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ENERGY POLITICAL PROSPECTS OF BIOGAS

Study on Selected Countries for Wärtsilä Energy Solutions

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Opinnäytetyö tutkii biokaasun mahdollisuuksia valituissa Euroopan ja Aasian maissa energiapoliittisesta näkökulmasta. Työ tuli toimeksiantona Wärtsilän Energy Solutionsilta. Wärtsilällä on mielenkiintoa uusia biokaasumarkkinoita kohtaan ja tämän työn tavoite on tarjota Wärtsilälle tietoa, jota he voivat käyttää myöhemmässä markkinasuunnittelussa hyväkseen.

Tutkimus keskittyy maiden uusiutuvan energian tilaan nyt ja lähitulevaisuudessa, energiapoliittisiin säädöksiin, biokaasun asemaan energiantuotannossa ja biokaasulla tuotetulle energialle mahdolliseen tukipolitiikkaan. Työn kannalta oleelliset käsitteet ja organisaatiot on käyty läpi työn teoriaosuudessa. Tutkimuksen lähtötilanteessa valittiin kuusi kohdemaata kaikista Euroopan ja Aasian maista Maailman Pankin tunnuslukujen ja Wärtsilän kiinnostusten perusteella. Kohdemaiden tutkimus tehtiin kirjoituspöytätutkimuksena. Tulokset saatiin yhdistelemällä tietoa, joka kerättiin tieteellisistä julkaisuista, kansainvälisten organisaatioiden julkaisuista ja kohdemaiden energia lainsäädännöstä.

Tutkituista maista, kolme tarjoaa hyvät mahdollisuudet biokaasulla tuotetulle sähkölle. Energia- ja tukipolitiikka maittain vaihtelee kuitenkin suuresti ja muuttuu jatkuvasti. Monessa maassa suurimmat tuet biokaasulle ovat jo loppuneet tai niitä on heikennetty.

Avainsanat Biokaasu, uusiutuva energia, energiapolitiikka ja tuki

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ABSTRACT

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The bachelor thesis studies the possibilities of biogas from an energy political perspective in selected European and Asian countries. The thesis was assigned by Wärtsilä Energy Solutions. Wärtsilä is interested in finding new biogas power plant markets. The objective of this thesis is to provide useful information to Wärtsilä to support their future market planning.

The thesis focuses on current and future renewable energy policy, international energy trade relations and current and future position of biogas in a country's energy mix. Essential concepts and organisations are described in the theoretic part of this thesis. From all European and Asian Countries, six countries were chosen as target countries. The countries were chosen based on World Bank's Development Indicators. The study of the target countries was made as a desk research. The research combines information from scientific journals, international organisations and national energy legislation.

From the researched countries, three offer good possibilities for biogas electricity production. Energy and subsidy policies vary a lot from country to country and year to year. The best subsidies for biogas energy seems to be already in the past.

Keywords Biogas, renewable energy, energy politics and subsidy

CONTENTS

LIST OF ABBREVIATIONS

°C	Degrees Celsius
AD	Anaerobic Digestion
c	Euro Cent
CEN	European Committee for Standardisation
CHP	Combined Heat and Power
CSP	Concentrating Solar Power
ETS	Emissions Trading System
EU	European Union
FYP	Five-Year-Plan
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GW	Giga Watt
GWh	Giga Watthour
ha	Hectare
IEA	International Energy Agency
INDC	Intended Nationally Deemed Contribution
INR	Indian Rupee
km	Kilo Meter
kWh	Kilo Watthour

LFG	Landfill Gas
LNG	Liquified Natural Gas
Mt	Mega Tonne
Mtce	Million tonnes of coal equivalent
Mtoe	Million tonnes of oil equivalent
MW	Mega Watt
MWh	Mega Watthour
OECD	Organisation for Economic Co-operation and Development
OPEC	Organization of the Petroleum Exporting Countries
PV	Photovoltaic
R&D	Research and Development
STE	Solar Thermal Electric
t	Metric ton
TFC	Total fuel Consumption
TJ	Tera Joule
TPES	Total Primary Energy Supply
TWh	Tera Watthour
UN	United Nations
USD	United States Dollar

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APPENDIX 1. Preliminary Dimensions and Country Selection

1 INTRODUCTION

The objective of this bachelor thesis is to provide useful information for Wärtsilä about the possibilities of biogas as a fuel in electricity production in selected European and Asian countries. The thesis looks at the possibilities of biogas from an energy political standpoint, which includes current and future renewable energy policy, international energy trade relations and current and future position of biogas in a country's energy mix. Wärtsilä should be able to make strategic decisions or focus their further research in those areas recommended in this thesis.

1.1 Structure

The thesis starts with introduction to the subject and gives some background for why this research was done. Important concepts are described briefly in the following chapter. The main findings follow the theoretic framework. The findings start with information about the European Union's energy policy and biogas, followed by country profiles for three European and three Asian countries. The thesis ends with conclusions, recommendations, and discussion.

1.2 Background for the Research

Energy can be included in the list of people's fundamental needs. The list includes water, food, shelter, and energy. The world is changing, and for the most part, for the better. People have more resources and absolute poverty is diminishing. All of this connects to ever-increasing need for energy. We now know how destructive the power production from fossil fuels, such as coal is to our planet. We need more energy in the coming decades than ever before, but we also need to produce in a more sustainable manner than in the history. (Roser, Ortiz-Ospina 2018; World Energy Council 2017.)

Wärtsilä is interested in alternative fuels for their engines different than the regularly used fuel oils and natural gas. Biogas is one of those fuels. Sustainable development and clean energy is a cornerstone in Wärtsilä's strategy (Wärtsilä 2018).

Therefore, it sparked Wärtsilä's attention that I would be interested in working with them to research the topic of this thesis.

A similar study which focuses on the same countries as this thesis, has not been done before. However, during the making of this thesis an in-depth article named "Biogas: developments and perspectives in Europe" was published by Nicolae Scarlat, Jean-François Dallemand and Fernando Fahl. A study which focuses on relatively same areas of interests in South Korea was published in 2012. The article, "Status of biogas technologies and policies in South Korea" was made by Yong-Sung Kim, Young-Man Yoon, Chang-Hyun Kim and Jens Giersdorf.

1.3 Wärtsilä

Wärtsilä is a multinational corporation based in Finland. Wärtsilä manufactures and services equipment for energy production and marine operations. Wärtsilä is best known for their large diesel engines. The company is the global leader in complete lifecycle solutions and smart technologies in energy and marine business. In 2017, Wärtsilä had 18 000 employees in more than 200 locations around the globe. Wärtsilä is listed in Nasdaq Helsinki and its total sales were 4.9 billion euros in 2017. (Wärtsilä 2018.)

Wärtsilä is divided into three divisions. The divisions are Marine Solutions, Energy Solutions and Services. Marine Solutions is focused on marine and oil & gas industry business, Energy Solutions in offering flexible internal combustion engine power plants and Services provide lifecycle services for all of Wärtsilä's customers. (Wärtsilä 2018.)

This thesis was done for Wärtsilä's Fuel Laboratory Services, which is part of Energy Solutions. The function of the Fuel Laboratory Services is to ensure that the engines operated by Wärtsilä's customers are running at optimal settings based on the properties of the fuel the customer uses. This includes both liquid and gaseous fuels.

1.4 Approach and Research Method

The research method used in this thesis was to do an extensive desk research. The main sources of information were scientific journals covering renewable energy, publications from multiple international economic and energy organizations, and government documents. The main sources for numerical data were the World Bank and the EU.

2 ESSENTIAL CONCEPTS

2.1 Electricity Demand

The electricity demand is constantly varying because consumers turn their electric appliances on and off at will. Currently it is not possible to balance the energy supply cost efficiently with direct electricity storage and therefore, electricity generators have to balance their output according to the demand. Electricity can be stored through conversion to kinetic energy, such as in a flywheel or as chemical energy. (Klimstra 2014, 12, 18.)

2.2 Renewable Energy

As it can be noticed further in this thesis, the renewable energy capacity is increasing all across Europe and Asia. Renewable energy sources are sources of energy that are continuously replenished in nature. Most of the renewable energy sources gain their energy directly, such as solar power or indirectly, such as wind power, from the sun. Renewable energy sources typically include solar power, wind power, geothermal power, hydro power, bio power and ocean power. These energy sources emit very little or no emissions at all and are therefore more sustainable alternative to fossil fuels, such as coal and oil. (Ellabban, Abu-Rub, Blaabjerg 2014, 2.)

As mentioned previously, electricity demand is constantly changing, and electricity cannot be stored directly. Some methods of renewable energy production, such as solar and wind power, fluctuate constantly. Examples can be seen in Figure 1 and Figure 2.

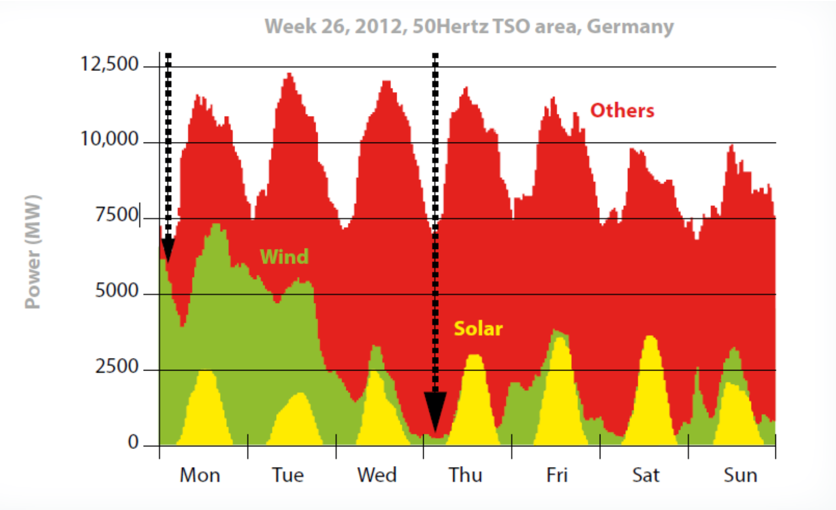


Figure 1. Power output during one week in an area in Germany. (Klimstra 2014, 19)

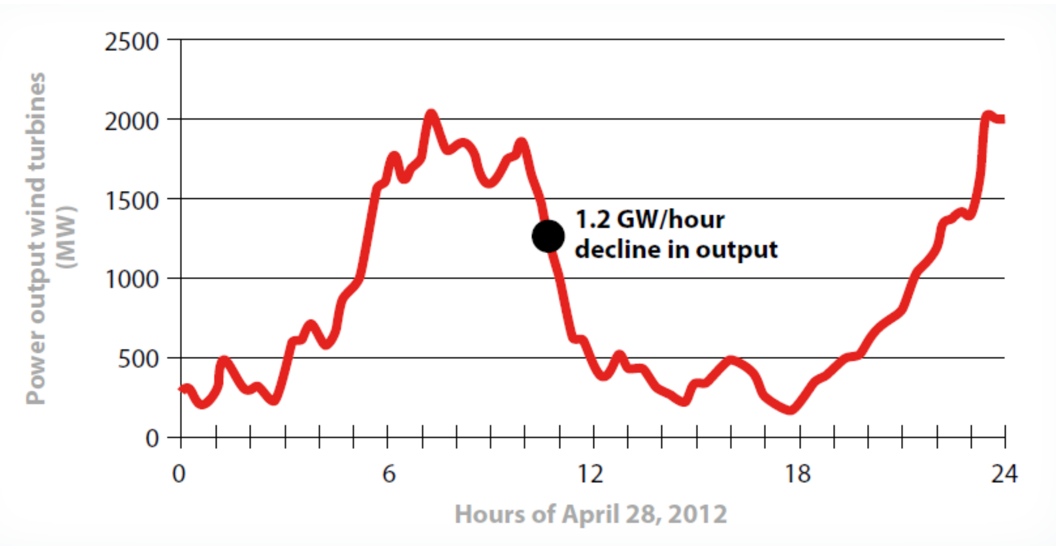


Figure 2. Wind power output during one day in a German region. (Klimstra 2014, 20)

The output of renewable sources like this vary greatly depending on weather and time of day. Hence, it is very difficult to forecast tomorrow's production the day before. As renewable energy is becoming increasingly common, it requires an ever-increasing amount of reserve power to balance according to the fluctuating production. (Klimstra 2014, 18-20.) Biogas is one of those energy sources that can be used to balance the renewable energy production. (Klimstra 2014, 118)

2.3 Greenhouse Gases

Greenhouse gas (GHG) is a common name which is used for gases that let through solar radiation but prevent its escape back to space. This causes the Earth's climate to warm up, like a greenhouse. The most common GHGs are carbon dioxide, methane, and nitrous oxides. GHGs are emitted naturally but since the pre-industrial times, the concentration of GHGs in the Earth's atmosphere has grown rapidly. This primarily due burning of fossil fuels. (Qiancheng 1998.)

2.4 Biogas Production

The theory on biogas production in this thesis will focus on anaerobic digestion (AD) of food waste, manure, and agricultural side products. According to Wärtsilä, biogas produced by other means, such as landfill recovery or from sewage sludge, is not suitable for their power plant engines due the impurities created in the previously mentioned methods. The anaerobic process is described in Figure 3. In an AD process the feedstock is put into a closed anaerobic space. The anaerobic space has a temperature of 35-37 °C or 55-55 °C. (Latvala 2009, 29.) During different phases of the process, different strains of microbes degrade the organic material, which at the beginning consist of components, such as carbon hydrates and proteins. The first phase is hydrolysis and it degrades the organic material into soluble organic materials, such as long chain fatty acids, sugars, and amino acids. The second phase is acidogenesis, which further degrades the material into ammonia, carbon dioxide (CO_2) and hydrogen sulphide (H_2S). The third phase is acetogenesis which further splits the components into acetic acid, CO_2, and hydrogen (H_2). The last phase is methanogenesis. During the last phase two groups of methanogenic bacteria split the remaining components into methane (CH_4) and CO_2. (Apples, Baeyens, Degrève, Dewil 2008, 4; Latvala 2009, 29.)

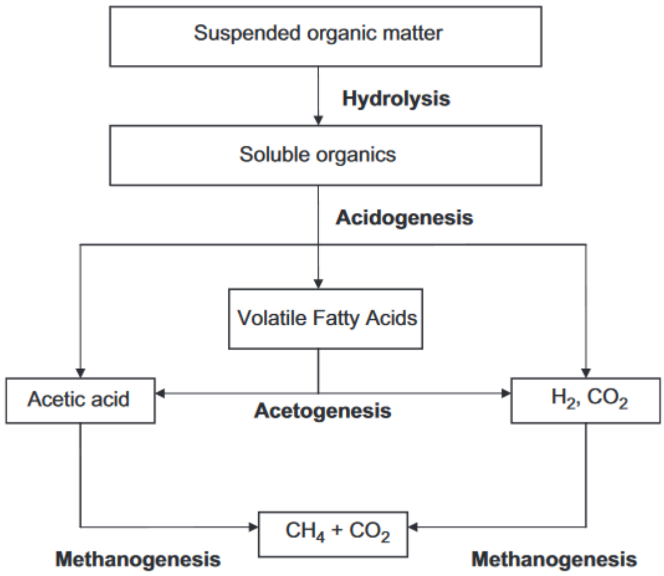


Figure 3. Subsequent steps in the anaerobic digestion process. (Apples, Baeyens, Degrève, Dewil 2008, 4)

The AD process for one batch of organic material typically takes about 12-30 days, depending on composition and other factors (Latvala 2009, 29). The end product is some solid waste and biogas. The produced biogas consists of CH_4 and CO_2 and small amounts of oxygen (O_2) and nitrogen (N_2). The biogas can then be stored, used as a fuel for engines, or upgraded further. Upgrading biogas to biomethane in essence means removing the CO_2 from the gas. All of the remaining gas will be practically methane and can be used like natural gas. The remaining solid waste can be treated and used as a fertilizer. (Apples et al. 2008, 4)

2.5 Gas Engine Power Plant

Biogas can be used as a fuel in a gas engine. The gas burnt in the cylinders of an engine drives pistons down. The pistons are connected to a crankshaft via a connecting rod. The connecting rod transforms the reciprocating movement of the pistons to rotational movement of the crankshaft. A crankshaft is connected to a generator, which converts the kinetic energy to electricity. The combination of an engine and a generator is typically referred as generating set. A power plant usually has multiple generating sets (Clarke Energy 2018.) A basic layout of a generating set can be seen in Figure 4 and a basic layout of a gas power plant in Figure 5.

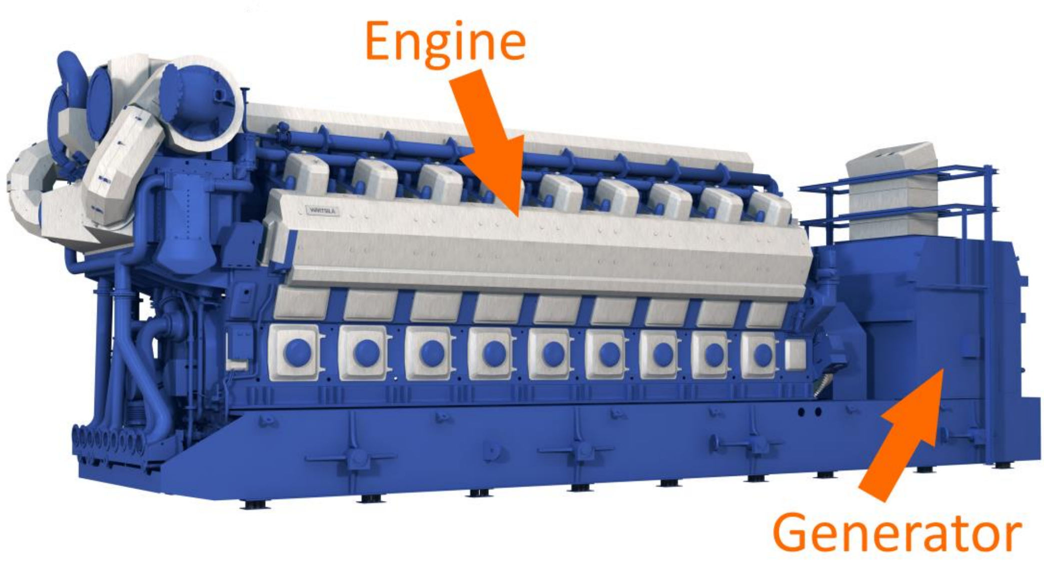


Figure 4. Wärtsilä 18V50SG generating set. (Wärtsilä 2015.)

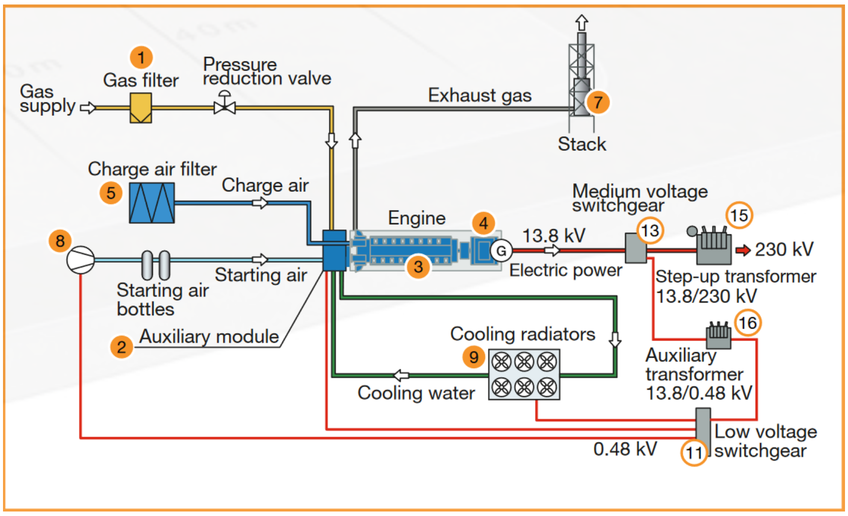


Figure 5. Wärtsilä's Typical 50 MW smart power generation power plant. (Wärtsilä 2016.)

A lot of heat is created in this process. The heat of the engine can be used to heat up water, which can then be transmitted via pipes to heat spaces. A power plant, which produces electricity and heat is called combined heat and power plant (CHP). As can be seen in Figure 6, a CHP plant has much higher efficiency than a plant that generates only electricity. (Clarke Energy 2018.)

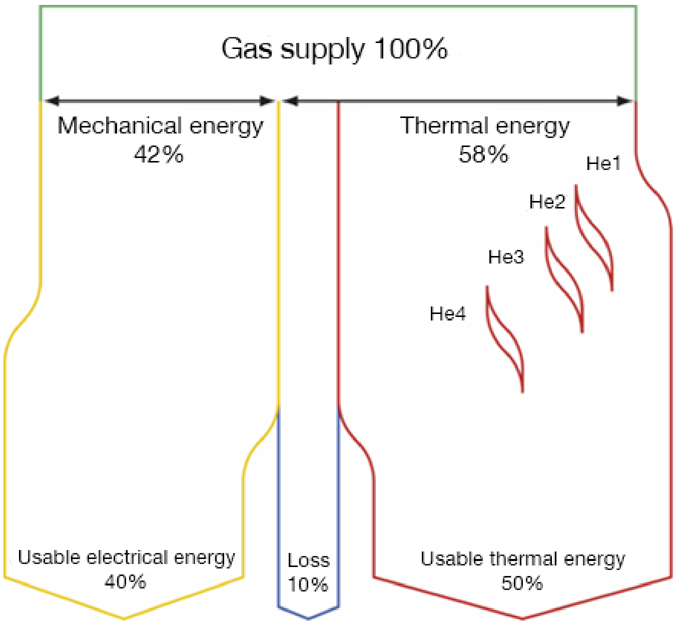


Figure 6. Efficiency of a CHP engine. (Clarke Energy 2018.)

2.6 Energy Security

Energy security is a vital part of national security for many countries. Energy security has three main components: "reliability of supply, affordability of supply and friendliness to the environment". Nations can improve their energy security through different techniques. These include: diversity of energy sources, diversity of suppliers, domestic energy and fuel reserves, backup energy infrastructure and fuel flexibility. Each of these techniques play a part in improving a nation's energy security. However, energy security is the sum of different factors and therefore, not one of these techniques can provide sufficient energy security alone. (Shaffer 2009, 91-93.)

The World Energy Council published World Energy Trilemma Index in 2017. This index is used in all of the researched countries and provides a good overall picture of a country's energy security. An example of Finland's trilemma index is presented in Figure 7 and Figure 8 shows Finland's trilemma index with the country's balance score. The main components are the same as Shaffer listed, but use different phrasing. In the trilemma index "Energy security" (in blue) means reliability of supply, “Energy equity” (in red) means affordability of supply and “Environmental sustainability” (in green) means friendliness to the environment.

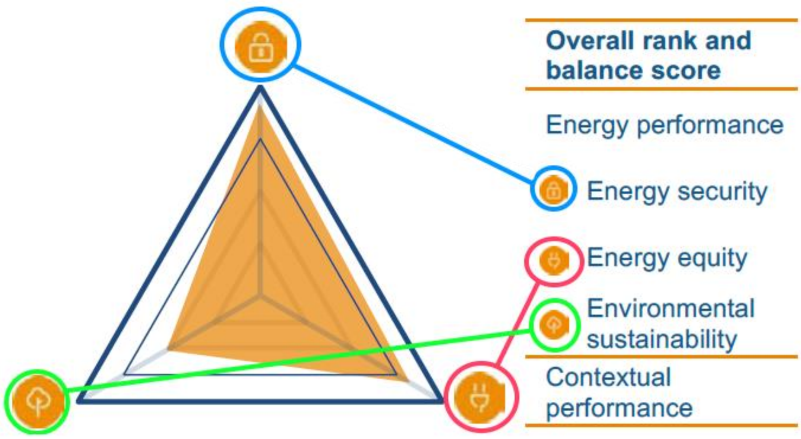
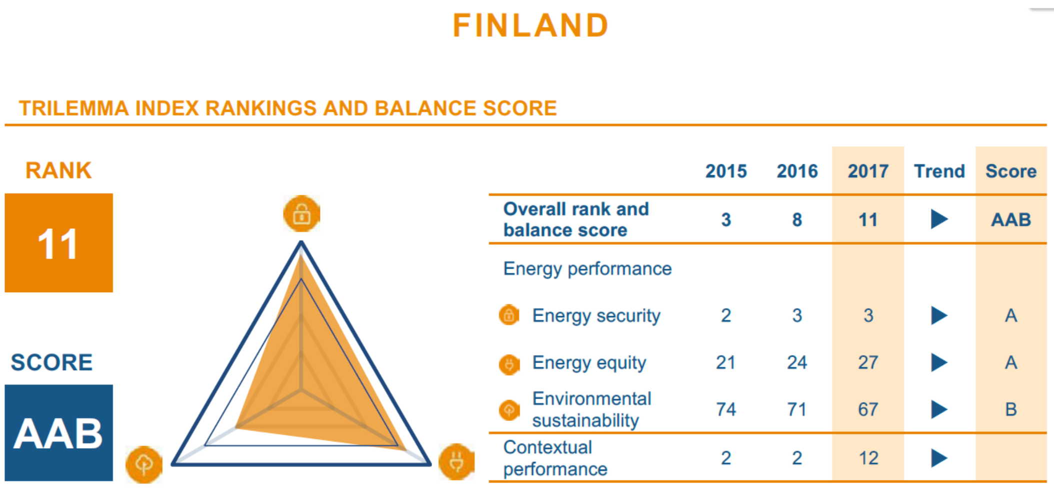


Figure 7. The three main components of energy security. (World Energy Council 2017, 67.)



	2015	2016	2017	Trend	Score
Overall rank and balance score	3	8	11	▶	AAB
Energy performance					
Energy security	2	3	3	▶	A
Energy equity	21	24	27	▶	A
Environmental sustainability	74	71	67	▶	B
Contextual performance	2	2	12	▶	

Figure 8. Finland’s trilemma index rankings and balance score. On energy performance, lower is better. (World Energy Council 2017, 67.)

Each country is scored on a scale from A to D, A being the highest, according to their performance in each of the three areas. This gives a country an overall score.

For Finland the overall score is **AAB**, **A** from reliability of supply, **A** from affordability of supply and **B** from friendliness to the environment (World Energy Council 2017, 67). The order is always the same of every country.

2.7 Essential Organizations

2.7.1 OECD

The Organisation for Economic Co-operation and Development (OECD) is an international economic organization. The OECD's mission is to promote policies that improve the economic and social well-being in its member countries and partners. The OECD was established in 1960 by the USA, Canada and 18 European countries. Currently, the OECD has 35 member countries. (OECD 2018a, 2018b.)

Currently the OECD is focused on restoring people's confidence in the financial markets, help public finances to ensure sustainable economic growth and support environmentally friendly innovation. (OECD 2018a.)

2.7.2 OPEC

The Organization of Petroleum Exporting Countries (OPEC) is economic alliance created by Iraq, Iran, Kuwait, Saudi Arabia, and Venezuela in 1960. Currently OPEC has 12 member states and is practically led by Saudi Arabia. The OPEC was created to counter the major international oil companies in oil production and distribution. The OPEC is best known from its declaration of oil embargo on the United States, Israel, and the Netherlands following in 1973. The declaration caused a 400% increase in global oil prices. Typically, the declaration of the oil embargo is cited as the oil crisis of 1973. Shaffer 2009, 7-8.)

2.7.3 International Energy Agency

The International Energy Agency's (IEA) mission is to promote energy security of in its member countries and promote global energy security. The IEA was established in 1974 as a response the oil crisis that OPEC members created in 1973. The IEA is affiliated with the OECD, but they do not share exactly the same members.

(Shaffer 2009, 101-102.) The IEA's publications have been used a lot in making of this thesis.

2.7.4 The European Union

The European Union (EU) is an economic and political union of 28 European countries. The union began as the European Coal and Steel Community established in 1951, after the Second World War, to guarantee peace in Europe. Over time, the European Coal and Steel Community formed into the European Union. (European Union 2018c.)

Today, most of the EU countries use euro as their currency. The EU does not have any customs inside the union and the movement of workforce and goods is not restricted. Climate change has one of the highest priorities in the EU's agenda. (European Union 2018c.)

2.7.5 The United Nations

The United Nations (UN) is an international organization consisting of 193 member countries. The UN works with global issues, such as peace and security, climate change and human rights. The UN was established in 1945 after the Second World War. (United Nations 2018a.)

2.7.6 The World Bank

The World Bank Group is one of the world's largest sources of financing projects the developing countries. The World Bank also has an extensive database of Development Indicators, which includes a large amount of energy statistics. The World Bank has 189 member countries and has provided financial assistance of 45.9 billion US dollars for 12 000 projects during its existence. Its two main objectives are to reduce the share of the global population that lives in extreme poverty to 3 percent by 2030 and to increase the income of the poorest 40% of the population globally. (World Bank 2018a.)

Wärtsilä's wish was that the data provided by the World Bank would be used in this research. The World Bank has also funded projects in developing countries, in which Wärtsilä has been involved in.

3 INTERNATIONAL CLIMATE TREATIES

3.1 The Paris Agreement

The Paris Agreement is a climate agreement made in 2015 United Nations Climate Change Conference in Paris, also known as Conference of Parties 21 (COP21). The Paris agreement is the first ever universal climate deal signed by almost every country in the world. (United Nations Climate Change 2018a). Out of the 195 signed parties, 176 have ratified the (United Nations 2018b).

The goal of the Paris Agreement is to keep global warming under 2 °C and to pursue even more limited global warming of 1.5 °C compared to pre-industrial levels. Additional aims are to enable countries to deal with climate change, and to make consistent low greenhouse gas emissions a financially attractive and climate-resilient pathway. To reach these goals, the UN will help to mobilize financial resources, create technology framework and will provide support to developing countries and countries at most risk of climate change effects. Additionally, the agreement enhances transparency framework for action and support. (United Nations Climate Change 2018a.)

“The Paris Agreement requires all Parties (signed countries) to put forward their best efforts through ‘nationally determined contributions’ (NDCs) and to strengthen these efforts in the years ahead.” (United Nations Climate Change 2018a), meaning that each country will use the Paris Agreement as a guideline to make changes within a nation so that the goal of limiting global warming is reached collectively. The national goals that a country makes are called Intended Nationally Deemed Contributions or INDCs. Countries are required to report regularly to the United Nations of their progress towards reduced emissions and implementation efforts. Also, a global review of current progress and future actions will be made every five years. (United Nations Climate Change 2018a; 2018b.) According to Paris Agreement countries are legally obligated to plan, inform, maintain, and reach successive national targets but it does not set binding targets for each country. (Ympäristöministeriö 2017.)

The key articles of the Paris Agreement include:

- **Article 2 Long-term temperature goal**
  - Limiting the global warming to 2 °C while reaching for just 1.5 °C compared to pre-industrial era.
- **Article 4 Global peaking**
  - Reaching the global peaking of greenhouse gas emissions as soon as possible, while understanding that it will take longer for developing countries to reach peak GHG emissions than more advanced countries.
  - Achieving balance between GHG sources and sinks by mid-21st century.
- **Article 4 Mitigation**
  - Establishing binding commitments for countries to prepare, inform and maintain nationally deemed contributions (NDC). Successive nationally deemed contributions should progress towards higher ambition at each step. Developed countries should focus on economy-wide reduction of GHG emissions and developing countries mitigate emissions where possible and move towards economy-wide reductions.
- **Article 5 Sinks and reservoirs**
  - All countries should protect and enhance existing GHG sinks and reservoirs.
- **Article 6 Voluntary cooperation/Market- and non-market-based approaches**
  - The agreement recognizes the possibility of voluntarily international cooperation to mitigate emissions and defines a framework for sustainable non-market cooperation.
- **➢ Article 7 Adaptation**
  - The agreement sets a goal to enhance adaptive capacity, strengthening resilience and reduction of vulnerability to climate change.

Adapting is a global challenge for everyone and developing countries should receive extra support for this.

- **Article 8 Loss and damage**
  - Supporting high-risk countries with damages and losses caused by changes in climate.
- **Articles 9, 10 and 11 Finance, technology, and capacity-building support**
  - Obligates developed countries to support developing countries build sustainable and climate-resilient futures. Support efforts should aim to find a balance between mitigation and adaptation of climate change. Developed countries will give information of future support efforts every two years.
  - Financial Mechanism of the Convention, including the Green Climate Fund (GCF) will serve the agreement.
  - International cooperation innovating climate friendly technologies.
- **Article 12 Climate change education, training, public awareness, public participation, and public access to information**
  - Education, training, public awareness, public participation, and public access to information about climate change must be improved.
- **Article 13 Transparency and Article 15 implementation and compliance**
  - The agreement is heavily dependent of transparency of the signed countries. All reports submitted about efforts toward the goals set in the agreement will be internationally reviewed.
- **Article 14 Global Stocktake**
  - The first global review of current progress will be made every five years. The first “stocktake” will be in 2023. Future developments will also be discussed in these stocktakes

(United Nations Climate Change 2018a.)

3.2 Kyoto Protocol

The Kyoto Protocol is an international agreement which commits signed countries to reduce GHG emissions to set targets. The agreement acknowledges that developed countries are responsible for the vast majority of GHG emissions. These developed countries are called Annex I parties in the agreement. The agreement was adopted in Kyoto, Japan, 1997 and entered into force on 2005. The original Kyoto Protocol had a commitment period from 2008 to 2012. The so-called Doha Amendment to the Kyoto Protocol included a new commitment period for Annex I parties. The second commitment period is currently ongoing. The period started in January of 2012 and lasts until December of 2020. (United Nations Climate Change 2018c.)

During the first commitment period, the target for Annex I parties was to reduce GHG emissions by 5% compared to 1990 levels. The second commitment period set target to reduce the emissions by 18% compared to 1990 levels. (United Nations Climate Change 2018c.)

The main difference between the Paris Agreement and Kyoto Protocol is that the targets set in Kyoto protocol have legal force. Paris Agreement is trusting on voluntary action and nationally setting emission targets (INDCs). Still, it is to be noted that nationally set emission targets to reach the goals set in the Paris Agreement have legal force in their respective countries. (Taraska 2015.)

The scope of these two climate agreements are also different. The Paris Agreement is global when the Kyoto Protocol set emission targets only for developed countries. For example, China and India did not receive any mandatory emission targets in the Kyoto Protocol (Taraska 2015.)

4 EUROPEAN UNION

4.1 Energy Policy in the European Union

4.1.1 2020 Energy Strategy

The EU set so-called 20-20-20 targets in the 2020 Energy Strategy. By 2020, The EU aims to reduce GHG emissions by 20%, increase the share of renewable energy of at least 20% of energy consumption and improve energy efficiency by 20%. The purpose of these targets is to help combat climate change, improve energy security in the EU countries and keep energy prices affordable for the EU citizens. (European Commission 2018a.) By 2015, the EU had already reduced its GHG emissions by 19% (Republic of Latvia 2015).

4.1.2 2030 Energy Strategy

The 2030 Energy Strategy targets cover the same sectors as 2020 Energy Strategy but sets more ambitious goals. The 2030 targets include reducing GHG emissions by 40% compared to 1990 levels, reaching 27% share of renewable energy of energy consumption and improve energy efficiency by 27% compared to business-as-usual scenario. The purpose of the 2030 Energy strategy is the same as in 2020 Energy Strategy and to provide a mid-way goal to meet the long term 2050 Energy Strategy goals. (European Commission 2018b.)

4.1.3 2050 Energy Strategy

The EU's long-term climate and energy policy is called Energy Strategy 2050. By 2050, GHG emissions should be 80-95% lower than they were in 1990. It introduces the Energy Roadmap 2050, which introduces tools to help the EU to transition towards carbon neutral energy system. (European Commission 2018c.)

4.1.4 European Energy Union

The purpose of European Energy Union is to provide secure, competitively priced, and environmentally sustainable energy supply for all EU citizens. Important aspects are that energy can be supplied inside EU across borders and that it is produced with sustainability in mind. The Energy Union programme is also a tool to reach the targets set in 2020, 2030 and 2050 Energy Strategies. (European Commission 2017a.)

The vision of European Energy Union is to interconnect EU member states in terms of energy so that solidarity and trust is formed. This enables the Energy Union to speak for all EU member states. The end goal is to involve all EU citizens in energy transition to sustainable energy and enable them to participate in energy markets rather than being passive consumers by means of innovative technology. This should provide citizens with cheaper energy. Other vision is that the Energy Union is supporting companies working in energy field on sustainable solutions, sending a strong message to investors that this is the way forward and enabling European work force to manage the future energy systems with sufficient skills. (European Commission 2015a, 2-4.)

Currently the EU has some energy rules on the EU level but practically all of the regulations are still on the national level. The Energy Union's target is to integrate all of these regulations into one EU wide policy, the same for every member state. The retail network of energy is not working properly. Too many households cannot afford to pay for their energy bills. The infrastructure is also old and aging day by day. Many nations are still dependent on one external energy supplier. This greatly affects the reliability of energy supply. (European Commission 2015a, 2-4.)

If the EU does not continue to pursue new sustainable energy technology together, this could result in fractured energy market inside the EU. This would have major economic, social and environmental costs for everyone. An integrated energy infrastructure from state to state and supplier to consumer is the way forward. (European Commission 2015a, 2-4.)

The European Energy Union has five dimensions that reinforce one another.

These dimensions are:

1. Energy security, solidarity, and trust;

2. A fully integrated European energy market;
3. Energy efficiency contributing to moderation of demand;
4. Decarbonising the economy, and
5. Research, Innovation and Competitiveness

(European Commission 2015a, 4.)

1. **Energy security, solidarity, and trust**

The EU is still vulnerable for external energy disruptions. The clear goal is to reduce energy dependency on external energy. Key elements to fight this is to further integrate the EU's energy market and reduce energy consumption. Solidarity is one of the ideas that whole the EU is built on. This is especially important in energy sector. (European Commission 2015a, 4-7.)

Diversification of energy supply is crucial. As the old saying goes, 'don't put all your eggs in one basket'. Diverging energy sources would create more secure energy supply since disruptions on specific source would not have such paralyzing effect. Plans to diversification of natural gas supply include work on Southern Gas Corridor between Europe, Central Asia and liquid gas hubs in Northern Europe and continuing to explore the potential of LNG. Also, the EU is very dependent on nuclear fuels originating outside the EU. Domestically produced energy also diminishes the energy dependency on non-EU states, like Russia. (European Commission 2015a, 4-7.)

Cooperation with member states, transmission system operators and the energy industry are required to ensure energy security. In event of tightened energy supply the EU states must be able to rely on each other. Currently the EU states have little security infrastructure in place in case of a crisis. The European Commission is trying to establish a series of mechanisms to soften the impact of an energy crisis in a member state. (European Commission 2015a, 4-7.)

The EU wants to gain a stronger role in global energy markets. Energy can be used as a tool or even a weapon by major exporter and transit countries. This has to be taken into account when drafting policies. Working together with other major players in energy field, the EU would strengthen its position on a global scale. The most important factors affecting energy security are transit role of Ukraine, development in Middle-East and North Africa, partnership with Norway and relationship with Russia. (European Commission 2015a, 4-7.)

Transparency is also a concern when buying energy, especially gas, from third countries. The EU has to make sure that the agreements and supply is compliant with EU law. The European Commission should be informed at an early stage when a member state is starting to negotiate an energy agreement with a non-EU country and should be involved in the negotiations. (European Commission 2015a, 4-7.)

2. A fully-integrated internal energy market

Despite recent progress, Europe's energy system is still not performing at optimal level. Currently the energy system is fractured, markets are concentrated and there is not sufficient investment. The Energy Union wishes to boost the development to complete internal energy market. (European Commission 2015a, 7-12.)

The problem for incomplete internal market lies in insufficient cross-border gas and electricity networks. However, there are multiple ongoing projects to improve the situation. By year 2020 interconnection target has been set to 10% of electricity production capacity. (European Commission 2015a, 7-12.)

Future energy market requires a flow of information in both direction, from supplier to consumer and vice versa. In the case of the EU's internal electric grid this information usually has to travel across borders. The duty of the Energy Union is to make sure that there is legislation in place to support this and enforce this legislation. Future energy market has to be transparent and accessible to monitor. (European Commission 2015a, 7-12.)

A Europe wide energy market has to work for every state. This requires developing and coordination from the EU. Customers should be able to make informed choices in this market. Combining smart technologies, such as smart meters with modern energy market enables the customer to be more flexible and might even save the money. However, not all EU citizens are equal. Solidarity is also something to think about when arranging these markets so that low income households are able to meet their energy demands. (European Commission 2015a, 7-12.)

3. Energy efficiency as a contribution to the moderation of energy demand

The European Council has set a target that by 2030 energy efficiency is improved by 27%. The energy sector has to be considered as a whole rather than just producing according to the demand. Demand has to also react to the generating side. (European Commission 2015a, 12-14.)

Heating and cooling of buildings are one of the largest sources of energy consumption. The EU is trying to help on the local and regional level to improve energy efficiency of building by offering financial support for developers. (European Commission 2015a, 12-14.)

Transportation accounts for about 30% of total energy consumption in the EU. The main focus of traffic regulation is to cut CO_2 emissions. Main tools for these are pollution -based charges and promoting sustainable methods, such as railway and maritime transport of goods and people. Breaking oil dependency should be mainly achieved by electrifying the road transport. (European Commission 2015a, 12-14.)

4. Decarbonisation of the economy

Climate policy in the EU is based on the EU-wide carbon market better known as ETS or Emissions Trading System. The EU has set ambitious target of reducing greenhouse emissions by 40% by year 2030. This should be achieved as a result of large number of connected environmental policies. The role of ETS is to guide investments in low-carbon investments. Decarbonisation of the economy is the most crucial step in fight against climate change. (European Commission 2015a, 14-15.) The EU ETS is described in detail in chapter 4.1.5.

The European Union is strongly committed to renewable energy sources. EU countries are likely going to reach the 2020 target of 20% share of renewable energy, set in the EU's 2020 Energy Strategy, but the future targets are still challenging. The current electric grid systems are not going to be able to handle the year 2030 target share of renewables. The solution to this would be smart grid technologies. Renewable energy should also be supported by markets and low-cost financing to make them more financially feasible. Basically, the goal is to make renewable energy business more attractive than fossil fuel alternatives. (European Commission 2015a, 14-15.)

5. An Energy Union for Research, Innovation and Competitiveness

Research and innovation is at the very centre of the Energy Union. The Energy Union has to be the leader in renewable energy production and energy storage research to become the number one in renewable energy. To further empower research, the EU and national scale research projects must be combined to gain synergies in research. There is still much to be done to connect these projects to each other. Research should be grouped in categories. These categories are generation of renewable energy, smart grids and appliances, energy efficiency improvements and sustainable transport. Addition to these categories would be carbon capture technology and safe nuclear power. (European Commission 2015a, 16-17.)

Innovation-driven economy would also create new jobs for energy sector. This would benefit industries and employees. Current free movement of work force is an important policy to enable this kind of development. In addition, this would require collaboration with public officials and private companies. Also, education of people has to be considered that the EU would have capable personnel for this kind of jobs. (European Commission 2015a, 16-17.)

4.1.5 EU ETS

The European Union Emissions Trading System (EU ETS) is a trading system for GHG emissions. It was introduced in 2005. The system is based on ‘cap’ and ‘trade’ of emissions. The EU ETS operates in all EU countries and in few outside EU. Currently the EU ETS limits emissions of 11 000 high energy using industries and accounts for 45% of all GHG emissions in the EU. (European Commission 2017c.)

The ‘cap’ is the maximum annual amount of allowed emissions in the EU. The annual caps are presented in Figure 9.

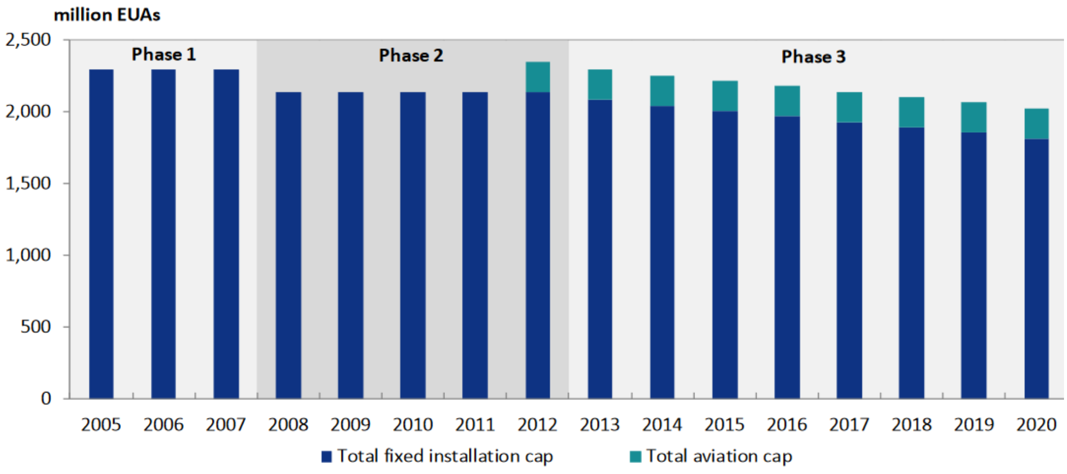


Figure 9. Yearly emission cap from 2005 to 2020. EUA = EU Allowance Unit of one tonne of CO_2. (European Commission 2015, 23.)

A share of this total amount was allocated to each participant and this share is the company’s maximum yearly emissions. These shares are usually called allowances or EU allowance units (EUA). (European Commission 2017d.). Nowadays, the default method to gain allowances is through auctioning. (European Commission 2017c.) Companies are able to trade these emissions with each other. For example, Company A and B each have 10 units of emissions for 2018. Company A can operate with lower emissions during 2018 and only uses 8 units. However, company B would need 12 units to operate. Company A can sell the 2 extra units to company B and so the total amount of emissions is not exceeded. If a company operates with lower emissions than its allowances, it can also choose to save the extra for next years. (European Commission 2014.) The process is described in Figure 10. If a company exceeds its allowances, it has to pay heavy fines of 100 €/t of CO_2 and rising since 2013 (European Commission 2015, 16).

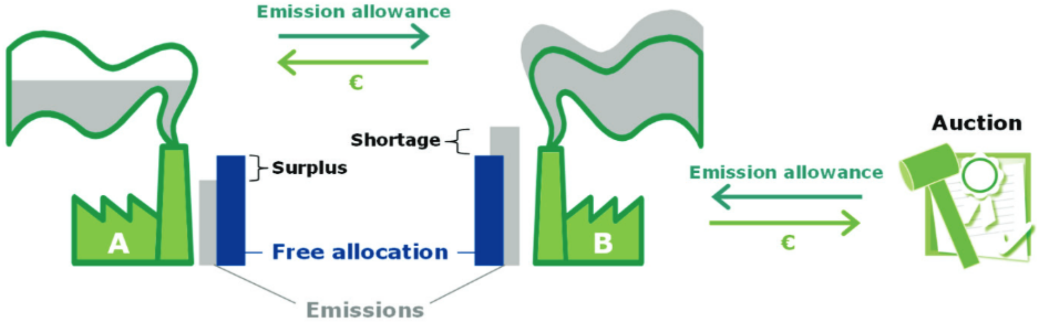


Figure 10. Emissions trading example. (European Commission 2015, 17.)

During the past year, the price of the Emission Allowances has increased rapidly. Between 2013 and 2017, the price of EUA was about 5 euros per unit, but it reached 14 euros during April of 2018. (EEX 2018.) The price development since May of 2017 is presented in Figure 11.

Figure 11. Price of EU Emission Allowances 5/2017-5/2018. The price is in euros. (EEX 2018.)

4.1.6 The European Union's INDC

All of the EU countries are committed to the Paris Agreement. The EU has its own INDC which are common for all of the member countries. By 2030, the EU promises to reduce GHG emissions by 40% compared to 1990 levels in order to reach the Paris Agreement's temperature goal. The reduction target covers all of the economic sectors. (Republic of Latvia 2015.) The target is the same as in 2030 Energy Strategy (European Commission 2018b). The EU member countries can and do have their own climate policies in addition to the EU's INDC. However, the national climate policies cannot be more relaxed than the EU's INDC.

4.2 Biogas in the European Union

4.2.1 Current Status of Biogas in the EU

The European Union is the global leader in biogas production. In 2015, the combined electric capacity of the EU countries' biogas plants was 10.1 GW and combined electricity production from biogas was 61 TWh. There has been a constant expansion in biogas production since 1990's. Since 2000, the annual primary energy production from biogas has grown by 562 PJ, equal to 156 TWh. Most of the biogas in the EU is used for electricity production. The majority of the biogas in the EU countries is produced by anaerobic digestion. (Scarlat et al. 2018, 3, 12, 38.) The evolution of biogas production is presented in Figure 12. And production methods in Figure 13.

Climate and energy policies have been strong drivers for biogas in the EU. The EU has its own policies in place, such as EU's 2020 and 2030 Energy Strategies. All of the EU countries have ratified global climate agreements, such as The Paris Agreement and Kyoto Protocol. The EU also offers guidelines for national support schemes for renewable energy. (Scarlat et al. 2018, 4-6.)

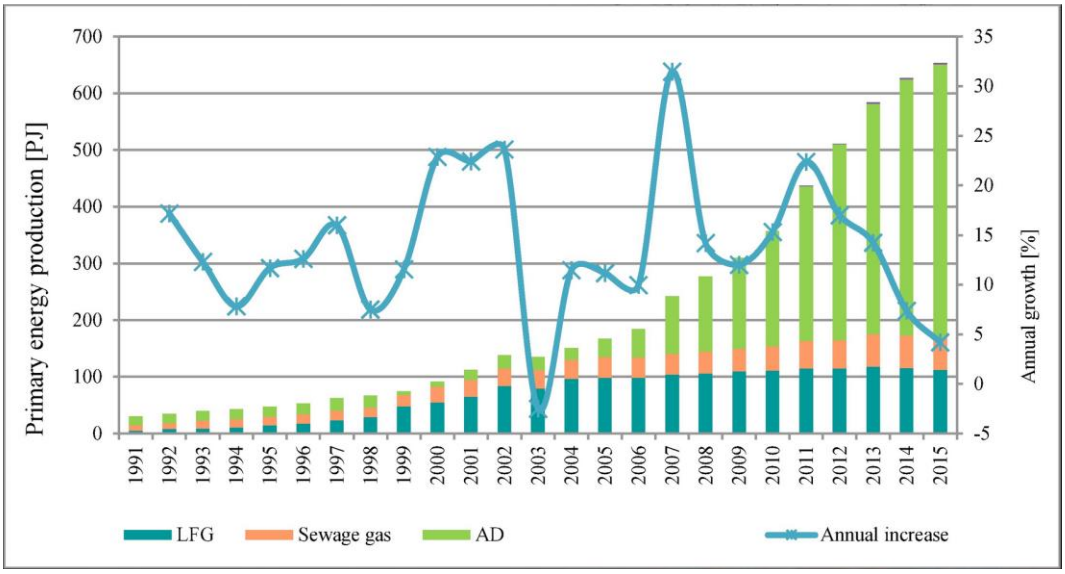


Figure 12. Evolution of primary energy biogas production in the EU. (Scarlat et al. 2018, 12.)

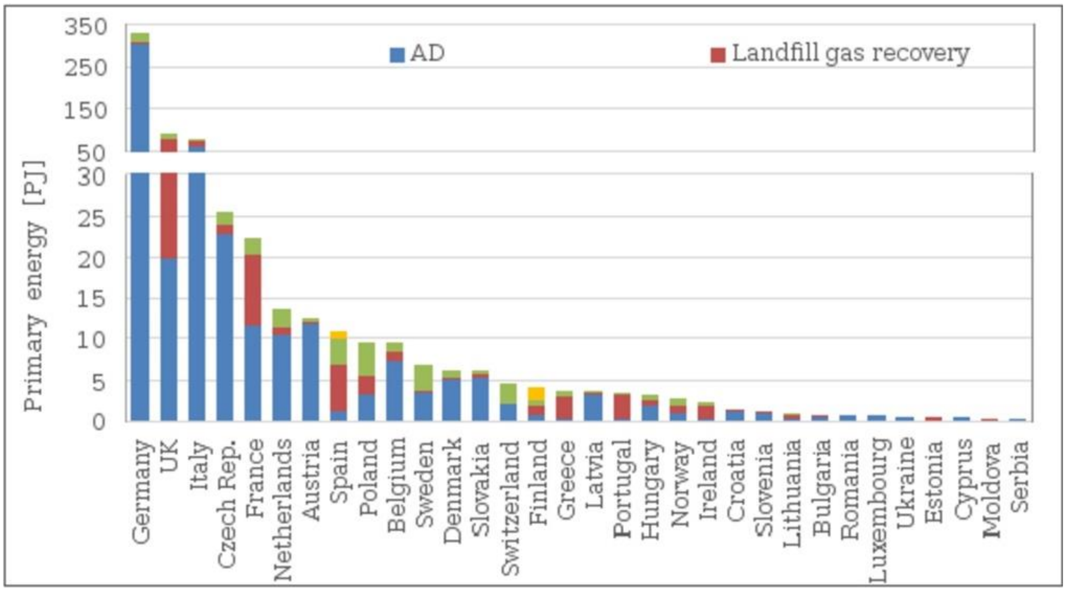


Figure 13. Primary energy production from biogas in European countries in 2015. Blue = Anaerobic digestion, Red = Landfill recovery, Green = Sewage sludge, Yellow = Thermochemical processes. (Scarlat et al. 2018, 38.)

4.2.2 Biogas Potential in the European Union

There are various estimations of the potential of biogas in the EU countries. According to German Biomass Research Centre (DBFZ) the technical potential of biogas in the EU is 151-246 billion m^3/year. The Green Gas Grids Project estimates that 48-50 billion m^3 could be achieved by 2030 out of the potential estimated by the German Biomass Research Centre. The estimate by The European Biomass Association (AEBIOM) is about 78 billion m^3 of biomethane in a year. (Scarlat et al. 2018, 13-14.) Biomethane is the upgraded form of raw biogas.

The current biogas production in the EU is about 18 billion m^3 of methane. The EU estimates that by 2020 biogas could represent 5% of natural gas consumption. Currently the EU's average in biogas share in natural gas use is 4.0%. (Scarlat et al. 2018, 13-14, 32.) When comparing even the lowest estimations of the potential of biogas in the EU with current production, it can be seen, that there is still a lot of untapped potential.

4.2.3 Biogas Standards in the European Union

A Technical Committee TC408 was set up by the European Committee for Standardisation (CEN) in 2014 to harmonise biomethane standards across Europe. The committee published two standards, Standard EN 16723-1:2016 - Part 1: Specifications for biomethane for injection in the natural gas network and EN 16723-2:2017 - Part 2: Automotive fuels specification. (Scarlat et al. 2018, 12.) The specification for biogas according to the Standard EN 16723-1:2016 - Part 1 Specifications for biomethane for injection in the natural gas network is presented in Table 1.

Table 1. Mandate M/475 –EN 16723-1 (grid injection). (Wellinger 2017.)

Parameter	Unit	Limit values	
		Min	Max
Total volatile silicon (as Si)	mgSi/m³		0,3 (pure) to 1 (diluted)
Compressor oil		free from impurities	
Dust impurities		free from impurities	
CO	% mol	–	0,1
NH3	mg/m³		10
Amine	mg/m³		10

Another standard for gas quality published by the CEN is the Standard EN16726:2015 which "specifies gas quality characteristics, parameters and their limits, for gases classified as group H that to be transmitted, injected into and from storages, distributed and utilized" (European network of transmission system operators for gas 2016). The Standard is summarised in Table 2.

Table 2. Summary of EN1676:2015. (European network of transmission system operators for gas 2016.)

Parameter	Unit³	Min	Max
Relative density	-	0,555	0,700
Total sulfur without odourant	mg/m³	-	20 (30*)
H2S + COS	mg/m³	-	5
Mercaptan sulfur	mg/m³	-	6
Oxygen	mol/mol	-	10 ppm to 1%
CO2	mol/mol	-	2.5% to 4%
HC dew point	°C (up to 70 bar)	-	-2
Water dew point	°C (at 70 bar)	-	-8
Methane number	-	65	-

5 PRELIMINARY DIMENSIONS AND TARGET COUNTRIES

The complete table of dimensions for all of the European and Asian countries is attached as Appendix 1. countries. The final dimensions to select the target countries is presented in Figure 14.

Figure 14. Final preliminary dimensions.

At the beginning of the research, a large matrix of multiple dimensions was gathered for all European and Asian countries. The dimensions were compiled from World Bank's World Development Indicators, which enabled us to see trends and current situation of the countries in Europe and Asia. The final dimensions selected to determine target countries were discussed with Wärtsilä. The dimensions were selected according to Wärtsilä’s recommendations. Dimensions that were not used, such as electrification rate, Human Development Index and literacy rate, were removed from the matrix presented in Appendix 1.

Based on the preliminary dimensions, 12 countries were selected out of the 94 countries. For the 12 countries, some additional dimensions were gathered to help choose the main countries which would be researched in detail. The dimensions were combined with Wärtsilä’s business interests to decide the final target countries. The final target countries with selection criteria are presented in Table 3.

Table 3. Final 12 countries. Selected five countries underlined and reference country in bold letters.

Country	**Criteria**
<u>Austria</u>	<u>Energy imports, load adjustment, landlock</u>
Estonia	Very high emissions
Georgia	Growth potential, energy imports
Germany	**Energy imports, load adjustment**
<u>Netherlands</u>	<u>Agriculture, high emissions, load adjustment</u>
Bangladesh	Population, growth potential
Cambodia	Growth potential
<u>China</u>	<u>Population</u>
<u>India</u>	<u>Population</u>
Indonesia	Population, geography, growth potential
Japan	Energy imports
<u>South Korea</u>	<u>Energy imports, low renewable energy share</u>

The final five countries selected for this research were Austria, Netherlands, China, India, and South Korea. Germany was chosen as a reference country, since it has the most developed biogas sector in the world (Scarlat, Dallemand, Fahl 2018, 13-16).

6 GERMANY

6.1 Germany in General

Germany is used primarily as a reference country in this research since it has a well-established biogas sector.

Germany is a country located in Central Europe, see Figure 15. Germany is one of the founding countries of the European Union (European Union 2018c) and has been a member country since 1958. Thus, it is subject to the directives and regulations of the EU (European Union 2018a). Germany is also a part of the IEA and OECD (International Energy Agency 2014a, 2; OECD 2018b). Germany has surface area of 357 300 km^2 and population of 81.2 million, which makes it the most populous country in the EU. (European Union 2018b).

Figure 15. Germany in dark green. Members of European Union in lighter green. (Wikipedia 2018c.)

6.2 Energy in Germany

Germany being the largest country in Europe, in terms of population and GDP, also uses the most energy. Still, Germany's final energy consumption has been declining since 1996. (European Commission 2018d.) Germany's final energy consumption is presented in Figure 16.

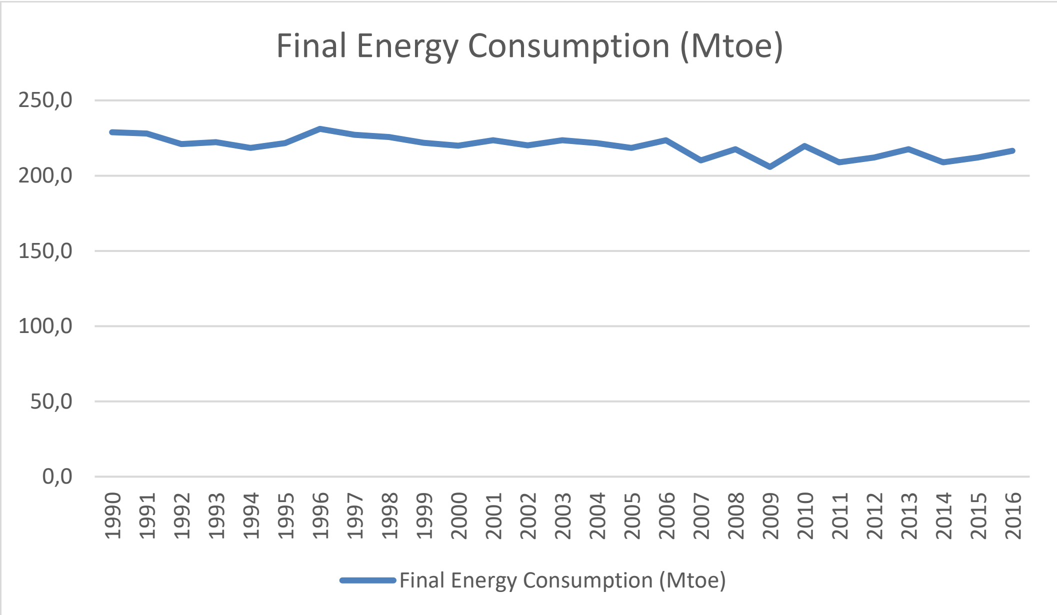


Figure 16. Germany's final energy consumption from 1990 to 2016. (European Commission 2018d.)

Germany has an interesting energy mix. Germany produces a lot of renewable energy but also produces and imports a lot of coal (International Energy Agency 2017c). In 2016, almost a third of all the coal imported in the EU went to Germany. Germany produces minute amounts of natural gas and oil but is the largest importer of both in the EU. (European Commission 2018d.) Germany's energy supply and demand are presented in Figure 17 and electricity generation in Figure 18.

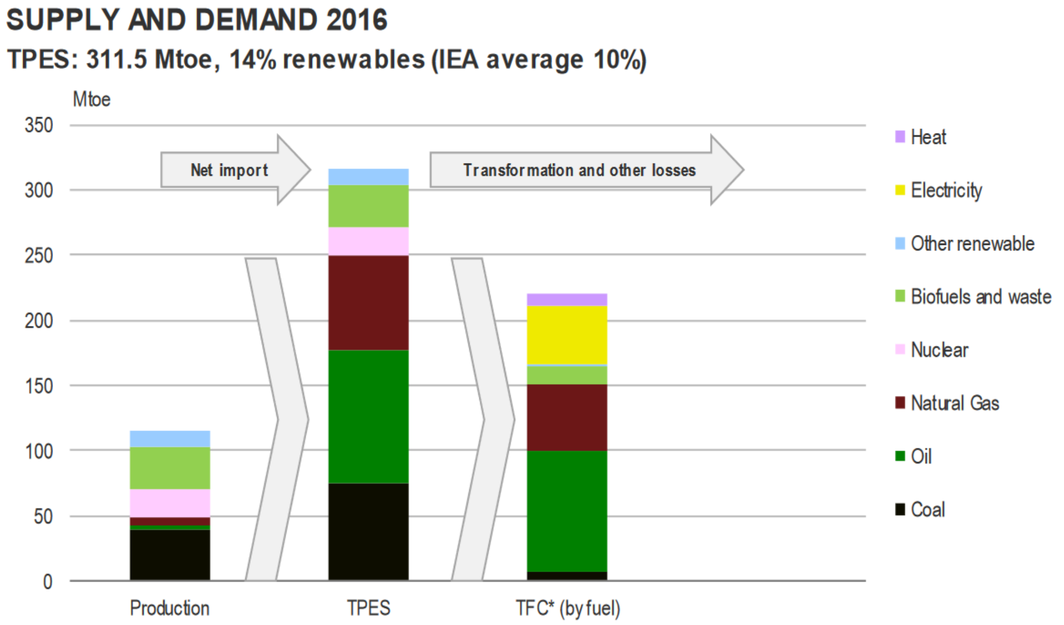


Figure 17. Germany's energy mix in 2016. (International Energy Agency 2017c.)

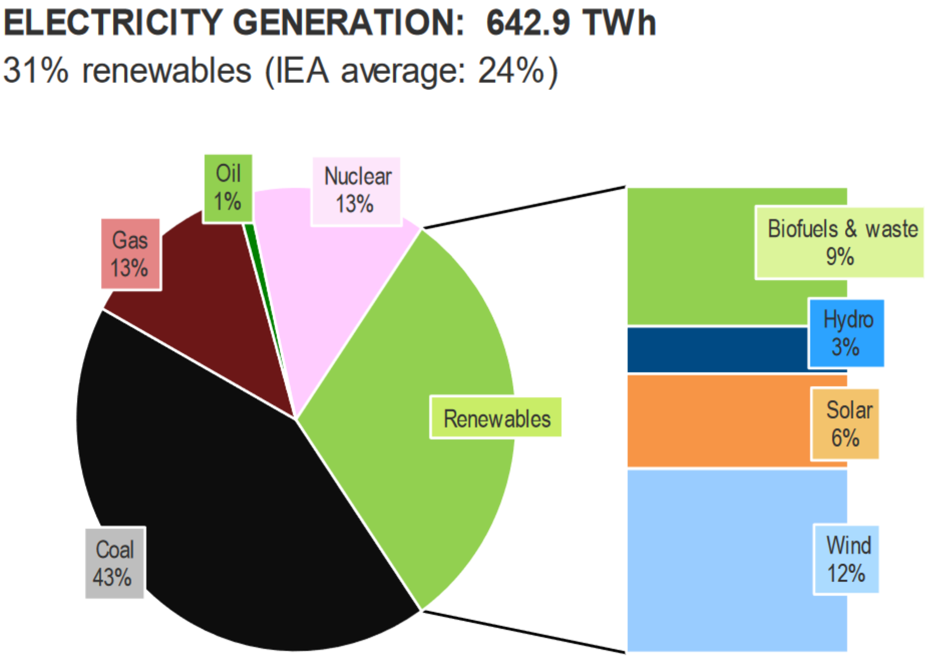


Figure 18. Germany's electricity production by source in 2016. (International Energy Agency 2017c.)

Electricity production in Germany relies heavily on coal (43%) and renewable energy (31%). Germany produced 642.9 TWh of electricity in 2016. (International

Energy Agency 2017c). The average household electricity price in Germany is 0.33 USD/kWh, which is the highest in this study. (World Energy Council 2017.70).

Germany has a very highly developed natural gas grid. The gas grid has a total length of over 436 000 km. (GreenGasGrids 2018.)

6.3 Energy Policy in Germany

Germany's CO_2 per capita is presented in Figure 19. The emissions have been higher than average, but they closely resemble the EU wide trend. Germany's GHG emissions were 336.5 Mt CO_2-equivalent lower in 2015 than in 1990 (European Commission 2018a).

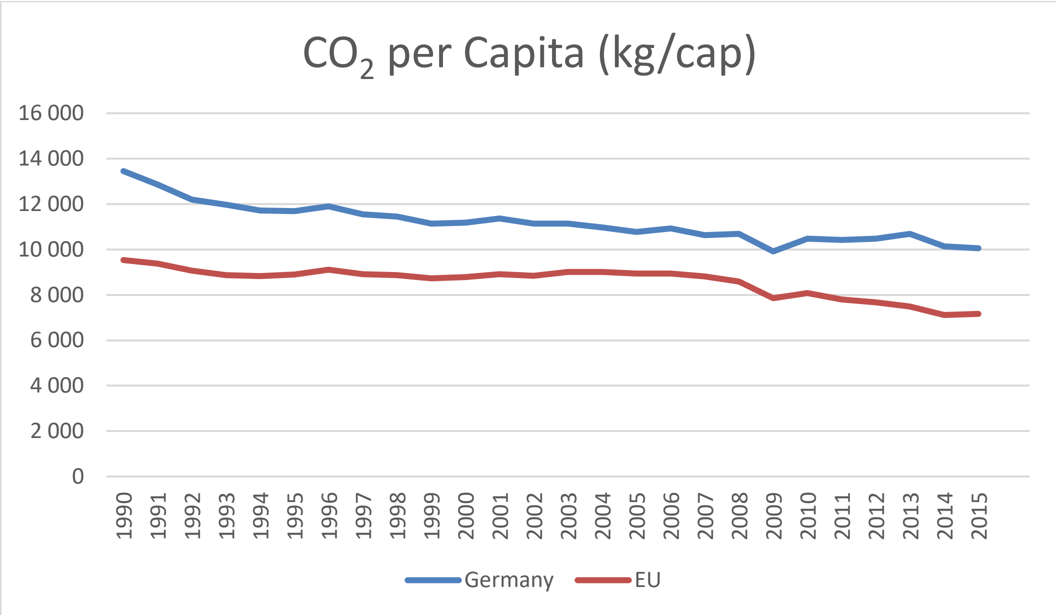


Figure 19. CO_2 per Capita in Germany between 1990 and 2015. (European Commission 2018d.)

Germany adopted a new energy strategy called the Energy Concept in September 2010. The Energy Concept establishes Germany's energy policy until 2050. In the strategy it is determined that renewable energy is the foundation of future of the energy in Germany. (International Energy Agency 2013, 11.) The energy Concept uses year 1990 as a baseline. (International Energy Agency 2013, 58.)

The key reduction targets of the Energy Concept are presented in Table 4. The targets are ambitious, to say at least.

Table 4. Key targets of the Germany's Energy Concept. (International Energy Agency 2013, 58.)

ENERGY CONCEPT TARGETS	2020	2030	2040	2050
Reduction of GHG emissions*	40 %	55 %	70 %	80-95%
Reduction of primary energy consumption*	20 %	30%	40%	50 %
Reduction of electricity consumption**	10 %	15%	20%	25 %
Share of renewable energy of final energy consumption	18 %	30 %	45 %	60 %
Share of renewable electricity of consumption	35 %	50 %	65 %	80 %
*COMPARED TO 1990 LEVEL				
**COMPARED TO 2008 LEVEL				

Prior to 2010 Energy Concept, the German government adopted Integrated Energy and Climate Programme. The key elements of the package are improved energy efficiency and sustainable energy production. The emission reduction targets are presented in Table 5.

Table 5. Components of the Integrated Energy and Climate Programme and GHG emissions reduction targets. Emission reductions are compared to year 1990. (International Energy Agency 2013, 57.)

Policy	Emissions reduction per year by 2020
Reduce electricity consumption	40 Mt CO_2-eq
Modernisation of fossil-fired power stations	30 Mt CO_2-eq
Promotion of electricity generation from renewable energies	55 Mt CO_2-eq
Promotion of combined heat and power generation	20 Mt CO_2-eq
Modernisation of buildings and heating systems	41 Mt CO_2-eq
Heat saving in production processes	n/a
Use of renewable energies in heat production	14 Mt CO_2-eq
Energy saving measures in the transport sector	30 Mt CO_2-eq
Other GHG emissions reduction measures	40 Mt CO_2-eq
Total reductions	**270 Mt CO_2-eq**

The Renewable Energies Act or Erneuerbare Energien Gesetz (EEG) in German is a German energy policy. The aim of the policy is to increase the share of renewable energy in electricity generation by 40-45% by 2025, 55-60% by 2035 and 80% or higher by 2050. (Federal Republic of Germany 2017, 9) The Act was introduced in 2000 and offered fixed feed-in tariffs for installations feeding renewable energy into the grid. The new revision of EEG came into force in 2017 and has moved from fixed feed-in tariffs to a tendering system in which a certain amount of capacity for each renewable technology is auctioned. The auctioning process covers majority of new installations. (The London School of Economics and Political Science 2016.) The details of the bidding process and tariffs are described in chapter 6.5.1.

Since 2004, Germany has more than doubled its renewable energy production (Eurostat 2018b). Renewable energy capacity in Germany has been predicted to grow by 28 GW from 2015 to 2021. The predicted additions to the renewable capacity are wind power, both on- and off-shore, and solar energy. In 2021 the renewable electricity generation would be 38% of the total amount of electricity produced. In 2015, Germany's renewable energy capacity was 105 GW (International Energy

Agency 2016a, 70, 73, 76.) The 38% share is in line with Germany's Action Plan and the EU's 2020 targets.

Germany will phase out nuclear power completely by 2022. By 2017, nine of the 17 nuclear plants have been shut down. (World Energy Council 2017, 70).

Germany ranks 6th globally in terms of energy security, energy equity and environmental sustainability with a rank of AAB respectively (World Energy Council 2017, 70). The trilemma index and balance score are presented in Figure 20.

GERMANY

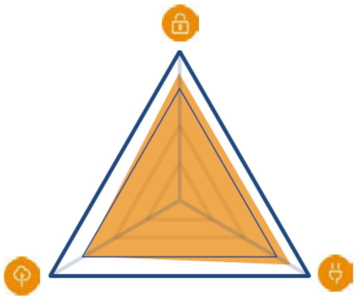
TRILEMMA INDEX RANKINGS AND BALANCE SCORE

RANK

6

SCORE

AAB



	2015	2016	2017	Trend	Score
Overall rank and balance score	5	5	6	▶	AAB
Energy performance					
Energy security	6	7	12	▶	A
Energy equity	22	15	17	▶	A
Environmental sustainability	29	31	32	▶	B
Contextual performance	16	15	16	▶	

Figure 20. Germany's trilemma index rankings and balance score. On energy performance, lower is better. (World Energy Council 2017, 70.)

As Germany produces a large share of its energy with renewable technologies, its security of supply is quite good. Germany's domestic coal production also improves its energy security. Yet, practically all of the natural gas and oil is imported to Germany from abroad. Germany has a large diversity of foreign suppliers to enhance its supply security. (World Energy Council 2017, 70).

The phasing out of nuclear power has created additional challenges to Germany's energy mix. Conventional power plants are required to fill the gap in production that nuclear power left. However, regulatory uncertainty has slowed down investment. (World Energy Council 2017, 18).

6.4 Biogas in Germany

Germany is the leading biogas nation in the EU. Germany produces about half of the biogas in the whole EU. So far Germany is the only EU country which has really engaged with the country's biogas potential. (Scarlat et al. 2018, 13-16) Germany's biogas capacity is presented in Figure 21.

Germany produced 9,160 billion m^3 of biogas in 2015. The same year, Germany consumed about 76 billion m^3 of natural gas. The share of biogas in natural gas use was 12.1%, which is second highest of all the EU countries. Sweden has the highest share of biogas in natural gas use, but the country uses about 90 times less natural gas than Germany. Germany's biogas production is by far the largest in the EU. (Scarlat et al. 2018, 32)

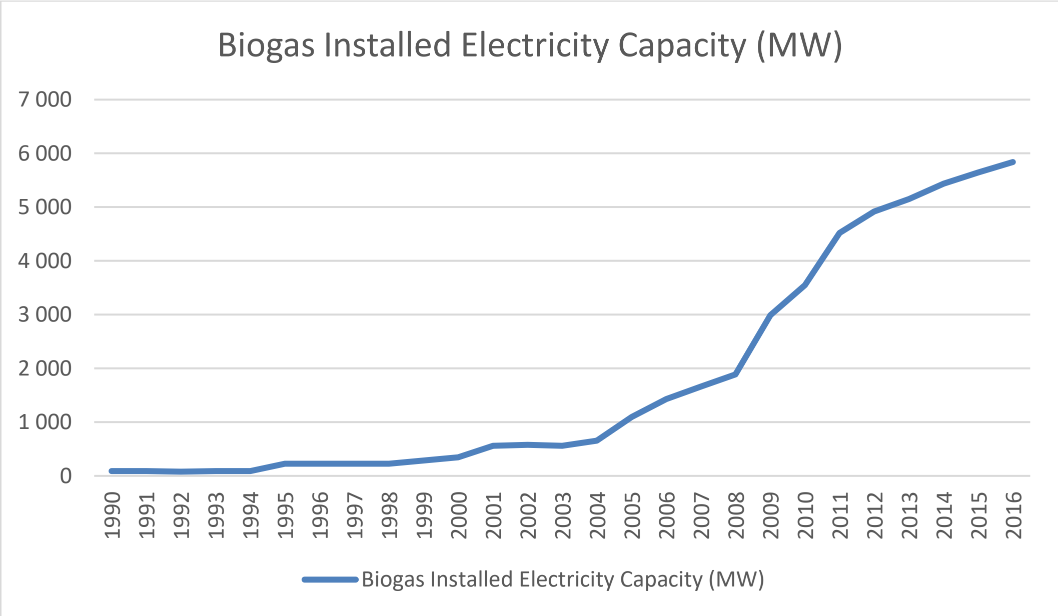


Figure 21. Biogas installed electric capacity in Germany from 1990 to 2016. (European Commission 2018d.)

In 2015, there were 10 846 biogas plants operating in Germany. 185 of Germany's plants upgrade the biogas to biomethane. (European Biogas Association 2016). Germany's biomethane production was 898 million m3 in 2015, which is about 75% of Europe's biomethane production the same year. Virtually all of Germany's biogas is produced by anaerobic digestion (Scarlat et al. 2018, 33, 38)

6.5 Support Schemes for Biogas in Germany

6.5.1 Operating subsidies

The Renewable Energies Act or EEG establishes economic support mechanisms for renewable energy producers. The support is granted as a result of an auction. Bids are based on a reference value of 100% which has a specific maximum feed-in tariff. Companies that bid for the lowest feed-in tariff, win the auction. This continues until the specified capacity has been auctioned. There are corrective factors based on the installation's location which determine the final feed-in tariff. (Federal Ministry of Economic Affairs and Energy 2016.)

For biomass, including biogas installations, 150 MW of capacity will be auctioned each year between 2017 and 2019. The capacity is increased to 200 MW for years 2021 and 2022. Biogas plants can only receive tariffs for 50% of nominal generation capacity per year. The aim of this is to encourage biogas plants to generate when the electricity wholesale price is high, or in other words, when wind or solar energy is not available. (Federal Ministry of Economic Affairs and Energy 2016.) The maximum feed-in tariff will decrease 1% per year since 1.1.2018 (Federal Republic of Germany 2017, 59,). The feed-in tariffs are granted for 20 years (Wedemeyer 2017).

The maximum feed-in tariffs for biogas installations, which use biogas gained from anaerobic fermentation of biomass are 14.88 c/kWh. The producer has to also make a security pursuant if they wish to receive the feed-in tariffs. For biomass the security pursuant is 60 € per kW of capacity bid. (Federal Republic of Germany 2017, 59,)

Feed-in tariffs for biogas installations, which use biogas gained from fermentation of manure is 23.14 c/kWh. However, the maximum capacity for installations which use biogas fermented from is only 75 kW. (Federal Republic of Germany 2017, 67.)

In 2017, 24 bidders were granted feed-in tariffs for biogas installations out of 33 bidders. The combined capacity of installations awarded with the grant was 27.5 MW. The average feed-in tariff of the awarded bids was 14.30 c/kWh. (Wedemeyer

2017.) In 2014 feed-in tariffs for biogas ranged from 5.85 c/kWh to 13.66 c/kWh (KPMG 2015, 30).

Biogas plants with rated output greater than 100 kW will receive an additional flexibility premium of 40 €/kW installed capacity per year (Federal Republic of Germany 2017, 76-77).

6.5.2 Investment and Other Subsidies

The KfW Renewable Energies Program offers funding for renewable energy projects. The program is run by government owned development bank KfW Bankengruppe. The bank offers standard funding for electricity generation from renewable sources, such as biogas and premium funding for heat generation for large plants. The funding is long-term, low-interest loans up to 100% of the investment. The loan term is "5, 10 or 20 years with a repayment-free, start-up period of up to 3 years." In 2014, the Kfw funded premium programmes 234 million euros and standard programmes 3.9 billion. (KPMG 2015, 30.)

The Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) Environmental Innovation Program funds major industrial pilot projects in the environmental sector. The funding can be an interest subsidy of or a loan with interest grant from the BMUB. There is no maximum amount for either. The loan-term is up to 30 years with five repayment years at the most (KPMG 2015, 30.)

7 AUSTRIA

7.1 Austria in General

Austria is a country located in Central Europe, see Figure 22. The country has been a member of the European Union since 1995 and is thus subject to the directives and regulations of the EU (European Union 2018a). Austria is also a part of the IEA and OECD (International Energy Agency 2014a, 2; OECD 2018b). Austria has surface area of 83 900 km^2 and population of 8.6 million (European Union 2018b).

Figure 22. Austria in dark green. Members of the EU in lighter green. (Wikipedia 2018a.)

7.2 Energy in Austria

Austria’s total primary energy supply (TPES) has been increasing since 1973 (International Energy Agency 2017a). The final energy consumption from 1990 to

2016 is presented in Figure 23. Austria is heavily reliant on foreign energy imports, as can be seen in Figure 24. Austria imports a large majority of its oil and natural gas and all of its coal. The total net primary energy imports are about 64% of the required supply. Geographically Austria is a landlocked country, meaning that it does not have access to an ocean and is hence reliant on oil and gas pipelines crossing neighbouring countries. (International Energy Agency 2017a; 2014a, 82-92.)

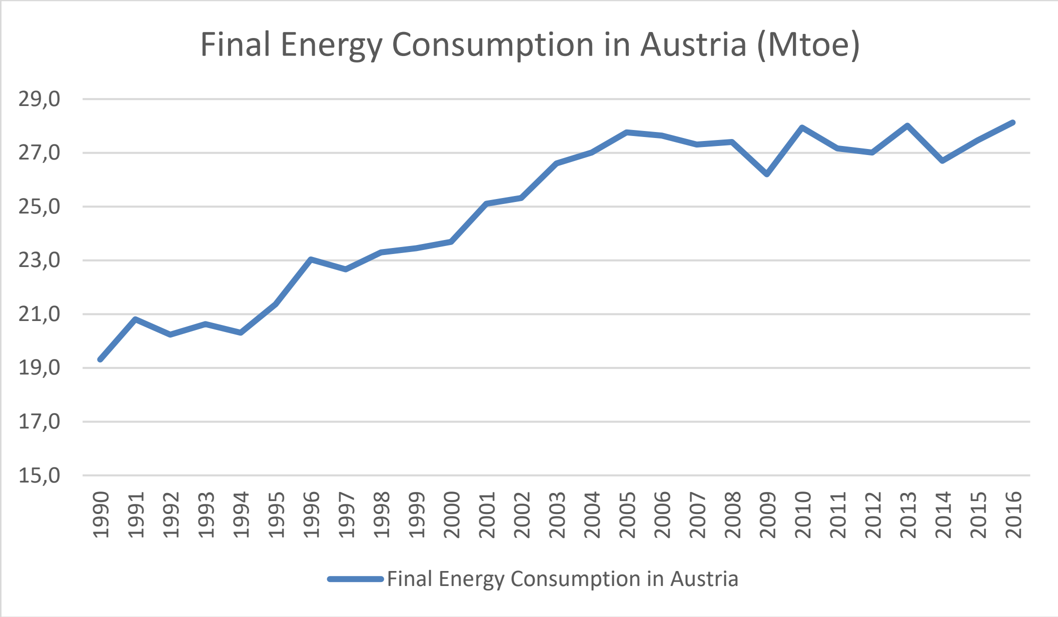


Figure 23. Final Energy Consumption in Austria from 1990 to 2016. (European Commission 2018d.)

Austria's annual renewable energy capacity and production is predicted to reach 21 GW and 61 TWh respectively in 2021. In 2015 renewable energy capacity was 18 GW and production 51TWh. (International Energy Agency 2016a, 273-274.) The average household electricity price in Austria is 0.22 USD/kWh (World Energy Council 2017, 43). The electric power generation by source is presented in Figure 25.

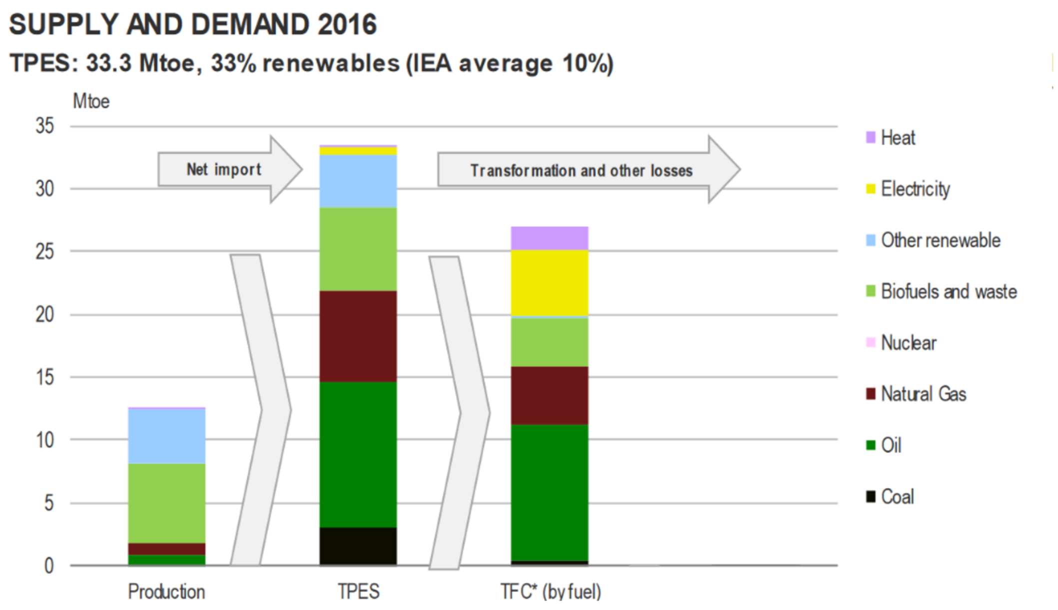


Figure 24. Austria's energy mix in 2016. (International Energy Agency 2017a.)

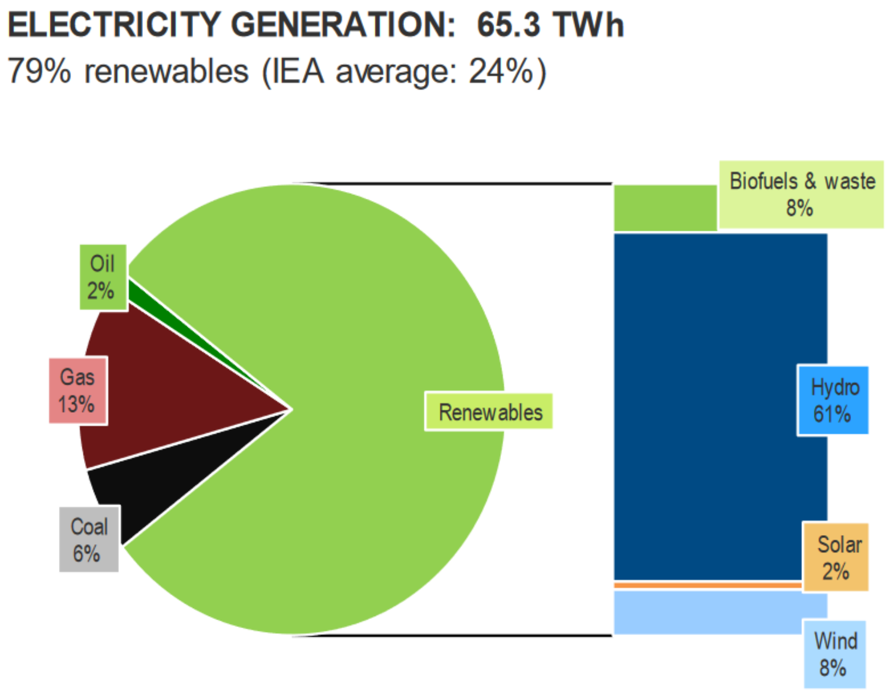


Figure 25. Austria's electricity generation by source in 2016. (International Energy Agency 2017a.)

Austria has over 40 000 km of gas pipelines. 90% of the total pipelines is distribution pipelines and rest are transmission pipelines. Baumgarten, located near the eastern border, is the most important gas transmission hub in Austria. The gas grid is presented in Figure 26.

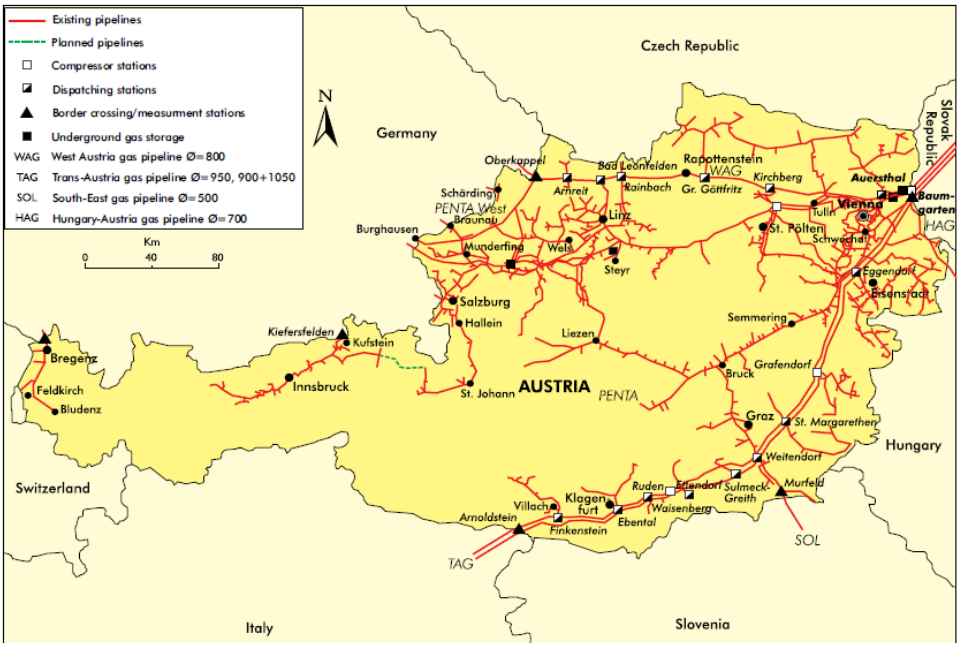


Figure 26. Gas infrastructure of Austria. (International Energy Agency 2014a, 84.)

7.3 Energy Policy in Austria

As seen in Figure 27, Austria's CO_2 emissions have been slowly declining since 2005. Austria's National Renewable Energy Action Plan 2010, which is part of Austrian Energy Strategy 2010, states that "Austria must increase its share of renewable energy in gross final consumption of energy to 34%" and reach "13% reduction of final energy consumption" by 2020 compared to 2005 figures. The efficiency target has different targets for different sectors. For electricity consumption it is 5%. (Federal Ministry of Economy, Family and Youth 2010, 13, 89.) In 2005, Austria final electricity consumption was 6987 kWh/capita and 7118 kWh/capita in 2016. The highest final electricity consumption has been 7253 kWh/capita in 2013. (European Commission 2018d.) By 2016, Austria had already reached 33% share of renewable energy of TPES (International Energy Agency 2017a).

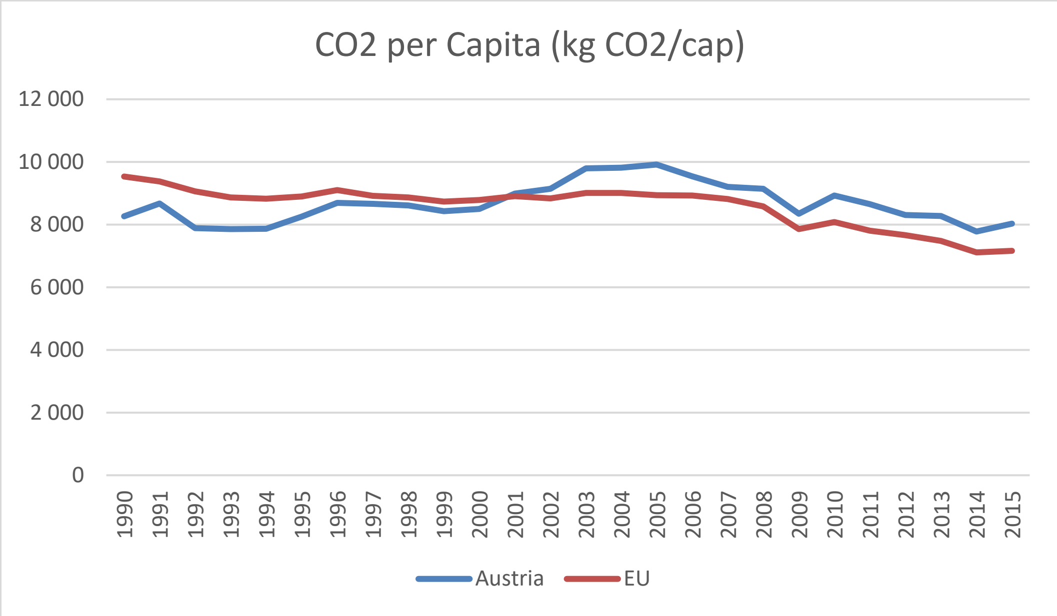


Figure 27. CO_2 per Capita in Austria between 1990-2015. (European Commission 2018d.)

Austria has announced that it will phase out coal by 2025. There are two coal plants remaining at the moment. (International Energy Agency 2016a, 152). In 2014, renewable energy production reduced CO_2 emissions by 11.2 million tons or 13% of the total GHG emissions (European Environment Agency 2017, 39).

Austria ranks 12th globally in terms of energy security, energy equity and environmental sustainability with a rank of AAB respectively (World Energy Council 2017, 43). The trilemma index and balance score are presented in Figure 28.

AUSTRIA

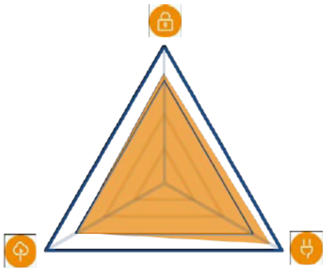
TRILEMMA INDEX RANKINGS AND BALANCE SCORE

RANK

12

SCORE

AAB



	2015	2016	2017	Trend	Score
Overall rank and balance score	**11**	**10**	**12**	▶	**AAB**
Energy performance					
Energy security	26	20	18	▶	A
Energy equity	5	6	8	▶	A
Environmental sustainability	24	23	30	▶	B
Contextual performance	15	16	22	▶	

Figure 28. Austria's trilemma index rankings and balance score. On energy performance, lower is better. (World Energy Council 2017, 43.)

One of the main focuses of Austrian energy policy has been to improve the security of supply to combat the dependency on energy imports (International Energy Agency 2014a, 89). Even though Austria is heavily reliant on foreign fossil fuel imports, it has high diversity of international energy suppliers, which improves energy security. The process of improving energy self-sufficiency in Austria started in 1980's. The self-sufficiency has improved largely, mostly due increase in renewable energy production. (World Energy Council 2017, 43.) A large majority of Austria's oil products are refined in nearby European countries and oil is imported from the Organization of the Petroleum Exporting Countries (OPEC) and countries in the former Soviet Union. A vast majority of natural gas is imported from Russia. Austria's gas companies hold large commercial stocks and have large gas storage capacity of around 78% of annual consumption. Austria has a so-called Stockholding Act in case of energy emergencies. The domestic energy reserves cover 90 days and Austria obligates its supplier to hold 25% of the previous year's imports plus 10% extra. (International Energy Agency 2014a, 83-95.)

7.4 Biogas in Austria

Austria produced almost 350 million m^3 of biogas in 2015. Austria used almost eight billion m^3 of natural gas the same year so the share of biogas in natural gas use was 4.4%. (Scarlat et al. 2018, 32.) All of the biogas produced in Austria was used domestically (Eurostat 2018a).

There were 444 biogas producing plants in Austria in 2015 (European Biogas Association 2016). As can be seen in Figure 13, practically all of Austria's biogas is produced by anaerobic digestion. 13 of the 444 biogas plants upgrade the biogas to biomethane and feed it to the national gas grid. The biogas capacity is presented in Figure 29. The biomethane fed to the national gas grid has to meet national standards in terms of gas quality. (Scarlat et al. 2018, 11-13.) In 2006 Austria had 1.37 million ha of land suitable for farming. During that time 50 000 ha of the area was used to farm energy crops. The Chamber of Agriculture of Lower Austria estimated that up to 250 000 ha could be used to farm energy crops without it affecting food production. (Federal Ministry of Economy, Family and Youth 2010, 78.)

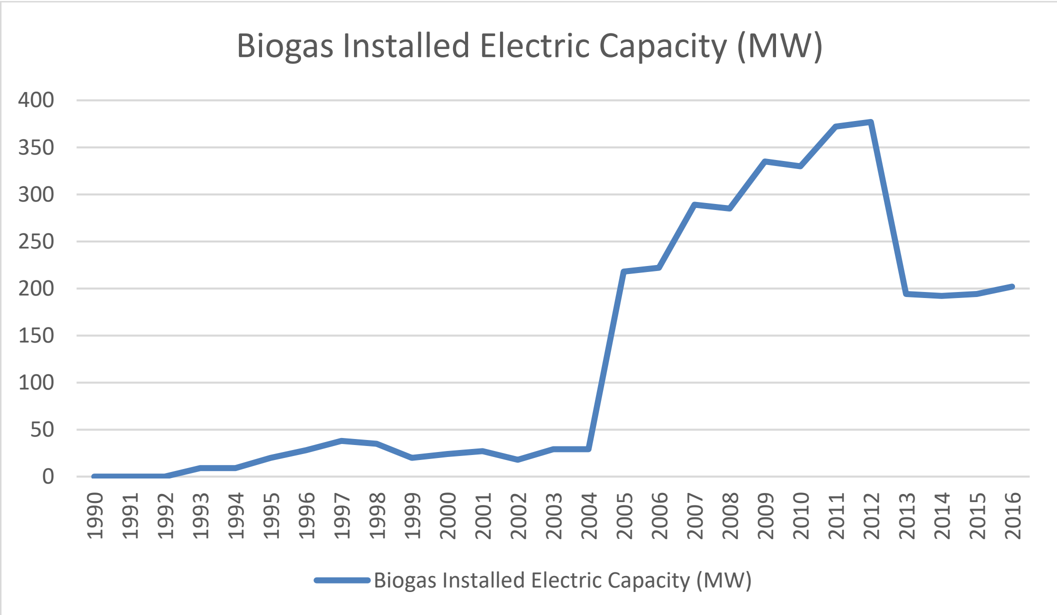


Figure 29. Biogas installed electric capacity in Austria from 1990 to 2016. (European Commission 2018d.)

The jump in biogas capacity between 2004 and 2013 in Figure 29, is explained by feed-in tariffs. The feed-in tariffs for biogas were introduced in Austria's first green electricity act of 2002. The tariffs were granted for 13 years and the original support period closed to its end in 2013. (Stürmer 2017, 2.)

In 2015 Austria's electricity capacity from biogas was 194 MW with the average capacity of 0.4 MW and production of 624 GWh and 2036 TJ or 566 GWh heat (Scarlat et al. 2018, 34.) Austria has already surpassed its 2020 target of 581 GWh of electricity produced with biogas, set in the National Renewable Energy Action Plan 2010 for Austria. The targets are part of the European Union's 2020 targets and legally binding. (Federal Ministry of Economy, Family and Youth 2010, 86.)

7.5 Support Schemes for Biogas in Austria

7.5.1 Operating Subsidies

The Austrian government offers economic support for electricity generated from renewable sources, including biogas. For biogas the Austrian State offers feed-in tariffs. Table 6 includes the biogas tariffs according the National Renewable Energy Action Plan 2010. (International Energy Agency 2016a, 268; Federal Ministry of Economy, Family and Youth 2010, 149-152).

Table 6. Feed-in tariffs for biogas in Austria in 2010. (International Energy Agency 2016a, 268; Federal Ministry of Economy, Family and Youth 2010, 149-152.)

<table>
<tr><td rowspan="4">Fixed prices for bio-gas*</td><td>System output</td><td>Support (c/kWh)</td></tr>
<tr><td>Systems up to 250 kW</td><td>18,50</td></tr>
<tr><td>Systems from 250 kW to 500 kW</td><td>16,50</td></tr>
<tr><td>Systems over 500 kW</td><td>13,00</td></tr>
<tr><td colspan="3">*Each plus 2 cent/kWh technology bonus and 2 cent/kWh CHP bonus for compliance with certain conditions</td></tr>
<tr><td rowspan="2">Fixed prices for land-fill and sewage gas</td><td>Sewage gas</td><td>6,00</td></tr>
<tr><td>Landfill gas</td><td>5,00</td></tr>
</table>

In 2014 the feed-in tariffs were from 12.80 c/kWh to t19.31 c/kWh (KPMG 2015, 15).

Austria later gave up the output restrictions but divided biogas into two, biogas and upgraded biogas (biomethane). (Republic of Austria 2018.) Upgraded biogas is biogas which has been upgraded to natural gas quality. The newest tariffs are presented in Table **7**. Feed-in tariffs for biogas are granted for 15 years (KPMG 2015, 15).

Table 7. Green Electricity Feed-in Tariff Regulation 2018 in Austria. (Republic of Austria 2018.)

Source	Application year	Support (c/kWh)
Biogas*	2018	19,14
	2019	18,97
Upgraded biogas*	2018	16,24
	2019	16,10
*Each plus 2 cent/kWh technology bonus and 2 cent/kWh CHP bonus for compliance with certain conditions		
Sewage gas	2018	5,65
	2019	5,60
Landfill gas	2018	4,70
	2019	4,66

There are some requirements to be eligible for the feed-in tariffs.

- A biogas plant must have an annual fuel efficiency of at least 60%, which in essence requires Combined Heat and Power (CHP) technology.
- A support contract between the power plant operator and the eco-electricity processing and administration centre, OeMAG, must be designated. The support contract is subject to an annual cap.
- The electrical power units should as such generally be approved under electricity law.
- In some cases, additional authorisation, permit and/or notification is required under Austria's law.

(Federal Ministry of Economy, Family and Youth 2010, 61, 149-152.)

There is no cap for tariffs, since the total volume of electricity produced, or installation capacity is not restricted. However, from 2009 onwards the support budget for all of the renewable technologies is 21 million euros per year. (Federal Ministry of Economy, Family and Youth 2010, 61)

7.5.2 Investment and Other Subsidies

Austria has a research and development (R&D) fund called Climate and Energy Fund with annual budget of 150 million euros. The fund was set up in 2007 and is a strategic instrument to support Austria to reach the EU 2020 targets. “The Fund is owned by the Federal Ministry of Transport, Innovation and Technology and the Federal Ministry of Agriculture, Forestry, Environment and Water Management”. (International Energy Agency 2014b, 119-121.)

E!Missi0n+ is an R&D program, funded by the Climate and Energy Fund, with 30-million-euro annual budget. It focuses on energy infrastructure, which renewable energy, like biogas, is a part of.

8 NETHERLANDS

8.1 The Netherlands in General

The Netherlands is a North-western European country located on the coast of the North Sea, see Figure 30. 20% of the country is located below and 50% less than one metre above sea level. The Netherlands is one of the founding countries of the European Coal and Steel Community, which later formed the European Union (European Union 2018c). The country has been a member of the European Union since 1958 and is thus subject to the directives and regulations of the EU (European Union 2018a).

Figure 30. The Netherlands in dark green. Members of the EU in lighter green. (Wikipedia 2018b.)

The Netherlands is also a part of the IEA and OECD (International Energy Agency 2014a, 2; OECD 2018b). The Netherlands has a surface area of 41 500 km^2 and population of 16.9 million, which makes it the most densely populated country in Europe (European Union 2018b). The Netherlands also has special municipalities in the Caribbean (International Energy Agency 2014c, 19). The overseas Dutch regions are excluded from this research.

8.2 Energy in the Netherlands

As can be seen in Figure 31, the Netherlands' final energy consumption has remained quite stable, with a declining trend over the past few years. Still, the country's GDP grew 50% from 1990 to 2012 (International Energy Agency 2014c, 11).

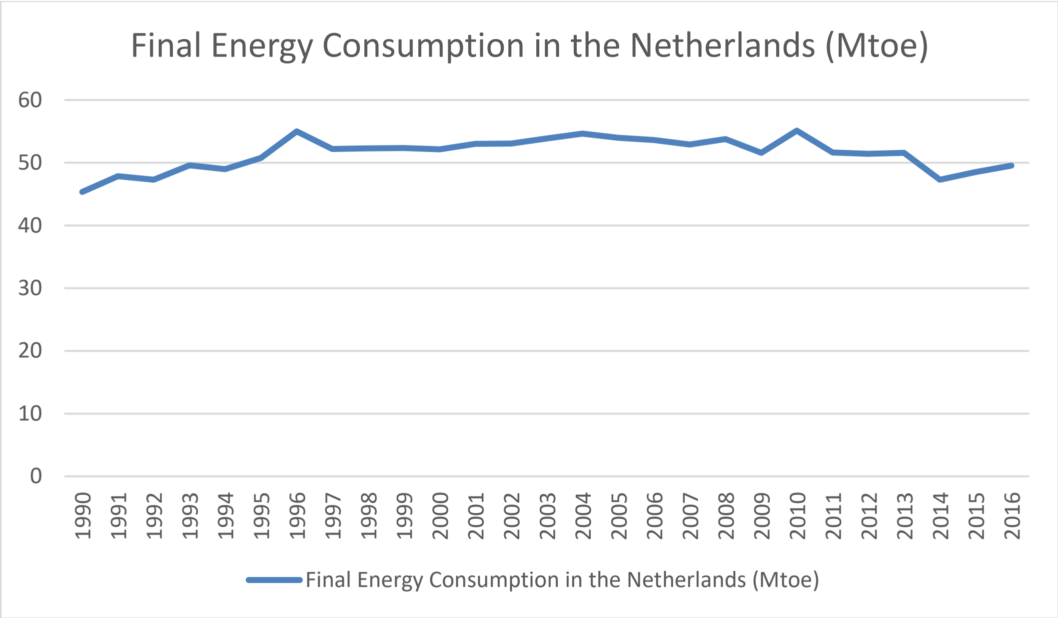


Figure 31. Final Energy Consumption in the Netherlands from 1990 to 2016. (European Commission 2018d.)

Fossil fuels dominate the Netherland's energy mix. Renewable energy accounts for 10% of the total primary energy supply (International Energy Agency 2017b). The supply and demand of primary energy is presented in Figure 32 and electricity generation by source in Figure 33. The Netherlands has one of the lowest shares of energy from renewable sources in the EU, second only to Luxemburg (Eurostat 2018b).

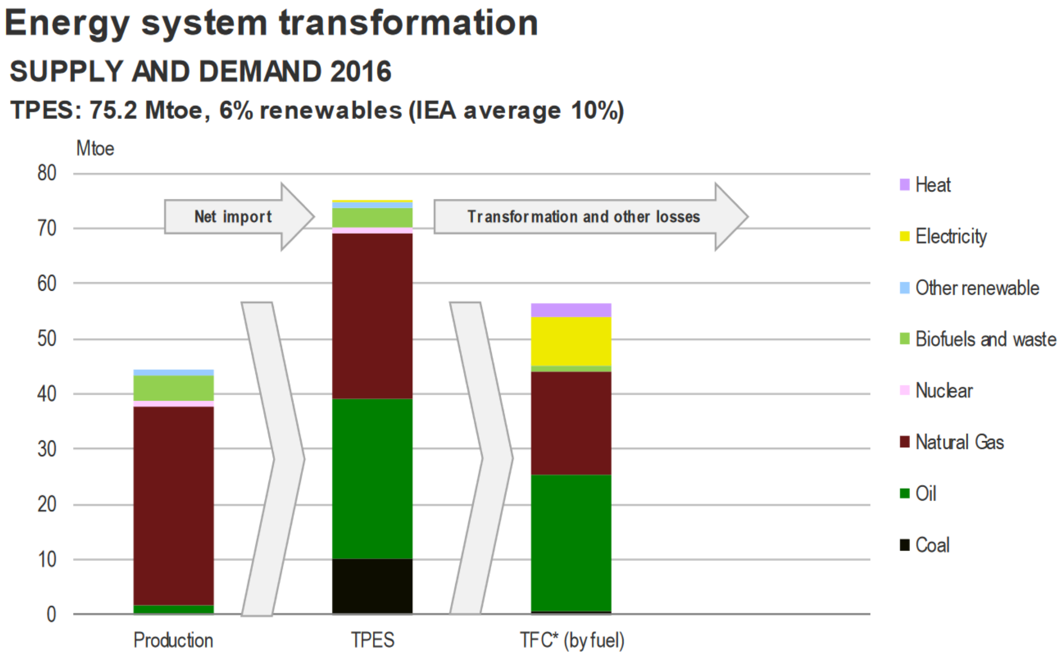


Figure 32. Energy mix of the Netherlands in 2016. (International Energy Agency 2017b.)

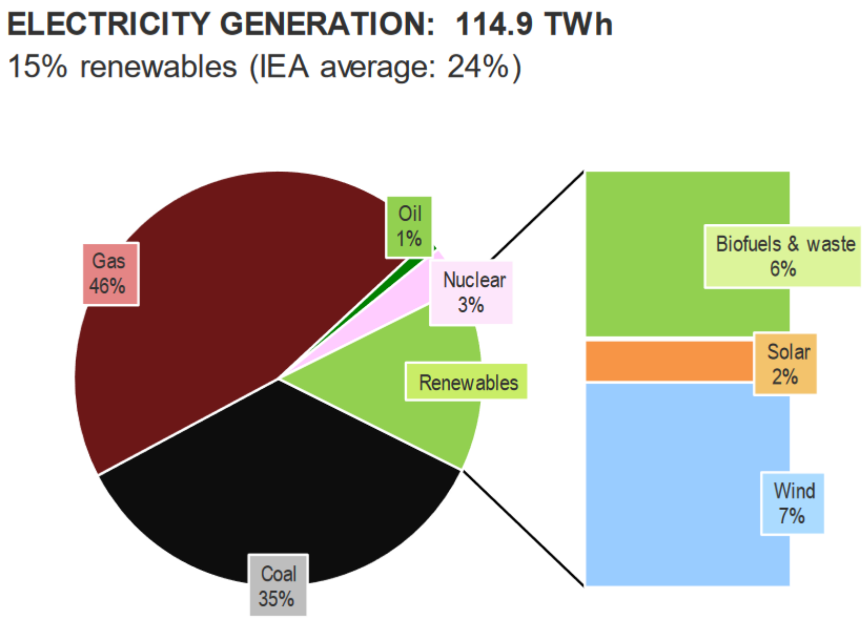


Figure 33. Electricity generation by source in the Netherlands in 2016. (International Energy Agency 2017b.)

Natural gas is the dominant source of electricity generation in the Netherlands. Electricity production from gas declined from 63% in 2010 to 44% in 2015. The decline in gas use was a result of coal's competitiveness in electricity generation. (Honoré 2017, 15.) The average household electricity price in the Netherlands is 0.20 USD/kWh (World Energy Council 2017, 98).

Europe's largest natural gas deposit is in the northern Netherlands, close to the city of Groningen. The Netherlands is the largest gas producer and exporter in the EU and second only to Norway in Europe. (Honoré 2017, 13.) The Netherlands serves as an important hub for gas exports, mainly from Russia and Norway, to Central Europe. (Honoré 2017, 42, 48.)

The Netherlands also has a very extensive domestic gas grid. 98% of the Dutch households are connected to the gas grid (Honoré 2017, 6). However, new energy policies promote other energy sources for households. Therefore, new homes built in the Netherlands will not be connected to the gas grid. (Pieters 2017a.)

The Netherlands has a few off-shore oil rigs but is still 95% dependant on imported oil. Russia is the most important oil supplier for the Netherlands. (International Energy Agency 2014a, 319-322.)

8.3 Energy Policy in the Netherlands

As can be seen in Figure 34, the Netherlands' CO_2 emissions have been high but quite stable over the last decade, with a declining trend over the 2010's.

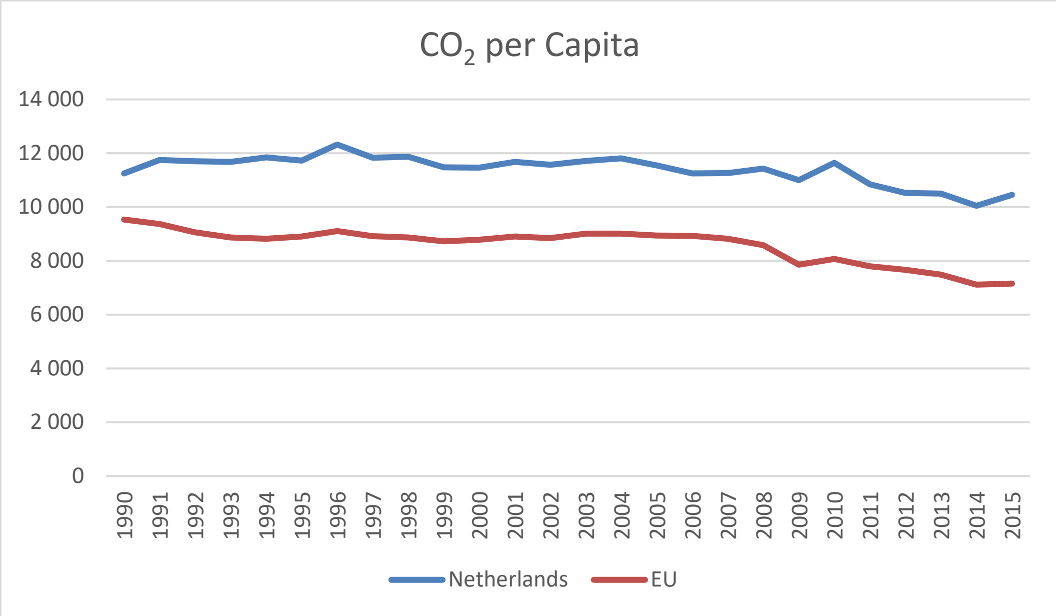


Figure 34. CO_2 per Capita in the Netherlands between 1990-2015. (European Commission 2018d.)

In late 2017, the Dutch government presented very ambitious goals for Dutch climate policy. According to the new policy, the GHG emissions should be lowered by 49% by 2030 compared to GHG emissions in 1990. In order to reach this, the government will make 4 billion euros available for technologies to help the transition to green energy, transform taxes to favour more sustainable choices and close its remaining coal fired power plants by 2030. The government of the Netherlands is also planning to advocate a 55% reduction of emissions in Europe. (Pieters 2017a; 2017b). The Energy Agreement published in 2016 sets targets for efficiency improvement of 1,5% of final energy consumption, increasing the share of renewable energy to 14% of final consumption by 2020 and to 16% by 2023. The ultimate target for the Netherlands is to have a CO_2 neutral energy system by 2050. (Ministry of Economic Affairs of the Netherlands 2016, 3.) Renewable energy capacity is expected to reach 13 GW by 2021. In 2015, the installed renewable capacity was 14.4 GW. (International Energy Agency 2016a, 73.)

The new policies target the stretch goal of limiting the global temperature increase to 1.5 ºC, which was set in §2 of the Paris Agreement (United Nations Climate

Change 2018a), and are in line with the EU's 2030 emission targets (European Commission 2018b).

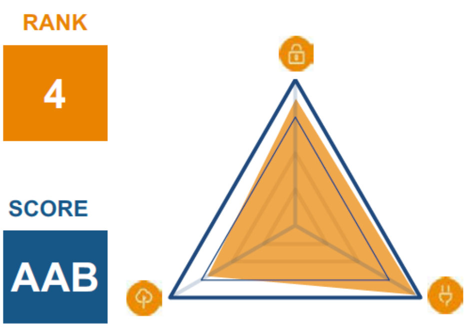
The Dutch government acknowledges that "renewable sources are intermittent because they are dependent on the weather. This means that both the demand and the supply will need to become more flexible." (Ministry of Economic Affairs of the Netherlands 2016, 10-11.) 60% of the renewable production in the Netherlands was produced with solar and wind energy (International Energy Agency 2017b).

The Dutch Ministry of Economic affairs also criticises the EU ETS for giving all the Member States the same target, regardless of the starting position. The Dutch power plants are among the most efficient in Europe, so the companies will not have any pressure to reduce their emissions anytime soon. The tightening EU ETS caps will affect the Dutch energy producers at some point, but according to the Ministry, not soon enough. (Ministry of Economic Affairs of the Netherlands 2017.)

The Netherlands ranks 4th globally in terms of energy security, energy equity and environmental sustainability with a rank of AAB respectively (World Energy Council 2017, 98). The trilemma index and balance score are presented in Figure 35.

NETHERLANDS

TRILEMMA INDEX RANKINGS AND BALANCE SCORE



	2015	2016	2017	Trend	Score
Overall rank and balance score	8	4	4	▶	AAB
Energy performance					
Energy security	20	9	10	▶	A
Energy equity	4	3	3	▶	A
Environmental sustainability	42	42	38	▶	B
Contextual performance	5	6	5	▶	

Figure 35. Netherlands' trilemma index rankings and balance score. On energy performance, lower is better. (World Energy Council 2017, 98.)

As the Netherlands is a net exporter of energy, their supply security is very good. The country also has a high diversity of suppliers, which further improves supply security. The main challenges are related to the slower than expected shift to more sustainable energy. (World Energy Council 2017, 98.)

Due seismic activity in the Groningen area, the government has reduced and has pressure to reduce the natural gas production even further. For 2016 the production cap was set at 40 billion m^3 and in April of 2017, the government announced that the cap will be set to less than 22 billion m^3 for gas year of 2017-2018. The Dutch gas grid operator Gasunie has calculated that a minimum annual production of 21-22 billion m^3 would be required to secure the gas supply to the Dutch market and neighbouring countries. (Honoré 2017, 31-33.)

8.4 Biogas in the Netherlands

The Netherlands produced almost 381 million m^3 of biogas in 2015. However, this only accounts for a 1.1% biogas share in natural gas use, since the Netherlands consumed about 34 billion m^3 of natural gas in 2015. About 78% of Dutch biogas is produced by anaerobic digestion. The rest is sewage gas or recovered from land-fills. (Scarlat et al. 2018, 32, 40.)

In 2015, there were 268 biogas plants in the Netherlands (European Biogas Association 2016). 21 plants in the Netherlands upgrade the biogas to biomethane. The combined annual biomethane production in 2015 was 72 million m^3. The majority of the produced biomethane is injected in the Dutch national gas grid. (Scarlat et al. 2018, 14, 33). The installed electric capacity of the Dutch biogas plants is presented in Figure 36. The government of the Netherlands has set targets to increase biogas production to 3 billion m^3 by 2030 and 20 billion m^3 by 2050 (Honoré 2017, 43).

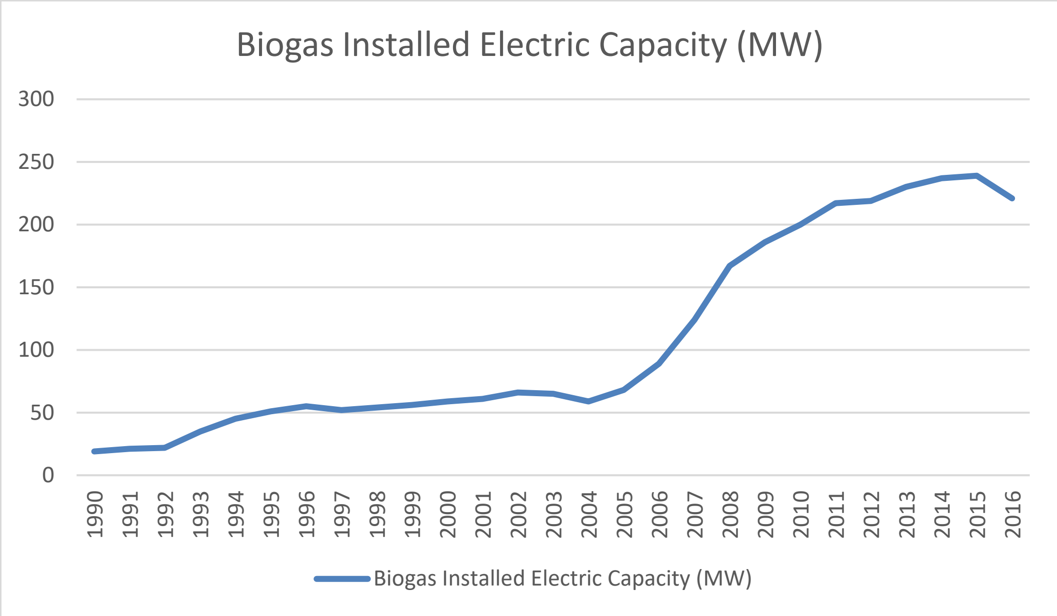


Figure 36. Biogas installed electric capacity in the Netherlands from 1990 to 2016. (European Commission 2018d.)

8.5 Support Schemes for Biogas in the Netherlands

8.5.1 Operating Subsidies

The Stimulation of Sustainable Energy Production (SDE+), or Stimulering Duurzame Energieproductie in Dutch, is a feed-in tariff scheme. The composition of the tariff is presented in Figure 37. The incentive scheme was put in place by the government of the Netherlands to support and accelerate the transition towards more sustainable energy production. Target groups for the subsidies are companies, institutes and (non-profit) organizations that intend to produce renewable energy. (Ministry of Economic Affairs and Climate Policy 2018, 3.)

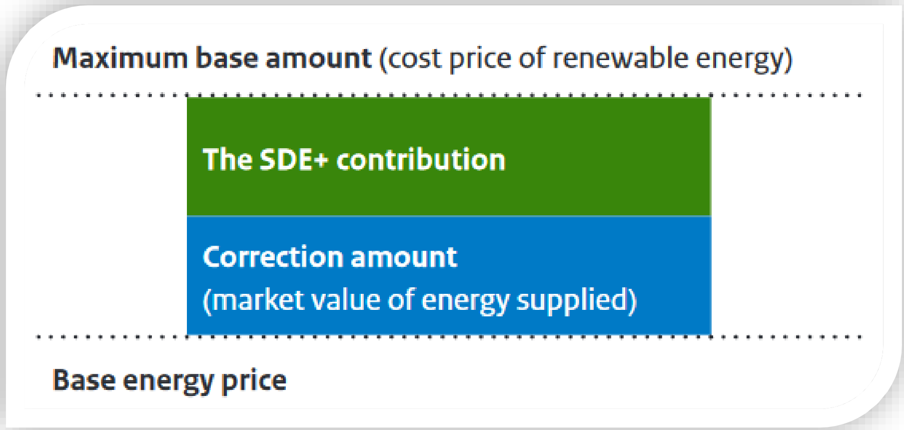


Figure 37. The Composition of the SDE+. Maximum SDE+ contribution = maximum base amount - correction amount. (Ministry of Economic Affairs and Climate Policy 2018, 5.)

Incentivised technologies include biomass (together with biogas), geothermal, hydro, wind and solar. Grants are assigned for periods of 8, 12 or 15 years. The operation must start within 4 years after the application and a maximum subsidy period for biogas is 12 years. (Ministry of Economic Affairs and Climate Policy 2018, 1, 10-13.) In 2015, the annual SDE+ budget was only 3.5 billion euros (KPMG 2015, 47), whereas for the spring application period of 2018 the budget was 6 billion euros (Ministry of Economic Affairs and Climate Policy 2018, 1).

The year 2018 is divided into two rounds and each round into three phases. Each phase has a maximum subsidy amount that an applicant can apply for. The first phase has the lowest maximum subsidy and the third phase the highest. An operator can also apply for lower subsidies since there will be more competition on higher subsidies. In spring round 2018, the subsidies for renewable gas range from 6.4 c/kWh during phase 1 to 9.2 c/kWh during phase 3. (Ministry of Economic Affairs and Climate Policy 2018, 3-4, 10-13.)

Eligible biogas installations for SDE+ subsidy are mono- and co-fermentation of manure, all-purpose fermentation and sludge fermentation installations which produce renewable gas, renewable heat, and/or renewable electricity. For mono-fermentation of manure installations the maximum capacity is 400 kW. Categories mono-fermentation of manure larger than 400 kW and co-fermentation are categorized under fermentation of manure. The gasification of biomass is also stimulated. (Ministry of Economic Affairs and Climate Policy 2018, 7-9.) A complete subsidy table for biogas is presented in Table 8 and an example can be seen in Table 9.

Table 8. Phasing and rates for Biomass. Renewable heat, gas, and CHP SDE+ 2018 spring period. (Ministry of Economic Affairs and Climate Policy 2018, 10-11.)

Renewable heat, gas and CHP from Biomass 2018		**Phase 1**	**Phase 2**	**Phase 3**	**Base energy price**	**Provisional correction amount 2018**	**Maximum full load hours per annum**
		Maximum base amount / phase amount (€/kWh)			(€/kWh)		h
All purpose fermentation	Heat	0,061	0,061	0,061	0,023	0,024	7000
	Gas	0,055	0,055	0,055	0,016	0,017	8000
	CHP	0,067	0,067	0,067	0,025	0,031	7623
Mono-fermentation of manure ≤ 400 kW	Heat	0,090	0,100	0,100	0,054	0,054	7000
	Gas	0,064	0,078	0,092	0,016	0,017	8000
	CHP	0,090	0,110	0,124	0,040	0,046	6374
Fermentation of manure	Heat	0,065	0,065	0,065	0,023	0,024	7000
	Gas	0,064	0,065	0,065	0,016	0,017	8000
	CHP	0,068	0,068	0,068	0,028	0,035	7322
Sewage treatment, improved sludge fermentation	Heat	0,033	0,033	0,033	0,023	0,024	7000
	Gas	0,046	0,046	0,046	0,016	0,017	8000
	CHP	0,049	0,049	0,049	0,028	0,035	5729
Gasification of biomass	Gas	0,064	0,078	0,092	0,016	0,017	7500

If the yearly cap is not reached, the subsidies can be banked for next year or if the cap is exceeded, a producer can choose to be subsidised for the previous year’s overproduction next year. The Ministry is expected to announce the terms and budget for the autumn period during the summer of 2018 (Netherlands Enterprise Agency 2018a).

Table 9. Calculation example: SDE+ contribution – Mono-fermentation (100% animal manure) ≤ 400 kW heat. (Ministry of Economic Affairs and Climate Policy 2018, 13.)

Maximum base amount from phase 2	10.0 €ct/kWh
Provisional correction amount 2018	5.4 €ct/kWh
Provisional SDE+ 2018 contribution applied for from phase 2 at 10.0 €ct/kWh	10.0 - 5.4 = 4.6 €ct/kWh = 46 €/MWh
Maximum number of full load hours eligible for subsidy	7,000
Maximum annual production eligible for subsidy for an installation with 0.4 MWth thermal power rating	0.4 * 7,000 = 2,800 MWh
Scenario: the thermal power rating of the installation for which you have applied for a subsidy is 0.4 MWth, and the installation is expected to run for 7,500 hours per annum at full load. The annual production of your installation is then 3,000 MWh. This is higher than the maximum annual production eligible for subsidy. In this case, a subsidy is granted for a maximum of 2,800 MWh/annum.	
Provisional SDE+ contribution for 2018 applied for from phase 2 at 10.0 €ct/kWh	**46 €/MWh * 2,800 MWh = €128,000**
If your business case shows that your project is profitable with less than the maximum possible subsidy, you have the option of applying for a lower subsidy. As all projects for which a subsidy is applied for compete on the basis of the sum applied for, applying for a lower subsidy gives you a better chance of having your application approved. Your project therefore has an advantage compared with less cost-effective projects.	

8.5.2 Investment and Other Subsidies

Energy Investment Allowance (EIA) is a tax reduction program targeted for companies to encourage investment in energy-efficient technologies. On average, the EIA gives a company a 13.5% tax advantage. Companies can deduct 55% of the investment costs of specified technologies from the fiscal profits. The budget for 2017 was 166 million euros. The supported technologies are listed on the Netherlands Enterprise Agency's Energy list. The Energy list essentially includes anything that improves energy efficiency. If a product is not on the said list, a company can submit it to be added to the list. (Netherlands Enterprise Agency 2018b; KPMG 2015, 47.)

MIA (Environmental investment rebate) and Vamil (Arbitrary depreciation of environmental investments) are additional tax deductions granted for investing in environmentally friendly assets. The deduction ranges from 13.5 to 36% of the investment costs. These costs can be purchasing costs or production costs if a company produces a business asset for its own use. The qualifying products are listed on Energy and environmental investment list (Milieulijst) published by Netherlands Enterprise Agency. The budget in 2016 was 97 million euros for MIA and 40 million euros for Vamil. Both schemes are funded by the Ministries of Finance and Infrastructure and Water Management. (Netherlands Enterprise Agency 2018c; KPMG 2015, 47.)

9 CHINA

9.1 China in General

China is a country located in East Asia, see Figure 38. China is the most populated country in the world with a population of 1,379 billion people. A great majority of the people are located on the eastern half of the country. China is world's fourth largest country with surface area of 9 596 960 km^2. China is also the world's largest single economy in terms of total GDP. The country has a communist party-led government and the country can be classified as autocratic socialist system. (CIA 2018a.) China is not a member of the OECD but is a key partner of the organization (OECD 2018b). Despite the massive economy, China is still classified as a developing country (International Energy Agency 2017d, 131).

Figure 38. Area controlled by the People's Republic of China shown in dark green; claimed but uncontrolled regions shown in light green. (Wikipedia 2018d.)

9.2 Energy in China

China is the largest energy consumer in the world (Qilin Qi Huiming Jiahai 2018, 1). In 2016 China's total primary energy consumption was 2538 Mtoe, which is over 500 Mtoe higher than the second largest consumer, the USA, in the world. (Enerdata 2017). The combined energy consumption in the EU countries was 1 641 Mtoe in 2016 (European Commission 2018a).

As can be seen in Figure 39, coal dominates China's energy mix. In 2013, China consumed half of the whole world's coal production. China is investing a lot in renewable energy production, but China's coal consumption is still growing by 4% per year on average. In 2015, China accounted for 45% of global installed capacity of coal power. (International Energy Agency 2015, 290, 331.)

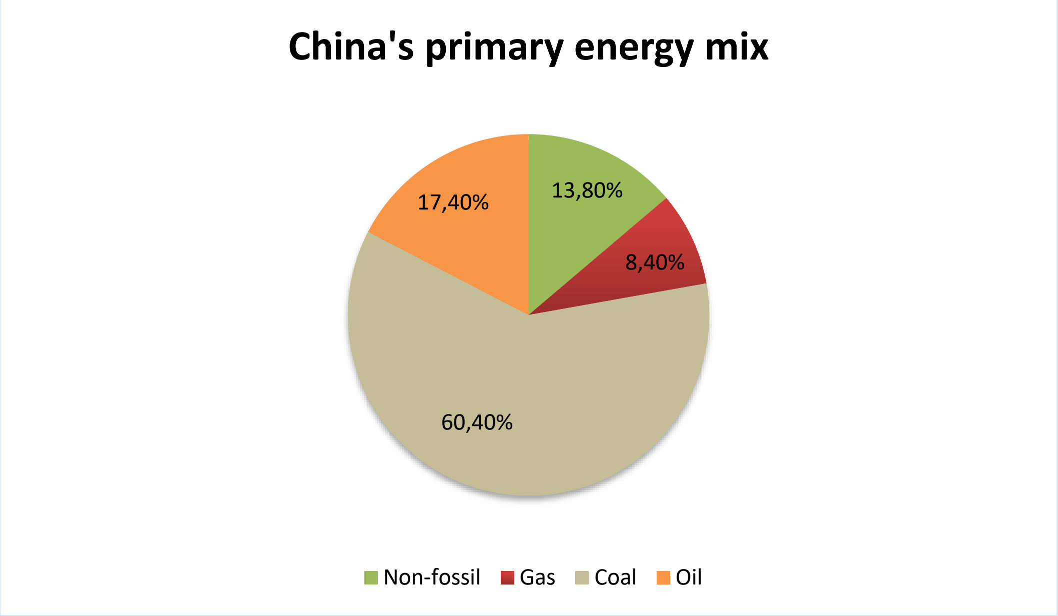


Figure 39. China's projected primary energy mix in 2018. (Qilin Qi Huiming Jiahai 2018, 4.)

China's power generation sector is still growing. China reached universal electrification just in 2015 (International Energy Agency 2017d, 11). China's electricity production in 2015 was 5 700 TWh (International Energy Agency 2016a, 48).

China’s renewable energy production is predicted to be about 1850 TWh in 2020. 64% of the production would be produced by hydro power. (Qilin Qi Huiming Jiahai 2018, 11.) Renewable energy production is estimated to account for 60% of all the capacity additions between 2015 and 2040. (International Energy Agency 2015, 314). The country’s electricity demand is expected to grow to 6 254 TWh by 2020. (International Energy Agency 2015, 307). China has more than tripled its renewable energy capacity in past ten years. China’s evolution of renewable energy capacity is presented in Figure 40.

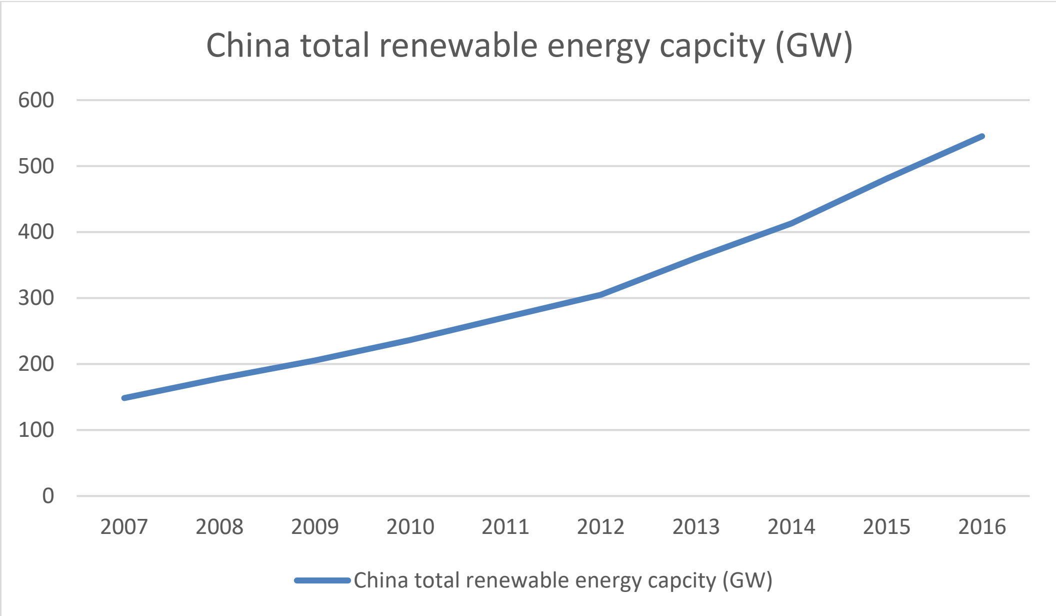


Figure 40. China's total renewable energy capacity from 2007 to 2016. (IRENA 2017, 12.)

In 2014, China had about 63 000 km of natural gas pipelines. The most extensive gas grid in China is located in Sichuan-Chongqing region, North China, and the Yangtze Delta region. China also has 12 LNG terminals. (Xiucheng, Guanglin, Zhengwei, Cong 2017.)

9.3 Energy Policy in China

China is the world’s largest GHG emitter. It has been estimated that China’s emissions keep on increasing in the coming years. China should reach their peak GHG emissions sometime in the 2030’s. China passed the EU in per capita CO_2 emissions in 2011. (Qilin Qi Huiming Jiahai 2018, 1.) China's CO_2 emissions are presented in Figure 41.

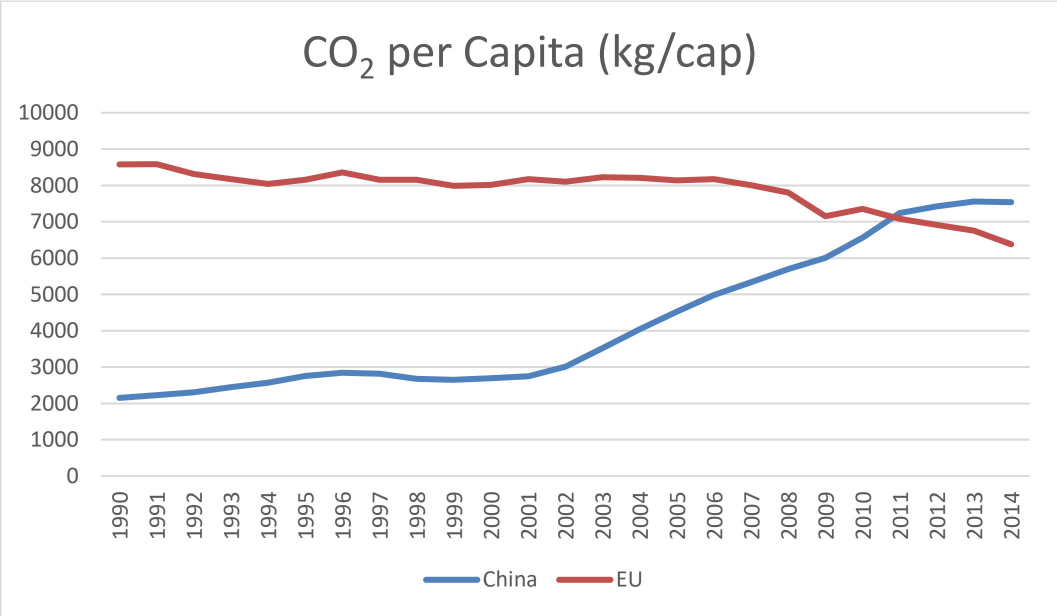


Figure 41. CO_2 emissions in China from 1990 to 2014. (World Bank 2018b.)

China has set remarkable increase targets for renewable energy capacity in the country's 13th five-year-plan (FYP). The capacity targets at the end of the 13th FYP are presented in Table 10. IEA's projection of China's renewable capacity is presented in Table 11.

Table 10. China's 13th FYP targets for renewable energy capacity. (International Energy Agency 2017f.)

13TH FYP 2016-20, TARGETS BY 2020	HYDRO-POWER	WIND ENERGY	SOLAR ENERGY	BIOEN-ERGY	GEOTHER-MAL
	380 GW	210 GW	115 GW	15 GW	0,5 GW

Table 11. China's renewable electricity capacity projection (GW). (International Energy Agency 2016a, 54.)

	2015	2016	2017	2018	2019	2020	2021
Hydropower	319.4	330.4	339.4	348.4	356.4	363.4	368.4
Bioenergy	10.3	11.7	13.0	14.4	15.7	17.1	18.4
Wind	129.3	149.7	169.2	189.4	210.4	232.9	257.1
Onshore	128.3	148.3	167.3	186.8	206.8	227.8	250.3
Offshore	1.0	1.4	1.9	2.6	3.6	5.1	6.8
Solar PV	43.2	70.2	87.2	104.2	122.2	140.2	160.2
CSP/STE	0.0	0.5	0.9	1.5	2.1	2.6	3.1
Geothermal	0.0	0.0	0.1	0.1	0.1	0.1	0.1
Ocean	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**502.3**	**562.4**	**609.7**	**657.8**	**706.8**	**756.2**	**807.3**

China has signed and ratified the Paris Agreement (United Nations 2018b). China's INDCs include reaching the peak CO_2 emissions by around 2030 or as early as possible, reducing CO_2 emissions per unit of GDP by 60-65% from the 2005 level and increasing the share of non-fossil fuels in the country's energy mix to 20% by 2030. By 2014 it had already achieved to lower CO_2 emissions per unit of GDP by 33.8% compared to 2005 level and increase the share of non-fossil fuels in primary energy consumption to 11.2%. Unlike many European countries, China has no active plans to phase out coal but is trying to increase the efficiency of its coal fired power plants. (People's Republic of China 2015, 17-22.) China is also a subject of great international focus after the president of the USA, Donald Trump announced that the USA will withdraw from the Paris Agreement (Qilin Qi Huiming Jiahai 2018, 1).

In 2013, China attracted almost one third of all global investment in renewable energy. The combined value of the investments was about 68 billion euros. (KPMG 2015, 4).

China ranks 86th globally in terms of energy security, energy equity and environmental sustainability with a rank of BBD respectively (World Energy Council 2017, 54). The trilemma index and balance score are presented in Figure 42.

CHINA

TRILEMMA INDEX RANKINGS AND BALANCE SCORE

	2015	2016	2017	Trend	Score
Overall rank and balance score	87	87	86	▶	BBD
Energy performance					
Energy security	70	62	58	▲	B
Energy equity	77	77	76	▶	B
Environmental sustainability	116	117	117	▶	D
Contextual performance	63	62	47	▶	

Figure 42. China's trilemma index rankings and balance score. On energy performance, lower is better. (World Energy Council 2017, 54.)

China is still in process of rapid industrialisation and urbanisation. During China's 12th five-year-plan from 2010 to 2015, the country's GDP grew by 7.8%. China's overall score is brought down by the massive GHG emissions from energy production. (World Energy Council 2017, 54).

China launched its own emissions trading system in December of 2017. At the first stage the ETS only covers power generation sector. The power generation sector accounts for 65% of China's GHG emissions. China piloted the project on regional level in years 2013 and 2014. (Harvey, Min 2017.)

9.4 Biogas in China

It was estimated that China had 100 000 modern biogas plants and 43 million household scale digesters in 2014. The combined biogas production of these facilities was about 15 billion m^3 of biogas or 9 billion m^3 of biomethane equivalent. The 2014 production is equal to 7.74 ktoe of primary energy, which is a bit less than three millionth of China's primary energy consumption. (Scarlat et al. 2018, 10)

The combined electric capacity of China's biogas plants was 350 MW in 2016 (IRENA 2017, 47). China's13th FYP includes a target of increasing the electric capacity of biogas to 500 MW by 2020. The target for 2015, set in the 12th FYP, was

300 MW. The production target for the year 2020 is 8 billion m^3 of biogas from large scale biogas plants. (International Energy Agency 2017g.) The electric capacity of China's biogas plants from 2010 to 2016 is presented in Figure 43.

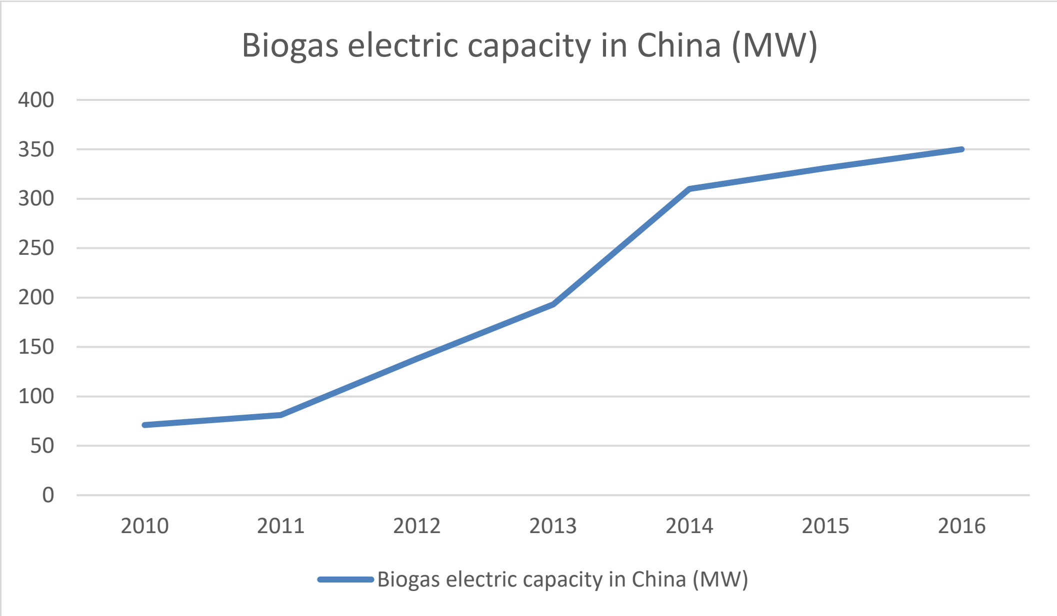


Figure 43. Estimation of electric capacity of biogas plants in China from 2010 to 2016. (IRENA 2017, 47.)

The biogas potential in China is massive. It is estimated that the potential biogas production could be 200-250 billion m^3 per year. (Scarlat et al. 2018, 10) That is about the same as estimates for the EU's biogas potential.

9.5 Support Schemes for Biogas in China

9.5.1 Operating Subsidies

According to China's Renewable Energy Law, electricity grid operators have to buy all of the renewable energy when it is generated at a guaranteed price. The price for the generated renewable energy is determined by the State Council energy and finance departments, and the state power regulatory agency. The price is based on the area and the method of generation. Renewable energy has a priority dispatching before energy generated from fossil fuels. (KPMG 2015, 23; International Energy Agency 2017h.)

China’s 2006 Energy Law includes a Renewable Energy Surcharge, a fixed tariff added to the price of each kWh of electricity sold through the electricity grid. The revenue generated from this tariff is split between power distributors and producers. The tariff is paid by end users as an addition on top of the price of the electricity consumed. The surcharge has been 0.019 CNY/kWh or 0.0025 EUR/kWh since 1.1.2016. (International Energy Agency 2016c.)

9.5.2 Investment and Other Subsidies

China offers companies a reduced corporate income tax rate of 15% to advanced and new technology companies. Fields included are solar energy, wind energy, biomaterial energy, and geothermal energy. (KPMG 2015, 22.)

Companies involved in environmental protection and energy or water conservation projects are exempt from corporate income tax for three years and pay a 50 % reduced corporate income tax for the following three years. The reduction starts from the year in which the first revenue is generated. The reduction applies to biomaterial energy, synergistic development and utilization of methane, and technological innovation in energy conservation and emission. (KPMG 2015, 22.)

A 10% credit of the investment in some equipment is applied against corporate income tax, which is payable for the current year. The equipment has to be related to environmental protection, energy or water conservation and production safety. (KPMG 2015, 22.)

Value added tax paid on the sale of products produced from waste residuals, agricultural residual, recycled materials, or waste is 50-100% refunded. Sewage treatment, garbage disposal and sludge treatment services are also exempt from value added tax. (KPMG 2015, 22.)

The Chinese government also offers subsidies for e.g. development and utilization of renewable and new energy, development of platforms for renewable and new energy and integration of renewable and new energy utilization. The amount of subsidy granted is reviewed case by case. (KPMG 2015, 22.)

10 INDIA

10.1 India in General

India is a country located in south Asia, see Figure 44. India has the second largest population in the world of 1,281 billion people. Except for deserts and the mountains close to the north boarder, India is a very densely populated country. The country has a surface area of 3 287 263 km^2. India is the fourth largest economy in the world in terms of GDP. (CIA 2018b.) India is not a member but is a key partner of the OECD (OECD 2018b).

Figure 44. Area controlled by India shown in dark green; claimed but uncontrolled regions shown in light green. (Wikipedia 2018e.)

India is still a developing nation. Over 40% of the people get their living from agriculture and agriculture accounts for about 18% of the country's GDP. GDP figures still underestimate the impact of agriculture since small scale farming is difficult to measure accurately. (International Energy Agency 2017d, 30-31,131)

10.2 Energy in India

India's energy sector is still developing. Since year 2000 over 500 million people have gained access to electricity. In 2016 the electrification rate was 82%. India is on track to reach universal electrification by early 2020's. The Indian government has made a commitment to reach full electrification by 2022. The electrification progress is presented in Figure 45. (International Energy Agency 2017d, 11-13, 43.)

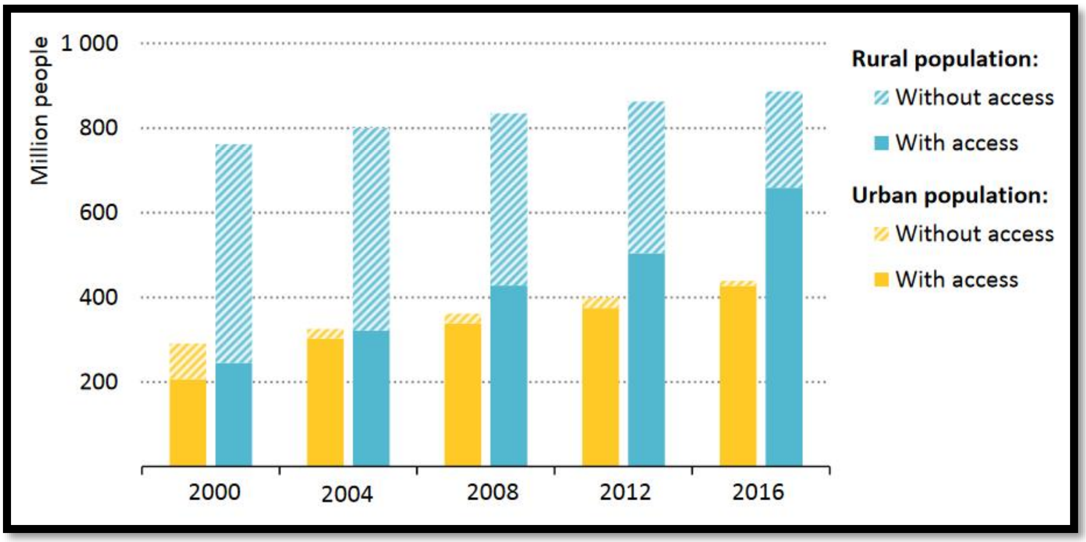


Figure 45. Rural and urban populations with and without electricity access in India. (International Energy Agency 2017d, 43.)

Biomass is a vital part of an Indian household's primary energy. Unlike in e.g. European countries, where biomass is produced and treated carefully, biomass for India's population is virtually burning wood. In 2015, 780 million people, about 60% of the population still relied on basic biomass for cooking. The situation has not improved during the last 15 years. (International Energy Agency 2017d, 61.)

In 2013 India's electricity demand was 897 TWh. It has grown by over 500 TWh since the year 2000. (International Energy Agency 2015, 433) Coal fired power plants produce an overwhelming majority of India's electricity as can be seen in Figure 46. About 85% of the coal fired power plants use outdated technology and have a low average efficiency compared to more modern coal plants. In 2013, India's coal production was close to 340 million tonnes of coal equivalent (Mtce) and imported 140 Mtce the same year. About 12% of the world's coal reserves are in India. (International Energy Agency 2015, 436,439) India's fossil fuel imports and exports are presented in Figure 47.

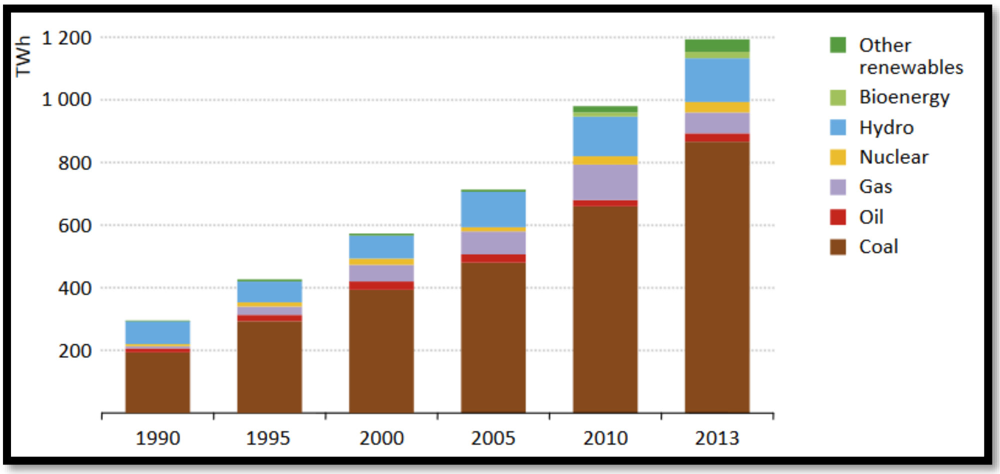


Figure 46. Total electricity generation in India by fuel. (International Energy Agency 2015, 435)

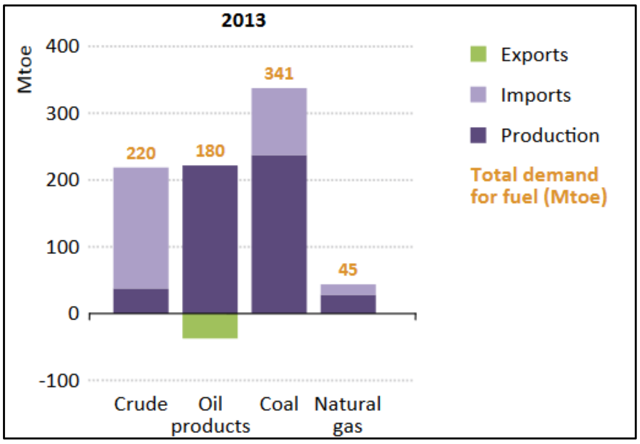


Figure 47. Fossil-fuel balance in India. (International Energy Agency 2015, 441)

In 2014, India's renewable energy generation was about 220 TWh or 16% of the country's electricity production. About two thirds of the 220 TWh was hydro power. (International Energy Agency 2016a, 32.) India has set a target of increasing its renewable electricity capacity to 175 GW by 2022. India's renewable capacity was 82.5 GW in 2015. (International Energy Agency 2016a, 35-36.) India’s renewable energy capacity is presented in Figure 48. The average household electricity price in the India is 0.08 USD/kWh (World Energy Council 2017, 76).

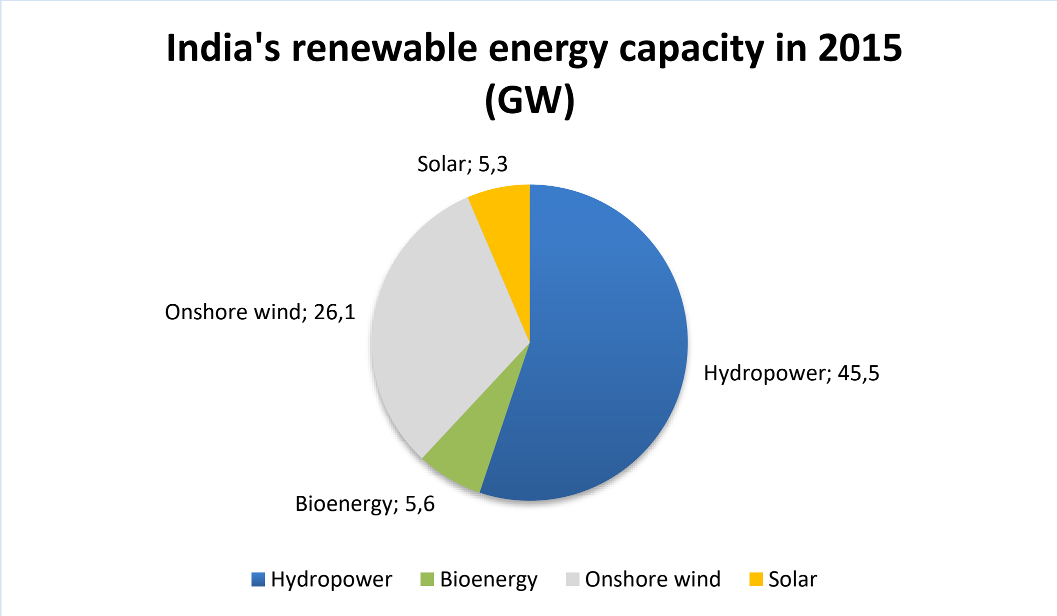


Figure 48. India's renewable energy capacity in 2015 (International Energy Agency 2016a, 36.)

10.3 Energy Policy in India

India’s per capita CO_2 emissions are relatively low compared to more developed countries. India’s CO_2 emissions per capita are presented in Figure 49.

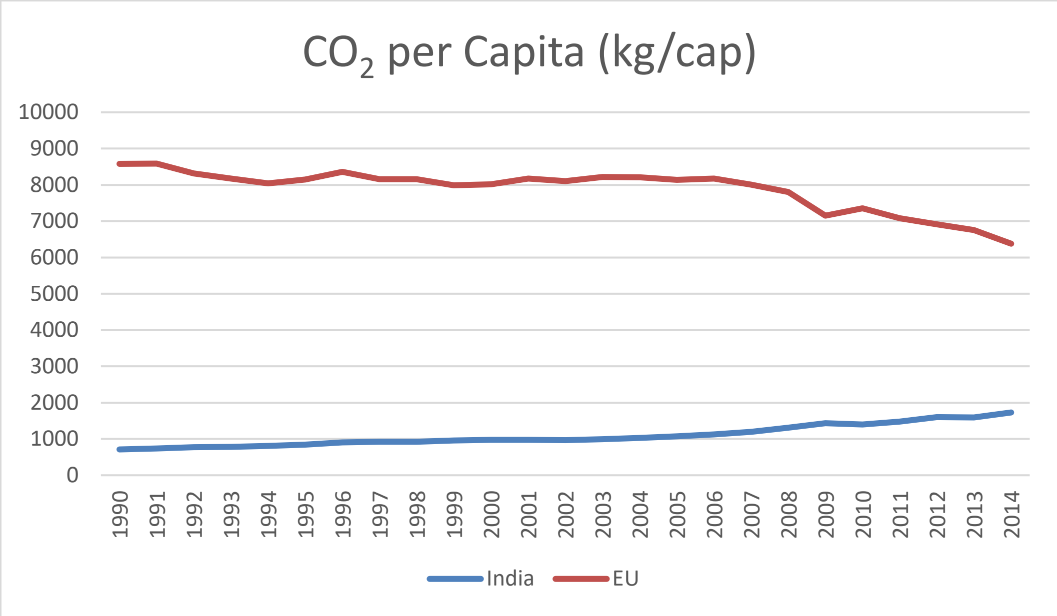


Figure 49. CO_2 per capita in India from 1990 to 2014. (World Bank 2018b.)

As India is not classified as an industrial nation, it did not receive any mandatory GHG reduction targets in the Kyoto Protocol (Taraska 2015, 3). India has signed and ratified the Paris Agreement (United Nations 2018b). It submitted its INDCs for the period 2021 - 2030 by the time of the 21st Conference of the Parties to the U.N. Framework Convention on Climate Change. India's INDCs include reduction of emission intensity of the GDP by 33-35% by 2030 from 2005 levels, achieve 40% capacity of non-fossil electricity production by 2030 with the help of the Green Climate Fund and create a carbon sink of 2,5-3 billion tonnes of CO_2 by additional forestation by 2030. (Government of India 2015, 1-4, 29)

India also introduced some financial policies to support its INDCs. The government set up a National Adaptation Fund of 43 million euros, reduced subsidies on fossil fuels including diesel, kerosene and domestic LPG, quadrupled coal tax from 50 INR (0,61 €) to 200 INR (2,45 €) per tonne and introduced Tax Free Infrastructure Bonds for funding of renewable energy projects. (Government of India 2015, 37)

India ranks 92nd globally in terms of energy security, energy equity and environmental sustainability with a rank of CCC respectively (World Energy Council 2017, 70). The trilemma index and balance score are presented in Figure 50.

INDIA

TRILEMMA INDEX RANKINGS AND BALANCE SCORE

	2015	2016	2017	Trend	Score
Overall rank and balance score	**92**	**91**	**92**	▶	**CCC**
Energy performance					
Energy security	60	51	66	▶	C
Energy equity	93	93	96	▶	C
Environmental sustainability	96	97	92	▶	C
Contextual performance	105	100	86	▲	

Figure 50. India's trilemma index rankings and balance score. On energy performance, lower is better. (World Energy Council 2017, 76.)

As India’s energy production is largely based on fossil fuels, it is highly dependent on foreign energy exports, such as coal and oil. India has announced that its goal is to reduce its dependency on oil imports by 10% by 2022. To accomplish this, India will increase its domestic production under India’s Hydrocarbon Exploration and Licensing Policy (HELP). India will also rise the share of natural gas in its energy mix from 8% in 2013 to 15% by 2022. (World Energy Council 2017, 70; International Energy Agency 2015, 434.)

10.4 Biogas in India

India’s installed bio energy capacity was 4.7 GW in 2015. In 2016, biogas plants in India had an electric capacity of 187 MW. (Scarlat et al. 2018, 7, 10.) The development of biogas plants is presented in Figure 51.

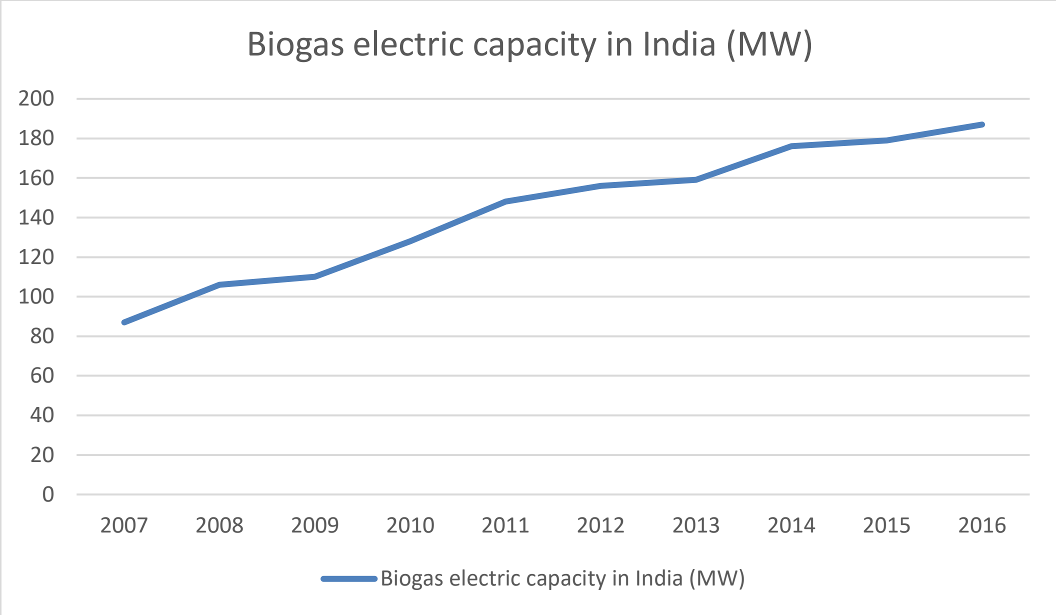


Figure 51. Biogas electric capacity in India from 2007 to 2016. (IRENA 2017, 47.)

For the period of 2014-2019, India has plans to build 110 000 biogas plants with a capacity of 1-6 m^3 biogas production per day under the National Biogas and Manure Management Programme (NBMMP). There is enough potential in India to build 12 million biogas plants which would produce 10 billion m^3 of biogas per year. (Scarlat et al. 2018, 7, 10.) India's future plans for biogas are mainly focused on improving the quality of life in rural areas. Biogas produced there would be used as fuel for cooking stoves instead of electricity or heat production (Ministry of New and Renewable Energy 2014.) India also has national standards for biogas, which are presented in Table 12.

Table 12. India's requirements for biomethane. (Ministry of New and Renewable Energy 2014.)

Sl.No.	Characteristic	Requirements	Method of Test, Ref to.
1	CH_4, Percent, Min	90.00	IS 15130(Part 3): 2002
2	Moisture, mg/m^3 Max	16.00	IS15641 (Part 2): 2006
3	H_2S, mg/m^3 Max	30.30	ISO 6326-3: 1989
4	CO_2+N_2+O_2, Percent, Max (v/v)	10.00	IS15130 (Part 3): 2002
5	CO_2, Percent, Max (v/v), (When intended for filling in cylinders)	4.00	IS15130 (Part 3): 2002
6	O_2, Percent, Max (v/v)	0.50	IS15130 (Part 3): 2002

10.5 Support Schemes for Biogas in India

10.5.1 Operating Subsidies

The Indian government offers Generation Based Incentives for independent power producers. However, this only covers wind and solar power. It does not offer any operating subsidies for electricity produced from biogas. (International Energy Agency 2018.)

India does offer accelerated depreciation tax benefit for renewable energy producers. This includes biogas plant and biogas engines. As of 1st of April 2017 producers are provided with accelerated depreciation at 40% on a written down value. (International Energy Agency 2018.)

10.5.2 Investment and Other Subsidies

India permits foreign direct investment up to 100% in renewable energy generation sector (KPMG 2015). For India's budget 2017-2018, basic customs duty for all items of machinery required for balance of systems operating on biogas or biomethane was reduced to 5% and the previous budgets 10-year income tax holiday for renewable electricity producers was not reinstated and ended in 2017. All in all, the 2017-2018 budget was a disappointment for renewable energy sector. (Prabhu 2017.)

11 SOUTH KOREA

11.1 South Korea in General

South Korea is a country located in eastern Asia, on southern half of the Korean Peninsula, as can be seen in Figure 52. South Korea's official name is Republic of Korea and is not to be mixed with Democratic People's Republic of Korea, which is the official name of North Korea. The country has surface area of 99 730 km^2 and population of 51.2 million people. South Korea has experienced remarkable economic growth since the 60's, when it was among the poorest countries in the world. Nowadays, South Korea's economic growth has slowed down as is considered as an advanced economy. (CIA 2018c.) South Korea is a member of the IEA and OECD (International Energy Agency 2014a, 2; OECD 2018b).

Figure 52. Area controlled by South Korea is shown in dark green; South Korean-claimed but uncontrolled regions shown in light green. (Wikipedia 2018f.)

11.2 Energy in South Korea

South Korea's energy consumption has more than tripled since 1990 while the population grew only from 43 million to 51 million. The growth has slowed down a bit in recent years, but it keeps growing by about 1% each year. There has been only one year in the past 20 years when the country's energy consumption did not grow. The total energy consumption is presented in Figure 53. (Korea Energy Economics Institute 2016, 10.)

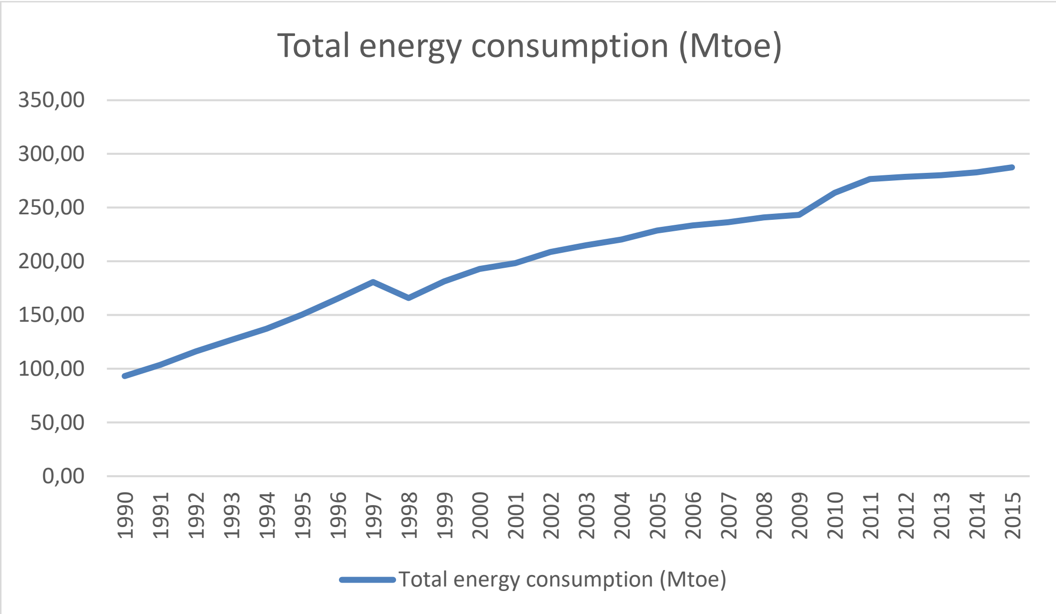


Figure 53. Total energy consumption in South Korea from 1990 to 2015. (Korea Energy Economics Institute 2016, 10)

As can be seen in Figure 54, South Korea imports an overwhelming majority of its primary energy. The country runs on fossil fuels, which are all practically imported. Nuclear power is included in IEA's figure of domestic production, but South Korea does not produce any nuclear fuels itself. South Koreas overseas dependence on primary energy imports is staggering 94.8%. (Korea Energy Economics Institute 2016, 6.)

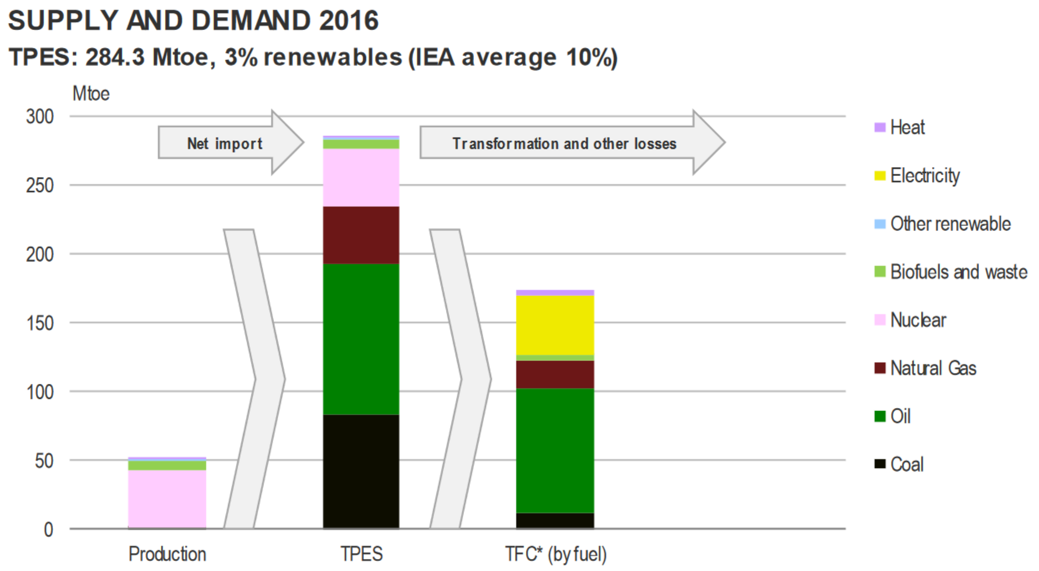


Figure 54. South Korea's energy mix in 2016. (International Energy Agency 2017e.)

As can be seen in Figure 55, fossil fuels dominate South Korea’s electricity production. The share of renewable energy of total electricity generation is one of the lowest in the world. The only countries which have a lower share of renewable electricity production are major oil and gas exporter countries, such as OPEC members. (World Bank 2018c) The average household electricity price in South Korea is 0.21 USD/kWh (World Energy Council 2017, 87).

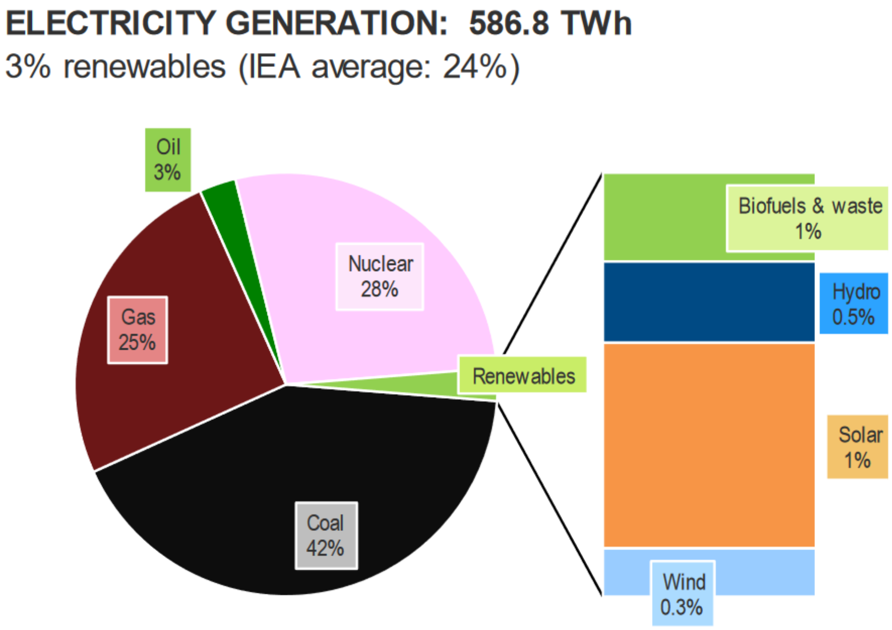


Figure 55. South Korea's electricity production by source in 2016. (International Energy Agency 2017e.)

South Korea has about 3500 km of trunk natural gas lines and has plans to extend the national trunk lines to about 5000 km by 2027. South Korea also has four LNG terminals for overseas LNG imports. In 2008, South Korean gas company KOGAS and Russian Gazprom signed a memorandum of understanding in which a new pipeline would be built via North Korea and Russia would supply South Korea with natural gas. North Korea has not given consent for this construction. So far, South Korea does not have any international pipelines. (International Energy Agency 2014a, 299-300.)

11.3 Energy policy in South Korea

South Korea's CO_2 emissions are high compared to e.g. EU member countries. South Korea surpassed the EU in CO_2 per capita in the year 2000. The drop between 1997 and 2000 can be explained by the Asian financial crisis of 1997-98 (CIA 2018c). South Korea's CO_2 per capita are presented in Figure 56.

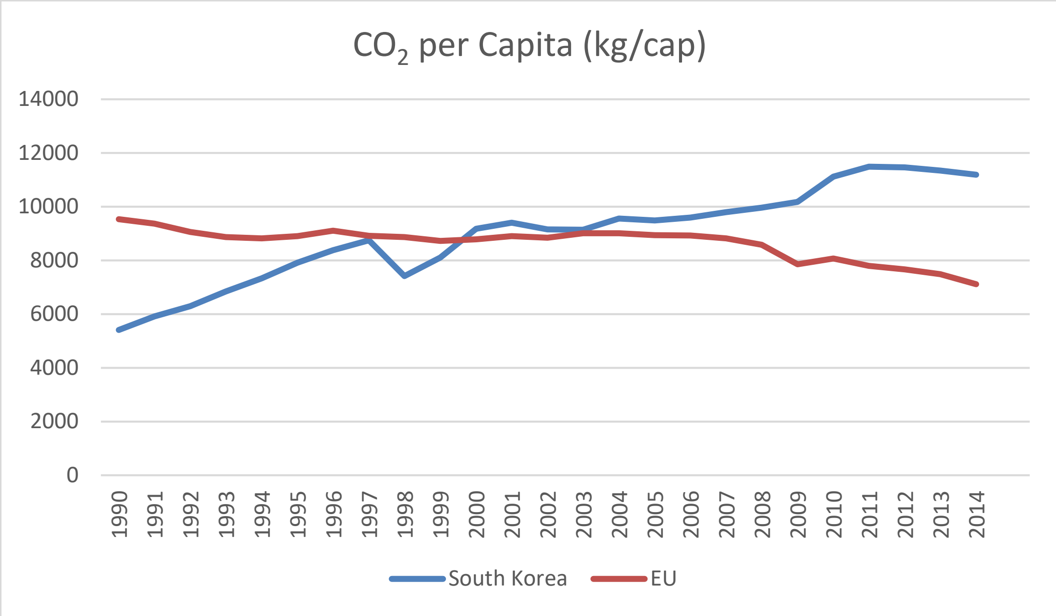


Figure 56. CO_2 per Capita in South Korea between 1990 and 2015. (European Commission 2018a; Korea Energy Economics Institute 2016, 11.)

In 2014, South Korea published its 2nd National Energy Master Plan up to year 2035. The plan sets six major tasks: to reduce electricity demand by 15% by 2035, at least 15% of electricity should be generated by distributed sources by 2035, latest GHG reduction technologies is to be applied in all new power plants, the share of renewable energy in the energy mix should be 11% by 2035, guarantee the supply of fossil fuel imports and introduce an "Energy Voucher System". (MOTIE 2014, 30.)

The Master Plan also includes a Renewable Fuel Standard (RFS), which requires transportation fuels to contain a minimum volume of renewable fuel. So far it only applies to biodiesel but might be extended to cover biogas as well in the future. (MOTIE 2014, 120.)

South Korea also has an Emissions Trading System in place, which was introduced in the first National Energy Master Plan. The ETS covers 67.7% of the nation's GHG emissions. In the final phase of South Korea's ETS, the government buys emission credit from renewable energy producers and sells it to industries with

GHG emissions. (Republic of Korea 2015; MOTIE 2014, 25; International Energy Agency 2016b.)

South Korea has signed and ratified the Paris Agreement (United Nations 2018b). South Korea's INDCs include a target to reduce country's GHG emissions by 37% compared to "business-as-usual" -scenario by 2030. In business-as-usual -scenario South Korea's emissions would be 850.6 Mt of CO_2 equivalent in 2030. The reduction target covers all economic sectors. (Republic of Korea 2015). In 2014, South Korea's CO_2 emissions were 567.8 Mt (Korea Energy Economics Institute 2016, 10).

The government is also obligating electricity producers to provide a part of the electricity from renewable sources. This is described in detail in chapter 11.5.1. (Republic of Korea 2015). It is expected that renewable electricity generation will reach about 38 TWh by 2021. In 2015, the renewable production was about 15 TWh. (International Energy Agency 2016a, 34.)

South Korea ranks 39th globally in terms of energy security, energy equity and environmental sustainability with a rank of CAC respectively (World Energy Council 2017, 87). The trilemma index and balance score are presented in Figure 57.

KOREA (REP.)

TRILEMMA INDEX RANKINGS AND BALANCE SCORE

	2015	2016	2017	Trend	Score
Overall rank and balance score	**46**	**44**	**39**	▶	**CAC**
Energy performance					
Energy security	76	72	64	▲	C
Energy equity	38	35	26	▶	A
Environmental sustainability	89	88	84	▶	C
Contextual performance	29	28	28	▶	

Figure 57. South Korea's trilemma index rankings and balance score. On energy performance, lower is better. (World Energy Council 2017, 87.)

While South Koreans have cost efficient access to energy, the score is considerably brought down by a massive share of energy imports and environmentally unsustainable energy sources. South Korea has a high diversity of energy suppliers, which benefits the energy security by some degree. The government is also working closely with nations overseas to strengthen South Koreas influence and this way increase the supply security. (World Energy Council 2017, 87).

11.4 Biogas in South Korea

An extensive study was published on South Korea's biogas policies and current status in 2012. The study was made by Yong-Sung Kim, Young-Man Yoon, Chang-Hyun Kim and Jens Giersdorf and was first one of its kind.

In 2010, there were 49 biogas plants operating in South Korea. The plants produced 3363 MWh of electricity in 2008. Two plants are fed by food waste, five plants by food wastewater, nine plants by livestock manure, 13 plants by mixture of substrates, and 20 plants by sewage sludge. About 95% of the existing plants use wet fermentation system to produce biogas. (Kim, Yoon, Kim, Giersdorf 2012, 3.) The electric capacity of biogas plants in South Korea is presented in Figure 58.

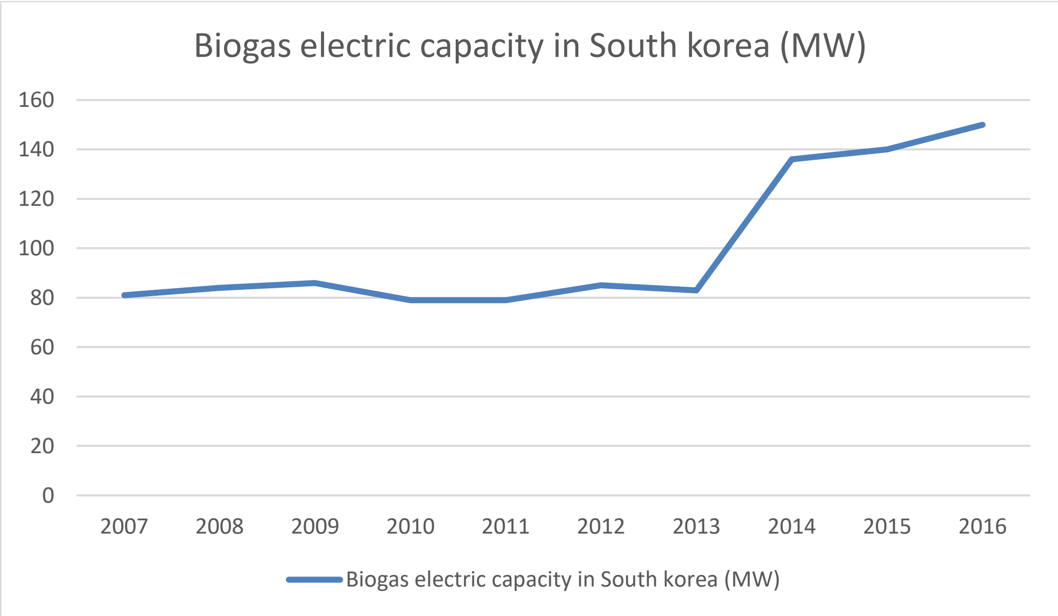


Figure 58. Biogas installed capacity in South Korea in 2016. (IRENA 2017, 47.)

South Korea generated 61.9 million tonnes of food waste and animal manure in 2010. Biogas potential of food waste and animal manure is 700 million m^3 per year. Farming dedicated biogas crops is not an option in South Korea since the country has only 27% of food self-sustainment. (Kim et al. 2012, 2-3.)

The study concludes that South Korea has sufficient infrastructure for biogas market. Currently biogas is used more as a tool for waste management rather than an energy source. No clear biogas market was formed at the time of the study and it would be difficult to run a profitable biogas operation in South Korea. However, with the optimized technology, energy production from biogas could be profitable. (Kim et al. 2012, 8.)

Swedish biogas company Scandinavian Biogas invested 10 million euros in South Korea to upgrade a wastewater treatment plant to digest a mix of food waste and sewage. The company's head of operations in South Korea said in an interview that "There is a lot of potential" in South Korea. (Olsen 2018.)

11.5 Support Schemes for Biogas in South Korea

11.5.1 Operating Subsidies

South Korea used to provide feed-in tariffs for renewable power producers. In 2008, the fixed feed-in tariff for biogas installations under 50 MW and over 150 kW was 72.73 KRW/kWh, which in today's rates is 0.055 €/kWh. (KEMCO 2018.) South Korea moved from feed-in tariffs to Renewable Portfolio Standard (RPS) in 2012. (KPMG 2015, 63). The RPS requires major power providers to increase the share of renewable energy production from 2% in 2012 to 10% by 2022. The yearly increase in renewable energy requirement is presented in Figure 59. The RPS programme is mandatory for companies that own power plants generating more than 500 MWh of electricity annually and use fossil fuels as an energy source. (KEMCO 2018.)

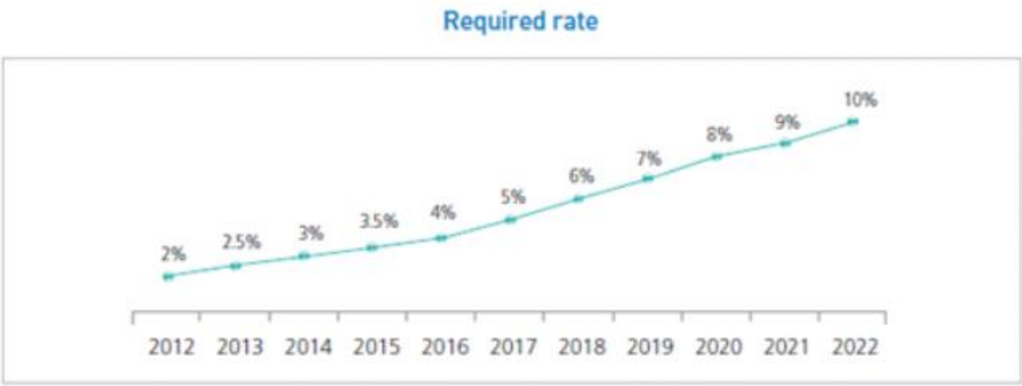


Figure 59. RPS's required share of renewable production. (KEMCO 2018.)

The required renewable share can be produced by the major energy company itself or the company can purchase a Renewable Energy Certificates (REC) from renewable energy producers. Renewable energy companies receive RECs for their renewable energy production. If a major energy company does not want to produce renewable energy itself, it has to buy the required number of RECs straight from the renewable energy producers or they can be bought through Korea Power Exchange (KPX). The rate which a renewable energy company earns RECs is dependent on a weighing factor ranging from 0.5 to 4.5 for different means of production. For biogas energy producers, the weighted factor for REC is 1, which means that per 1 MWh of electricity produced, the company earns 1 REC, which it can then sell. In 2014, average REC price for non-solar power was 113 174 KRW or 86.05 €. The final electricity price that the renewable energy producer receives is the price of the REC and energy wholesale price. The differences between RPS and traditional feed-in tariffs are presented in Figure 60. (KEMCO 2018; KPMG 2015, 63.)

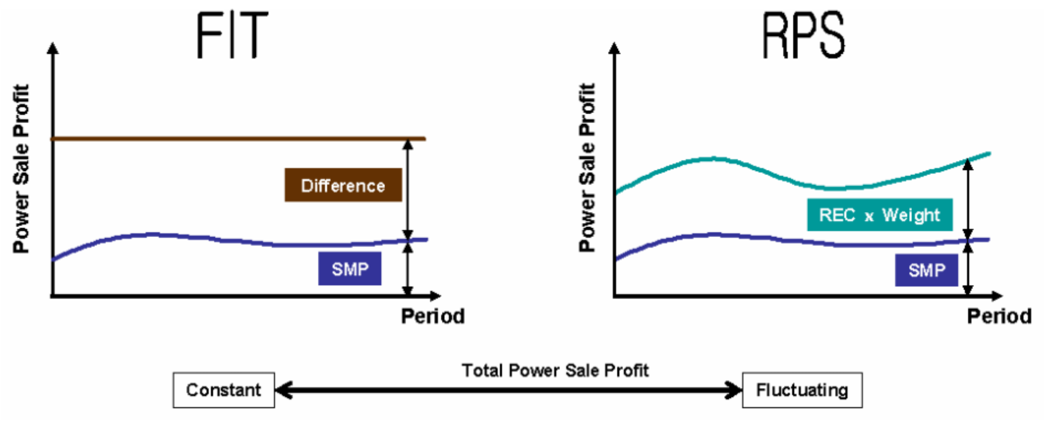


Figure 60. Feed-in tariff vs. Renewable Portfolio Standard. (Jeon, Park, Hong 2011, 5.)

11.5.2 Investment and Other Subsidies

Korea Energy Agency (KEA) offers long-term, low-interest loans to companies who will install new renewable energy production facilities. Besides that, South Korea does not offer any additional financing from biogas projects. (Korea Energy Agency 2018.)

12 CONCLUSIONS AND DISCUSSION

12.1 Wärtsilä's perspective

Each country was analysed in terms of advantages and disadvantages. The analysis is made from Wärtsilä's business perspective and focuses on biogas electricity markets. The analysis is based on information of this thesis and Wärtsilä's previous business experience.

12.1.1 Germany

Advantages and disadvantages in Germany are listed in Table 13.

Table 13. Advantages and disadvantages in Germany's biogas electricity market.

<table>
<tr><th>Advantages</th><th>Disadvantages</th></tr>
<tr><td>Largest energy market in Europe</td><td rowspan="2">Regulatory uncertainty</td></tr>
<tr><td>High GHG emissions</td></tr>
<tr><td>Ambitious climate and energy targets</td><td rowspan="2">Large share of coal in energy production</td></tr>
<tr><td>Trend of biogas capacity additions is still rising</td></tr>
<tr><td>Established renewable energy sector</td><td rowspan="2">Competition for feed-in tariffs</td></tr>
<tr><td>Advanced biogas sector</td></tr>
<tr><td>Government funding for renewable energy projects</td><td rowspan="2">Feed in tariffs for biogas are only granted for 50% of nominal generation capacity per year</td></tr>
<tr><td>High consumer electricity price</td></tr>
</table>

As mentioned several times before, Germany is the global leader in biogas production. It also a large renewable energy sector and has ambitious plans to develop it even further. The other side of the coin is that since Germany is phasing out nuclear power, the void in production is so far filled with coal fired power plant. This has slowed down the GHG emissions reduction in the country. Germany still has high emissions compared to the EU average. The regulatory uncertainty has also slowed down the energy investments.

Germany’s renewable energy targets offer possibilities to further expand its biogas capacity. Much of Germany’s renewable capacity is wind and solar power, which requires balancing power to balance the production. However, there are already other players on the market. Since the feed-in tariffs are auctioned, there will be competition for the highest grants. Grants are also declining over time, so entering the German energy market should be done as soon as possible. Still, the German energy market is the largest in Europe and will remain so in the foreseeable future despite the total energy consumption is slowly declining.

12.1.2 Austria

Advantages and disadvantages in Austria are listed in Table 14.

Table 14. Advantages and disadvantages in Austria's biogas electricity market.

<table>
<tr><th>Advantages</th><th>Disadvantages</th></tr>
<tr><td>Increasing energy consumption</td><td rowspan="2">Smallest energy market</td></tr>
<tr><td>Established renewable energy sector</td></tr>
<tr><td>Renewable energy targets</td><td rowspan="3">Feed-in tariffs are declining</td></tr>
<tr><td>Phasing out coal</td></tr>
<tr><td>High share of energy imports</td></tr>
<tr><td>Targets to improve supply security</td><td rowspan="3">Unclear trend in biogas capacity over years</td></tr>
<tr><td>Good feed-in tariffs for biogas</td></tr>
<tr><td>No caps on tariffs</td></tr>
</table>

Austria has the smallest energy sector of the researched countries. It consumes about the same amount of energy in a decade than Germany does in a single year.

However, Austria's energy consumption is still rising. The biogas sector in Austria does not have a steady rising trend but it has not declined during the past few years, either.

Austria's potential lies in the generous and uncapped feed-in tariffs and improving the supply security. Austria offers the highest feed-in tariffs for electricity produced from biogas of all the countries in this thesis. The feed-in tariffs are declining each year. Currently, a large share of Austria's energy is supplied by foreign countries. Domestic biogas production would improve Austria's self-sufficiency. Austria already produces a large share of its electricity be renewable methods. It has set targets to increase the share of renewable energy even further and will phase out coal in the coming years.

12.1.3 Netherlands

Advantages and disadvantages in the Netherlands are listed in Table 15.

Table 15. Advantages and disadvantages in the Netherlands' biogas electricity market.

Advantages	Disadvantages
Highly developed gas infrastructure	Very low share of renewable energy
Stable energy consumption	Biogas capacity has declined a little
Gas production is reducing	
Household gas use is declining	Feed-in tariffs are capped
High GHG emissions	
Renewable energy targets	Lower operating subsidies
Tax reductions	

The Netherlands is the natural gas giant of the EU. The positive side of this is that the Netherlands has a highly developed gas infrastructure in place. The negative is that the country basically runs on natural gas and has very little renewable capacity. This shows in the country's high GHG emissions.

The Dutch are trying to distant themselves from the natural gas. The Dutch gas production is declining, and new homes are using other energy sources, in practice electricity, for cooking and heating. The Netherlands is increasing its renewable energy capacity in the future and due its geography, it is left with fluctuating renewable energy sources, such as solar and wind power. This will require balancing power for calm and cloudy days. The Netherlands SDE+ operating subsidy is not great, and it has a yearly production cap.

12.1.4 China

Advantages and disadvantages in the Netherlands are listed in Table 16.

Table 16. Advantages and disadvantages in China's biogas electricity market.

<table>
<tr><th>Advantages</th><th>Disadvantages</th></tr>
<tr><td>Huge population</td><td rowspan="2">Government control</td></tr>
<tr><td>Rapidly growing economy</td></tr>
<tr><td>Highest GHG emissions</td><td rowspan="2">High amount of red tape</td></tr>
<tr><td>Growing electricity consumption</td></tr>
<tr><td>Rapidly growing renewable energy sector</td><td rowspan="2">No operating subsidies</td></tr>
<tr><td>Renewable energy targets</td></tr>
<tr><td>World leader in renewable energy investment</td><td rowspan="3">Limited natural gas infrastructure</td></tr>
<tr><td>Huge biogas potential</td></tr>
<tr><td>Reduced income tax and VAT</td></tr>
</table>

China is the world's factory and its energy needs are growing constantly. The country has a larger population and GDP than any other country on the planet. Therefore, the growth potential is huge and extends to the biogas sector as well. Despite the massive capacity increases in renewable energy, China will not reach its peak GHG emissions since 2030’s. It already is the world’s worst emitter.

China is promoting renewable energy heavily in the countries latest five-year plan. The targets and IEA’s predictions are well connected. Massive capacity additions for wind and solar power require balancing. Combining the requirement for balancing power with the country’s huge biogas potential, it is plausible that feasible operation could be possible in the future. However, China does not offer any feed-in tariffs or other operating subsidies for biogas, but the state will set the price of electricity that grid operators have to buy the electricity from a producer. This can vary a lot and producers might have difficulties negotiating a fair price.

When talking about economic activities in China, it is to be remembered, that a communist party runs the country. Nothing happens in China without the party leaders’ permission.

12.1.5 India

Advantages and disadvantages in the India are listed in Table 17.

Table 17. Advantages and disadvantages in India's biogas electricity market.

Advantages	Disadvantages
Huge population	Developing country
Increasing electrification rate	Low utilization of biomass
Increasing energy consumption	Dependency on coal
Growing GHG emissions	Low electricity price
Targets to double renewable energy capacity	No operating subsidies for biogas
Increasing tax on coal	Little to no investment subsidies

India is a developing country in general and so is its energy sector. The country's electrification rate has improved during the past years but will not be completed since early 2020's. Increasing electrification rate leads to higher electricity demand. It is to be noted that even a few percentages in electrification rate increase accounts for millions of people.

India's CO_2 emissions per capita are very low but the trend is rising. Also, the country is the second most populated country in the world, so the emissions add up. India is almost completely dependent on coal has no plans to phase it out in the near future. Biomass is widely used by Indian households, but it is not utilized to its full potential.

India has set targets to double its renewable energy production by 2022 and will tax coal more strictly. Despite that, India does not offer any operating subsidies for biogas operation and little to no investment subsidies. Electricity price in India is very low so profitable biogas operation would be very difficult.

12.1.6 South Korea

Advantages and disadvantages in South Korea are listed in Table 18.

Table 18. Advantages and disadvantages in South Korea's biogas electricity market.

Advantages	Disadvantages
Rising energy consumption	Cheap imported energy
Massive share of imported energy	
High GHG emissions	
GHG emission reduction targets	
Power producers required to increase renewable energy production	Currently very little renewable energy production
Energy certificate trade	
Increasing biogas capacity	
Sufficient infrastructure for biogas	

South Korea is a highly developed nation, but it is completely dependent on imported fossil fuels. The imported energy is quite unsecure and very unsustainable, but it might be too cheap to move away from. South Korea's CO_2 emissions per capita are by far the highest in this study.

South Korea has plans to reduce its emissions significantly and is requiring the major power producers to increase the share of renewable energy in their production yearly. Currently the country has one of the lowest shares of renewable energy in their energy mix compared to the rest of the world.

The energy certificate trade benefits biogas operations since they receive RECs from their production. The price of the RECs is comparable to some of the previously mentioned feed-in tariffs. It is also likely that the price of the RECs will increase since the renewable energy quotas for the major power producers are rising and therefore increases the demand. According to the study made in early 2010's the country already had a sufficient infrastructure for biogas market. The country's biogas capacity has increased during past years.

12.2 Recommendations for Wärtsilä

My recommendations for Wärtsilä are to focus on Austria, China and South Korea. Austria being a smallest market of these, could provide an excellent proving ground for Wärtsilä's first large-scale biogas operation. The country's energy policy supports biogas as it would improve the country's energy self-sufficiency and sustainable energy production. The country also offers generous uncapped feed-in tariffs for biogas. A problem is that the feed-in tariffs are declining so Wärtsilä would have to move quickly.

China is just too huge to pass. It attracts more investment for renewable energy than any other country, it is the world's largest energy consumer and has pressure to clean up its energy sector, especially now that the USA is leaving the Paris Agreement. To succeed in China, Wärtsilä must have expertise on how to co-operate with the Chinese officials. Like most things in China, the energy sector is tightly in the government's control. The biggest problem in China is that the country does not offer any direct operating subsidies for biogas.

South Korea might be the best target of all the countries discussed in this thesis. A remarkably big share of imported energy is disadvantageous for the country's energy security, no matter how good the trade relations are. Currently the country is lacking in renewable energy production but there is a lot of pressure to increase it due the global climate agreements and government's requirements for major power producers. If the REC pricing enables profitable biogas operation, the potential could be huge. The country already has the infrastructure in place and energy demand is still growing. The only danger is that like all renewable energy in South Korea, biogas would also have to compete with the cheap imported energy.

12.3 Discussion

I am very pleased that I got to work with Wärtsilä with this thesis. The subject was interesting, and my previous studies helped a lot understanding the bigger picture of energy politics of different countries. I think it is very important to have an overall image of where the energy sector is heading around the world now that climate change is making headlines weekly.

The findings of this study are reliable since it uses multiple trustworthy sources, such as established scientific journals and well-known international organisations, such as the IEA and the EU. The majority of the energy policies examined in this study originate directly from each country's government. Numerical data about e.g. CO_2 emissions or total energy consumption are not completely accurate, since there are some variances among sources, such as the World Bank and the EU. All references used in this thesis are presented in detail to enable others to evaluate this work. Overall, the objective set at the beginning of this thesis was met, and the results are objective.

This study alone cannot answer directly where Wärtsilä should invest. It provides useful information, but further research is needed to make informed decisions. Countries consist of multiple much smaller regions and it would be important to research the topics of this thesis on a regional level. This of course varies greatly from country to country. The overall image of this thesis might work fairly well for a country like Austria but not as much so for China. As intended, this thesis hardly explored the technical aspects of biogas production. One major area of future research would be to study what kind and how much of feedstock is available, since it has a major effect on the scale of the operation. The feedstock studies should also be done on a regional level. The next step from the feedstock studies would be to compare different solutions for facilities since there are multiple ways that biogas can be produced. Like in all energy production, technical side of things cannot be detached from energy policies. It would be important to have a holistic approach in the future studies.

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APPENDIX 1

Preliminary Dimensions and Country Selection

Countries			Selection		Demographic key figures			Energy key figures				
					Mil. of people	USD	USD/Year	kWh/capita	% of net consumption	% of total	USD/MWh	million m^3
					2018	2016	2017 or latest	2014	2016 or latest available	2015	2017 or latest	2016 or latest
Country	**Continent**	**Landlocked**	**Selected**	**Criteria**	**Population**	**GDP per capita**	**Average wages**	**Electric power consumption**	**Energy imports**	**RE share**	**Price of electricity**	**Natural gas consumption**
Afghanistan	Asia	**Yes**			36,37	$ 561,78		N/A	N/A	19 %		816
Albania	Europe	No			2,93	$ 4 124,98		2309	13,8 %	83 %		200
Andorra	Europe	**Yes**			0,08	$ 36 988,62		N/A	N/A	0 %		0
Armenia	Asia	**Yes**			2,93	$ 3 614,69		1966	71,3 %	41 %		2730
Armenia	Europe	**Yes**			2,93	$ 3 614,69		1966	71,3 %	41 %		2730
Austria	Europe	**Yes**	X	Energy imports, load adjustment, landlock	8,75	$ 44 757,63	$ 39 109,89	8361	63,5 %	73 %	$ 0,15	12120
Azerbaijan	Asia	**Yes**			9,92	$ 3 878,71		2202	-310,4 %	9 %		18200
Azerbaijan	Europe	**Yes**			9,92	$ 3 878,71		2202	-310,4 %	9 %		18200
Bahrain	Asia	No			1,57	$ 22 579,09		19592	-61,6 %	0 %		21920
Estonia	Europe	No	X	Very high emissions	1,31	$ 17 736,80	$ 18 779,40	6732	-2,7 %	20 %	$ 0,11	964
Belarus	Europe	**Yes**			9,45	$ 4 989,43		3680	86,8 %	1 %		26500
Belgium	Europe	No			11,50	$ 41 271,48		7709	80,1 %	19 %		23010
Bhutan	Asia	**Yes**			0,82	$ 2 773,55		N/A	N/A	297 %		0
Bosnia and Herzeg	Europe	No			3,50	$ 4 808,41		3366	22,7 %	48 %		881
Brunei	Asia	No			0,43	$ 26 939,42		10243	-357,4 %	0 %		4545
Bulgaria	Europe	No			7,04	$ 7 469,03		4709	36,6 %	27 %		3209
Finland	Europe	No	ref	ref	5,54	$ 43 401,23	$ 50 225,02	15250	45,3 %	39 %	$ 0,13	3243
Georgia	Europe	No	X	Growth potential, energy imports	3,91	$ 3 865,79	$ 15 802,70	2688	68,8 %	67 %	$ 0,10	2180
Croatia	Europe	No			4,16	$ 12 149,19		3714	45,9 %	47 %		3590
Cyprus	Europe	No			1,19	$ 23 541,49		3625	94,0 %	10 %		0
Czech Republic	Europe	**Yes**			10,63	$ 18 483,72		6259	31,6 %	15 %		#N/A
Denmark	Europe	No			5,75	$ 53 578,76		5859	1,8 %	63 %		4392
Germany	Europe	No	X	Energy imports, load adjustment	82,29	$ 42 161,32	$ 55 856,49	7035	61,4 %	38 %	$ 0,17	773200
Netherlands	Europe	No	X	Agriculture, high emissions, load adjust	17,08	$ 45 637,89	$ 44 963,07	6713	35,0 %	14 %	$ 0,14	39960
France	Europe	No			65,23	$ 36 857,12		6938	44,1 %	21 %		42510
Bangladesh	Asia	No	X	Population, growth potential	166,37	$ 1 358,78	$ 1 853,92	310	16,8 %	1 %	$ 0,07	39880
Cambodia	Asia	No	X	Growth potential	16,25	$ 1 269,91	$ 1 881,00	271	33,1 %	41 %	$ 0,18	0
Greece	Europe	No			11,14	$ 17 890,57		5063	64,2 %	28 %		4354
Hungary	Europe	**Yes**			9,69	$ 12 820,09		3966	57,7 %	9 %		17140
Iceland	Europe	No			0,03	$ 59 764,71		53832	11,6 %	103 %		0
China	Asia	No	X	Population	1415,05	$ 8 123,18	$ 10 670,43	3927	15,0 %	24 %	$ 0,09	210300
India	Asia	No	X	Population	1354,05	$ 1 709,59	$ 1 053,39	806	34,3 %	19 %	$ 0,08	102300
Iran	Asia	No			82,01	$ 5 219,11		2986	-33,4 %	6 %		186000
Iraq	Asia	No			39,34	$ 4 609,60		1306	-229,4 %	4 %		1270
Ireland	Europe	No			4,80	$ 64 175,44		5722	85,7 %	33 %		5060
Israel	Asia	No			8,45	$ 37 180,53		6601	65,0 %	2 %		13610

Countries	Renewable energy composition														Emissions	Waste
	TWh	TWh	TWh	TWh	TWh	TWh	TWh	%	%	%	%	%	TWh	TWh	t/capita	%
	2015,00	2015,00	2015,00	2015,00	2015,00	2015,00	2015	2015	2015	2015	2015	2015	2015	2015	2014	2014 or latest
Country	Hydropower	Wind	Solar	Geothermal	Bio	Wave & tidal	Hydro share of RE	Wind share of RE	Solar share of RE	Geothermal share of RE	Bio share of RE	Wave & tidal share of RE	Combined RE	Total consumption	CO2 emissions	Muncipal waste recycled
Afghanistan	0,89	0	0	0	0	0	100 %	0 %	0 %	0 %	0 %	0 %	0,89	4,741	0,30	MSW recycled
Albania	5,87	0	0	0	0	0	100 %	0 %	0 %	0 %	0 %	0 %	5,866	7,094	1,98	per MSW
Andorra	N/A	N/A	N/A	N/A	N/A	N/A	0 %	0 %	0 %	0 %	0 %	0 %	N/A	0,2216	5,83	generated
Armenia	2,18	0,00	0,00	0	0	0	100 %	0 %	0 %	0 %	0 %	0 %	2,188	5,331	1,90	
Armenia	2,18	0,00	0,00	0	0	0	100 %	0 %	0 %	0 %	0 %	0 %	2,188	5,331	1,90	
Austria	34,92	4,56	0,88	0,00	5,19	0	77 %	10 %	2 %	0 %	11 %	0 %	45,5534	62,78	6,87	56 %
Azerbaijan	1,62	0,01	0,01	0	0,18	0	89 %	0 %	0 %	0 %	10 %	0 %	1,813	20,27	3,93	
Azerbaijan	1,62	0,01	0,01	0	0,18	0	89 %	0 %	0 %	0 %	10 %	0 %	1,813	20,27	3,93	
Bahrain	0	0,00	0	0	0	0	0 %	100 %	0 %	0 %	0 %	0 %	0,001	26,09	23,45	
Estonia	0,03	0,72	0	0	0,89	0	2 %	44 %	0 %	0 %	54 %	0 %	1,63	8,158	14,85	31 %
Belarus	0,11	0,03	0,01	0	0,19	0	33 %	8 %	2 %	0 %	57 %	0 %	0,326	31,75	6,70	
Belgium	0,32	5,49	3,04	0	6,76	0	2 %	35 %	19 %	0 %	43 %	0 %	15,612	81,96	8,33	
Bhutan	7,73	0	0	0	0	0	100 %	0 %	0 %	0 %	0 %	0 %	7,731	2,6	1,29	
Bosnia and Herzeg	5,50	0,00	0	0	0	0	100 %	0 %	0 %	0 %	0 %	0 %	5,496	11,44	6,23	
Brunei	0	0	0,00	0	0	0	0 %	0 %	100 %	0 %	0 %	0 %	0,002	3,679	22,12	
Bulgaria	5,60	1,45	1,38	0	0,27	0	64 %	17 %	16 %	0 %	3 %	0 %	8,706	31,79	5,87	
Finland	16,58	2,33	0,01	0	11,81	0	54 %	8 %	0 %	0 %	38 %	0 %	30,726	79,07	8,66	33 %
Georgia	8,37	0	0	0	0	0	100 %	0 %	0 %	0 %	0 %	0 %	8,369	12,44	2,41	0-10%
Croatia	6,33	0,80	0,06	0	0,27	0	85 %	11 %	1 %	0 %	4 %	0 %	7,453	15,8	3,97	
Cyprus	0	0,22	0,13	0	0,05	0	0 %	56 %	32 %	0 %	13 %	0 %	0,396	4,028	5,26	
Czech Republic	1,78	0,56	2,24	0	4,87	0	19 %	6 %	24 %	0 %	51 %	0 %	9,454	61,16	9,17	
Denmark	0,02	14,13	0,60	0	4,96	0	0 %	72 %	3 %	0 %	25 %	0 %	19,713	31,41	5,94	
Germany	18,67	78,87	38,73	0,09	57,38	0	10 %	41 %	20 %	0 %	30 %	0 %	193,735	514,6	8,89	64 %
Netherlands	0,09	7,55	1,12	0	6,56	0	1 %	49 %	7 %	0 %	43 %	0 %	15,329	106	9,92	51 %
France	53,77	21,25	7,26	0	8,17	0,49	59 %	23 %	8 %	0 %	9 %	1 %	90,94	436,1	4,57	
Bangladesh	0,56	0,00	0,15	0	0	0	78 %	1 %	21 %	0 %	0 %	0 %	0,714	48,98	0,46	Source
Cambodia	1,98	0	0,00	0	0,04	0	98 %	0 %	0 %	0 %	2 %	0 %	2,021	4,952	0,44	Source
Greece	5,78	4,62	3,90	0	0,34	0	39 %	32 %	27 %	0 %	2 %	0 %	14,646	53,05	6,18	
Hungary	0,23	0,67	0,12	0	2,30	0	7 %	20 %	4 %	0 %	69 %	0 %	3,321	38,66	4,27	
Iceland	13,54	0,01	0	5,00	0	0	73 %	0 %	0 %	27 %	0 %	0 %	18,554	17,98	6,06	
China	1103,33	185,77	45,25	0,13	63,73	0,01	79 %	13 %	3 %	0 %	5 %	0 %	1398,207	5920	7,54	2 %
India	120,27	42,79	5,64	0	26,54	0	62 %	22 %	3 %	0 %	14 %	0 %	195,242	1048	1,73	Source
Iran	13,95	0,22	0,00	0	0,01	0	98 %	2 %	0 %	0 %	0 %	0 %	14,184	220,9	8,28	
Iraq	2,55	0	0	0	0	0	100 %	0 %	0 %	0 %	0 %	0 %	2,546	66	4,81	
Ireland	0,80	6,57	0,00	0	0,55	0	10 %	83 %	0 %	0 %	7 %	0 %	7,923	23,79	7,38	
Israel	0,02	0,01	1,12	0	0,07	0	2 %	1 %	92 %	0 %	6 %	0 %	1,214	52,78	7,86	

Countries			Selection		Demographic key figures			Energy key figures				
					Mil. of people	USD	USD/Year	kWh/capita	% of net consumption	% of total	USD/MWh	million m^3
					2018	2016	2017 or latest	2014	2016 or latest available	2015	2017 or latest	2016 or latest
Country	Continent	Landlocked	Selected	Criteria	Population	GDP per capita	Average wages	Electric power consumption	Energy imports	RE share	Price of electricity	Natural gas consumption
Italy	Europe	No			59,29	$ 30 661,22		5002	76,4 %	37 %		70910
Indonesia	Asia	No	X	Population, geography, growth potential	266,79	$ 3 570,29	$ 1 460,98	812	-103,1 %	12 %	$ 0,11	53150
Jordan	Asia	No			9,90	$ 4 087,94		1888	96,8 %	1 %		3509
Kazakhstan	Asia	**Yes**			18,40	$ 7 714,69		5600	-116,9 %	10 %		13100
Kuwait	Asia	No			4,20	$ 27 359,23		15213	-391,1 %	0 %		33180
Kyrgyzstan	Asia	**Yes**			6,13	$ 1 077,60		1941	49,5 %	103 %		773
Laos	Asia	**Yes**			6,96	$ 2 338,69		N/A	N/A	261 %		0
Latvia	Europe	No			1,93	$ 14 071,03		3507	45,2 %	41 %		2200
Lebanon	Asia	No			6,09	$ 8 257,29		2893	97,9 %	3 %		150
Liechtenstein	Europe	**Yes**			0,04	N/A		N/A	N/A	0 %		#N/A
Lithuania	Europe	No			2,88	$ 14 900,78		3821	75,0 %	18 %		2930
Luxembourg	Europe	**Yes**			0,59	$ 100 738,68		13915	96,3 %	8 %		1108
Macedonia	Europe	**Yes**			2,09	$ 5 237,15		3497	51,8 %	31 %		471
Malaysia	Asia	No			32,04	$ 9 508,24		4596	-5,5 %	11 %		40670
Maldives	Asia	No			0,44	$ 9 875,28		N/A	N/A	0 %		0
Malta	Europe	No			0,43	$ 25 145,39		5007	98,4 %	5 %		0
Moldova	Europe	**Yes**			4,04	$ 1 900,23		1386	90,0 %	7 %		3480
Monaco	Europe	No			0,04	N/A		N/A	N/A	0 %		#N/A
Mongolia	Asia	**Yes**			3,12	$ 3 694,08		2018	-168,1 %	3 %		0
Montenegro	Europe	No			0,63	$ 7 028,93		4612	27,6 %	52 %		0
Myanmar	Asia	No			53,86	$ 1 195,52		217	-33,0 %	72 %		#N/A
Nepal	Asia	**Yes**			29,62	$ 729,12		139	16,7 %	93 %		0
Japan	Asia	No	X	Energy imports	127,19	$ 38 900,57	$ 34 566,26	7820	93,0 %	18 %	$ 0,10	123600
North Korea	Asia	No			25,61	$ -		600	-74,8 %	88 %		#N/A
Norway	Europe	No			5,35	$ 70 868,12		23000	-581,3 %	105 %		9428
Oman	Asia	No			4,83	$ 14 982,36		6554	-206,2 %	0 %		38030
Pakistan	Asia	No			200,81	$ 1 443,63		471	24,1 %	40 %		48060
Palestine	Asia	No			5,05	N/A		N/A	N/A	0 %		#N/A
Philippines	Asia	No			106,51	$ 2 951,07		699	45,8 %	28 %		3196
Poland	Europe	No			38,10	$ 12 414,10		3972	28,5 %	16 %		26780
Portugal	Europe	No			10,29	$ 19 838,03		4663	76,9 %	52 %		8371
Qatar	Asia	No			2,69	$ 59 324,34		15309	-399,0 %	0 %		49640
Romania	Europe	No			19,58	$ 9 522,77		2584	16,8 %	54 %		17330
Russia	Asia	No			143,96	$ 8 748,37		6603	-83,7 %	19 %		418900
San Marino	Europe	**Yes**			0,03	$ 47 908,56		N/A	N/A	0 %		#N/A
Saudi Arabia	Asia	No			33,55	$ 20 028,65		9444	-191,5 %	0 %		102300
Serbia	Europe	**Yes**			8,76	$ 5 426,20		4272	28,8 %	37 %		2250
Singapore	Asia	No			5,79	$ 52 962,49		8845	97,7 %	3 %		19730
Slovakia	Europe	**Yes**			5,45	$ 16 529,54		5137	60,7 %	23 %		7868
Slovenia	Europe	No			2,08	$ 21 650,21		6728	48,5 %	30 %		837

Countries	Renewable energy composition														Emissions	Waste
	TWh	TWh	TWh	TWh	TWh	TWh	TWh	%	%	%	%	%	TWh	TWh	t/capita	%
	2015,00	2015,00	2015,00	2015,00	2015,00	2015,00	2015	2015	2015	2015	2015	2015	2015	2015	2014	2014 or latest
Country	Hydropower	Wind	Solar	Geothermal	Bio	Wave & tidal	Hydro share of RE	Wind share of RE	Solar share of RE	Geothermal share of RE	Bio share of RE	Wave & tidal share of RE	Combined RE	Total consumption	CO_2 emissions	Muncipal waste recycled
Italy	45,02	14,71	22,59	5,82	21,83	0	41 %	13 %	21 %	5 %	20 %	0 %	109,962	296	5,27	
Indonesia	13,60	0,00	0,01	10,05	1,13	0	55 %	0 %	0 %	41 %	5 %	0 %	24,797	199,3	1,82	2 %
Jordan	0,05	0,12	0,00	0	0,01	0	28 %	67 %	1 %	0 %	3 %	0 %	0,183	16,13	3,00	
Kazakhstan	9,18	0,13	0,05	0	0	0	98 %	1 %	1 %	0 %	0 %	0 %	9,358	95,26	14,36	
Kuwait	0	0	0	0	0	0	0 %	0 %	0 %	0 %	0 %	0 %	0	54,11	25,22	
Kyrgyzstan	10,99	0	0	0	0	0	100 %	0 %	0 %	0 %	0 %	0 %	10,989	10,68	1,65	
Laos	11,06	0	0	0	0	0	100 %	0 %	0 %	0 %	0 %	0 %	11,06	4,239	0,30	
Latvia	1,84	0,15	0,00	0	0,77	0	67 %	5 %	0 %	0 %	28 %	0 %	2,757	6,712	3,50	
Lebanon	0,47	0,01	0	0	0	0	99 %	1 %	0 %	0 %	0 %	0 %	0,48	15,66	4,30	
Liechtenstein	N/A	N/A	N/A	N/A	N/A	N/A	0 %	0 %	0 %	0 %	0 %	0 %	N/A	0,3936	1,19	
Lithuania	0,35	0,81	0,07	0	0,51	0	20 %	47 %	4 %	0 %	29 %	0 %	1,733	9,848	4,38	
Luxembourg	0,10	0,10	0,10	0	0,19	0	19 %	21 %	21 %	0 %	39 %	0 %	0,493	6,178	17,36	
Macedonia	1,85	0,12	0,02	0	0	0	93 %	6 %	1 %	0 %	0 %	0 %	1,986	6,455	3,61	
Malaysia	13,79	0	0,27	0	0,75	0	93 %	0 %	2 %	0 %	5 %	0 %	14,806	133	8,03	
Maldives	0	0	0	0	0	0	0 %	0 %	0 %	0 %	0 %	0 %	0	0,3255	3,27	
Malta	0	0	0,09	0	0,01	0	0 %	0 %	93 %	0 %	7 %	0 %	0,097	2,103	5,49	
Moldova	0,31	0,00	0,00	0	0,02	0	94 %	1 %	1 %	0 %	5 %	0 %	0,324	4,611	1,39	
Monaco	N/A	N/A	N/A	N/A	N/A	N/A	0 %	0 %	0 %	0 %	0 %	0 %	N/A	N/A	N/A	
Mongolia	0	0,17	0	0	0	0	0 %	100 %	0 %	0 %	0 %	0 %	0,17	5,785	7,13	
Montenegro	1,48	0	0	0	0	0	100 %	0 %	0 %	0 %	0 %	0 %	1,476	2,834	3,56	
Myanmar	9,31	0	0	0	0	0	100 %	0 %	0 %	0 %	0 %	0 %	9,305	12,91	0,42	
Nepal	3,46	0	0,03	0	0	0	99 %	0 %	1 %	0 %	0 %	0 %	3,493	3,746	0,28	
Japan	84,85	5,16	35,86	2,34	41,46	0	50 %	3 %	21 %	1 %	24 %	0 %	169,66	933,6	9,54	19 %
North Korea	9,90	0	0	0	0	0	100 %	0 %	0 %	0 %	0 %	0 %	9,9	11,24	1,61	
Norway	137,31	2,52	0	0	0,42	0	98 %	2 %	0 %	0 %	0 %	0 %	140,24	133,1	9,27	
Oman	0	0	0	0	0	0	0 %	0 %	0 %	0 %	0 %	0 %	0	27,62	15,44	
Pakistan	33,66	0,84	0	0	0	0	98 %	2 %	0 %	0 %	0 %	0 %	34,504	85,9	0,90	
Palestine	0	0	0	0	0	0	0 %	0 %	0 %	0 %	0 %	0 %	0	N/A	N/A	
Philippines	8,58	0,75	0,14	11,04	0,37	0	41 %	4 %	1 %	53 %	2 %	0 %	20,875	74,15	1,06	
Poland	1,81	10,73	0,06	0	10,01	0	8 %	47 %	0 %	0 %	44 %	0 %	22,61	141,3	7,52	
Portugal	8,62	11,48	0,79	0,18	3,40	0	35 %	47 %	3 %	1 %	14 %	0 %	24,477	47,03	4,33	
Qatar	0	0	0	0	0	0	0 %	0 %	0 %	0 %	0 %	0 %	0	36,53	45,42	
Romania	16,47	7,06	1,98	0	0,52	0	63 %	27 %	8 %	0 %	2 %	0 %	26,031	48,28	3,52	
Russia	166,31	0,15	0,34	0,46	2,82	0	98 %	0 %	0 %	0 %	2 %	0 %	170,077	890,1	11,86	
San Marino	N/A	N/A	N/A	N/A	N/A	N/A	0 %	0 %	0 %	0 %	0 %	0 %	N/A	N/A	N/A	
Saudi Arabia	0	0	0,00	0	0	0	0 %	0 %	100 %	0 %	0 %	0 %	0,001	292,8	19,53	
Serbia	9,98	0,00	0,01	0	0,03	0	100 %	0 %	0 %	0 %	0 %	0 %	10,018	26,78	5,28	
Singapore	0	0	0,06	0	1,49	0	0 %	0 %	4 %	0 %	96 %	0 %	1,551	46,6	10,31	
Slovakia	3,70	0,01	0,51	0	1,69	0	63 %	0 %	9 %	0 %	29 %	0 %	5,901	25,87	5,66	
Slovenia	3,75	0,01	0,27	0	0,28	0	87 %	0 %	6 %	0 %	6 %	0 %	4,305	14,57	6,21	

Countries			Selection		Demographic key figures			Energy key figures				
					Mil. of people	USD	USD/Year	kWh/capita	% of net consumption	% of total	USD/MWh	million m^3
					2018	2016	2017 or latest	2014	2016 or latest available	2015	2017 or latest	2016 or latest
Country	Continent	Landlocked	Selected	Criteria	Population	GDP per capita	Average wages	Electric power consumption	Energy imports	RE share	Price of electricity	Natural gas consumption
South Korea	Asia	No	X	Energy imports, Low RE share	51,16	$ 27 538,81	$ 39 414,46	10497	81,4 %	2 %	$ 0,21	69630
Spain	Europe	No			46,40	$ 26 616,49		5356	71,4 %	40 %		39840
Sri Lanka	Asia	No			20,95	$ 3 909,99		535	50,3 %	54 %		0
Sweden	Europe	No			9,98	$ 51 844,76		13480	24,7 %	82 %		1250
Switzerland	Europe	**Yes**			8,54	$ 79 887,52		7520	50,1 %	72 %		4639
Syria	Asia	No			18,28	N/A		950	47,8 %	3 %		4900
Taiwan	Asia	No			23,69	N/A		N/A	N/A	4 %		31710
Tajikistan	Asia	**Yes**			9,11	$ 795,84		1480	36,2 %	129 %		189
Thailand	Asia	No			69,18	$ 5 910,62		2540	41,6 %	9 %		114800
Timor-Leste	Asia	No			1,32	$ 1 405,39		N/A	N/A	0 %		0
Turkey	Europe	No			81,92	$ 10 862,60		2855	75,2 %	38 %		81350
Turkmenistan	Asia	**Yes**			5,85	$ 6 389,33		2679	-191,5 %	0 %		67520
Ukraine	Europe	No			44,01	$ 2 185,73		3419	27,2 %	5 %		41100
United Arab Emira	Asia	No			9,54	$ 37 622,21		11264	-183,8 %	0 %		186000
United Kingdom	Europe	No			66,57	$ 40 367,04		5130	34,6 %	29 %		186200
Uzbekistan	Asia	**Yes**			32,36	$ 2 110,67		1645	-26,2 %	24 %		10440
Vietnam	Asia	No			96,49	$ 2 170,65		1411	-15,1 %	42 %		15500
Yemen	Asia	No			28,92	$ 990,33		216	-120,6 %	0 %		1190

Countries	Renewable energy composition														Emissions	Waste
	TWh	TWh	TWh	TWh	TWh	TWh	TWh	%	%	%	%	%	TWh	TWh	t/capita	%
	2015,00	2015,00	2015,00	2015,00	2015,00	2015,00	2015	2015	2015	2015	2015	2015	2015	2015	2014	2014 or latest
Country	Hydropower	Wind	Solar	Geothermal	Bio	Wave & tidal	Hydro share of RE	Wind share of RE	Solar share of RE	Geothermal share of RE	Bio share of RE	Wave & tidal share of RE	Combined RE	Total consumption	CO2 emissions	Muncipal waste recycled
South Korea	2,12	1,20	3,88	0	3,15	0,53	19 %	11 %	36 %	0 %	29 %	5 %	10,878	497	11,57	59 %
Spain	27,66	48,12	13,35	0	6,53	0	29 %	50 %	14 %	0 %	7 %	0 %	95,66	240,4	5,03	
Sri Lanka	5,91	0,34	0,02	0	0,06	0	93 %	5 %	0 %	0 %	1 %	0 %	6,327	11,72	0,89	
Sweden	74,73	16,27	0,10	0	11,97	0	73 %	16 %	0 %	0 %	12 %	0 %	103,067	125,4	4,48	
Switzerland	37,88	0,11	1,12	0	2,81	0	90 %	0 %	3 %	0 %	7 %	0 %	41,922	58,45	4,31	
Syria	0,41	0	0	0	0	0	100 %	0 %	0 %	0 %	0 %	0 %	0,409	13,96	1,60	
Taiwan	4,43	1,53	0,82	0	3,79	0	42 %	14 %	8 %	0 %	36 %	0 %	10,563	255,3	N/A	
Tajikistan	16,73	0	0	0	0	0	100 %	0 %	0 %	0 %	0 %	0 %	16,731	12,94	0,62	
Thailand	4,69	0,33	2,38	0,00	7,73	0	31 %	2 %	16 %	0 %	51 %	0 %	15,134	168,3	4,62	
Timor-Leste	0	0	0	0	0	0	0 %	0 %	0 %	0 %	0 %	0 %	0	0	0,39	
Turkey	65,86	11,59	0,19	2,92	1,35	0	80 %	14 %	0 %	4 %	2 %	0 %	81,911	213,2	4,49	
Turkmenistan	0,00	0	0	0	0	0	100 %	0 %	0 %	0 %	0 %	0 %	0,003	15,09	12,52	
Ukraine	5,34	1,08	0,48	0	0,15	0	76 %	15 %	7 %	0 %	2 %	0 %	7,048	133,4	5,02	
United Arab Emira	0	0,00	0,30	0	0	0	0 %	1 %	99 %	0 %	0 %	0 %	0,297	110,6	23,30	
United Kingdom	6,24	40,31	7,56	0	32,97	0,00	7 %	46 %	9 %	0 %	38 %	0 %	87,083	301,6	6,50	
Uzbekistan	11,70	0	0	0	0	0	100 %	0 %	0 %	0 %	0 %	0 %	11,7	48	3,42	
Vietnam	55,56	0,12	0	0	0,06	0	100 %	0 %	0 %	0 %	0 %	0 %	55,742	134,3	1,80	
Yemen	0	0	0	0	0	0	0 %	0 %	0 %	0 %	0 %	0 %	0	3,634	0,86	