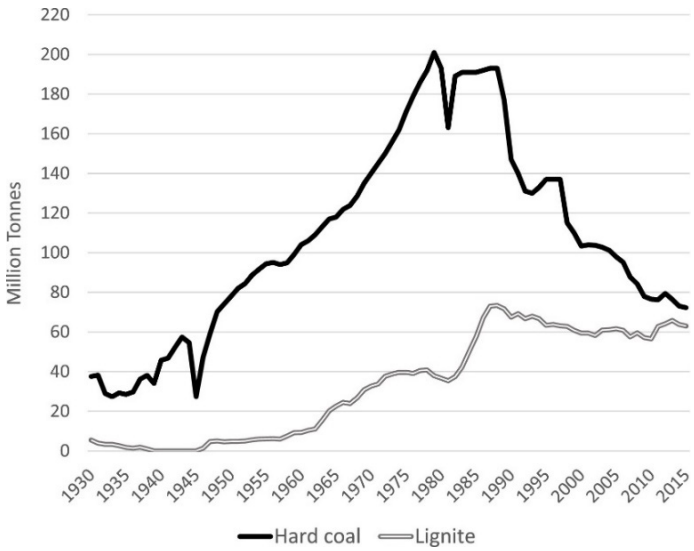

Figure 2, Hard coal and lignite production in Poland, 1930–2015 (Kuchler & Bridge, 2018).

The household sector accounts for a large part of Poland's energy consumption (Kuchler & Bridge, 2018). Energy consumption by the household sector as a percentage of final energy consumption is 24.8% in the EU and this is 31% in Poland (Borozan, 2018; Peryt, Jurgas, Roman, & Dziedzina, 2014). More than two-thirds of the household sector's energy

consumption is used for heating and another 15% for the heating of water (Peryt, Jurgas, Roman, & Dziedzina, 2014). In 2017, electricity consumption was higher in rural areas compared to urban areas (Sobczyk, 2018). The average electricity consumption being 2407.3 kWh per consumer in rural areas, while this was almost 28% lower in urban areas with 1736.8 kWh per consumer (Sobczyk, 2018). This trend can also be observed in the consumption of gas in Poland (Sobczyk, 2018). In 2017, the consumption of gas in rural areas was 10,344 kWh per consumer, while this is almost half in urban areas with 5606 kWh per consumer (Sobczyk, 2018). Even though households were given less attention in EU climate policies and objectives, especially those located in rural areas, households play a big role in the process of reducing emissions (Kaya, Klepacka, & Florkowski, 2019). Due to outdated energy infrastructure, rural households often experience an unreliable and interrupted energy supply (Kaya, Klepacka, & Florkowski, 2019). Four percent of rural households experience a disruption in the electricity supply once or twice a week and thirty-four percent report a similar experience once or twice a month (Kaya, Klepacka, & Florkowski, 2019).

1.3 Climate Goals

Recent studies have shown that on its current course, neither Poland or the European Union as a whole will achieve the EU climate goals set for 2030 and 2050 (European Environment Agency, 2018). The goals of the European Energy Policy named in the Lisbon Treaty concerned energy efficiency, energy savings and the development of renewable energy sources (Gouarderes & Beltrame, 2019). The current policy agenda is driven by key targets set out in the climate and energy policy from 2014 and revised upwards in 2018, to achieve by 2030 (Gouarderes & Beltrame, 2019). The 2030 climate and energy framework key targets are the following: a reduction of at least 40% in greenhouse gas emissions compared to 1990 levels; an increase to 32% of the share of renewable energies in energy consumption; an improvement of 32.5% in energy efficiency and the interconnection of at least 15% of EU's electricity systems (European Commission, 2019).

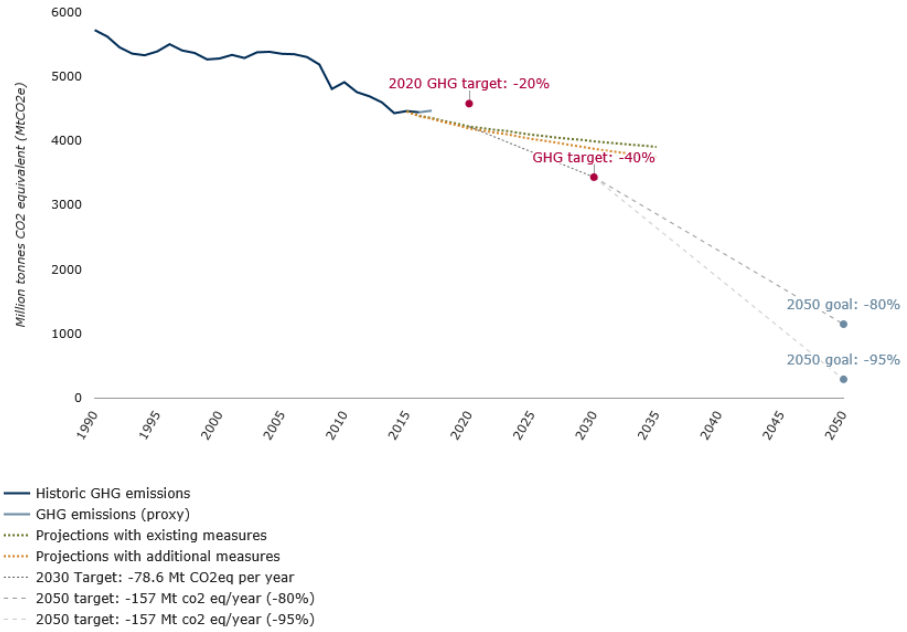

Figure 3, Greenhouse gas emission trends, projections, and targets in the EU (European Environment Agency, 2018).

The trends of the European Union's greenhouse gas emissions compared to its projections and targets can be seen in Figure 3 (European Commission, 2018). Greenhouse gas emissions in the European Union have decreased by 16% between 2005 and 2017 (European Commission, 2018). Greenhouse gases in the European Union are expected to further decrease to 26% below 1990 levels in 2020 (European Environment Agency, 2018). A 32% decrease of greenhouse gases in the European Union below the 1990 levels could be achieved by 2030 (European Environment Agency, 2018). However, the European Union will still fall short on the 40% target set out in the European Energy policy (European Environment Agency, 2018).

While greenhouse gas emissions have decreased in most member states of the European Union, these emissions have increased in Poland (European Commission, 2018). As can be seen in Figure 4, greenhouse gas emissions in Poland increased by 3% between 2005 and 2017 (European Commission, 2018). The main greenhouse gas in Poland is carbon dioxide, with an 81.3% share in 2017, while methane contributes 11.9% and nitrous oxide (N2O) contributes 5% to the national total (Olecka, et al., 2019). In 2017, the CO2 emissions were estimated to be 336.56 million tonnes in Poland (Olecka, et al., 2019). Fuel combustion from the energy industries is estimated to be the source of almost half of the CO2 and methane emissions in Poland (Olecka, et al., 2019).

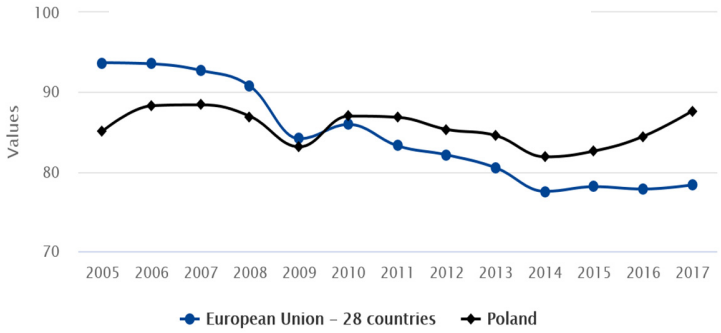

Figure 4, Greenhouse gas emissions in Poland and the EU, base year 1990 (European Commission, 2018).

Every member state of the European Union has its own 2020 target for the share of renewable energy (export.gov, 2019). These national targets take starting points, potential and economic performance into account (export.gov, 2019). Poland's 2020 target for renewable energy is set at 15% (export.gov, 2019). Between 2004 and 2017, Poland's share of renewable energy sources (as a percentage of final energy consumption) saw significant growth and rose from 6.9% to 10.9% (Eurostat, 2019). This means that Poland will need to further increase its share of renewable energy 4.1% between 2017 and 2020 to reach the goal of 15% (Eurostat, 2019). As can be seen in Figure 5, Poland's share of renewable energy steadily increased together with the share of the entire EU (European Commission, 2018). In 2015, Poland's share of renewable energy peaked at 11.74% and has slowly decreased between 2015 and 2017 (European Commission, 2018). Poland's share of renewable energy had a small increase between 2017 and 2018, totaling to 11.16% in 2018 (PolandIn, 2019). Data for the EU's

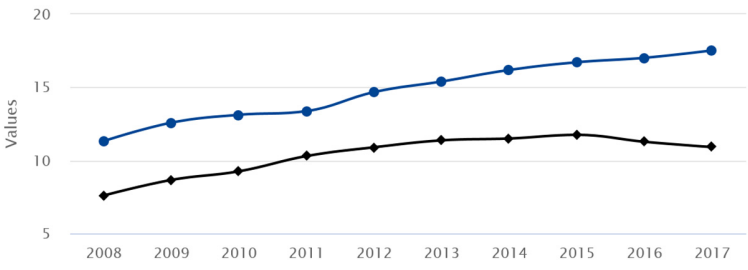

Figure 5, Share of renewable energy as a percentage of gross final energy consumption (European Commission, 2018)

share in 2018 is not yet known (European Commission, 2018). As Poland's goal is to have a 15% share of renewable energy by 2020, some major changes are needed to the Polish energy sector to increase this share at a faster rate (Kuchler & Bridge, 2018). For Poland to make this energy transformation, major investments, changes in regulations and several years are required (Kuchler & Bridge, 2018).

1.4 Bioenergy

The promotion of renewable energy sources has been one of the key pillars of the European Union energy strategy of the last 25 years (Banja, Jegard, Motola, & Sikkema, 2019). Bioenergy is expected to increasingly contribute to achieving the Paris Agreement goals and the United Nations Sustainable Development Goals (Zyadin, et al., 2018). When looking at renewable energy sources, modern bioenergy is often overlooked (Banja, Jegard, Motola, & Sikkema, 2019). According to the International Energy Agency, bioenergy can be defined as: "Bioenergy is the energy generated from the conversion of solid, liquid and gaseous products derived from biomass," (International Energy Agency, 2017). Biomass can be defined as: "Any organic matter, i.e. biological material, available on a renewable basis. Includes feedstock derived from animals or plants, such as wood and agricultural crops, and organic waste from municipal and industrial sources," (International Energy Agency, 2017). Globally, bioenergy generated half of all renewable energy used in 2017 (International Energy Agency, 2017). Bioenergy generated as much as five times the contribution from solar PV and wind energy combined (International Energy Agency, 2017). The forecast for the bioenergy market has been lowered, however, the United Kingdom and the Netherlands remain major markets (Banja, Jegard, Motola, & Sikkema, 2019).

What does the Netherlands have to offer?

As can be seen in Figure 6, the increase in the share of renewable energy of gross final energy consumption in the Netherlands is mainly due to higher biomass consumption. Biomass is the Netherlands' largest source of renewable energy, with a share of 61% of the total renewable energy consumption (CBS, 2019). The share of biomass as a part of gross final energy consumption in the Netherlands is slightly above the EU average of 59% (EU Science Hub, 2019). This above-average share makes the Netherlands one of the leading countries in electricity generation from solid biomass and could indicate a wide range of bioenergy producers operating in the Netherlands (Proskurina, Sikkema, Heinimo, & Vakkilaien, 2016). The total renewable energy consumption in the Netherlands in 2018 was 158 PJ (petajoules) and gross final energy consumption was around 2100 PJ (CBS, 2019). Biomass consumption in the Netherlands rose with 13% to a total of 96 PJ in 2018 (CBS, 2019).

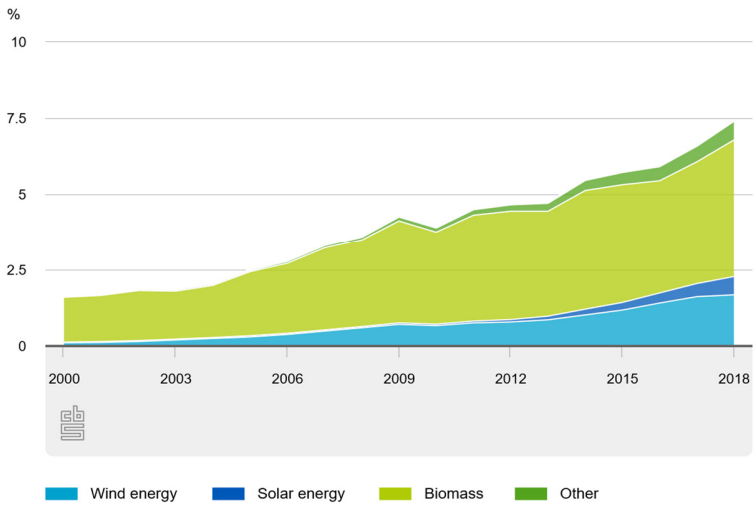

Figure 6, Development of total primary energy supply from bioenergy in the Netherlands (CBS, 2019).

The Netherlands is well-positioned for the export of bioenergy technologies (Netherlands Enterprise Agency, 2014). The Netherlands has a high innovation level and knowledge position in biotechnology, food-chemistry, agro-food, and chemistry (Netherlands Enterprise Agency, 2014). Additionally, the Netherlands has an economic structure with a well-positioned agricultural and chemical industry, as well as a strong export position (Netherlands Enterprise Agency, 2014). The Dutch companies operating in the renewable energy sector strive to increase their competitive edge by leading the way in technological innovation (Langeveld, Meesters, & Breure, 2016). With its ports, industries, and infrastructure, the Netherlands is in a strong position to process and trade within the bioenergy industry (Langeveld, Meesters, & Breure, 2016). However, the Netherlands has limited room available to produce bioenergy. The Netherlands' biomass potential is currently estimated to be 200 petajoules (PJ) (Geothermie, 2018), which is relatively low compared to Poland's biomass potential of 895 PJ (Jezierska-Thole, Rudnicki, & Kluba, 2016).

What could Poland gain from bioenergy?

Poland will need to make some major changes to transform its energy sector and to further increase the share of renewable energy in order to meet the EU Climate Goals (Kuchler & Bridge, 2018). Power generation from bioenergy sources could meet the needs of Poland at a suitable level in a continuous and natural way (Piwowar & Dzikuc, 2019). The rural regions in Poland are highly dependent on coal power plants (Kaya, Klepacka, & Florkowski, 2019). Many rural regions in Poland experience increasingly more power interruptions (Kaya, Klepacka, & Florkowski, 2019). These interruptions are mainly caused by the outdated energy infrastructure in rural Poland (Kaya, Klepacka, & Florkowski, 2019). There are major differences between energy distribution infrastructure in rural and urban Poland (Kaya, Klepacka, & Florkowski, 2019). The energy distribution infrastructure in rural Poland needs to be renovated and modernized for rural households to receive energy in a continuous way (Hernik, Noszczyk, & Rutkowska, 2019). Since bioenergy does not depend as strongly on atmospheric conditions as other renewable energy sources, bioenergy could meet the needs of rural Poland in a proper and less interrupted way (Runyon, 2017). By allowing rural households to generate their own energy, independence from the outdated energy infrastructure and its interruptions could be gained (Iglinski, Buczkowski, & Cichosz, 2015).

Currently, the Law of Renewable Energy Sources (RES) in Poland is being amended (Hanas, 2019). Part of these amendments regard prosumers (Hanas, 2019). In the Polish prosumer model, a prosumer is an entity that is in possession of a RES installation that generates energy and uses it up for its own purposes, of which the surplus is transferred to the distribution network, which serves as an energy repository (Hanas, 2019). These changes in the RES law regard definitions, surplus sizes, investment opportunities, and ownership (Hanas, 2019). These amendments seem to be beneficial for the prosumers (Hanas & Pytko, 2019). Under this prosumer model, farmers and rural households could generate their own green energy and store or sell their surpluses to the energy grid (Hanas, 2019). The draft amendments were presented in June 2019, accepted by the Senate in August and are now pending the President's signature (Hanas & Pytko, 2019).

Bioenergy could be a competing alternative to the existing coal-based power plants, as their resources are limited and its utilization costs are increasing (Iglinski, Buczkowski, & Cichosz, 2015). Most of

Poland's power plants are between 30-40 years old and should be replaced by 2020 (Iglinski, Buczkowski, & Cichosz, 2015). This could be an opportunity to replace these with bioenergy plants (Iglinski, Buczkowski, & Cichosz, 2015). The initial investment for the construction of bioenergy plants in Poland is lower than those of wind-powered, coal-fired or nuclear power plants of the same energy capacity (Iglinski, Buczkowski, & Cichosz, 2015). It takes approximately 8 months to 2 years to build a running moderate to large scale biogas plant (Biogas World, sd). For a smaller plant (10 m^3 or less) this is 1 to 2 months (Electrigaz, 2017). For a biomass energy plant, this is generally longer. Most companies offer a construction period of 18 months (Ministry of New and Renewable Energy, n.d.). As a comparison, it takes 4-7 years for a hydroelectric power station to be operational, 5-10 years for a wind farm, a nuclear power station 7.5 years and around 4 years to have an operational coal power plant (Association québécoise de la production d'énergie renouvelable, n.d.; Futuren, n.d.; Mearns, 2016; Fickling, 2019). The shorter construction periods favor bioenergy plants over the construction of other renewable or unsustainable power plants (Iglinski, Buczkowski, & Cichosz, 2015). Additionally, there are plentiful biomass resources in Poland, also favoring the construction of bioenergy plants (Iglinski, Buczkowski, & Cichosz, 2015).

About 60% of Poland's land is agricultural land, of which 40% is arable land, totaling almost 14 million hectares of arable land (Flanders Investment & Trade in Poznan, 2019). This large area of arable land gives Poland a high biomass supply (Flanders Investment & Trade in Poznan, 2019). Poland's energetic biomass resources are estimated to be 30 million tonnes per year (Flanders Investment & Trade in Poznan, 2019). This 30 million tonnes includes 9 million tonnes from wood and wood waste, 8 million tonnes of cereals straw and 6 million tonnes of various types of biowaste and other types of materials (Flanders Investment & Trade in Poznan, 2019). Other big masses of biomaterials are manure and slurry. Poland produces an estimated 80 million tonnes of manure and 20 million tonnes of slurry per year (Flanders Investment & Trade in Poznan, 2019).

The total energy value from bioenergy sources produced in Poland was 298,487 TJ (terajoules) in 2017 (Berent-Kowalska, Kacprowska, Piwko, & Jurgas, 2018). Poland's biomass potential is among the highest in Europe and is estimated to be 895 PJ equaling 895,000 TJ, meaning that the biomass industry has only reached one-third of its potential (298,487/895,000*100=33.35%) (Jezierska-Thole, Rudnicki, & Kluba, 2016). A major part of this high biomass potential seems to come from a surplus of straw (Tergopower, 2016). In Poland, straw surpluses averaged at 10,000,000 tons per year between 1999 and 2013 (Tergopower, 2016). This surplus of straw is very favorable since it will lessen the utilization of fuel wood from forests and thereby have a lesser contribution to deforestation (Baum, Wajszczuk, Peplinski, & Wawrzynowicz, 2013). Also, straw and energy crops are the most suitable biomass input for large commercial heating facilities (Baum, Wajszczuk, Peplinski, & Wawrzynowicz, 2013). Of all plant species, the power industry mainly uses straw (Baum, Wajszczuk, Peplinski, & Wawrzynowicz, 2013). However, recent literature has shown a decline in straw surpluses, especially in certain Polish regions with a higher livestock density (Grabarz, 2017). The prices for straw in these regions has risen to 250-260 zlotys per ton of straw, while the straw price in Poland averages between 150 and 170 PLN per ton of straw (BioBoost, 2013; Grabarz, 2017). Since farmers have low inventory themselves, mainly due to droughts in recent years, many farmers prefer to use the straw on their own farms (Grabarz, 2017). In other Polish regions where fewer livestock is kept, there are major straw surpluses on the market (Grabarz, 2017). The

transport of straw from one region to another might be an issue since this is quite expensive and transport costs are usually covered by the farmers (Grabarz, 2017).

The agricultural biogas sector also seems to have high potential in Poland (Iglinski, Buczkowski, & Cichosz, 2015). In total, 39.44 PJ of energy could be obtained from biogas, which could help meet 7.5% of Poland's energy demand (Iglinski, Buczkowski, & Cichosz, 2015).

1.5 Problem Description

Recently, there have been discussions about bioenergy on the news (United Nations, 2019). These discussions were on the subjects of the use of land to produce biomass and biomass not being sustainable (United Nations, 2019). The first subject on land use will only partly be covered as this research will focus on Poland and these discussions are mainly about other regions of the world (United Nations, 2019). However, certain parts of this discussion could impact interested Dutch companies. Since several biomass plants use imported wood pellets, that according to the discussions cause deforestation in other regions in the world (van Dongen, 2019). These discussions could directly impact these Dutch bioenergy companies using wood pellets in their biomass plants and are interested in the Polish bioenergy sector (van Dongen, 2019). The second discussion about biomass not being sustainable will be covered as the Dutch Health Organization has asked the Dutch government to stop subsidizing biomass plants, which would have major consequences for the Dutch bioenergy companies and since the legislation of sustainability will be covered in the second sub-question (van Dongen, 2019).

Poland still has a lot of changes ahead that are necessary, especially in rural areas, if Poland wants to reach the climate goals set by the European Union (Kuchler & Bridge, 2018). Bioenergy could be a great option for Poland since it could help transform the Polish energy market to reach the EU Climate Goals (Kuchler & Bridge, 2018). With the use of bioenergy, there are fewer greenhouse gases emitted, it could help decrease air pollution, it is a consistent source of energy that experiences fewer power interruptions and the initial investments are lower than those of unsustainable power plants (Balezentis, Streimikiene, Zhang, & Liobikiene, 2019; Kaya, Klepacka, & Florkowski, 2019; Iglinski, Buczkowski, & Cichosz, 2015). The Netherlands is one of the main exporters of technology and a main leader in innovation within the bioenergy sector but has a relatively low biomass potential, which is less than one-fourth of Poland's biomass potential (Netherlands Enterprise Agency, 2014; Jezierska-Thole, Rudnicki, & Kluba, 2016; Ministry of Economic Affairs of the Netherlands, 2016). Poland has a high biomass potential and still a lot of room to grow in the bioenergy sector (Korys, Latawiec, Grolkiewicz, & Kubon, 2019).

Since 40% of Poland's population lives in rural areas and rural households are one of the main contributors to air pollution in Poland, rural areas are a major part of the problem (Kobza, Geremek, & Dul, 2018; Kaya, Klepacka, & Florkowski, 2019). Many rural regions in Poland have an outdated energy infrastructure and thereby experience increasingly more power interruptions (Kaya, Klepacka, & Florkowski, 2019). If farmers and rural households would start generating their own energy, independence from the outdated power grids and its interruptions could be gained (Iglinski, Buczkowski, & Cichosz, 2015). Also, rural Poland is coal-dependent and uses inefficient stoves that emit large amounts of particulate matter and greenhouse gases (Kobza, Geremek, & Dul, 2018). The household sector is the main cause of Poland's unacceptable PM concentrations (Kobza, Geremek, & Dul, 2018).

Therefore, the household sector plays a key role in the reduction of emissions (Chambers & Podstawczynska, 2019). Since major differences could be seen in the energy usage between rural and urban households, there should be a special focus on the opportunities within the rural household sector (Sobczyk, 2018).

Several Dutch companies that are operating in the bioenergy construction and technology sector have shown interest in the Polish bioenergy market. Many of these companies are already operating in other central and eastern European countries but are still hesitant about entering the Polish market. There are obstacles that are stopping these Dutch companies from entering the Polish market and to some, the opportunities are unknown or uncertain.

One of the main obstacles seems to be a changing and unpredictable energy market and legislation (Buzek & Ksiezopolski, 2017). The Polish regulatory policies around renewable energies are regarded as unstable (Buzek & Ksiezopolski, 2017). This perception of the Polish renewable energy policies is caused by a postponement of the full transposition of the EU renewable energy directive followed by several big changes in the RES support system field (Buzek & Ksiezopolski, 2017). These changes happened in, for example, the basic support model for installations up to 1 MW and above 1 MW, replacements of green certificates for the auction system, changes for prosumer energy receivers and micro-installations (Buzek & Ksiezopolski, 2017). These changes in the Polish legislation slowed down the development of the Polish renewable energy market (Buzek & Ksiezopolski, 2017). Another clear example of unstable renewable energy policies is what happened to the Polish wind energy market (Deign, 2018). Poland was the second-largest wind market in the EU in 2015 (Deign, 2018). However, investments fell through when taxes on turbines were quadrupled and when it became illegal to build plants within 2 kilometers of buildings or forests, ruling out 99% of Poland's land area (Deign, 2018). These regulations restricted the growth of the Polish wind energy sector (export.gov, 2019). Since then, the capacity of wind energy generation in Poland has only grown by 0.87% (export.gov, 2019).

Since the Polish energy market and its legislation is constantly changing, there is a knowledge gap on where the opportunities and obstacles in the market currently exist. The proposed research will review previous research findings and by gaining a broader understanding of the subject and sector, be able to identify where the opportunities and obstacles occur in the Polish bioenergy sector, especially in the rural context. The proposed research will give a clear overview of the status and structure of Poland's current energy sector, the relevant regulations and legislation, costs, support schemes, and the found obstacles and opportunities that lie within the Polish bioenergy market. Additionally, the report will analyze, compare and give a clear overview of the found data. This overview will show the data that of importance to the Dutch companies that have shown interest in the Polish bioenergy market and data that will contribute to answering the main and sub-research questions. These questions will all be answered with a focus on the rural communities. There are scientific articles available on renewable energy in Poland or Poland's biomass potential or the legislation, however, none are specifically targeted towards rural Poland's bioenergy opportunities. The unstable and changing energy market and regulations also make it harder to find information that is relevant, since it needs to be very recent. The research is aimed to help Dutch companies that are already operating in the bioenergy sector to enter (rural) Poland's bioenergy market.

1.6 Research Questions

From the described problem statement the following main research question emerged:

"What are the obstacles and opportunities for Dutch companies in the bioenergy sector in rural Poland?"

To examine this question the following sub-questions were formulated:

1. What is the status and structure of rural Poland's current energy sector?
2. What is the legislation regarding bioenergy in Poland?
3. What are the development costs of bioenergy plants in Poland?
4. What support can foreign companies in the bioenergy sector get?
5. What are the current obstacles to entering the rural Polish energy market?

Chapter 2. Methodology

In the previous chapter, the problem was described. The main question that emerged was: **"What are the obstacles and opportunities for Dutch companies in the bioenergy sector in rural Poland?"** The main research question was answered through 5 sub-questions. The sub-questions are the following:

2.1 What is the status and structure of Poland's current energy sector?

The first sub-question: *"What is the status and structure of Poland's current energy sector?"* was answered by looking at current numbers and data. The question was answered by looking at the following topics: the number and types of energy plants, numbers on the energy consumed, number of jobs in the sector, biggest energy companies, the trade of energy and energy sources. Search terms were used are: *Poland energy consumption 2018, number energy plants Poland, size energy plants Poland, renewable energy plants Poland, number/size biogas plants, number/size biomass plants, Poland energy mix, renewable energy share, Poland biomass share, employment energy sector Poland, large energy companies Poland, export energy Poland, import energy Poland.* The introduction gave a short overview of the Polish energy sector. Data from the introduction was used and more details on this information was given on these topics. The topics used in the introduction were the following: the consumption and production of energy, data on renewable energy and bioenergy.

2.2 What is the legislation regarding bioenergy in Poland?

The second sub-question: "*What is the legislation regarding bioenergy in Poland?"* was answered by looking through Polish and European Union legislation. The sub-question covered topics such as permits, requirements by the Polish legislation, requirements by the European legislation and those of sustainability and renewable energy. The following search terms were used: *bioenergy permits, RES act Poland, changes/amendments RES Poland, requirements bioenergy RES, prosumer laws, legislation bioenergy, legislation renewable energies, sustainability requirements.* From the introduction, information on the changing RES and prosumer laws was used and was explained in more detail to answer the sub-question.

2.3 What are the development costs of bioenergy plants in Poland?

The third sub-question: *"What are the development costs of bioenergy plants in Poland?"* was answered by looking at journal and research articles. The sub-question covered the following topics: development periods, construction costs, administrative costs, and other costs. The search terms were used are the following*: costs bioenergy construction, costs bioenergy development, costs biogas plant Poland, costs biomass plant Poland, costs bioenergy EU, costs bioenergy Poland, administrative costs bioenergy, construction costs biomass plant, construction costs biogas plant.* From the introduction, the development periods of the different energy plants were used, as these are connected with costs.

2.4 What support can foreign companies in the bioenergy sector get?

The fourth sub-question: *"What support can foreign companies in the bioenergy sector get?"* was answered by looking at legislation, journal and research articles. The sub-question was split into 2 main

topics: support by the Polish government and the support by the European Union and other funds. The search terms that were used are the following*: support schemes renewable energy, support schemes bioenergy Poland, support schemes bioenergy EU, auctions RES Poland, feed-in premiums, green deals, biofuels obligations, research support bioenergy, financial support bioenergy*. From the introduction, the part about changing legislation regarding renewable energies was used.

2.5 What are the current obstacles to entering the Polish energy market?

The last sub-question: *"What are the current obstacles to entering the Polish energy market?",* was answered through research found for other sub-questions and by questioning international and Dutch companies that have entered, tried entering or want to enter the Polish bioenergy sector. The chapter gives an overview of the obstacles found and will look at which changes would have to be made to concur these obstacles. In Appendix 1, a list of questions that was used in the interviews with these companies is shown. The first three questions will give a general idea of the company and its experience. Questions 4 and 5 will show any potential obstacles to the Polish bioenergy market. Question 6 will show any possible opportunities. Questions 7 will give more information on the found opportunities and/or obstacles. Question 8 will show which information would be necessary to include and where possible lacks in information might exist, which could have something to do with the costs, changing legislation or support schemes.

The list with these companies was already available, as it was received through a contact of the embassy. These companies were contacted and those that were interested in the results of the research were asked for an interview. These companies were chosen for the interviews as they have first-hand experience with the obstacles and opportunities on the Polish bioenergy market. Five companies expressed interest in the research and a willingness to help gather results. The interviewed respondents can be found in Table 1. The table shows that the respondents are from different sectors within the bioenergy market and have different relations to Poland. This wide range of sectors and relations will show different perspectives and experiences. The results from these interviews helped to answer the sub-questions as the questions cover subjects such as the Polish energy structure, costs, financing, legislation, opportunities and threats. A summary of these interviews is given in Appendix 8.

Table 1, Interview Respondents

Respondents	Job title	Sector	Relation to Poland
1	Area Sales manager	Biogas products	Operating for 6 years
2.	Marketing & Sales manager	Bioliquids	Not operating yet
3.	Sales manager	Biomass technologies	Operating for 15+ years
4.	Managing director	Biogas upgrading (biomethane) installations	Not operating yet
5.	Project Manager	Biogas	Failed to enter the market

The research is mainly qualitative and data was collected through desk-research and through interviews with specialists from the bioenergy sector. The data needed to answer the sub-questions was found through data collection from legislation, journals, research articles, reports from well-known and governmental institutions and other peer-reviewed sources. Peer-reviewed articles are articles written by experts and reviewed by several other experts, to ensure the article's quality (Angelo State University, n.d.). The use of peer-reviewed articles ensures the validity and reliability of the collected data and information. The criteria used when evaluating the importance of results from analyzed data and information was the following:

- Is the information of interest to the interested Dutch companies?
- Is the information from a reliable or peer-reviewed source?
- Is the information recent and still relevant?
- Does the information contribute to answering the sub-question?
- Does the information contribute to answering the main research question?

Chapter 3. Results

This chapter will look into the results of the research. To answer the first sub-question, the status and structure of rural Poland's energy sector will be given, including energy production, consumption, and market. For the second sub-question, the legislation regarding bioenergy in Poland will be explained. This section will explain the requirements of both the Polish and European legislation. Afterwards, the third sub-question will be answered by analyzing the development costs using the development periods, construction costs and other costs. Sub-question four will be answered by looking into the financial support of the Polish government, European Union and other funds. Lastly, the findings from the first four sub-questions, together with the interview results will help to answer the fifth sub-question, in which the obstacles and opportunities on Poland's rural bioenergy market will be given.

3.1 What is the Status and Structure of Rural Poland's Current Energy Sector?

This sub-question will be answered by looking at (rural) Poland's generation and consumption of energy and the economical side of the energy market. This chapter will express energy and power in Watts and Joules. Energy capacity is typically expressed in Watts, as this is the unit of power (StouchLighting, sd). Energy production, consumption, and potential are typically expressed as Joules as this is the unit of energy (StouchLighting, sd). The conversion rate is the following: 1 Watt is 1 Joule per second or 1 kW (kilowatt) is 1000 Joules/second (StouchLighting, sd). Another energy rate that will be used is kWh (kilowatt-hours), which is the watthours of energy per hour (StouchLighting, sd).

3.1.1 Energy Generation

Fossil fuels have a dominant position in Poland's energy sector (Kuchler & Bridge, 2018). Poland burns more coal than any other European country, apart from Germany (Eurostat, 2019). This can be seen in the share of coal in electricity production (Eurostat, 2019). In Poland, about 80% of Poland's electricity is generated by burning coal, while the average in Europe is 25% (Kuchler & Bridge, 2018). Coal is also Poland's dominant heat source, as it accounts for 71% of total heat consumption (Awe, et al., 2019) As can be seen in Figure 7, Poland's main energy source is hard coal with a share of 57.9% of Poland's energy production, other sources are lignite with 18.1%, renewables with 11.16%, natural gas with 5.5% and crude oil with 1.6% (Statistics Poland, 2019).

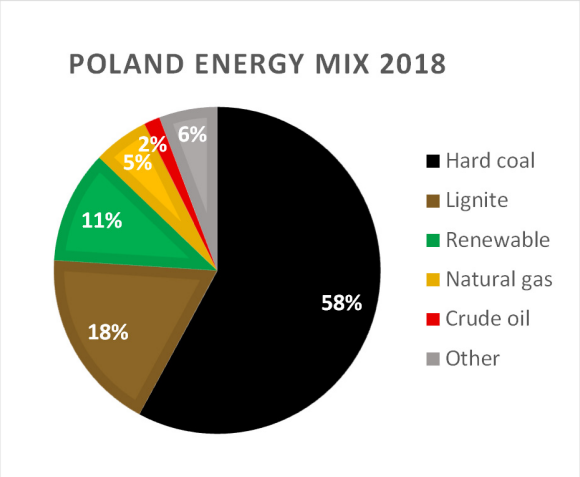

Figure 7, Poland energy mix 2018 (Statistics Poland, 2019).

Poland is Europe's biggest coal producer and second-biggest lignite producer (Eurostat, 2019). In 2018, Poland produced 63.4 million tonnes of hard coal, which is about 86% of the total EU production (Eurostat, 2019). The production of lignite is quite similar to that of hard coal and is mainly produced in the countries of consumption, the main producers and consumers being Germany and Poland (Eurostat, 2019). It is estimated that 80% of Poland's coal mines are unprofitable (Herold, Siemons, & Wojtal, 2017). Despite heavy subsidies by the Polish government, the coal mining sector generated a loss of 4.5 billion PLN in 2015 (Herold, Siemons, & Wojtal, 2017).

Rural Polish households have limited access to the technical infrastructure (Kaya, Klepacka, & Florkowski, 2019). As only 5% of rural Polish households have access to piped natural gas, this has resulted in greater use of coal in rural areas compared with urban areas (Kaya, Klepacka, & Florkowski, 2019). In 2015, 76% of rural households received most of their energy from coal, whereas this is 24.7% of the urban households (Kaya, Klepacka, & Florkowski, 2019).

Poland plans to launch its first nuclear power plant by 2033, followed by five more every 2 to 3 years (World Nuclear Association, 2019). The first nuclear plant is supposed to generate 1 to 1.5 GW of nuclear energy, which is about 3.5% of Poland's current energy production (World Nuclear Association, 2019; export.gov, 2019). Poland's most recent energy strategy stated that Poland will get 15% of its total energy consumption from nuclear energy sources by 2040 (World Nuclear Association, 2019).

Renewable energy production

Of all renewable energy sources in Poland, energy generated from (offshore) wind and biomass is seeing the most growth. Most of this growth in biomass is due to the increasing use of agricultural elements (Banja, Jegard, Motola, & Sikkema, 2019). As can be seen in Figure 8, the main renewable energy source in Poland is biomass, followed by wind energy and other bioenergy sources (Statistics Poland, 2019). In 2018, 67.7% of Poland's renewable energy was from biomass sources (solid biofuels), 14.1% from wind energy, 10.1% from (liquid) biofuels, 3.1% from biogas, 2.4% from hydro energy, 1% from municipal waste, 0.8% from solar energy, 0.6% from heat pumps and 0.2% from geothermal sources (Statistics Poland, 2019). Of these renewable energy sources, solar PV, wind and hydro will be given a short description. The Polish biogas and biomass energy sectors will also be explained in more detail.

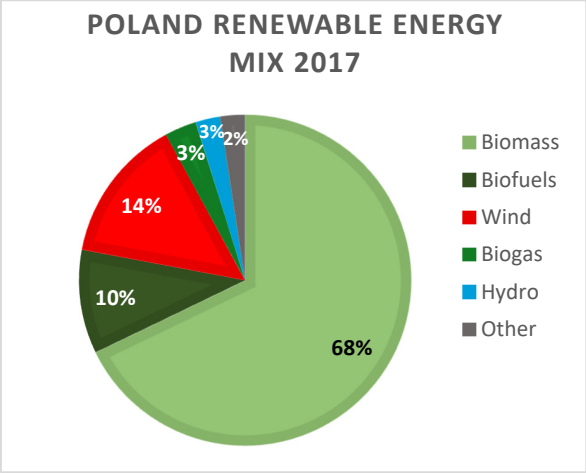

Figure 8, Poland renewable energy mix 2017 (Statistics Poland, 2019).

Other renewable energies

Poland's photovoltaic (PV) energy production capacity reached a peak high in 2018, reaching a total of 486 megawatts (MW) (Bellini E. , 2019). Poland's PV capacity was around 214 MW in 2017, meaning it doubled over 2018 (Bellini E. , 2019). The increased capacity is mainly due to the success of renewable energy project auctions (Bellini E. , 2019). The energy auctions will be further explained in chapters 3.2 and 3.4.

Poland was the second-largest wind market in the EU during 2015 (Deign, 2018). However, investments fell through when taxes on turbines were quadrupled and when it became illegal to build plants within 2 kilometers of buildings or forests, ruling out 99% of Poland's land area (Deign, 2018). These regulations restricted the growth of the Polish wind energy sector. Since then, the capacity of wind energy generation has only grown by 0.87% (export.gov, 2019). To reach the 2020 energy targets, the Polish government has begun investing in offshore wind farms (TPA, 2017). Poland's current energy strategy includes a plan to build offshore wind farms with an energy capacity of 6 GW before the year 2030 (TPA, 2017).

Poland currently has 761 hydro-power plants and generate a total of 994 megawatts (Igliński, 2019). Hydropower accounted for approximately 1.3% of Poland's total generated power in 2018 (Igliński, 2019). Hydropower gives a stable energy production, there is high technical potential and small power plants can be built in many places (Igliński, 2019).

Biogas production

According to data from the Energy Regulatory Office, biogas production in Poland was carried out in 303 biogas plants, with a total power of 240 MW (Wozniak & Twardowski, 2017). Of these biogas plants, 93 were agricultural, which had a total power of more than 100 MW (Wozniak & Twardowski, 2017). The average capacity of a biogas plant in Poland is 0.8 MW (Chodkowska-Miszczuk, Martinat, & Cowell, 2019). Current biogas production has only reached 0.6% of the potential production (Iglinski, Buczkowski, & Cichosz, 2015). The technical potential of biogas in Poland is estimated to be 2.5 million m³ or 39.44 PJ (Iglinski, Buczkowski, & Cichosz, 2015). As can be seen in Table 2, this potential consists of 82 million m³ from municipal waste, 20 million m³ from sewage sludge, 1606 million m³ from animal droppings, 551 million m³ from maize and 254 million m³ from grass (Iglinski, Buczkowski, & Cichosz, 2015). The use of all of Poland's biogas potential could result in meeting 7.5% of Poland's energy demand (Iglinski, Buczkowski, & Cichosz, 2015).

Table 2, Sources of biomass waste and their energy potential (Iglinski, Buczkowski, & Cichosz, 2015).

Item	Substrate	Biogas volume [million m³]	Energy [PJ]
1.	Municipal waste	82	1.28
2.	Sewage sludge	20	0.32
3.	Animal droppings	1603	25.19
4.	Maize	42	0.66
5.	Maize from untilled/fallow land	509	8.00
6.	Grass	254	3.99
	Total	*2510*	*39.44*

The distribution of this biogas potential in Poland can be seen in Figure 9 (Iglinski, Buczkowski, & Cichosz, 2015). The highest amount of biogas energy could be obtained in the following voivodeships: Wielkopolskie (6.54 PJ), Mazowieckie (5.51 PJ) and Podlaskie (3.55 PJ) (Iglinski, Buczkowski, & Cichosz, 2015). Current agricultural biogas production in Mazowieckie is relatively low (Rzeznik & Mielcarek-Bochenska, 2018). Mazowieckie produced 4.9 MW from agricultural biogas in 5 plants (Rzeznik & Mielcarek-Bochenska, 2018). In Podlaskie, 7.6 MW of agricultural biogas was produced in 9 plants. Wielkopolski produced 9.46 MW of agricultural biogas in 10 plants (Rzeznik & Mielcarek-Bochenska, 2018). The most energy produced from biogas was in West-Pomerania with 12.69 MW in 13 plants (Rzeznik & Mielcarek-Bochenska, 2018).

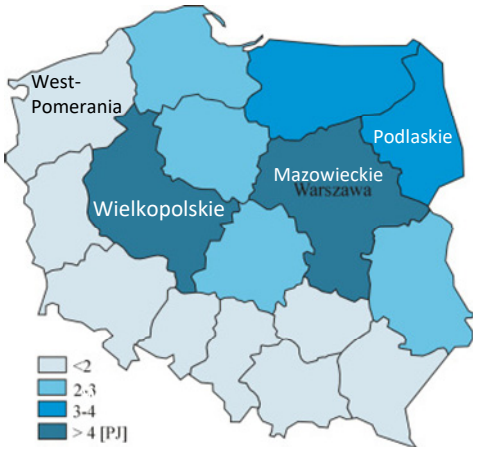

Figure 9, Energy from biogas per voivodeship (Iglinski, Buczkowski, & Cichosz, 2015).

Biomass production

Poland has the 6th largest surface area in the European Union, of which 40% is arable land, totaling to almost 14 million hectares (European Union, n.d.; Flanders Investment & Trade in Poznan, 2019). This large area of arable land gives Poland a large biomass supply (Flanders Investment & Trade in Poznan, 2019). A can be seen in Table 3, Poland's biomass resources are estimated to be 30 million tonnes per year, this includes 9 million tonnes from wood and wood waste, 8 million tonnes of cereals straw and 6 million tonnes of various types of biowaste (Flanders Investment & Trade in Poznan, 2019). Poland's high potential includes other big masses of biomass resources, which are 80 million tonnes of manure and 20 million tonnes of slurry per year (Flanders Investment & Trade in Poznan, 2019).

Table 3, Biomass resources Poland (Flanders Investment & Trade in Poznan, 2019)

Biomass resource	***Millions of tonnes available***
Biowaste	6
Cereals straw	8
(waste) wood	9
Slurry	20
Manure	80

As mentioned in the introduction, the total energy value from bioenergy sources produced in Poland was 298,487 TJ (terajoules) in 2017 (Berent-Kowalska, Kacprowska, Piwko, & Jurgas, 2018). Poland's biomass potential is one of the highest in Europe and is estimated to be 895,000 TJ or 895 PJ, meaning that Poland has only reached one-third of its biomass potential (Jezierska-Thole, Rudnicki, & Kluba, 2016). This high biomass potential is linked to Poland's large surpluses of agricultural sources (Tergopower, 2016). Poland's straw surpluses averaged around 10 million tons annually between 1999 and 2013, which can provide 934 TJ of energy (Tergopower, 2016). The use of straw as biomass could replace over 9.16 million tonnes of coal (Korys, Latawiec, Grolkiewicz, & Kubon, 2019). Of all plant species, the power industry mainly uses straw as straw and other energy crops are most suitable as biomass input for large commercial heating facilities (Baum, Wajszczuk, Peplinski, & Wawrzynowicz, 2013). Poland's major straw surpluses were also mentioned by interviewee 3, who sees a lot of potential in straw as biomass input.

Due to major droughts in recent years, Poland's straw surpluses have seen a decline in certain regions (Grabarz, 2017). These declines are especially noticeable in regions with a high livestock density as these farmers will use the straw for their livestock (Grabarz, 2017). However, in regions where fewer livestock is kept, there are still major straw surpluses on the market (Grabarz, 2017). Transportation of straw between regions can also be a problem since transportation costs are usually covered by the farmers and these costs can be quite high (Grabarz, 2017).

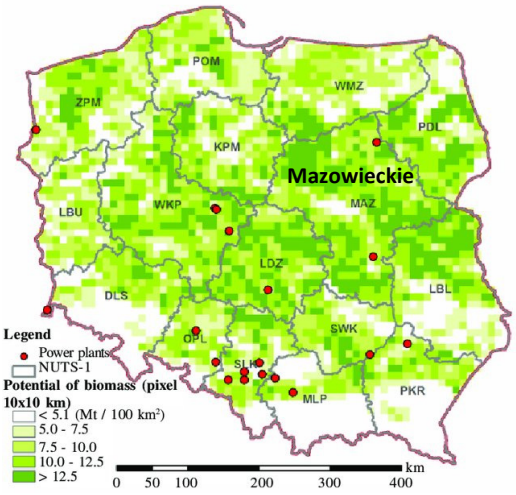

Figure 10, Biomass potential distribution Poland (Zaliwski, et al., 2013)

As can be seen in Figure 10, the highest biomass potential is in the Mazowiecki and surrounding voivodeships (Zaliwski, et al., 2013). The map takes protected areas and the Land Protection Law into consideration (Zaliwski, et al., 2013). The red dots in Figure 10 represent Poland's 20 biggest biomass power plants, which are mainly located in Southern-Poland (Zaliwski, et al., 2013).

To summarize, coal has a share of about 80% of Poland's energy mix, while energy from renewable sources has an 11.16% share (Kuchler & Bridge, 2018; Statistics Poland, 2019). More than two-thirds of

Poland's renewable energy is already generated through bioenergy but there is still room to grow, as Poland is currently only using one-third of its biomass potential (Statistics Poland, 2019). Poland has high biogas and biomass potential, mainly due to the high surpluses of agricultural sources (Flanders Investment & Trade in Poznan, 2019).

Table 5, Energy consumption per consumer in rural & urban Poland (Sobczyk, 2018)

3.1.2 Energy Consumption

Gross final energy, renewable energy, and bioenergy consumption

Poland's total energy consumption was the 6th highest in the EU in 2018, behind Germany, France, the United Kingdom, Italy and Spain (Statista, 2019). However, this high energy use is mainly due to Poland's large population, as Poland also has the 6th largest population in the EU, behind the same abovementioned countries (Eurostat, 2019). Table 4 shows that Poland's gross final energy consumption in 2017 amounted to 4149.1 PJ (EU commission, 2018). Energy use per capita in Poland is below the EU average and totaled at 104.3 GJ per capita, while the EU average is 134.3 GJ (The World Bank, 2015).

Table 4 shows the consumption of gross final energy, renewable energy, and bioenergy of the European Union and Poland. The percentage of bioenergy as a part of the energy from renewable sources (RES) is quite similar between Poland and the EU as they both range around 60% (EU Science Hub, 2019; Statistics Poland, 2019).

Poland has only reached one-third of its bioenergy potential (Jezierska-Thole, Rudnicki, & Kluba, 2016). Poland still has (100-34.2) 65.8% room to grow whereas this is less than half for the EU (29.9%) (Jezierska-Thole, Rudnicki, & Kluba, 2016). This means that Poland has a high unused biomass potential (Jezierska-Thole, Rudnicki, & Kluba, 2016).

Table 4, Energy consumption in the EU and Poland

2017	Gross final energy consumption	RES consumption *(%RES of total consumption*total consumption*100)*	%RES of total consumption	Bioenergy consumption *(%bioenergy of RES * RES consumption*100)*
EU	65,380.61 PJ [1]	11,441.61 PJ*	17.5%[1]	6750.55 PJ*
Poland	4149.1 PJ[2]	452.3 PJ*	10.9% [1]	306.2 PJ*
	% bioenergy of total energy consumption *(bioenergy consumption/total consumption*100)*	% bioenergy of total RES	Bioenergy potential	% bioenergy potential achieved *(bioenergy consumption/potential*100*)
EU	10.3%[7]	59%[3]	9629.6 PJ [4]	70.1%*
Poland	8.3%*	67.7%[5]	895 PJ[6]	34.2%*

1. (Eurostat, 2019), 2. (EU commission, 2018), 3. (EU Science Hub, 2019), 4. (European Commission, n.d.), 5. (Statistics Poland, 2019), 6. (Jezierska-Thole, Rudnicki, & Kluba, 2016), 7. (Banja, Sikkema, Jegard, Motola, & Dallemand, 2019) *From calculations using available data

Biomass potential estimates within the EU and Poland vary between different studies as different types of biomass use considered, and/or the different types of approaches and methodologies implemented in the bioenergy assessment studies (Zyadin, et al., 2018)*. The numbers used were chosen as these numbers are most common in these studies.*

In recent years, Poland's overall energy use has gone up with 1.76% annually (PolandIn, 2019). This is mainly due to the household sector as the sector accounts for a large part of Poland's energy consumption (Peryt, Jurgas, Roman, & Dziedzina, 2014).

The share of energy consumption by households in Poland is higher than the EU average (Borozan, 2018; Peryt, Jurgas, Roman, & Dziedzina, 2014). Energy consumption by the household sector as a percentage of final energy consumption is 24.8% in the EU and this is 31% in Poland (Borozan, 2018; Peryt, Jurgas, Roman, & Dziedzina, 2014).

	Rural	Urban	% difference
Electricity	2407.3 kWh	1736.8 kWh	28%
Gas	10,344 kWh	5606 kWh	46%

More than two-thirds of the household sector's energy consumption is used for heating and another 15% for the heating of water (Peryt, Jurgas, Roman, & Dziedzina, 2014). Within the household sector, differences could be seen between rural and urban areas (Sobczyk, 2018). In 2017, electricity consumption was higher in rural areas compared to urban areas (Sobczyk, 2018). These differences are shown in Table 5. The average electricity consumption being 2407.3 kWh per consumer in rural areas, while this was almost 28% lower in urban areas with 1736.8 kWh per consumer (Sobczyk, 2018). This trend can also be observed in the consumption of gas in Poland (Sobczyk, 2018). In 2017, the consumption of gas in rural areas was 10,344 kWh per consumer, while this is almost half in urban areas with 5606 kWh per consumer (Sobczyk, 2018). A difference between farm and non-farm rural households could also be observed, as farm households used 24.3% more electricity (Kaya, Klepacka, & Florkowski, 2019). This greater energy use of rural households compared to households in urban areas is due to a number of factors (Kaya, Klepacka, & Florkowski, 2019). The average living space for rural households is 108.3 m^3 and consists of 3.4 members, while the average household in Poland has a living space of 74 m^3 and consists of 2.66 persons. Larger households imply higher energy consumption (Kaya, Klepacka, & Florkowski, 2019).

To summarize, compared to the EU, Poland has a high untapped biomass potential. Poland's energy consumption is high but the energy consumption per capita in Poland is lower than the EU average (The World Bank, 2015). Energy consumption in rural Polish households was found to be higher than in urban households (Sobczyk, 2018).

3.1.3 Energy Market

Employment of the energy sector

Part of the Polish National Development strategy stated the importance of employment within the bioenergy sector (Jezierska-Thole, Rudnicki, & Kluba, 2016). Priority number 3 of the national development strategy: "Increase employment and improvement of its quality", lists alternative energies as one of its areas where 'green jobs' can be created (Jezierska-Thole, Rudnicki, & Kluba, 2016). Poland is the EU's fourth-largest employer in the renewable energy sector, with 72,200 jobs (International Renewable Energy Agency, 2019). As can be seen in Table 6, most jobs are in the biofuel, biomass, wind energy or biogas sector. Poland's liquid biofuel sector employs an estimated 31,400 people, the solid biomass sector 25,900; wind energy 8000 and biogas 2300 (International Renewable Energy Agency, 2019).

Table 6, Renewable energy jobs in Poland (International Renewable Energy Agency, 2019).

Polish renewable energy sector	*Number of jobs*
Liquid biofuel	31,400
Solid biomass	25,900
Wind energy	8,000
Biogas	2,300
Total	**72,200**

Other sectors of energy sources employ thousands of people in Poland (International Institute for Sustainable Development, 2018). The hard coal mining sector employed around 98,000 people in 2015 (International Institute for Sustainable Development, 2018). This means that employment in the mining and renewable energy sectors are comparable in the number of jobs (International Institute for Sustainable Development, 2018). Employment of the mining industry is

expected to keep declining as the number has gone down already from 388,000 miners in the year 1990 (International Institute for Sustainable Development, 2018).

Major companies

The three biggest energy companies in Poland are PGE, Tauron, and Enea, which together produced about 63% of Poland's total electricity (Polish Information and Foreign Investment Agency, 2013). With a 40% share of domestic production, the biggest energy company in Poland is Grupa Kapitalowa (PGE) (Polish Information and Foreign Investment Agency, 2013). The company operates 40 power plants, 8 power distribution grids, 7 retailers and 3 mines (Polish Information and Foreign Investment Agency, 2013). The second biggest company, GK Tauron operates a coal-fired plant, 35 hydro plants and two wind farms (Polish Information and Foreign Investment Agency, 2013). GK Tauron produces about 14% of domestic production and 16% of Poland's thermal energy (Polish Information and Foreign Investment Agency, 2013). The third biggest company, GK Enea has a share of 9% of domestic production (Polish Information and Foreign Investment Agency, 2013). GK Enea has a coal-fired plant and is a distributor of energy in Western Poland (Polish Information and Foreign Investment Agency, 2013).

Energy trade

As can be seen in Figure 11, Poland's energy imports were higher than its energy exports (Statistics Poland, 2019). This difference has become significantly larger over the years (Statistics Poland, 2019). Poland's energy imports amounted to 2692.5 PJ in 2018. Poland's energy exports totaled at 708 PJ (Statistics Poland, 2019). Poland's energy imports mostly consisted of crude oil, natural gas, and hard coal. (Statistics Poland, 2019). Energy dependency is the proportion of energy than an economy must import (Eurostat, 2010). Poland's energy dependency was 38.3% in 2018, which is relatively low compared to the EU average of 55% (Statistics Poland, 2019; Eurostat, sd). Poland's energy imports were worth 16.3 billion USD, which accounts for approximately 7.3% of Poland's total imports, were mostly from Russia and consisted of crude petroleum, refined petroleum, coal briquettes and petroleum gas (OEC, n.d.).

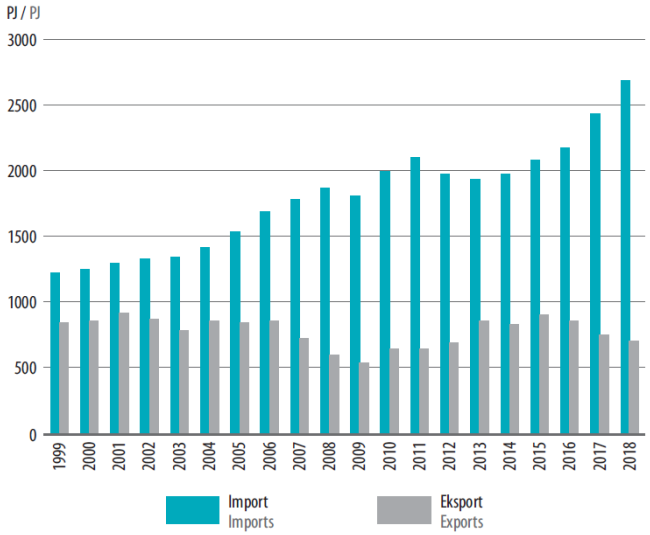

Figure 11, Poland energy exports and imports (Statistics Poland, 2019).

To summarize, employment in the Polish renewable energy sector is comparable to the Polish mining sector (International Institute for Sustainable Development, 2018). The three largest energy companies in Poland are PGE, Tauron, and Enea, which together produced about 63% of Poland's total electricity (Polish Information and Foreign Investment Agency, 2013).

3.2 What is the Legislation Regarding Bioenergy in Poland?

3.2.1 Requirements Polish Legislation

The Energy Policy of Poland until 2040 (EPP2040) has the objective to provide energy security, while ensuring the competitiveness of the economy, energy efficiency and a reduction of the environmental impact of the energy sector, with the optimum use of Poland's own energy resources (Ministry of Energy, 2018). To measure the achievements of EPP2020, the following indicators are used: a 60% share of coal in the generation of electricity in 2030, a 21% share of renewable energy sources in gross final energy consumption in 2030, the introduction of nuclear energy in 2033, improvement of energy efficiency by 23% by 2030 relative to 2007 forecasts, and reducing CO2 emissions by 30% by 2030 (in relation to 1990) (Ministry of Energy, 2018).

As a member of The European Union, Poland had to make amendments to its Energy Law act, as it was obliged to increase its share of renewable energy according to the EU climate goals (Gnatowska & Moryn-Kucharczyk, 2019). These amendments resulted in the development of the act of renewable energy sources (RES-Act) (Gnatowska & Moryn-Kucharczyk, 2019). The Polish RES-Act includes: "the principles for the implementation of the national action plan in the field of energy from renewable sources" as well as the "mechanisms and instruments supporting the production of: electricity from RES, agricultural biogas, and heat in renewable energy installations" (Gnatowska & Moryn-Kucharczyk, 2019).

As mentioned in the introduction, the Polish legislation regarding renewable energies is regarded as unstable (Buzek & Ksiezopolski, 2017). This perception is caused by recent big changes in the RES support system field (Buzek & Ksiezopolski, 2017). Some of these changes were in, for example, the basic support model for installations up to 1 MW and above 1 MW, replacements of green certificates for the auction system, changes for prosumer energy receivers and micro-installations (Buzek & Ksiezopolski, 2017). The importance of a stable energy market was highlighted in interviews 2 and 3. Interviewee 2 mentioned that their company would not enter an unstable energy market. Interviewee 3 mentioned that because of these major changes, he lost sight of the Polish legislation and support schemes. A summary of the interviews can be found in Appendix 8. The current state of the RES-Act will be explained further within this chapter and in chapter 3.4.1 Support by the Polish government.

Certification of installers

According to Article 136 or the RES-Act, installers of micro or small renewable energy installations, including biomass boilers and stoves, may need to request a certificate from the President of the Office of Technical Inspection (Ignaciuk, 2019). This certificate is issued for 5 years (Ignaciuk, 2019). The requirements for an installer to receive such a certificate are the following: to have full legal capacity, to have a diploma or equivalent evidence confirming qualifications, a certificate of completion of training by the manufacturer, to not have been convicted for an offense regarding the credibility of documents or business transactions, to have graduated from basic training on RES installation by an accredited training provider and to have passed an examination conducted by the examination committee not later than 12 months after the completion of this basic training (Ignaciuk, 2019).

Energy auctions

Poland has RES energy auctions, where the Ministry of Economy will announce how much of renewable energy from each group it will need and announce the reference prices for each group (Bellini E. , 2019). These auctions are the replacement of the green certificate system (Ignaciuk, 2019). The green certificate worked as a certificate of origin (Ignaciuk, 2019). The Energy law obliged certain industries, end-users, electricity generators, and suppliers to meet a quota of green certificates (Ignaciuk, 2019). All renewable energy technologies were eligible for the quota system (Ignaciuk, 2019). After July 2016, operators could choose between the quota system and using the tender system (Ignaciuk, 2019). The tenders use a sealed bid system with only one stage (Ignaciuk, 2019). The winners of the tenders have a guaranteed price for 15 years (Ignaciuk, 2019). There is a price cap that is set by the Minister of Energy before every tender (Ignaciuk, 2019). The tender has 5 baskets (Diallo, et al., 2019). The first basket is for non-agricultural biogas and biomass installations; the second for hydropower, geothermal and offshore wind energy; the third for agricultural biogas installations; the fourth for onshore wind and solar PV installations and the fifth for hybrid installations (Diallo, et al., 2019). The auctions have two categories, small installations with a capacity of under 1 MW and large installations with a capacity of more than 1 MW (Diallo, et al., 2019).

The tenders are in 'Contract-for-Difference' form (ICIS, 2019). This means that if the supplied power price is below the producer's agreed-upon price, the operator would receive a 'negative balance' (ICIS, 2019). This negative balance is the difference between the auction price and market electricity price. In the case of a 'positive balance', this would be settled against the next negative balance (ICIS, 2019). If a positive balance remains at the end of the 15 year period, the renewable energy generator will pay it back in six equal installments (ICIS, 2019). For the operators, a negative balance is more beneficial, as the buyer would pay the difference between the auction price and market price (Corporate Finance Institute, n.d.). In case of a positive balance, this would be the other way around and the operator would pay for the difference (Corporate Finance Institute, n.d.).

Furthermore, according to RES-Act article 75.5, energy producers need to have a legally binding building permit, environmental permit, grid connection agreement, a local land-use plan, a schedule of works and expenditure, and a schematic drawing of the installation including the location of electricity generating units and point of grid connection (Diallo, et al., 2019) Any restrictions or further requirements depend on the rules of the particular tender (Ignaciuk, 2019). The latest amendment of the RES-Act in 2019 stated that the winner of the auction can now make one change to its auction offer in, for example, the start date, installed capacity and allocation of electricity generation (Rogalski, 2019).

Prosumer law

A prosumer is both a consumer and producer of energy (GfK Belgium consortium, 2017). In Poland, laws regarding prosumers are described and regulated in the RES-Act (GfK Belgium consortium, 2017). The act states that a prosumer in Poland is the owner of a micro renewable energy installation that is connected to the low voltage power network (GfK Belgium consortium, 2017). Prosumers in Poland can sell renewable energy produced in micro-installations to the electric power network at 80% of the sale price of the previous year, which is published by the Energy Regulatory Office (GfK Belgium consortium, 2017).

Poland has a support program for all types of micro-installations (GfK Belgium consortium, 2017). In 2015 this price was 0.163 PLN/kWh (Ignaciuk, 2019). As shown in Table 7, the RES-Act states that micro-installations running on biogas with a capacity between 3 kW and 10 kW, should get a price of 0.7 PLN/kWh for agricultural biogas (Ignaciuk, 2019). This price is between 0.46 and 0.55 PLN/kWh for biogas installations running on landfill and between 0.33 PLN and 0.45 PLN/kWh for biogas from wastewater (Ignaciuk, 2019). The National Fund for Environmental Protection and Water Management also gave out subsidies to prosumers to support the purchase and installation of small and micro renewable energy installations (Ignaciuk, 2019). The support scheme started in 2015 and ended in 2019, with no renewal or replacement foreseen in the near future (Ignaciuk, 2019).

Table 7, Micro-installations price (Ignaciuk, 2019)

Type of installation	*Price*
Biogas, capacity between 3-10 kWh	0.7 PLN/kWh
Biogas, running on landfill	0.46 – 0.55 PLN/kWh
Biogas, running on wastewater	0.33-0.45 PLN/kWh

Blending quota

The Act on Bio components and Liquid Biofuels (Sejm of the Polish Republic, 2006) obliges producers, importers, and suppliers of fuels to meet a defined quota of biofuels. The act introduces national indicative targets, which are annual minimum percentages of biofuels and other renewable fuels as a total amount of liquid fuels (Sejm of the Polish Republic, 2006). For 2018, this quota was 7.5%; for 2019 8% and for 2020 8.5% (Ignaciuk, 2019).

The requirements in Polish legislation seem to be quite specific and detailed. As for the legislation of the European Union, most requirements are non-binding, very general or up for the member states.

3.2.2 Requirements European Union and Other Legislation

The European Union has released definitions for bioenergy, specific blending quotas, non-obligatory guidelines on national support schemes, sustainability criteria and technical specifications (European Parliament and Council, 2003; European Commission, 2019; Ignaciuk, Promotion in Poland, 2019; European Parliament and Council, 2009).

The European Union has released guidelines regarding the design of renewable energies support schemes (European Commission, 2013). Document (SWD(2013) 439 final) states: "*Financial support for renewables should be limited to what is necessary and should aim to make renewables competitive in the market,"* (European Commission, 2013). The recommendations include using a feed-in premium (FIP) over a feed-in tariff (FIT), as the FIT does not expose producers to market price indicators (European Commission, 2013). In recent years, many support schemes haves shifted from FIT to FIP models (European Commission, 2013). Poland applies a combination of a feed-in tariff (FIT), a sliding feed-in premium (FIP) and a tendering system (Banja, Sikkema, Jegard, Motola, & Dallemand, 2019).

Renewable energy directive

The Renewable Energy Directive 2009/28/EC compelled the EU to have a share of at least 20% from renewable energy sources as a part of their final energy consumption by 2020 (Piwowar, Dzikuc, & Adamczyk, 2016). Additionally, climate goals for 2030 were named in the Lisbon treaty (COM(2014) 15 final) (European Commission, 2014). The Lisbon treaty concerned energy efficiency, energy savings and the development of renewable energy sources (Gouarderes & Beltrame, 2019). The current policy agenda is driven by key targets set out in the climate and energy policy from 2014 and revised upwards in 2018, to achieve by 2030 (Gouarderes & Beltrame, 2019). The 2030 climate and energy framework key targets are the following: a reduction of at least 40% in greenhouse gas emissions compared to 1990 levels; an increase to 32% of the share of renewable energies in energy consumption; an improvement of 32.5% in energy efficiency and the interconnection of at least 15% of EU's electricity systems (European Commission, 2019).

As mentioned in the introduction, every member state of the European Union has its own 2020 target for the share of renewable energy (export.gov, 2019). These national targets take starting points, potential and economic performance into account (export.gov, 2019). Poland's 2020 target for renewable energy is set at 15% (export.gov, 2019). Current data suggests that Poland will not meet this goal (export.gov, 2019). Major changes are needed to the Polish energy sector to increase this share at a faster rate (Kuchler & Bridge, 2018). For Poland to make this energy transformation, major investments, changes in regulations and several years will be required (Kuchler & Bridge, 2018). If Poland would not meet this renewable energy share, high costs would be the consequence (The Institute of International and European Affairs, 2018). This could be a motivation for Poland to realize the EU climate goals (The Institute of International and European Affairs, 2018). More information on the EU renewable energy goals can be found in Appendix 5.

Sustainability criteria

Sustainability criteria for biomass are not yet obligatory on the EU-level (Banja, Sikkema, Jegard, Motola, & Dallemand, 2019). The European Commission has issued non-binding recommendations on sustainability criteria for biomass that apply for installations of at least 1 MW (Banja, Sikkema, Jegard, Motola, & Dallemand, 2019). These recommendations are the following: forbid the use of biomass from land converted from forest, and other high carbon stock areas, as well as highly biodiverse areas; ensure that biofuels emit at least 35% fewer greenhouse gases over their lifecycle (cultivation, processing, transport, etc.) when compared to fossil fuels (European Commission, 2019). For new installations, this amount rises to 50% in 2017 and 60% in 2018; to favor national biofuels support schemes for highly efficient installations; and encourage the monitoring of the origin of all biomass consumed in the EU to ensure their sustainability (European Commission, 2019).

A recent proposal for a change in the Directive on the promotion of the use of energy from renewable sources has included obligatory sustainability criteria (European Parliament and Council, 2018). This proposal was only partly accepted, as the obligatory sustainability criteria were left out of the recast directive (European Parliament and Council, 2018). However, as anticipation for any future changes, many EU member states have developed their own criteria from these recommendations (European

Commission, 2019). This is not the case for Poland, where there are no obligatory sustainability criteria (Banja, Sikkema, Jegard, Motola, & Dallemand, 2019). There are other sustainability criteria that are relevant to biomass, for instance, criteria by intergovernmental bodies like Forest Europe, FSC, PEFC certification schemes and industry-led initiatives such as the sustainable biomass partnership or ENplus certification for wood pellets (Bourguignon, 2015).

Definitions

Other regulations and directives that are related to bioenergy are in directive 2003/30/EC (European Parliament and Council, 2003), which established definitions for biofuels, biomass, and biogas. Article 2 of the directive states: "biofuels means liquid or gaseous fuel for transport produced from biomass; 'biomass' means the biodegradable fraction of products, waste and residues from agriculture (including vegetal and animal substances), forestry and related industries, as well as the biodegradable fraction of industrial and municipal waste (European Parliament and Council, 2003).

Standards

The European Union has not given any technical specifications for renewable energies, as this is mainly member state-specific (European Parliament and Council, 2009). The European Union has given a set of standards that are of importance for companies operating in the bioenergy industry (European Parliament and Council, 2009). Directive 2009/29/EC (European Parliament and Council, 2009) states: ´Member States shall clearly define any technical specifications which must be met by renewable energy equipment and systems in order to benefit from support schemes," (European Parliament and Council, 2009). The European Committee for Standardization has developed European standards and a selection of definitions for bio-based products (European Committee for Standardization, 2014). The horizontal (general) standards are the following: common terminology (EN 16575), methods for determining bio-based content (CEN/TR 16721, CEN/TS 16640, EN 16785), sustainability aspects (EN 16751), life cycle assessment (EN 16760) and declaration tools (European Committee for Standardization, 2014). Other standards by the European Committee for Standardization are CEN/TC 19 for bio-lubricants and CEN/TC 411 on bio-based products (European Committee for Standardization, 2014).

CO2 / Emissions

Greenhouse gas emissions associated with biomass combustion are not included in the energy sector under both EU and legislation (The European Parliament and Council, 2013). This is under the assumption that carbon released when solid biomass is burned will be re-absorbed during tree growth (The European Parliament and Council, 2013). In Decision No 529/2013/EU, the European Parliament and Council have set up rules regarding greenhouse gases from activities relating to land-use change and forestry (The European Parliament and Council, 2013). These decisions do not specifically name biomass. However, rules on forestry do impact, for example, biomass installations running on wood pellets (The European Parliament and Council, 2013).

3.3 What are the Development Costs of Bioenergy Plants in Poland?

Development costs are especially important for prosumers or owners of micro installations (Klepacka, Florkowski, & Meng, 2018). Rural households generally have an income that is below the national average, which would suggest an economic reality with greater attention to specific reasons related to costs, gains and reliability rather than environmental concerns (Klepacka, Florkowski, & Meng, 2018). This makes the development costs of importance to the rural Polish bioenergy market (Klepacka, Florkowski, & Meng, 2018).

3.3.1 Development Periods

The development periods for biomass and biogas plants favor the construction of plants running on bioenergy sources (Iglinski, Buczkowski, & Cichosz, 2015). The average development periods of different energy plants are shown in Figure 12. It takes approximately 8 months to 2 years to build a running moderate to large scale biogas plant (Electrigaz, 2017). For a smaller plant (10 m^3 or less) this is 1 to 2 months (Electrigaz, 2017). For a biomass energy plant, this is generally longer, as most companies offer a construction period of 18 months (Ministry of New and Renewable Energy, n.d.). To compare, it takes 4-7 years for a hydroelectric power station to be operational (Association québécoise de la production d'énergie renouvelable, n.d.), 2 months to 2 years for a wind farm (Futuren, n.d.), a nuclear power station 7.5 years and 4 years to have an operational coal power plant (Mearns, 2016; Association québécoise de la production d'énergie renouvelable, n.d.; Futuren, n.d.; Fickling, 2019). The shorter construction periods favor bioenergy plants instead over the construction of other renewable or unsustainable power plants (Iglinski, Buczkowski, & Cichosz, 2015). Additionally, there are plentiful biomass resources in Poland, also favoring the construction of bioenergy plants (Iglinski, Buczkowski, & Cichosz, 2015).

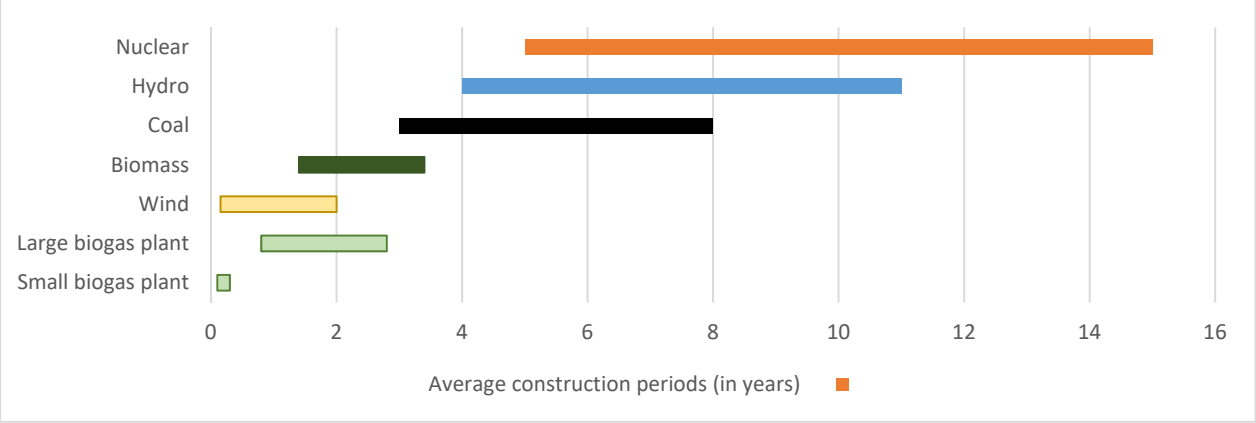

Figure 12, Construction periods energy plants (Electrigaz, 2017; Ministry of New and Renewable Energy, n.d.; Association québécoise de la production d'énergie renouvelable, n.d.; Futuren, n.d.; Fickling, 2019).

3.3.2 Construction Costs

The development costs for bioenergy plants are highly heterogeneous and strongly vary from case to case (Chasnyk, Solowski, & Shkarupa, 2015). The development costs depend on a wide range of variables (Chasnyk, Solowski, & Shkarupa, 2015). Sub-question 3 covers the average development costs. However,

it should be kept in mind that these costs can vary significantly between different projects (Chasnyk, Solowski, & Shkarupa, 2015).

The total capital expenditure of a biogas plant with a capacity of 1.6 MW is estimated to be around 6 million EUR (Chasnyk, Solowski, & Shkarupa, 2015). Literature has shown the estimated average investment costs for a biogas project in Poland range between 7.6 and 13.1 million PLN or 15 to 19.5 million PLN per MWel (Chasnyk, Solowski, & Shkarupa, 2015). Using the 2016/2017 average exchange rate of 1 EUR = 4.3 PLN, the average biogas project costs between 1.8 million and 3 million EUR or 3.5 to 4.5 million EUR/MWel (Eurostat, 2019).

As can be seen in Table 8, to produce the same amount of energy from nuclear sources compared to a biogas plant, the capital expenditures would be double and the implementation would be 15 times as long (Iglinski, Buczkowski, & Cichosz, 2015). As mentioned in the introduction, the initial investment for a biomass or bioenergy plant is lower than those using other renewable energies or fossil fuels (Iglinski, Buczkowski, & Cichosz, 2015). Table 8 shows that a biogas plant has a lower initial investment than power plants running on fossil fuels or nuclear energy and that development periods are significantly lower (Iglinski, Buczkowski, & Cichosz, 2015).

Table 8, Comparison of capital expenditures between power plants in Poland (Iglinski, Buczkowski, & Cichosz, 2015).

Type of a power plant	**Total power [GW]**	**Capital expenditures [10^9EUR]**		**Duration of implementation [years]**
		Per unit	Total	
Single nuclear unit	1.6	12	12	15
2 Coal-fired units with CCS	1.7	4	8	10
1000 Biogas plants of power rating 1.6 MW each	1.6	0.006	6	1

Even though the initial investment costs are relatively low for bioenergy plants, the operating costs are quite high (European Commission, 2014). The EU Guidelines on State aid for environmental protection and energy (2014/C200/01) (European Commission, 2014) states the following:

Higher operating costs may prevent a biomass plant from operating even after depreciation of the installation as the operating costs can be higher than the revenues (the market price). On the other hand, an existing biomass plant may operate by using fossil fuel instead of biomass as an input source if the use of fossil fuel as an input is more economically advantageous than the use of biomass. To preserve the use of biomass in both cases, the Commission may find operating aid to be compatible with the internal market even after plant depreciation (European Commission, 2014).

The higher operating costs are also shown in Table 9 (Budzianowski, 2011). Table 9 shows a relatively low range of production costs for biogas and this to be a relatively high range for electricity production from

biomass (Budzianowski, 2011). However, for Poland, large hydro power plants are not possible and energy capacities from small hydro power plants are limited (Budzianowski, 2011). Additionally, nuclear energy capacities are also limited as these require large investments and there is an uncertainty on long-term uranium availability, making wind and bioenergy the most interesting power technologies for Poland (Budzianowski, 2011).

Table 9, Production costs of electricity from power technologies in 2020 (Budzianowski, 2011)

Power technology	*Range production cost of electricity (EUR/MWh)*	*Referent value*
Large Hydro plant	30-140	50
Biogas	50-200	60
Nuclear	45-80	65
On-shore wind	55-90	70
Small Hydro plant	55-160	70
Off-shore wind	65-120	75
Coal	80-110	90
Solid biomass	80-200	95
Solar PV	270-460	320

3.3.3 Other Costs

Direct other costs can be linked to the grid connection agreement, a bank guarantee and penalties from the tenders. Other factors that could influence the development costs are the prices of land and labor, as prices of land differ greatly between the voivodeships and labor costs are rising. The average price of land per voivodeship and information on labor prices can be found in Appendix 6.

Grid connection agreement

According to Article 7 of the Polish Energy Law, the costs of connecting a power plant to the grid shall be covered by the plant operator (Gulczyński, 2015). Energy plants producing renewable energy at a capacity of less than 5 MW are subject to reduced connection charges (Gulczyński, 2015). Micro-installations can be connected to the grid for free (Gulczyński, 2015). The Energy Law also states that grid operators should give electricity from renewable sources priority of transmission (Gulczyński, 2015). The connection agreement between the plant operator and grid operator needs to include the deadline for completion of connection, connection fee, schedule of completing the connection, the expected date of conclusion of the electricity supply agreement, the quantity of electricity for reception and connection capacity (Gulczyński, 2015).

The costs for the use of the grid will be added to electricity prices, so ultimately consumers will pay for these costs (Gulczyński, 2015).

Bank guarantee

For producers to take part in the tenders, they need to be registered as an energy producer (Diallo, et al., 2019). Energy producers need to hand in a one-stage bid bond or bank guarantee before the auction date (Diallo, et al., 2019). In 2018, this guarantee was 30 PLN (7.02 EUR) per 1 kW for existing installations and 60 PLN (14.04 EUR) per 1 kW for new installations (Diallo, et al., 2019). This bond is refunded if the project does not win the auction or after the commencement of electricity generation (Diallo, et al., 2019).

Penalties tenders

Energy producers who fail to deliver the promised amount of energy of the RES auctions need to pay a fee (Ignaciuk, 2019). This fee is the difference between the energy produced and energy that was promised, multiplied by half the offered price (Ignaciuk, 2019). Additionally, the manager of the enterprise could get a penalty that is a maximum of three times the manager's salary (Ignaciuk, 2019). The RES amendments of 2019 stated that a penalty can only be given if less than 85% of electricity set out in the auction offer is delivered and if the producer managed to sell the electricity for the first time within the set deadlines (Rogalski, 2019).

Other costs could be connected to administrative steps such as obtaining a building permit, environmental permit, a local land-use plan, a schedule of works and expenditure, and a schematic drawing of the installation including the location of electricity generating units and point of grid connection (Rogalski, 2019). These documents would be needed to take part in renewable energy auctions (Rogalski, 2019).

To summarize, the development costs and periods for biomass and biogas installations favor bioenergy over other renewable energy sources and fossil fuels (European Committee for Standardization, 2014). However, especially for biomass plants, initial investments are lower but operating costs will be higher than in conventional plants (European Committee for Standardization, 2014). Other costs can relate to a grid connection agreement, bank guarantee, a penalty or other administrative steps necessary to participate in RES auctions (Gulczyński, 2015; Ignaciuk, Promotion in Poland, 2019; Rogalski, 2019).

3.4 What Support can Foreign Companies in the Bioenergy Sector get?

As mentioned in the previous chapter, rural households generally have incomes below the national average (Klepacka, Florkowski, & Meng, 2018). This gives rural households a different economic reality in which there is less focus on environmental concerns but more attention is directed to specific reasons related to costs, gains, and reliability (Klepacka, Florkowski, & Meng, 2018). Financial incentives have been shown to encourage the decision of rural households to install renewable energy installations (Klepacka, Florkowski, & Meng, 2018). In interviews 3 and 4, the interviewees mentioned the importance of (stable) support schemes. According to the interviewees, for bioenergy to be viable, support schemes are needed. A summary of the interviews can be found in Appendix 8.

The European Union member states are allowed to determine to what extent they support renewable energy produced in and imported from another member state (European Commission, 2013). The European Union has released guidelines regarding the design of renewable energies support schemes (SWD(2013) 439 final) (European Commission, 2013). In this document, the European Commission calls for more market exposure on renewable producers (European Commission, 2013). Market exposure is necessary for a competitive energy market driven by efficient production and investment decisions (European Commission, 2013). The document recommends using a feed-in premium (FIP) over a feed-in tariff (FIT), as the FIP exposes producers to market price indicators (European Commission, 2013). In recent years, many support schemes haves shifted from FIT to FIP models (European Commission, 2013). Poland applies a combination of a feed-in tariff (FIT), a sliding feed-in premium (FIP) and a tendering system (Banja, Sikkema, Jegard, Motola, & Dallemand, 2019). The different support schemes will be further explained in this chapter.

3.4.1 Support by the Polish Government

With a total of 28, Poland has the 5th most biomass incentives in the electricity sector in the EU (Banja, Sikkema, Jegard, Motola, & Dallemand, 2019). This is behind the Czech Republic (42), Greece (39), the Netherlands (36) and Germany (30) (Banja, Sikkema, Jegard, Motola, & Dallemand, 2019). An incentive can be defined as "something that encourages a person to do something," (Cambridge Dictionary, sd). Incentives typically include support schemes such as tax credits, exemptions, grants, loans, and cost-share programs (Wood-Energy, 2019). In the EU, 70% of all biomass incentives are used in the electricity sector (Banja, Sikkema, Jegard, Motola, & Dallemand, 2019). More than 40% of these incentives are dedicated to biogas (22.6%) and landfill or sewage gas (10.8%) (Banja, Sikkema, Jegard, Motola, & Dallemand, 2019). The share of other types of biomass is 28.6%. Smaller shares belong to co-firing (6.8%), CHP (5.5%), waste (4.3%) and anaerobic digestion (3.8%) (Banja, Sikkema, Jegard, Motola, & Dallemand, 2019).

According to Energypedia (2019), A FIT scheme can be defined as: "Feed-in tariffs (FIT) are fixed electricity prices that are paid to renewable energy (RE) producers for each unit of energy produced and injected into the electricity grid," (Energypedia, 2019). A FIP scheme can be defined as: "Electricity from renewable energy sources (RES) is typically sold on the electricity spot market and RES producers receive a premium on top of the market price of their electricity production," (Energypedia, 2019). A sliding FIP as: "Sliding (or "floating") FIP are calculated on a continuous basis as the difference between

(technology-specific) market prices (usually averaged over a certain period of time, e.g. one month) and a predefined reference tariff level (often corresponding to existing FIT).” (Energypedia, 2019). As mentioned earlier, Poland applies a combination of a feed-in tariff (FIT), a sliding feed-in premium (FIP) and a tendering system (Banja, Sikkema, Jegard, Motola, & Dallemand, 2019). Poland is the only EU member state to apply a combination of feed-in-tariffs with a tender. The average inventive in Poland for biogas is a FIT with a tender of 113.8 EUR/MWh (Banja, Sikkema, Jegard, Motola, & Dallemand, 2019).

The differences in support schemes can be seen in Figure 13 (Banja, Sikkema, Jegard, Motola, & Dallemand, 2019). Figure 13 shows a fixed price for FIT, regardless of the market price, a FIP that follows the market price and applies a premium and a sliding FIP that is fixed but calculated using the average market price of a certain period of time (Banja, Sikkema, Jegard, Motola, & Dallemand, 2019).

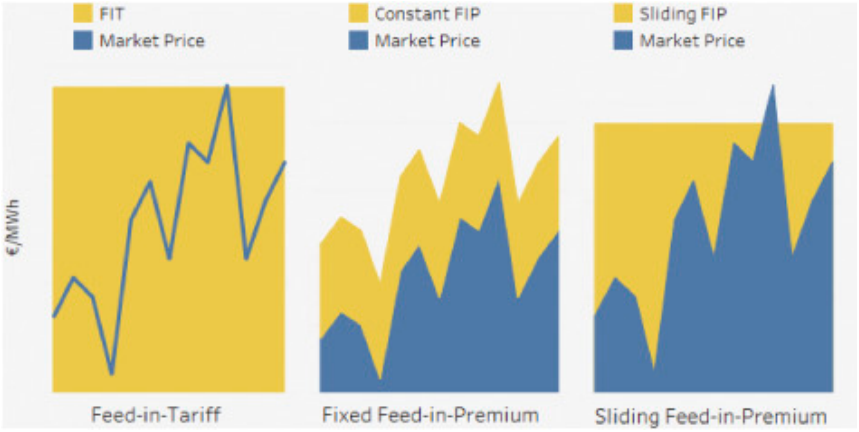

Figure 13, Main support schemes promotion of renewable energies (Banja, Sikkema, Jegard, Motola, & Dallemand, 2019).

Feed-in premiums

A guaranteed feed-in premium is available for biogas installations that have a capacity between 500 kW and 1 MW (under RES-Act, Art 70a2) and for those that run on agricultural sources, municipal waste, sewage sludge and other types of biogas (Ignaciuk, 2019). Guaranteed FIPs are also available for hydro power installations that have this same capacity (Ignaciuk, 2019). The premium is used to equalize a negative balance that is caused by a price for the unused electricity that is lower than the one mentioned in the approved declaration (Ignaciuk, 2019). The electricity generator must submit a declaration of intent of sale of unused electricity according to the fixed purchase price (Ignaciuk, 2019). This price is determined by the Energy Regulatory Office. According to article 70 f.1, the eligibility period is 15 years (Ignaciuk, 2019).

Feed-in tariffs

The feed-in tariff is available for biogas and hydro power installations with a capacity under 500 kW (Ignaciuk, 2019). The tariff amounts to 90% of the reference price set in the RES-Act, Article 77.3.1 (Ignaciuk, 2019). This tariff varies between different installations and is inflation-adjusted (Ignaciuk, 2019). The average inventive in Poland for biogas is a FIT with a tender of 113.8 EUR/MWh (Banja, Sikkema, Jegard, Motola, & Dallemand, 2019). The reference prices for 2017 can be seen in Table 10

(Cichocki, Mlodawski, & Lewicki, 2017). The application procedure for a FIT is similar to the FIP system, as a declaration of intent of sale of unused electricity needs to be submitted (Ignaciuk, 2019). The eligibility period is the same as in the FIP system (Ignaciuk, 2019).

Table 10, Reference prices 2017 (Cichocki, Mlodawski, & Lewicki, 2017). Using the 03-02-2020 exchange rate of 4.31 PLN/EUR (XE, 2020)

Type of RES installation	Reference price [PLN/MWh]	Reference price [EUR/MWh]* * exchange rate EUR/PLN 4,31
Agricultural biogas ≤1MW	550	127,61
Agricultural biogas >1MW	550	127,61
Landfill biogas	405	93,97
Sewage treatment plant biogas	365	84,69
Biogas not specified above	355	82,37
Biomass in dedicated biomass combustion installations and hybrid power plants ≤50MW	415	96,29
Biomass, biofuels, biogas or agricultural biogas in dedicated multi-fuel combustion installations	325	75,41
Biomass in CHP dedicated biomass combustion installations and CHP hybrid power plants ≤50MW	450	104,41
Biomass in CHP dedicated biomass combustion installations and CHP hybrid power plants >50MWe and ≤150MWt	435	100,93
Waste incineration plants	**385**	89,33
Biofuels	475	110,21
Onshore wind farm ≤1MW	320	74,25
Onshore wind farm >1MW	**350**	81,21
Hydro power plants ≤1MW	480	111,37
Hydro power plants >1MW	480	111,37
Geothermal power plant	455	105,57
Solar ≤1MW	450	104,41
Solar >1MW	**425**	98,61
Offshore wind farm	**470**	109,05
Renewable hybrid power plant irrespective of the fuel used ≤ 1 MW	455	105,57
Renewable hybrid power plant irrespective of the fuel used > 1 MW	405	93,97

Prosumers

For prosumers, the individual consumers of energy who produce energy in small installations (with a capacity of up to 50 kW), there is a special prosumer support scheme (Ignaciuk, 2019). Prosumer support schemes cover wind energy, solar energy, agricultural biogas installations, and biomass installations. Prosumers need to sign a complex agreement with the energy seller (Ignaciuk, 2019). The seller will calculate the difference between the energy that is produced and what is consumed (Ignaciuk, 2019). The competent authority is the Energy Regulatory Office (URE) (Ignaciuk, 2019). The support scheme does not include a fixed tariff but allows prosumers to exchange the surplus of energy produced by favorable conditions for gaps in energy production in the future (Ignaciuk, 2019). This is in a 1 to 0.8 relation for micro-installations (capacity up to 10 kW) and 1 to 0.7 for micro-installations with a capacity between 10 and 50 kW (Ignaciuk, 2019).

Loan and subsidies

The National Fund for Environmental Protection and Water Management offers low-interest loans as well as subsidies to support the purchase and installations of all RES installations, excluding geothermal (Ignaciuk, 2019). Subsidies were meant to support the purchase of renewable energy installations by residential single or multi-family houses (Ignaciuk, 2019). This subsidy program ended in 2019 (Ignaciuk, 2019). However, the low-interest loans are still offered (Ignaciuk, 2019). These support schemes are a part of the 'STORK RES Priority Programs' (Ignaciuk, 2019).

Table 11, Maximum installation costs per eligible installation (Ignaciuk, 2019). Using the 02-02-2020 exchange rate of 4.3 PLN/EUR (XE, 2020).

Max installation cost per MW (in millions)	**PLN**	**EUR**
Biogas, 40 kWe - 100 kWe	25	5.82
Biogas, 100 kWe - 300 kWe	20	4.66
Biogas, 300 kWe - 2 MWe	16	3.73
Biomass, 40 kWe - 500 kWe	7	1.7
Biomass, 500 kWe - 5 MWe	15	3.49
Biomass, with ORC	20	4.66

Table 11 shows the maximum installation costs per megawatts (MW) for bioenergy installations to be eligible for the low-interest loans (Ignaciuk, 2019). Biogas installations need to have a capacity between 40 kWe and 2 MWe (Ignaciuk, 2019). For biogas installations with a capacity between 40 kWe and 100 kWe, the maximum installation costs are 25 million PLN (5.82 million EUR) per megawatt (MW) (Ignaciuk, 2019). This is 20 million PLN (4.66 million EUR) per MW for an installation with a capacity between 100 and 300 kWe, and 16 million PLN (3.73 million EUR) per MW for a biogas installation with a capacity between 300 kWe and 2 MWe (Ignaciuk, 2019). For a biomass installation to be eligible for the low-interest loans, it needs to have a capacity between 40 kWe and 5 MWe (Ignaciuk, 2019). The maximum installation costs for biomass installations is 7 million PLN (1.7 million EUR) per MW for installations with a capacity between 40 and 500 kWe; 15 million PLN (3.49 million EUR) per MW for a capacity between 500 kWe and 5 MWe; and 20 million PLN (4.66 million EUR) per MW for installations with an Organic Rankine Cycle (ORC) (Ignaciuk, 2019).

The overall budget for the loan program is 570 million PLN for the years 2015-2023 (Chmielewski, Guminski, Maczak, Radkowski, & Szulim, 2016). The loan can cover a maximum of 85% of the investment's eligible costs (Chmielewski, Guminski, Maczak, Radkowski, & Szulim, 2016). The used interest rate for the loan is the Warsaw Interbank Offered Rate, which was 1.71% as of November 2019 (Polish Financial Markets Association ACI Polska, 2019). The application is done through an application for a loan to the National Fund for Environmental Protection and Water Management (Chmielewski, Guminski, Maczak, Radkowski, & Szulim, 2016).

Quota system/Tenders

Before the 1st of July 2016, Poland used a quota system for renewable energy (Ignaciuk, 2019). For every MWh of renewable energy, plant operators could receive one Green Certificate (Ignaciuk, 2019). The green certificate works like a certificate of origin (Ignaciuk, 2019). The Energy law obliged certain industries, end-users, electricity generators and suppliers to meet a quota of green certificates. All renewable energy technologies were eligible for the quota system (Ignaciuk, 2019).

After July 2016, operators that launched their installations before the 1st of July 2016 could choose between the quota system and using the tender system (Diallo, et al., 2019). Operators that chose to switch to the tender system were included in separate auctions (Diallo, et al., 2019). Out of these auctions, only 3 out of 9 were successful, of which none in 2018 (Diallo, et al., 2019). Additionally, the FIT system was introduced (Ignaciuk, 2019). The tender system is also available for all renewable energy technologies (Ignaciuk, 2019). Tenders use auctions and offer energy producers a guaranteed price for 15 years (Ignaciuk, 2019). The auction budgets for 2019 were published in the RES amendment act of 2019 (Ignaciuk, 2019). Installations that have a capacity of less than 500 kW are guaranteed to have their electricity purchased by the obliged retailers (Ignaciuk, 2019).

Table 12 shows the main characteristics of the 2018 auctions for biomass and non-agricultural biogas, and agricultural biogas (Diallo, et al., 2019). The table shows that the auction for biomass and non-agricultural biogas with a capacity of less than 1 MW was unsuccessful as it did not have valid bids (Diallo, et al., 2019).

Table 12, Main characteristics and results of auctions for biogas and biomass in 2018 (Diallo, et al., 2019).

Technology	**Offered amount**	**Auction budget**	**Auction successful**	**Number of valid bids**
Biomass or non-agricultural biogas, more than 1 MW	57 TWh	5.836 billion EUR	Yes	1
Biomass or non-agricultural biogas, less than 1 MW	13.31 TWh	1.289 billion EUR	No	0
Agricultural biogas, more than 1 MW	3.51 TWh	452 million EUR	Yes	3
Agricultural biogas, less than 1 MW	11.7 TWh	1.676 billion EUR	Yes	29

Table 13 shows the results of the three successful bids of the biogas and biomass auctions (Diallo, et al., 2019). For all three auctions, the actual auctioned amount was less than 30% of the offered volume (Diallo, et al., 2019). The prices are very close to the price caps (Diallo, et al., 2019). The average price was around 100 EUR/MWh and even 132 EUR/MWh for small agricultural biogas plants (Diallo, et al., 2019). More information on the RES Auctions and the 2020 auction budget can be found in Appendix 7.

Table 13, Results biogas and biomass RES auctions in 2018 (Diallo, et al., 2019).

Technology	Contracted volume (share of offered)	Minimum price	Average price	Maximum price
Biomass or non-agricultural biogas, more than 1 MW	0.97 TWh (1.70%)	93.65 EUR/MWh	93.65 EUR/MWh	93.65 EUR/MWh
Agricultural biogas, less than 1 MW	3.49 TWh (29.83%)	126.17 EUR/MWh	132.33 EUR/MWh	133.39 EUR/MWh
Agricultural biogas more than 1 MW	0.72 TWh (20.51%)	116.13 EUR/MWh	118.28 EUR/MWh	121.05 EUR/MWh

Tax exemption

All renewable energy technologies in Poland are eligible for tax exemption (Ignaciuk, 2019). Currently, the consumption tax on electricity amounts to 20 PLN/MWh (Ignaciuk, 2019). The subsidy is equal to the amount of taxes the energy generators and suppliers are exempted from (Ignaciuk, 2019). Generators and suppliers need to submit their certificates issued by the Energy Regulatory Office to the customs office (Ignaciuk, 2019).

To summarize, Poland applies a combination of a feed-in tariff (FIT), a sliding feed-in premium (FIP) and a tendering system (Banja, Sikkema, Jegard, Motola, & Dallemand, 2019). Additionally, prosumers are allowed to exchange their surpluses of energy for possible gaps in the future, certain bioenergy installations can apply for a low-interest loan and be eligible for tax exemption (Ignaciuk, 2019).

3.4.2 Support by the European Union

Cohesion funds

The European Commission has set up Cohesion Policies in order to reduce differences between regions (European Commission, n.d.). These funds can be divided into 3 different funds: the European Regional Development Fund (ERDF), the Cohesion Fund (CF) and the European Social Fund (European Commission, n.d.). The cohesion policies are aimed at member states whose gross national income per inhabitant is less than 90% of the EU average (European Commission, n.d.). With a value of 80 billion EUR until 2020, Poland remains the biggest EU cohesion funds beneficiary (Kryszkowska, 2016). Of these funds, the biggest investment area is transportation with 36% (Kryszkowska, 2016). The energy infrastructure has received 7% of these cohesion funds (Kryszkowska, 2016). Almost 9 billion EUR has been allocated to one of the fund's main objectives 'Shift to the Low-Carbon Economy', of which 10% went to renewable energy (Kryszkowska, 2016).

Research and Development funding

The European Union has funded 284 bioenergy projects through framework programs such as FP5 and Horizon 2020 (European Union, 2018). Approximately 580 million EUR of EU-funds were invested in

framework programs for bioenergy technologies (European Union, 2018). Of these funds, 32% were invested in combustion, making it the most funded bioenergy research and development (R&D) topic (European Union, 2018). The EU has the highest funding in bioenergy R&D globally with a yearly average of 144 million EUR (European Union, 2018).

Horizon 2020 is the European Union's main funding program for research and innovation (ETIP Bioenergy, sd). The total budget for the period 2014-2020 was approximately 80 billion EUR, of which more than 30 million EUR was spend on climate and decarbonization topics (ETIP Bioenergy, sd). As a part of Horizon 2020, there is the Bio-Based Industries Joint Undertaking, which is a Public-Private Partnership between the EU and the Bio-based industries consortium (ETIP Bioenergy, sd). During the same period, a total of 3.7 billion EUR was invested in bio-based innovation (ETIP Bioenergy, sd). Of these investments, 975 million EUR came from EU funds and 2.7 billion from private investments (ETIP Bioenergy, sd). The partnership focuses on sustainable biomass supply, optimizing the processing of biorefineries, developing markets for biobased products, and optimizing policy frameworks (ETIP Bioenergy, sd).

To summarize, the European Union supports bioenergy in EU member states through cohesion funds focused on energy infrastructure and renewable energy, as well as funds for research and development projects in the bioenergy sector (European Union, 2018; Kryszkowska, 2016).

3.4.3 Other Funds

Kyoto Protocol

The Kyoto Protocol is an agreement between 192 parties, mandating that industrialized nations cut their greenhouse gas emissions (United Nations, n.d.). The Kyoto Protocol set targets covering emissions of the six main greenhouse gases (United Nations, n.d.). All parties have a certain assigned amount of emissions that they may emit over a commitment period in order to comply with the emissions targets (United Nations, n.d.). Under the protocol, surpluses of assigned amount units can be bought by other parties (United Nations, n.d.). Poland's surpluses of assigned amount units were bought by the European Bank for Reconstruction and Development, the government of Spain, the government of Ireland, the Japanese Organization for the Development of New Energy and Industrial Technologies and private Japanese entities (Institute of Environmental Protection - National Research Institute, 2018). These funds from the abovementioned buyers amounted to 796.5 million PLN between 2009 and 2018 (Institute of Environmental Protection - National Research Institute, 2018). These funds were allocated to projects under the national green investment scheme, including projects in renewable energy sources (Institute of Environmental Protection - National Research Institute, 2018). The total costs of undertakings implemented in the years 2011 and 2017 was 2.5 billion PLN, of which 55% was covered by the Polish National Fund for Environmental Protection and Water Management (Institute of Environmental Protection - National Research Institute, 2018). Of this budget, 5% went to agricultural biogas plants and 1% to biomass burning-based electricity generation (Institute of Environmental Protection - National Research Institute, 2018).

Norway and EAA grants

In 2017, Iceland, Liechtenstein and Norway signed cooperation agreements with Poland on new agreements under the EEA and Norway Grants (EEA Grants, 2019). The total amount allocated to Poland in years 2014-2021 was 411.5 million EUR through Norway Grants and 397.8 million EUR through EEA grants, of which 140 million EUR went to energy and climate change (EEA Grants, 2019). These grants are mainly focused on supporting the reduction of CO2 emissions, energy efficiency, research cooperation between the parties, strengthening the business and innovation sector, promoting local development, supporting civil society and rule of law (EEA Grants, 2019). The EEA and Norway grants offer funding to individual projects in certain EU member states related to these support areas (EEA Grants, 2019). For example, the organization is accepting proposals in green industry innovation between the November 2019 and March 2020. The budget for this fund is 50 million EUR and the maximum grant amount per project is 1 million EUR (Polish Agency for Enterprise Development, 2019).

To summarize, funds from the Kyoto Protocol have supported the Polish bioenergy sector (Institute of Environmental Protection - National Research Institute, 2018). Additionally, Norway and EEA grants have supported individual projects in the Polish bioenergy sector (EEA Grants, 2019).

3.5 What are the Current Obstacles to Entering the Rural Polish Energy Market?

3.5.1 Found Obstacles

Support scheme

The European Commission recommends in their guidelines regarding the design of renewable energies support schemes (SWD(2013) 439 final) to use a feed-in premium (FIP) system, as the FIP exposes producers to market price indicators (European Commission, 2013). In recent years, many support schemes haves shifted from FIT to FIP models (European Commission, 2013). Market exposure is necessary for a competitive energy market driven by efficient production and investment decisions (European Commission, 2013). Poland applies a combination of a feed-in tariff (FIT), a sliding feed-in premium (FIP) and a tendering system (Banja, Sikkema, Jegard, Motola, & Dallemand, 2019). Poland's main support schemes, the FIT and auction system, are not recommended by the European Commission as they use a fixed price that is not influenced by the market which could hinder an efficient and competitive energy market (European Commission, 2013). According to the Commission, the sliding feed-in premium is more optimal, as it is calculated by using an average market price of a certain period and applying a premium (European Commission, 2013).

Baskets tenders

The Auctions for Renewable Energy Support II (AURES II), a research project financed by the European Union, aims at ensuring the effective implementation of auctions for Renewable Energy Sources in the EU member states (AURES II, n.d.). AURES II has published a report on Poland's RES Auctions (Diallo, et al., 2019). The report mentions flaws in the Polish auctions' cost efficiency, the categorization of baskets and transition tenders (Diallo, et al., 2019).

The Polish government tries to achieve several objectives under the RES auctions support scheme (Diallo, et al., 2019). The government tries to move away from the green certificate system, advance renewable energy capacities and expand market participation (Diallo, et al., 2019). However, the tendering system has some flaws (Diallo, et al., 2019). For example, the support for onshore wind and PV can be twice as high for smaller producers, resulting in a possible price difference of 40 EUR/MWh between small and large producers under the auction system (Diallo, et al., 2019). The participation of small-scale producers reduces the cost efficiency as the support for smaller producers is more costly than for bigger producers (Diallo, et al., 2019).

The guidelines regarding the design of renewable energies support schemes (SWD(2013) 439 final) also include recommendations regarding tenders (European Commission, 2013). The guidelines state that tenders need to have clear rules to stimulate competition between bidders, put producers from different technologies and locations into competition with each other, to be used to allocate other support instruments and have clear rules to ensure delivery (European Commission, 2013). According to AURES II, the categorization of the baskets in the RES auctions has raised some questions (Diallo, et al., 2019). It is not clear why agricultural biogas is separated from non-agricultural biogas and biomass (Diallo, et al., 2019). Also, bioliquids belong to the third basket, together with hydro, geothermal and offshore wind energy, which is a wide range of renewable energy technologies (Diallo, et al., 2019). Previously, auctions would only be seen as successful if they had more than 3 bids (Diallo, et al., 2019). However, after the

abolishment of the rule, two auctions remained unsuccessful (Diallo, et al., 2019). These unsuccessful auctions were for biomass and non-agricultural biogas under 1 MW and for hydro, bioliquids, geothermal and offshore wind energy under 1 MW (Diallo, et al., 2019). The basket for biomass and non-agricultural biogas with a capacity of more than 1 MW had the highest support of all baskets with almost 6 billion EUR for 57 TWh (Diallo, et al., 2019). Also, the auction for agricultural biogas with a capacity of less than 1 MW had 29 valid bids (Diallo, et al., 2019). These 29 valid bids are considerable more than the 1, 5 and 3 valid bids for the other successful auctions (Diallo, et al., 2019). This could indicate that the categories used in the basket are not optimal as the difference in support and valid bids for the baskets is quite large (Diallo, et al., 2019). The fact that less than 30% of total offered volume and only 1.7% for large biomass and non-agricultural biogas plants is auctioned off, shows poor cost efficiency and an insufficient level of competition (Diallo, et al., 2019). A large number of baskets has resulted in a very small number of bids per basket (Diallo, et al., 2019).

Transition tender

According to the AURUS II report, the transition for existing renewable energy installations from the green certificate system to the tendering system seems not to be working properly (Diallo, et al., 2019). Out of the 9 auctions that were held for the existing biogas and biomass plants, only 3 were successful as the other 6 did not have any participants (Diallo, et al., 2019). The three successful transition tenders were all in 2016 or the beginning of 2017 and no auctions were successful in 2018 (Diallo, et al., 2019). According to the Independent Commodity Intelligence Service (ICIS), the lack of interest for these auctions was caused by rising wholesale electricity prices and increased certificate prices (Diallo, et al., 2019). Renewable plant operators could earn up to 110 EUR/MWh under the green certificate system, which is very close to the price cap for the RES auctions (Diallo, et al., 2019). The Polish government has supported the co-firing of coal and biomass with 1.7 billion EUR between 2005 and 2012 (Olszewski, 2014). This amount is quite high, considering that all other new RES got a total of 1.5 billion EUR (Olszewski, 2014). This could demotivate operators to switch systems, especially if they expect the prices of energy to rise (Olszewski, 2014). Other possible causes for the low interest for energy auctions could be the changing regulations in the RES markets (Diallo, et al., 2019).

Legislative barriers

Bureaucracy seems to be one of the main barriers to entering the Polish bioenergy market (Chasnyk, Solowski, & Shkarupa, 2015). Bureaucracy can be defined as “excessively complicated administrative procedure,” (Lexicc, sd). The national report of Poland by FABbiogas, names the main disadvantage of the Polish bioenergy market as “Difficult administrative and legal procedures, as well as financial barriers, large number of formal requirements in realization of biogas projects (too extensive documentation to prepare an application and the lack of trust of banks for biogas projects),” (Chasnyk, Solowski, & Shkarupa, 2015). All operators questioned for the AURES II national report claimed that they had to wait more than two months before obtaining a connection to the grid as well as 6 to 8 months to receive all the necessary permits (FABbiogas, 2014). Several questioned companies stated that it was difficult to obtain external financing for biogas projects as the procedures require extensive documentation and because of a lack of trust from banks in biogas projects (FABbiogas, 2014).

Research has identified the quality of bureaucracy as a key determinant of corruption (Heywood & Meyer-Sahling, 2013). Especially in the new EU member states of Eastern and Central Europe, corruption has been widespread since the collapse of communism (Heywood & Meyer-Sahling, 2013). The Corruption Perceptions Index is the leading global indicator of public sector corruption (Transparancy International, 2020). The index ranges from zero (highly corrupt) to 100 (very clean). Poland has a Corruption Perceptions Index of 58, which is below the EU average of 63 (Transparancy International, 2020). However, Poland's corruption seems to have worsened over the last couple of years as the country's index was 63 in 2015 (Transparancy International, 2020).

These problems do not seem to be limited to Poland as they are widely seen within the European Union (European Commission, 2019). The European Commission stated: "One of the main difficulties for biomass producers is to get the proper permits to build installations. These problems are because of too many process steps and permits issued by separate authorities, permits that are subject to a wide range of legislative acts, lack of clear timetables, lack of local knowledge of how to analyze permit applications, lack of clear procedures to obtain energy grid access and a local resistance to bioenergy projects," (European Commission, 2019).

Unstable energy market

The unstable energy market seems to hinder companies from entering the market (Barteczko, 2019). Interviewee 2 mentioned that their company would not enter an unstable energy market. Interviewee 3 mentioned that because of these major changes, he lost sight of the Polish legislation and support schemes. A summary of the interviews can be found in Appendix 8.

Unpredictable decisions, aimed at protecting state-run businesses by the ruling Law and Justice (PiS) party have caused chaos in the Polish energy market (Barteczko, 2019). Since coming into power in 2015, PiS has introduced regulations that, as mentioned in the introduction, brought the growth of the wind energy market to a halt but introduced utilities to support the mining industry (Barteczko, 2019). Additionally, a cap on electricity prices for households was introduced. These measures have caused 'chaos' in the Polish electricity market (Barteczko, 2019). Maciej Bando, the head market regulator of the Polish Energy Regulatory Office (URE) stated: "I would not like investors to abandon our market. But reason tells me that in such conditions only speculative capital may remain here, hoping for higher profits, while the fundamental one will slowly change its location to a more stable, quieter location. That is very bad," (Barteczko, 2019).

Biomethane legislation

According to Interviewee 1, biomethane is quite a new energy source in Poland and there is little legislation or requirements for biomethane in Poland available. Interviewee 4, who is operating in the biogas upgrading industry, agreed with this statement.

To summarize, obstacles to the Polish bioenergy market were found in the support schemes, basket tenders, legislative barriers, bureaucracy, the unstable energy market, and biomethane legislation.

3.5.2 Found Opportunities

Green Deal

In December 2019, the European Commission presented the European Green Deal (General Secretariat of the Council, 2019). The conclusions from the European Council meeting on the Green Deal included: "In the light of the latest available science and of the need to step up global climate action, the European Council endorses the objective of achieving a climate-neutral EU by 2050, in line with the objectives of the Paris Agreement. One Member State, at this stage, cannot commit to implement this objective as far as it is concerned, and the European Council will come back to this in June 2020," (General Secretariat of the Council, 2019) This one member state that has not committed to implement the Green Deal is Poland (General Secretariat of the Council, 2019). However, according to Frans Timmermans, European commissioner of the Green Deal, Poland is not the most troublesome member state regarding climate change, in context of the Green Deal (van de Wiel & van der Walle, 2020). Other countries like Germany are seen as more troublesome, as Poland is used to implementing reforms (van de Wiel & van der Walle, 2020). As a part of a wider policy to ease tensions within the EU, Poland changed direction and is promoting investments in offshore wind projects and solar energy (Reuters, 2019).

The details of the Green Deal and the Just Transition Fund will be further elaborated in 2020 and could provide possible opportunities for the Polish bioenergy sector (General Secretariat of the Council, 2019).

Governmental support for prosumers

Part of Poland's strategy to increase the share of renewable energy is by supporting prosumers, the individual consumers of energy who produce energy with small installations (with a capacity of up to 50 kW) (Bellini E. , 2019; Ignaciuk, Promotion in Poland, 2019). Prosumers have a special support scheme that covers wind energy, solar energy, agricultural biogas installations and biomass installations (Ignaciuk, 2019). Additionally, prosumers have a simplified administrative path where it is not necessary to obtain an environmental decision (Zieniewicz, 2020).

Funds

There are many funds available for Poland to transition its energy market (Kryszkowska, 2016). Recently, Poland has been offered 100 billion PLN in just-transition funds by the European Union (Morgan, 2020). Additionally, Poland receives large cohesion funds, rural development funds, research and development funds, Norway and EEA grants and Kyoto Protocol funds (Kryszkowska, 2016; European Union, 2018; Institute of Environmental Protection - National Research Institute, 2018; EEA Grants, 2019). However, it should be kept in mind that changes due to, from example, the Green Deal, might influence the distribution of funds within the European Union (General Secretariat of the Council, 2019).

Biomass incentives

Poland has a total of 28 biomass incentives, which is the fifth-highest in the EU (Banja, Sikkema, Jegard, Motola, & Dallemand, 2019). In the EU, an average of 70% of these incentives are being used in the electricity sector, about 30% are dedicated to biomass and more than 40% to biogas (Banja, Sikkema, Jegard, Motola, & Dallemand, 2019).

High potential

Poland has a high biomass and biogas potential, mainly due to high manure and straw surpluses. Interviewee 3 sees Poland's straw surpluses as a major opportunity. The voivodeships with the highest biogas potential are Wielkopolskie, Mazowieckie, and Podlaskie (Iglinski, Buczkowski, & Cichosz, 2015). Poland's biogas production was 244.2 million m^3 and total bioenergy production 298 PJ (Piwowar, Dzikuc, & Adamczyk, 2016; Berent-Kowalska, Kacprowska, Piwko, & Jurgas, 2018). This means that Poland has only realized a small part of its potential, as Poland's potential is 2.5 billion m^3 of biogas and 895 PJ for biomass (Banja, Sikkema, Jegard, Motola, & Dallemand, 2019; Iglinski, Buczkowski, & Cichosz, 2015).

High prices

Interviewee 1 mentioned that energy prices were quite high at the moment. Even though Polish electricity prices were quite stable in recent years, they seem to be on the rise (Olsewski, 2018). Compared to 2017, power prices in 2018 went up with 25% (Olsewski, 2018). The town hall of the Polish city Olsztyn stated that the prices being tendered by suppliers in 2018 were 35% higher than in 2017 and that one supplier suggested a rate of 70% above last year's (Olsewski, 2018). Also, according to ICIS, the lack of interest for these auctions was caused by rising wholesale electricity prices and increased certificate prices (Olsewski, 2018). Renewable plant operators could earn up to 110 EUR/MWh under the green certificate system, which is very close to the price cap for the RES auctions (Diallo, et al., 2019).

Trust of banks

According to Interviewee 1, there is a growing trust of banks. More banks in Poland are offering lines of credit for bioenergy projects. Interviewee 1 mentioned Fundacja Banku Ochrony Środowiska, a Polish bank specialized in financing green projects, which is very active in offering lines of credit for bioenergy projects. The interviewee also spoke to someone from Rabobank Poland. Rabobank seems to be positive about the bioenergy market and according to the interviewee, the bank has begun offering lines of credit to bioenergy projects.

To summarize, opportunities on the Polish bioenergy market were found in the Green Deal, governmental support for prosumers, available international funds, biomass incentives, biomass potential, high prices and growing trust of banks.

Chapter 4. Discussion of Results

The main objective of the thesis was to review previous research findings and, by gaining a broader understanding of the subject and sector, be able to identify where the opportunities and obstacles occur in the Polish bioenergy sector, especially in the rural context. These opportunities and obstacles were found by looking at the status and structure of Poland's energy sector, Poland's bioenergy legislation, bioenergy plant development costs in Poland; and Poland's and the EU's support schemes. The most important findings are mentioned below.

4.1 Most Important Findings

What is the status and structure of Poland's current energy sector?

About 80% of Poland's electricity is generated with coal. Poland is the European Union's biggest consumer of coal. Poland's renewable energy share was 11.16% of its energy mix in 2018. This share is slightly higher than in 2017, but still lower than in the years 2013-2016. This slowdown in renewable energy growth is mainly due to Poland's increased energy use, which is 1.76% annually. However, at this rate, Poland will not reach its national 2020 renewable energy goal of 15%.

Of Poland's renewable energy, more than two-thirds is generated with solid biomass. Poland's biogas production was 244.2 million m^3 and total bioenergy production 298 PJ. This means that Poland has only realized a small part of its potential, as Poland's potential is 2.5 billion m^3 of biogas and 895 PJ for biomass.

Poland is the EU's fourth-largest employer in the renewable energy sector with 72,200 jobs, of which 59,600 were in the bioenergy sector. The three largest energy companies in Poland are PGE, Tauron, and Enea, which together produced about 63% of Poland's total electricity. Energy dependency is the proportion of energy than an economy must import. Poland's energy dependency was 38.8% in 2018. Poland imported 2692.5 PJ and exported 708 PJ of energy.

What is the legislation regarding bioenergy in Poland?

As a member of The European Union, Poland had to make amendments to its Energy Law act to increase its share of renewable energy. This resulted in the development of the act of renewable energy sources (RES-Act). The RES-Act includes legislation regarding the certification of installers, energy auctions, and prosumer laws. The European Union's renewable energy directive compels Poland to meet a renewable energy share of 15% of final energy consumption. The European Union has released definitions for bioenergy, specific blending quotas and non-obligatory guidelines on national support schemes, sustainability criteria and technical specifications.

What are the development costs of bioenergy plants in Poland?

Development periods for biogas plants are between 1 month to two years. For biomass plants, the development period is around 18 months. The average biogas project costs between 7.6 and 13.1 million PLN/MWel. For other types of energy plants, the development periods are longer and initial investments are higher. Other costs of bioenergy projects can be related to a grid connection agreement, a bank guarantee, a penalty or other administrative steps necessary to participate in RES auctions.

What support can foreign companies in the bioenergy sector get?

Poland applies a combination of a feed-in tariff (FIT), a sliding feed-in premium (FIP) and a tendering system. The feed-in premiums are used to equalize a negative balance that is caused by a price for the unused electricity that is lower than the one mentioned in the approved declaration. The feed-in tariff amounts to 90% of the reference price set in the RES-Act. Prosumers, using an installation with a capacity of up to 50 kW, are allowed to exchange their surpluses of energy for possible gaps in the future, with a 1 to 0.8 or 0.7 relation. Bioenergy installations with certain installation costs can apply for a low-interest loan.

In 2016, Poland switched from a green certificate/quota system to a tender/auction system. In these auctions, the Polish government will announce how much energy it will need from each renewable energy group (basket) and a maximum auction budget. There are two types of auctions, for new installations and for those that existed before 2016 and will need to transition between systems.

What are the current obstacles to entering the Polish energy market?

Poland uses a FIT system, which is not recommended by the European Union, as it uses a fixed price and does not expose producers to any market price indicators, which could hinder an efficient and competitive energy market. Similarly, the auction system uses a fixed price for 15 years. Additionally, certain baskets have many more bids than others, which raises questions on the categorization of the baskets. For example, the small agricultural biogas installations basket had 29 bids, the small non-agricultural biogas and biomass basket had no bids. It is not clear why the types of biogas are separated. Also, RES auctions used as a transition between systems for older installations often have zero bids.

The ruling government party has made unpredictable decisions that halted growth in the renewable energy sector and has supported more traditional types of energy, especially mining. Other obstacles that were found are the many difficult administrative and legislative procedures, including a large number of formal requirements and extensive documentation. This report also mentioned a long wait to be connected to the grid. Additionally, there is insufficient legislation available regarding biomethane.

As for opportunities, Poland has one of the highest biomass potentials in the EU. Currently, Poland is only using one-third of this potential. Poland has special support schemes and a simplified administrative path for prosumers. Additionally, Poland has a total of 28 biomass incentives, which is the fifth-highest in the EU. Many producers of renewable energy are not taking part in Poland's main support scheme, the RES auctions, as current energy wholesale and green certificate prices appear to be on the rise. The trust of banks in the bioenergy sector seems to be developing, as more and more banks are offering lines of credit for bioenergy projects. Furthermore, there are many funds available to help Poland transition its energy sector.

4.2 Reflection on Research Method

As all questions could be answered and all the wanted information could be found, the research could be seen as successful. The information that was found came from many, reliable sources. As can be seen from the list of references, many recent and peer-reviewed sources on the topics could be found.

The initial planning was less successful. The research proposal included a detailed plan in which certain steps of the final thesis would be finished before a certain date. If this plan would have been followed, the final thesis would have been handed in before the 13th of January, which was the initial set deadline. As the assessment of the research proposal took longer than planned, the initial deadline could not be met. Other dates, like the holidays or special events of the embassy, were also not accounted for in the initial planning. Even though the assessment period is a non-influential circumstance, more time for such assessments will be added in any further or later research.

For any later research, a topic could be chosen of which the author would be more familiar with. As this topic and country were both quite new for the author, preliminary research took longer than expected. Even though the preliminary research would have gone faster with a more familiar topic, renewable energy in Poland has shown to be a very relevant and interesting topic, which fits within both the agricultural and business parts of the International Food Business program.

As the topic was viewed as interesting by the author, especially subjects like climate change, Poland's macro-economics, and Poland within the EU, research on these topics became (too) detailed. Especially for a topic like climate change, bioenergy is a solution to the problem. However, companies operating in the bioenergy sector might not see climate change as their main driver as their main drivers might be financial or economical. Some parts of the thesis were very interesting for the author to write and to research, but were too detailed and not particularly necessary for the target group or to answer the main research question. Some of these parts ended up in the Appendices. For any further research, while analyzing data, the author would need to ask herself strictly whether this contributes directly to answering the sub-question and/or the main question.

4.3 Scope of Results

The target group, the interested Dutch companies are able to apply this research to better position themselves on or enter the Polish bioenergy market. As mentioned in the interviews, which can be found in Appendix 8, multiple questioned companies found information was hard to find. This research gives them a good overview of the rural Polish bioenergy market and where the obstacles and opportunities lie. A fact sheet, which can be found in Appendix 3, was created to give the companies a quick overview of the sector and research.

4.4 Comparison with Literature, Norms, and Expectations

The expectations that arose during the preliminary research are mostly comparable to the results. During the preliminary research, a lot of research on Poland's coal-dependent strategy was found. This can also be found in the results. However, Poland's energy strategy also shows that there is room for the development of the renewable energy sector. Although some are less efficient than others, Poland has the fifth-most biomass incentives in the European Union and has strong support for prosumers. Next to that, the preliminary research mentioned topics such as high biomass potential, which is very comparable to the final results.

As mentioned in the reflection of the research method, the support systems were not included in the preliminary research or introduction. The Polish support schemes were expected to be fully developed

and comparable to those of the Netherlands. However, as Poland had a support scheme comparable to the Netherlands up until 2016 but then completely changed the system, this expectation appeared to be incorrect. Information was harder to gather than expected. For example, the RES-Act is only partially translated into English. Information on the RES-Act had to be gathered through reports on the act which were not easy to find.

Chapter 5. Conclusions and Recommendations

Poland still has a lot of changes ahead that are necessary, especially in rural areas, if Poland wants to reach the climate goals set by the European Union. Bioenergy would tackle rural Poland's problems with greenhouse gas emissions, air pollution, and power interruptions. Poland has a high biomass potential and still a lot of room to grow in the bioenergy sector, making the Polish bioenergy market a possible opportunity for Dutch companies. However, many Dutch companies operating in the bioenergy sector are still hesitant about entering the Polish market.

From the described problem statement the following main research question emerged: *"What are the obstacles and opportunities for Dutch companies in the bioenergy sector in rural Poland?".* To examine this question the following sub-questions were formulated: "What is the status and structure of rural Poland's current energy sector?", "What is the legislation regarding bioenergy in Poland?", "What are the development costs of bioenergy plants in Poland?", "What support can foreign companies in the bioenergy sector get?" and "What are the current obstacles to entering the rural Polish energy market?".

The main objective of the thesis was to review previous research findings and by gaining a broader understanding of the subject and sector, be able to identify where the opportunities and obstacles occur in the Polish bioenergy sector, especially in the rural context.

5.1 Conclusions

One of the main obstacles of the Polish bioenergy market seems to be the support systems. Poland uses a feed-in tariff system, which is not recommended by the European Union, as it uses a fixed price and does not expose producers to any market price indicators, which could hinder an efficient and competitive energy market. The same could be said for the auction system, as a fixed price for 15 years is agreed upon. The renewable energy auctions do not seem to be working efficiently. Certain baskets have many more bids than others, which raises questions on the categorization of the baskets. It is not clear why the types of biogas are separated. This illogical categorization of baskets has caused an undistributed number of bids where, for example, some baskets have 29 bids while other baskets have none. This is also seen in the transition tenders, where there has not been a successful auction in years.

Additionally, Poland's unstable energy market seems to be a major obstacle. The current government has made major changes in Poland's renewable energy strategy. These changes made the Polish energy market seem unstable and has thereby halted growth within the renewable energy sector. Difficult legislative and administrative procedures seem to hinder companies wanting to enter the Polish bioenergy market. These procedures often include a large number of formal requirements and extensive documentation. Other obstacles are long waiting times to be connected to the grid. Lastly, there is insufficient legislation and information available for biomethane or biogas upgrading.

However, Poland also has many opportunities on its bioenergy market. Poland has one of the highest biomass potentials in the European Union. Currently, Poland is only using one-third of this potential, meaning there is a lot of unused biomass. Also, Poland seems to have high governmental support for bioenergy and prosumers. This is shown through the high number of bioenergy incentives. Poland has special support schemes and a simplified administrative path for prosumers. Additionally, Poland has a

total of 28 biomass incentives, which is the fifth-highest in the European Union. Many producers of renewable energy are not taking part in Poland's main support scheme, the renewable energy auctions, as current energy wholesale and green certificate prices appear to be on the rise. The trust of banks in the bioenergy sector seems to be developing, as more and more banks are offering lines of credit for bioenergy projects. Furthermore, there are many funds available to help Poland transition its energy sector. Next to that, as a part of a wider policy to ease tensions within the European Union, Poland changed direction and is promoting investments in offshore wind projects and solar energy. The fact that Poland has had some major transformations over the last decade, shows that Poland is able to change its course to ease tensions within the European Union. All of these points combined show promise and opportunities within the Polish bioenergy sector.

All findings and conclusions are given on a factsheet. The factsheet provides a quick overview of the research. This factsheet will be distributed among possibly interested companies. Companies looking for more detailed information can request for the research. This factsheet can be found in Appendix 3.

5.2 Recommendations

Using the conclusions, recommendations were formed. The recommendations could be split into three categories, short-term recommendations, long-term recommendations and those that would apply to both the short- and long-term.

Short-term recommendations:

Guidelines

To improve the development of the bioenergy sector in Poland, stakeholders should be educated and informed. In the short-term, this could be done by preparing clear guidelines for future bioenergy investors/operators with a detailed description of all the laws, costs and procedures needed for a successful bioenergy project. Part of this research and the factsheet could be used for the guidelines.

Location

It can be recommended for bioenergy plants to be located in the central/eastern parts of Poland. As could be seen in Figures 9 and 10, the most potential for both biogas and biomass can be found in Mazowieckie and surrounding voivodeships. Figure 9 showed that the three voivodeships with the highest biogas potential are Mazowieckie, Podlaskie, and Wielkopolskie. As can be seen in Appendix 6, the costs of land in the Podlaskie and Mazowieckie voivodeships is below the Polish average. Wielkopolskie, however, has the highest prices of agricultural land in all of Poland.

Long-term recommendations:

Educational campaigns

As for informing stakeholders, there are long-term options that could be considered. For example, training courses and informational campaigns could be organized. To tackle the problem of difficult administrative and legal procedures, educational courses like seminars or training courses could be organized. These courses could be aimed at the involved administrative bodies, authorities, bank employees and biogas investors in the renewable energy or bioenergy sector. Additionally, a big information campaign for the entire country could be arranged. This campaign could show the

advantages of bioenergy and the use of agricultural sources in energy production, which could influence the national opinion towards bioenergy and indirectly Poland's energy strategy. These campaigns could be a joint effort of the Dutch companies wanting to enter or better position themselves on the Polish bioenergy market or this could be organized by other stakeholders.

Energy strategy

As mentioned in the previous recommendation, it is suggested to try influencing the Polish energy strategy. A change in energy policy could be beneficial for the bioenergy companies as Poland uses an inefficient feed-in tariff and tendering system. The European Union recommends using a feed-in premium (FIP) system as it exposes energy producers to market price indicators. By exposing energy producers to market price indicators, this could accomplish the long-term goal of an efficient and competitive energy market.

To optimize the tendering system, the categorization of the baskets could be changed. Certain baskets seem to be categorized illogically. For example, agricultural biogas is separated from biomass and non-agricultural biogas. Also, bioliquids belong to a separate basket, together with hydro, geothermal and offshore wind energy, which is quite a wide range of renewable energy technologies. A more optimal categorization would have the bioliquids compete with biomass or biogas. A change in the categorization of the auction baskets could be a short-term solution.

Short- and long-term recommendations:

Biomass resources

As straw and energy crops are the most suitable biomass input for large commercial heating facilities, these could be recommended to use. One of Poland's biggest masses of biomass is straw, with 8 million tonnes of cereals straw annually. However, one should keep mind that due to droughts, surpluses in straw might decrease. The biomass input recommendation can be regarded as both long term and short-term. Using straw as biomass input will impact energy production on the short term. The decision to use straw can have an impact in the long term as the availability of straw might decrease due to droughts.

Compare prices

Before entering in the auction system, bioenergy operators could consider other options. As energy prices appear to be on the rise, operators should compare wholesale prices and auction prices. If wholesale prices are expected to keep rising, these prices might be more beneficial than a fixed price for 15 years. However, risks should also be considered. As the Polish bioenergy legislation is considered to be relatively unstable, a fixed price would have less risk. This recommendation can have an impact on both the short and long term, as companies that do not enter the energy auctions will be able to do so the next year, however, prices between years might differ.

Available funds

When starting a bioenergy project in Poland, bioenergy operators could look into which funds could be available for them. Certain funds could support bioenergy companies indirectly, for example, funds in research and development. Other funds like the EEA and Norway grants offer funds for individual projects. Funds regarding research and development in the bioenergy sector will be beneficial to companies in the long term and other funds for individual projects would be beneficial in the short term.

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Appendices

Appendix 1. Questions for sector

1. How many years has your company been operating in the bioenergy market?
2. In what countries is your company already operating?
3. Have you tried expanding your business to Poland?
4. If yes, were you successful and what happened? If no, why not or what stopped you?
5. What do you see as the main obstacles to entering the Polish market?
6. (Where) Do you see opportunities in the Polish bioenergy market?
7. Have you noticed any major differences between the Polish bioenergy market and those of other (central and eastern) European countries?
8. Is there any specific information that you are missing?

Appendix 2. Answers to questionnaire

1. How many years has your company been operating in the bioenergy market?

A. 25 years +

B. 10-15 years

C. 10-15 years

D. 10-15 years

2. In what countries is your company already operating?

A. Whole of Europe and South Africa. Focus countries: Holland, Ireland, Uk, Poland, Romania and Ukraine.

B. Sweden, Germany, Netherlands, Swiss, Liechtenstein, France

C. Netherlands, Ukraine, UK, Belgium

D. plant (projects) in NL, S, FIN - sales focus on Europe and North America

3. Have you tried expanding your business to Poland?

A. Yes

B. No

C. Yes

D. Not sure

4. If yes, were you successful and what happened? If no, why not or what stopped you?

A. We have another branch, Drying kilns for timber. We are more successful with this product in Poland.

B. We have focused on countries which support sustainable green gas

C. Partners, where not reliable they took the financial information and we could not contact them anymore.

D. –

5. What do you see as the main obstacles to entering the Polish market?

A. Financial barriers, Coal-dependent energy strategy

B. subsidy or incentives for green energy (or biofuel) are required to realize projects

C. Language barrier, National support schemes, Coal-dependent energy strategy, reliable construction partner

D. Legislative barriers, National support schemes

6. (Where) Do you see opportunities in the Polish bioenergy market?

A. Proces Industry, Timber Industry, City Heating.

B. Not yet, however I'm not familiar with the market, rules and subsidy yet

C. argo industry and co2 emissions

D. Sawmills

7. Have you noticed any major differences between the Polish bioenergy market and those of other (central and eastern) European countries? If yes, please explain.

A. Poland uses still a lot of Coal.

B. in the countries where green gas projects are realized there is a subsidy or incentive to realize green gas projects

C. No

D. not sure

8. Is there any specific information that you are missing?

A. Legislation about Biomass combustion is very hard to find in English language. Support or subsidy schemes are not clear.

B. subsidy and incentive for biogas, greengas, biofuel

C. No

D. no

9. Do you have any recommendations or further remarks?

A. What is the gas price in Poland, €/m3?

B. -

C. NO

D. no

Appendix 3. Factsheet Bioenergy Poland

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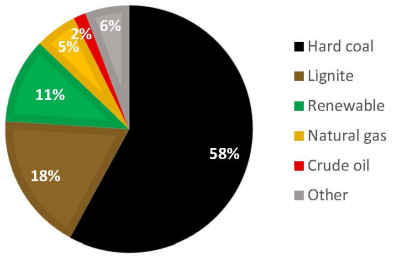
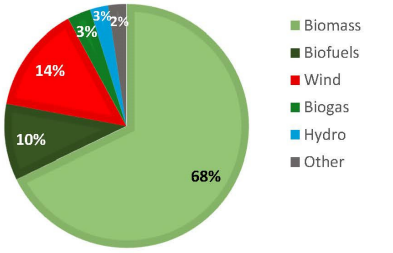
Bioenergy Poland

What are the obstacles and opportunities for Dutch companies in the bioenergy sector in rural Poland?

POLAND ENERGY MIX 2018



POLAND RENEWABLE ENERGY MIX 2017



Quick facts

- Poland is very dependent on fossil fuels as it produces more than 80% of the country's energy.
- Renewable energy accounted for 11.16% of total energy consumption in 2018. This is still below Poland's goal of 15% in 2020.
- With a biomass potential of 895 PJ, Poland has one of the highest biomass potentials in the EU. Biomass could generate more than 20% of Poland's total energy consumption.
- Poland has the fifth most biomass incentives in the EU.
- Poland is the EU's fourth-largest employer in the renewable energy sector with 72,200 jobs, of which 59,600 were in the bioenergy sector.

Legislation

- Poland had to make amendments to its Energy Law act, as it was obliged to increase its share of renewable energy according to the EU climate goals, which resulted in the act of renewable energy sources (RES-Act).
- Recent changes in the RES-Act has caused the act to be seen as unstable. These changes included the replacement of the green certificate for the auction system, changes in the basic support systems and legislation regarding prosumers.
- The European Union has released guidelines regarding financial support for renewables, technical specifications and sustainability criteria, however these criteria are non-binding.
- Poland has a blending quota of 8% as a minimum percentage of biofuels as a part of total liquid fuels.

Support system

- Poland applies a combination of a feed-in tariff (FIT), a sliding feed-in premium (FIP) and a tendering system.
- The feed-in premiums are used to equalize a negative balance that is caused by a price for the unused electricity that is lower than the one mentioned in the approved declaration.
- The feed-in tariff amounts to 90% of the reference price set in the RES-Act.
- In 2016, Poland switched from a green certificate/quota system to a tender/RES auction system. In these auctions, the Polish government will announce how much energy it will need from each renewable energy group (basket) and a maximum auction budget. The winners of the tenders have a guaranteed price for 15 years. There are two types of auctions, for new installations and for those that existed before 2016 and will need to transition between systems.
- The Polish government is supporting prosumers, which are consumers who are producing their own electricity (installation <50kW) by allowing them to store on or sell energy to the grid and by offering them low-interest loans.

Obstacles

- The EU does not recommend the FIT, sliding FIP or a fixed price auction system as they do not expose producers to market conditions.
- The auction system uses too many and an illogical categorization of baskets.
- The unstable energy market seems to be a major obstacle as recent changes in the RES-act have halted growth in the renewable energy sector and supported the coal industry.
- Difficult administrative and legal procedures, as well as financial barriers, large number of formal requirements in realization of biogas projects, too extensive paperwork and a lack of trust of banks for biogas projects.
- Legislation regarding biomethane is non-existing or not clear.
- There is a long wait to get connection to the grid or the necessary permits.

Poland has almost 14 million hectares of arable land, giving the country a very high biomass supply. The table below shows Poland's annual biomass resources.

Biomass resource	***Millions of tonnes available***
Biowaste	6
Cereals straw	8
(waste) wood	9
Slurry	20
Manure	80

Recommendations

- For Poland to switch to a feed-in premium support scheme.
- For Poland to change the categorization of the auction baskets.
- To launch educational campaigns, organize training courses and prepare clear guidelines.
- For bioenergy plants to locate themselves in Mazowieckie or surrounding voivodeships.
- For bioenergy plants to use straw and energy crops as biomass input.
- For bioenergy plants to consider all prices before entering the auctions (fixed price for 15 years).
- For bioenergy operators to look into which funds might be available for them.

Costs

Initial investments for bioenergy plants are lower but operating costs might be higher than in conventional plants. Other costs can relate to a grid connection agreement, bank guarantee, a penalty or other administrative steps necessary to participate in RES auctions.

For biogas, most potential is in the Wielkopolskie (6.54 PJ), Mazowieckie (5.51 PJ) and Podlaskie (3.55 PJ) voivodeships. The distribution of this biogas potential in Poland can be seen in the figure below.

Opportunities

- Poland has high biomass and biogas potential. Poland is only using one-third of its potential.
- Poland's electricity prices are on the rise. Many bioenergy producers choose not to participate in the RES auctions as wholesale electricity prices are rising and certificate prices have increased. Auction prices in 2018 were approximately 35% higher than in 2017.
- Poland has the 5th most biomass incentives in the EU.
- The details of the Green Deal and the Just Transition Fund will be further elaborated in 2020 and could provide possible opportunities in the Polish bioenergy sector.
- This lack of trust from banks seems to be fading as many banks have started to supply lines of credit for biogas projects.
- There are many EU and international funds available to help Poland in its energy transition.
- High governmental support for small installations (prosumers).

Appendix 4. Energy prices in Poland

The average electricity price for household consumers was 0.1343 EUR per kWh in the first half of 2019, which is the 6th lowest in the European Union (Eurostat, 2019). Household electricity prices went down with 0.067 EUR/kWh in the first half of 2019 compared to the same period in 2018 (Eurostat, 2019). The average household electricity price in the EU-28 was 0.2159 EUR/kWh (Eurostat, 2019). For non-households, the average electricity price in Poland was 0.1003 EUR per kWh in the first half of 2019 (Eurostat, 2019). This is still well below the EU-28 average of 0.1251 EUR/kWh (Eurostat, 2019). However non-household electricity prices have risen by 15% in the first half of 2019 compared to the same period in 2018 (Eurostat, 2019). For the same time period, natural gas prices in Poland for households was 0.0473 EUR/kWh and 0.0347 EUR/kWh for non-households (Eurostat, 2019).

Appendix 5. Energy goals

As can be seen in Figure 14, Poland's share of renewable energy steadily increased together with the share of the entire EU (Eurostat, 2019). In 2015, Poland's share of renewable energy peaked at 11.74% and has slowly decreased between 2015 and 2017. Poland's share of renewable energy had a small increase between 2017 and 2018, totaling to 11.16% in 2018 (European Commission, 2018). Data for the EU's share in 2018 is not yet known (European Commission, 2018). As Poland's goal is to have a 15% share of renewable energy by 2020, some major changes are needed to the Polish energy sector to increase this share at a faster rate (Kuchler & Bridge, 2018).

As can be seen in Figure 14, Poland's share of renewable energy as a part of gross final energy consumption in 2018 was slightly higher than the year before (PolandIn, 2019). The share of renewable energy in 2018 is still lower than in the years 2013-2016 (PolandIn, 2019). Poland's use of renewable energy was 350 PJ in 2018, which is 13% higher than in 2014 (PolandIn, 2019). However, in recent years Poland's overall energy use has gone up with 1.76% annually, this caused a decrease in growth and in some years even a decline of Poland's renewable energy share (PolandIn, 2019).

Using available data, linear trend lines for the EU and Poland were created and the 2020 goal for the share of renewable energy was added (Eurostat, 2019). For Poland, it can be seen that the share is below the trend and will need to increase with 3.84% over 2019 to reach the goal of 15% in 2020 (Eurostat, 2019). The linear trend ends with a share of approximately 14% in 2020, meaning that Poland could come close to reaching its renewable energy goal (export.gov, 2019). For the European Union, data about the share in 2018 was not yet available (Eurostat, 2019). The European Union's share of renewable energy was 17.5% in 2017 and has been quite linear over the last couple of years, as the data points all lie close to or on the trend line (Eurostat, 2019). This linear growth shows that on its current course, the European Union will meet its renewable energy goal of 20% in 2020 (Eurostat, 2019).

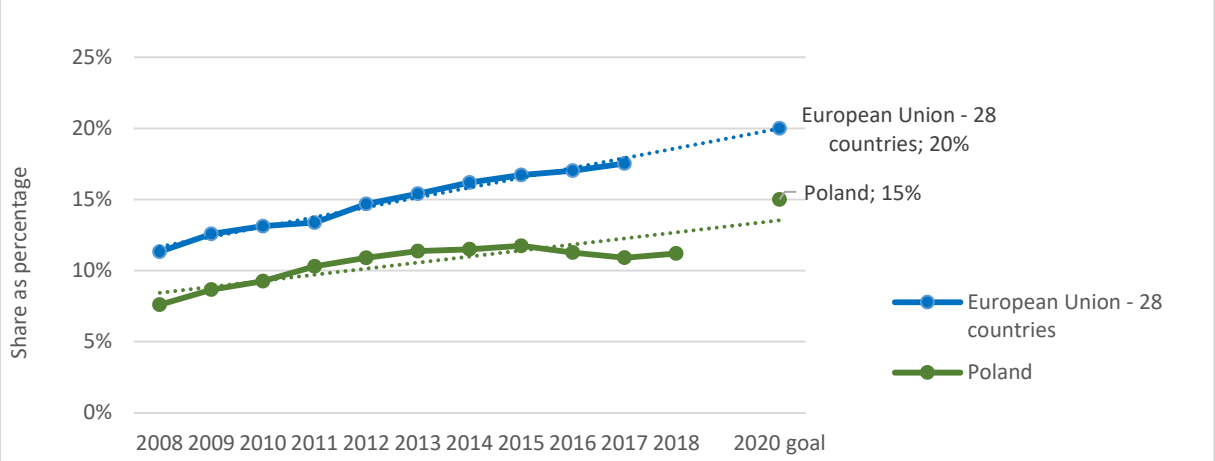


Figure 14, Share of energy from renewable sources in the EU and Poland (Eurostat, 2019; PolandIn, 2019).

If the EU member states would miss their 2020 renewable energy goals, high fines would be the consequence (The Institute of International and European Affairs, 2018). According to Article 6 of the 2009 Renewable Energy Directive (The Institute of International and European Affairs, 2018), statistical

transfers would be introduced. In a statistical transfer, a specified amount of renewable energy is deducted from one country's share of renewable energy as a part of total final energy consumption and is added to another country's share (The Institute of International and European Affairs, 2018). Only member states that have reached their renewable energy goals can sell statistical transfers (The Institute of International and European Affairs, 2018). Unless radical steps are taken, Poland will achieve a 12.1% share in 2020. The statistical transfers would cost Poland between 5 and 15 billion PLN (Polish News Bulletin, 2020).

Appendix 6. Land and labor costs

Prices of land in Poland appear to be volatile (Borawski, Beldeycka-Borawska, Szymanska, Jankowski, & Dunn, 2019). After Poland joined the European Union in 2004, agriculture became subsidized. This situation caused the demand for agricultural land to increase significantly (Borawski, Beldeycka-Borawska, Szymanska, Jankowski, & Dunn, 2019). As can be seen in Table 14, the price of land in Poland has increased with 381.8% between 2005 and 2016 on average (Borawski, Beldeycka-Borawska, Szymanska, Jankowski, & Dunn, 2019). Also, a major difference in price between the different voivodeships can be observed (Borawski, Beldeycka-Borawska, Szymanska, Jankowski, & Dunn, 2019). In 2018 the biggest difference was between the Wielkopolskie and Podkarpackie voivodeships, with a difference of 30,854 PLN per hectare (Borawski, Beldeycka-Borawska, Szymanska, Jankowski, & Dunn, 2019).

The minimum wage in Poland has increased with 344% between 1999 and 2018, from 653 to 2250 PLN (Majchrowska & Strawinski, 2018; NMW Poland, 2019). Poland's ruling party has said that the minimum wage will increase in steps from 2250 PLN (511 EUR) to 4000 PLN by the end of 2023, which is an increase of 78% (Shotter, 2019). Such a spike in labor costs could increase development costs.

Table 14, Price of land in PLN/ha (Borawski, Beldeycka-Borawska, Szymanska, Jankowski, & Dunn, 2019)

VOIVODESHIPS	2005	2016	CHANGE (%)
POLAND	8 244	39 706	381.6
DOLNOŚLĄSKIE	6 941	36 076	419.8
KUJAWSKO-POMORSKIE	12 209	53 916	341.6
LUBELSKIE	6 361	28 391	346.3
LUBUSKIE	4 364	27 707	534.9
ŁÓDZKIE	8 982	36 367	304.9
MAŁOPOLSKIE	8 644	30 480	252.6
MAZOWIECKIE	9 557	37 189	289.1
OPOLSKIE	7 100	45 997	547.8
PODKARPACKIE	4 318	23 231	438.0
PODLASKIE	9 410	37 170	295.0
POMORSKIE	9 137	39 220	329.2
ŚLĄSKIE	8 224	33 565	308.1
ŚWIĘTOKRZYSKIE	6 062	26 521	337.5
WARMIŃSKO-MAZURSKIE	5 737	39 427	587.2
WIELKOPOLSKIE	13 107	54 085	312.8
ZACHODNIOPOMORSKIE	5 057	28 241	458.5

Appendix 7. 2020 RES-auctions

For the 2020 RES-auctions, the estimated volume intended for sale in the 15 year support period is 57.8 TWh (Ministry of Energy, 2019). This includes 36.8 TWh for new installations and 21 TWh for existing installations (Ministry of Energy, 2019). The maximum value of these volumes is 25.36 billion PLN (5.93 billion EUR), of which 15.5 billion PLN (3.61 billion EUR) for new installations and 9.9 billion PLN (2.3 billion EUR) for existing installations (Ministry of Energy, 2019).

The estimated volumes and values for the bioenergy baskets used in the 2020 auctions are given in Table 12 (ICIS, 2019). If adopted, the 2020 auctions will mainly support new installations (ICIS, 2019). There will only be one basket for existing installations, which will be for non-agricultural biogas and biomass with a capacity of more than 1 MW, which is estimated to have a maximum volume of 21 TWh with a value of 9.9 billion PLN (ICIS, 2019). For new non-agricultural biogas and biomass installations with a capacity greater than 1 MW, the volume is estimated to be 11 TWh with a value of 5.2 billion PLN (1.2 billion EUR); for the same type of installations with a capacity less than 1 MW, the volume is estimated be 375 GWh with a value of 166.8 million PLN (38.9 million EUR); and for new agricultural biogas installations with a capacity of more than 1 MW, the volume is estimated to be 1.1 TWh with a value of 1.2 billion PLN (0.28 billion EUR) (ICIS, 2019).

Table 15, Estimated values and volumes of 2020 RES auctions (ICIS, 2019).

2020 Renewable energy auctions	*Volume*	*Value*
New installations:		
Non-agricultural biogas and biomass installations, with a capacity of more than 1 MW	11 TWh	5.2 billion PLN / 1.2 billion EUR
Non-agricultural biogas and biomass installations, with a capacity of less than 1 MW	375 GWh	166.8 million PLN / 38.9 million EUR
Agricultural biogas with a capacity more than 1 MW	1.1 TWh	1.2 billion PLN / 0.28 billion EUR
Existing installations/transition tender:		
Non-agricultural biogas and biomass installations, with a capacity of more than 1 MW	21 TWh	9.9 billion PLN / 2.3 billion EUR

Appendix 8. Interview Summaries

Interview 1. Area sales manager biogas utilities

The interviewee has lived in Poland for 20+ years. He has worked at his current company for 6 years. Before that, he worked for one of their competitors. He has seen the bioenergy market change over the last couple of years. Before, there was a lack of trust from the banks. Recently, he had a meeting with someone from the Rabobank. The Rabobank seems to have more trust in the biogas sector, as they are giving out lines of credit for biogas projects in Poland. Other banks like Fundacja Banku Ochrony Środowiska are specialized in financing green projects. Additionally, the prices for biogas are quite high. The interviewee mentioned prices around 14-15 eurocents per kWh for a fixed rate for 15 years. However, the market is not fully developed yet in some aspects. For biomethane, insufficient legislation is available in Poland.

Interview 2. Marketing and sales manager in bioliquid pyrolysis technologies

The company has developed technology in which biomass, from residues, is heated to create oils and fuels. Their mission is to replace fossil fuels with oils from residues. Their focus countries are mainly those with high biomass potential and countries with better environmental awareness. The company wants to stay out of social discussions (cutting down forests) which is why they are hesitant about Eastern-Europe. The interviewee cannot remember doing any projects in Poland, especially not in recent years. European Directive regarding the share of biofuels very important. Countries need to have a long-term vision regarding biofuel share and would not enter an unstable market. The interviewee sees opportunities in wood residues from sawmills. The company has tested over 50 types of biomass and wood products give the best bio-oil.

Interview 3. Sales manager biomass technologies

The company has been operating for over 15 years in Poland. The company is also operating in most Easter-European countries. Over the years, many big sawmills from the Netherlands have moved to Poland. He started doing business in Poland with these Dutch companies that relocated. He also saw changes in support schemes. Before, Poland had a support scheme similar to the Dutch SDE+ scheme, but they changed it a couple of years ago. The interviewee does not know how current support systems work as they are hard to find in English. There was a hard transition between the support schemes as many companies that were already building and had been granted subsidies, lost their subsidies. To change Poland's energy infrastructure, millions would be needed. The price of coal is too low in Poland making biomass very expensive.

The company did not profit as much from European funds. These funds are now mainly going to Bulgaria and Romania. In Bulgaria and Romania, there are administrative barriers to getting these subsidies. Poland does not uphold emission standards, especially regarding filters. Poles take initiative and have entrepreneurial spirit. The wood industry in Poland is very big. Wood exports to Western Europe have different quality requirements than for domestic sales. Poland is increasingly exporting more wood, making quality more important. This makes the drying rooms for wood in demand. Poland starts to offer more installations themselves and these can be cheaper, mainly due to lower labor costs of installers. The company is now looking for international installation teams for competitive labor costs.

Lots of opportunities as Poland's biomass potential is one of the highest in Europe. They are not using this potential and looking at the price, this could be a major opportunity. He sees a lot of potential in Poland's straw surpluses.

Interview 4. Managing director biogas upgrading technologies

The company is not operating in Poland as Poland (and other Eastern-European countries) has insufficient support to make biomethane installations viable. Without subsidies, biomethane is generally not financially viable. The market price of green gas is around 17 cents/m³ while the production costs range between 60 and 80 cents per m³, meaning that support would be necessary to make the production of biogas viable.

Their main focus countries are those that have a mandatory addition of or incentives for biogas. These focus countries are mainly Northern and West-European countries as they offer good support systems. The most important criteria for focus countries are requirements of and the support for green gas. Poland currently has no provisions for biomethane.

Interview 5. Project manager biogas operations

Around 6-7 years ago, the company began a partnership with a Polish company that ended badly. As this was the company's only lead, they did not try entering the market again. In other Eastern-European countries they did find a reliable partner, making them successful on these markets. Without a reliable partner that speaks the language, a language barrier exists. Not specifically for Poland, the interviewee sees opportunities in the emissions sector. As biogas can replace natural gases, emission credits can be spared. Emission rights can be bought per individual project.