Bachelor Integration Project

"Wind energy, Sustainable development, and the 2020 Goals in Groningen"

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Abstract

The production of renewable energy offshore and onshore through wind is a growing business. In 2016, 6.9 % of the total consumed energy in the Province of Groningen came from a natural resource and it needs to be 14% in 2020. It would be interesting to analyze how the Netherlands represented by the Province of Groningen is doing in order to achieve the agreed wind energy targets. Therefore, the goal of this research is to take a look into the future and into the reachability of these targets. Overviewing all ongoing and future wind park projects, analyzing the energy consumption profile and comparing them to the goals in 2020 and 2023. To conduct this research, specific data has to be requested from different organizations and comparisons will have to be made. The outcomes of these comparisons between targets, energy consumption and wind park projects will be leading to recommendations unique to the Province of Groningen for the years to come.

I. Introduction

1.1. Background Information

Since the relation between anthropogenic greenhouse gases emissions and climate change was scientifically proven, alternative ways to produce energy have been fostered in order to reduce the CO2 emission mainly from coal-fired power plant, transport, and industries.
And countries such as the Netherlands are working on a transition to a sustainable, reliable and affordable energy supply for their citizens. Reason for the majority of countries to sign the Paris agreement (2016) and before that the Kyoto protocol in 1992. In the latest agreement, a common target has been set at 14% of the total consumed energy is coming from renewable sources in 2020. While increasing this percentage up to 16 % in 2023.
While those agreements are the same for every signing party, the ways to achieve them are different. The Dutch government has made agreements with 40 parties, including employers, trade union and environmental organizations, written down in the “Energieakkoord”. Agreed is to no more emission of greenhouse gases, such as CO2 in 2050 and specific targets for each renewable resource.
This study concentrates itself on renewable energy producing through the wind as a natural resource, both on land and at sea. And the Netherlands, have been progressive in terms of wind energy production and technology.

Looking into the reachability of the specific targets for onshore and offshore wind energy will be the main theme during this Integration Project, while documenting the new developments for the years to come in Groningen and trying to take a look into the future in order to see if the targets can be met with the current development or if extra new projects need to be developed. The reason behind choosing the Provincie Groningen is that, in 2016, Groningen has behind Flevoland, the highest production power of wind energy of all provinces and it has interesting current projects both onshore and offshore.

1.2. Research Goal

This research proposal is aimed at assessing the development of onshore and offshore wind energy production and demand in Province of Groningen, the Netherlands. Current and future projects under construction or projects in design phase will be described. The increase in energy demand in the Province of Groningen and comparing it to the development of wind energy production in the same area and the agreed targets for 2020 will be analyzed. The research is in Energy Engineering.

For this integration project, the scope will exclude the improvement grid infrastructure storage of electricity and production of all other renewable energy. The time frame has been set from 2017 to 2023 and the expectation of technological evolution of how to produce more efficiently wind energy is also out of the scope. The analyze will be limited to existing predictions, and no new predictions will be made in this research.
Finally, a geographic constraint will be at the Provincie Groningen. The focus will lie on wind energy onshore and offshore in the Provincie Groningen because first, the conditions for on/offshore wind energy in the Netherlands are excellent: relatively shallow waters, good wind resource, good harbor facilities, experienced industry and a robust support system. Second, wind energy has, according to some the biggest potential in terms of renewable energy in the Netherlands and in the Provincie Groningen has the right infrastructure already in place. Finally, the Provincie Groningen has some large wind turbine parks planned to be constructed or in place on land and has the advantage of being a province at sea, so offshore wind-energy production will be included.

1.3. Problem Analysis

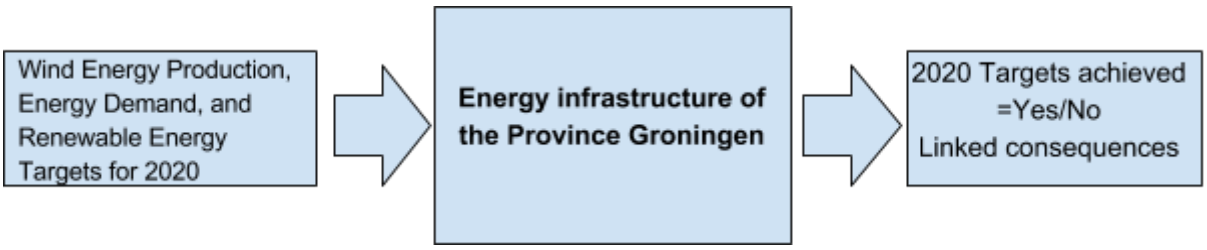
The problem owner in this report is Laiz Souto. This Integration project will be a small part of an over coupling study from Laiz Souto. Worldwide, with climate change, we have a common problem, involving every one of us. Climate change, a change in global or regional climate patterns, in particular a change apparent from the mid to late 20th century onwards and largely attributed to the increased levels of atmospheric carbon dioxide produced by the use of fossil fuels and by other human activities. The Netherlands is trying, through renewable energy sources such as wind energy, to reduce the impact of climate change. In 2016, renewable energy sources accounted for 5.9 % of total Dutch energy consumption. (CBS)
The Dutch government has planned and agreed upon that renewables energy be 14 % of the total Dutch energy consumption for 2020.
In order to achieve it, the government, which has an enormous influence on the permits, emplacement, and subventions given to new onshore/offshore wind farms, invest in the technological development of wind energy. Making a big impact to make the production of renewable energy more efficient.
Not only does the government and the province have a great influence but also the Dutch citizens themselves are involved because climate change affects everyone, and citizens are starting to demand green-energy, and so companies willing to fulfill the wishes of their customers invest in or produce renewable energy.

There are several stakeholders in this projects, the results will be used as a part bigger research project done by my supervisor Laiz Souto, and also researchers in general in this specific domain would be interested in the results.

Secondly, energy companies located in Groningen investing in wind energy, partly due to subventions from the Dutch Government but also in order to fulfill the increasing demand for green energy from the Groningen citizens. Those companies have invested in further development of efficient ways to produce green energy through wind energy.
Some wind parks in Groningen are in the possession of energy firms mentioned above, but most are in public hands (provinces or municipalities). And some are in shared ownership with developers. The owners would have a share of interest due to the use of different projections/expectations concerning their investment.

Last, the Province of Groningen has an interest in this Integration Project, due to the focus on their development in wind energy and ongoing projects within their geographical perimeter. The outcome could make them aware that more projects need to be created and solutions to be found in order to fulfill the agreed targets for 2020. For example, the plans to build one of the biggest wind turbine parks at sea (above “de Wadden”).

As input has been chosen, to assemble wind energy production data, energy demand data, and renewable energy targets for 2020. The system receiving this input will be the energy infrastructure (which includes generation, transmission, distribution, and consumption of energy as well as the planning, deployment, and operation of the grid) in the Province of Groningen. As output energy targets for 2020/2023 are achieved and if not achieved the required steps in order to meet the targets are shown. (Additional projects)



1.4. Methodology

The methodology used in this research is the empirical cycle, which functions as a guide, as shown in Figure 1.A. It captures the process of gaining knowledge by observation and experience. The choice was between 2 cycles, the Regulative Cycle or the Empirical Cycle, the first one is based on acting, design, normative and the researcher is an actor of the project, while the latter one is explaining, based on theory, predictive and the researcher is a spectator
The Empirical Cycle will be applied here because as a researcher in this subject, I can only be a spectator and base my research on a combination of projections for the upcoming years from reliable sources. The Empirical Cycle, which functions as a

guide, is shown below. It captures the process of gaining knowledge by observation and experience.

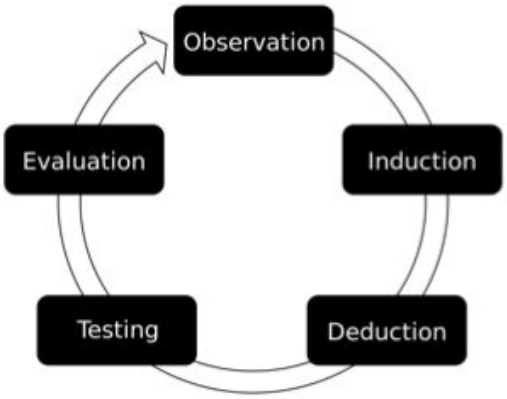


Figure 1: Empirical Cycle

First, the collection of data and information from different agencies (Enexis/Provincie Groningen/IEA/UNIDO) will be in the Observation part of the Empirical cycle. Secondly, an analysis of the collected data and information will be done as well as different comparisons between collected data and information (Induction /Deduction/Testing).
The comparisons will lead to a total picture and we will give a better understanding and idea of currently available infrastructure and ongoing projects. If Additional projects will be needed to achieve 2020 goals, is the Evaluation stage of the Empirical cycle.

1.5. Risk Analysis

The feasibility of this project depends on finding the right numbers and projections in terms of energy demand from Enexis and the rightful approximations of the energy targets given to the Netherlands and now approximated for the Province Groningen. Targets can be found on the websites of IRENA (International Renewable Energy Agency), IEA (International Energy Agency) and IPCC (Intergovernmental Panel on Climate Change). The feasibility will also be linked to the openness of new wind energy projects in Provincie Groningen to deliver their data and information. In case of a non-openness from the projects, the Province Groningen will have the available data as well due to their direct implication in these projects.

II. Literature

2.1. Research sub-questions :

Several research questions are formulated. Answering the first three questions will give a solid base to create an overview picture of wind energy developments, targets, and consumption. The answers to these questions will be derived from the literature and data found in Appendices. Answering all the questions below will finally lead towards the goal of this research. The research questions are :

- According to the climate Agreements for 2020, what are the targets given to the Netherlands and especially to the Provincie Groningen?

- What are the existing/ongoing/future projects for wind energy development with the Provincie Groningen?

- What will be the increase in energy demand and consumption from now to 2020?

- Considering climate agreement for 2020, how much wind energy is needed to achieve agreed targets?

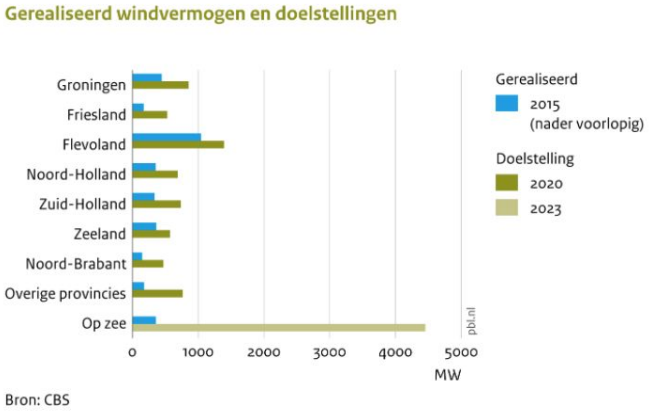
- Considering the full potential for wind energy in Groningen, how much energy can be covered now and by 2020?

- Will the targets give to the Province of Groningen in 2020 be achieved by the current infrastructure and the ongoing projects until 2020?

III. Wind energy targets Onshore and Offshore

3.1. Onshore

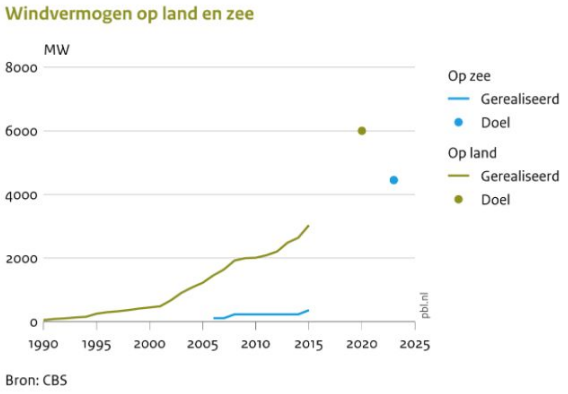
The Dutch Government and their provinces agreed to a wind energy onshore goal of 6.000 megawatts (MW) in 2020. This will produce enough electricity to supply seven million households. Each of the provinces has made an agreement with the government for a specific target. The Groningen Province has been given 855,5 MW.



Graph 1: Wind Power Goals specific for each Province

3.2. Offshore

In 2015, the total power capacity of offshore wind turbines in the Netherlands was 357 MW. With the signing of the Energieakkoord, there will be a minimal collection of 4.450 MW from turbines offshore in 2023. This will supply five millions households of electricity on a yearly basis. In 2023, wind-energy production offshore is projected to amount to 3,1% of all produced energy in the Netherlands, helping to reach the target of 16% of total produced energy being renewable energy in 2023.



Graph 2: Wind Power onshore and offshore Goals.

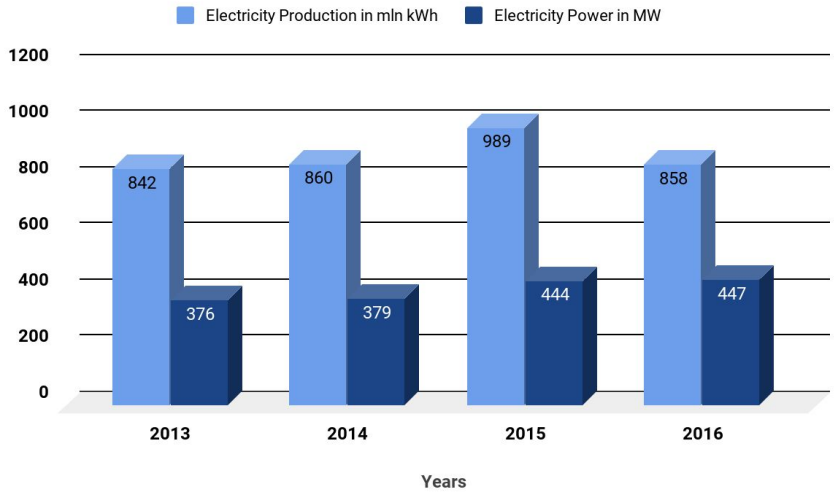
IV. Existing and future Wind Parks

4.1. Existing Infrastructure Onshore

Project Name	*Nb of turbines*	*Max MW per turbines*	*Brand turbines*
Delfzijl Noord	19	3.3	Nordex
Delfzijl Zuid	34	2.3 - 2	Enercon
GroWind	20	3 - 4.5	Vestas/Lagerwey
Harkstede	12	0.08	Lagerwey
Meedhuizen	5	0.6	Nordex
Westereems	69	3 - 6.1	Vestas/Enercon
Wintermolen	17	0.08	Lagerwey

Table 1: Windparks in Province of Groningen

In table 1.A., the wind parks with the highest number of turbines are stated but there are a lot of alone standing turbines all across the Province of Groningen, 42 turbines to be exact, which are often newer turbines. Newer turbines produce more electricity, which can be seen in table 1.A. where the power range is between 80 kW and 6150 kW. This is due to the different installations dates, wind parks as Harkstede and Wintermolen have been constructed respectively 1993 and 1995. While Westereems and GroWind have been partially constructed in respectively 2015 and 2017. The difference in power production of newer and older wind turbines. **(Appendix C)**
Onshore, the current electrical power in the Province of Groningen is equal to 11% of the total, which corresponds to 447,79 MW. **(Appendix D)**
The province of Groningen has the second highest electrical power through wind in the Netherlands behind Flevoland leading with a percentage of 28% of the total, corresponding to 1185,41 MW.



Graph 3: Wind energy Power and Production onshore Province of Groningen 2013-2016 (CBS)

The electricity produced by the Province of Groningen in 2016 is 858 mln kWh (million kilowatt-hours), which compared to the total production of electricity in the Netherlands 5892 mln kWh is 14,56 %. (According to Centraal Bureau voor de Statistiek)

4.2. Existing Infrastructure Offshore

Offshore, the current electrical power in the Netherlands is equal to 23% of the total, which corresponds to 957 MW. (According to https://windstats.nl)

Along the Dutch coast, there are 4 offshore wind parks, from which the Gemini Windpark is the only one under the supervision of the Groningen Province. The Gemini Windpark, composed of the “Buitengaats” part and the “Zee-energie” part, opened on May 8th, 2017, instantly becoming the second biggest wind park in the world. A partnership between sustainable energy company Northland Power (60%), wind turbines builder Siemens Wind Power (20%), the Dutch maritime contractor Van Oord (10%) and the sustainable waste, raw materials, and energy company HVC (10%), made this 600 MW producing wind park possible.
Gemini is located in the Dutch part of the North Sea, at 85 kilometers off the coastline, in the north of Groningen. On this specific location, the highest and most constant wind speeds are reached in the North Sea. In total, the Gemini Windpark host 150 turbines, divided equally over two locations, one north of Ameland and the other 55 kilometers north of Schiermonnikoog.

Windpark Gemini is composed of 150 turbines, each having a production power of 4 MW which leads to a total production power of 600 MW, almost ⅔ of the total offshore production power installed in Dutch waters.

Furthermore, 3 offshore wind parks, first, Windpark Eneco Luchterduinen, is owned by Eneco and Mitsubishi Corporation and comprises 43 Vestas 3 MW turbines located 23 km off the coast and has a total production power of 129 MW. Secondly, Windpark Egmond aan Zee (OWEZ), lies 10-18 km off the coast and comprises 36 Vestas 3 MW turbines, in total 108 MW. It is owned by Noordzeewind, a joint venture between NUON and oil company Shell.
And finally, Windpark Princess Amalia, owned by utility company Eneco located outside the 12-mile zone, 23 km off the coast. It comprises 60 Vestas 2 MW turbines, accommodating 120 MW in total.

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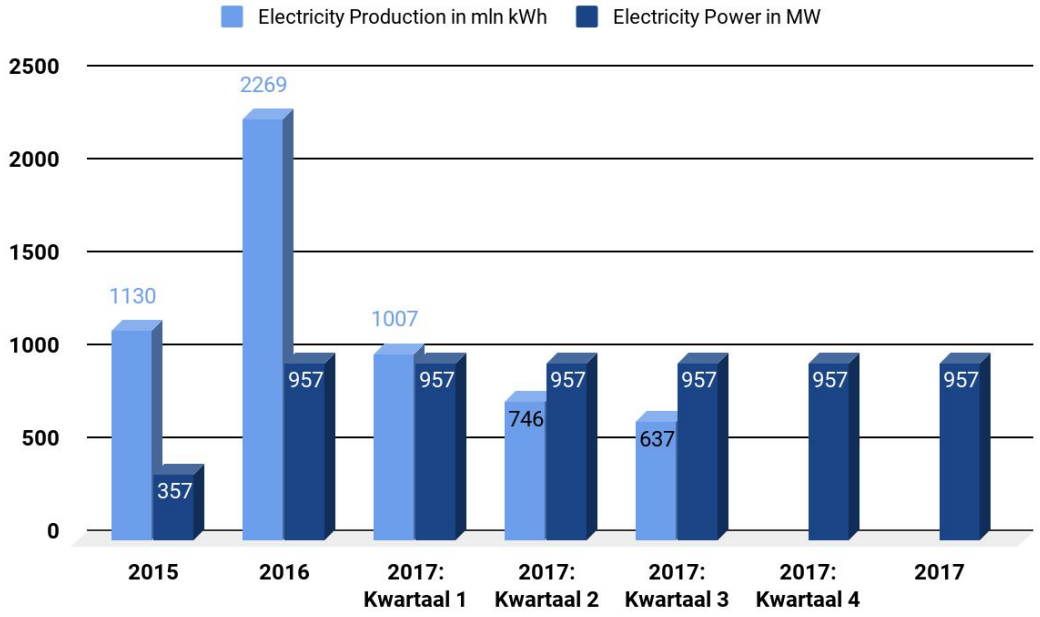


Graph 4: Overall Wind Energy electricity production Offshore (CBS)

In 2016, the total production of offshore electricity in the Netherlands was 2269 mln kWh, while in 2017 with three months left, already 2390 mln kWh has been produced.

4.3. Current Projects Onshore

In the Province of Groningen, situated in the north of the Netherlands, eight wind parks onshore are under construction or in the design phase. All eight wind parks are placed inside three areas: Delfzijl, Eemshaven, and N33. All projects are to be delivered and the wind turbines have to supply electricity to the electricity grid before or on 31 December 2020. Information available for every project is coming from a document published by the Province of Groningen. **[10]**

A. Delfzijl uitbreiding Zuid

Originally, Delfzijl Zuid started with 34 turbines producing 75 MW, with the projected expansion of 16 additional wind turbines delivering a power of 3,0-5,0 MW, leads to a total additional power of approximately 48 MW. The planning for this expansion is as follows: during 2018-2019, the financing and preparation of construction will be done, during 2019-2020, the wind turbines will be constructed and in 2020, wind park will be ready for exploitation. Developers on this project are Eneco, ZuidZes BV, Straathof Beheer BV and HiNerg BV.

B. Oosterhorn (Delfzijl)

The wind park constructed on a company's terrain Oosterhorn, in Delfzijl, will accommodate a total power of 54 MW, delivered by 18 wind turbines. This project is financed by Eneco Wind B.V. as an authorized representative for Millenergy BV (Yard Energy and Eneco).

C. Geefsweer (Delfzijl)

Wind park Geefsweer is an initiative of Millenergy, a collaboration of Eneco and Yard Energy. It states a wind park of 14 turbines, producing approximately 60 MW.

D. Oostpolder (Eemshaven)

Windpark Oostpolder is an initiative of a group farmers living in the area, in collaboration with Innogy (formerly RWE). 21 wind turbines will be constructed with a total power of approximately 90 MW. Innogy, owner of an existing wind park situated close by will shut down ten turbines, with a total power of 30 MW, otherwise the to develop turbines would be located to close. At the end of the count, 60 MW will be added by Windpark Oostpolder.

E. Oostpolderdijk (Eemshaven)

Windpark Oostpolderdijk is a project from Innogy (formerly RWE) and counts three turbines, delivering approximately 10 MW.

F. Zuidoost (Eemshaven)

Consisting of 6 turbines, good for a total power of 24 MW. The developers are Bakker Bierum en Intocon.

G. Eemshaven West

At this stage, there are two developers active for this project, known as NUON en Innogy (formerly RWE). The wind park will have a total power of 120 MW, which places it under the supervision of the Government. A project becomes automatically a Government project when it will be producing more than 100 MW. Additionally, a test field consisting of three to four prototypes offshore wind turbines and five research turbines.

H. N33

Windpark N33 is an initiative of developer Yard Energy in collaboration with Innogy. This wind park is counting 35 wind turbines, of those, 27 are situated in the northern cluster and 8 next to the N33 close to Veendam. The total produced power will lay around 120 MW which makes it a Governmental project.

The delivery of these projects mentioned above but also projects all over the Netherlands will help reach this expected wind energy production mentioned below.
The expected wind energy production onshore by the ECN in the Netherlands can be deducted from green line in the graph from **Appendix A** is 12.5 TWh in 2020 and 15.2 TWh in 2023, corresponding respectively to 12500 GWh and 15200 GWh.
And for the Province of Groningen only, the expected wind energy production onshore is 2500 GWh in 2020 and 3800 GWh in 2023. **(Appendix I)**

4.4. Current projects Offshore

Since the production of offshore wind energy is divided between provinces, all ongoing offshore wind farms projects on the Dutch coast are taken into account. Five wind parks in the area of Borssele, in Zeeland, Borssele I and II each minimal 350 MW will be finished in respectively 2020 and 2021 by Dong Energy Borssele 1 B.V, a Danish company.
Borssele III and IV, respectively generating a wind energy power of 330 MW and 350 MW will be constructed by Blauwwind II C.V. (a consortium of Shell, Van Oord, Eneco and Diamond Generating Europe). Finally, the tender for constructing Borssele V will open in January 2018 and can accommodate 20 MW. Last three Borssele sites will finish in respectively 2021, 2022 and 2023, leading to an accommodation of 1400 MW by the Borssele sites. **[1]**

A wind park named “Hollandse Kust Zuid” will follow, split up into 4 parts each delivering 350 MW in power. Finally, a wind park named “ Hollandse Kust Noord” completes the offshore projects and will bring the offshore energy power up to 4457 MW. Tenders for “Hollandse Kust Zuid” III / IV and for “Hollandse Kust Noord” will respectively be held in 2018 and 2019. Those 5 wind parks together will provide electricity for almost five million households.

The total expected wind energy production offshore by ECN in the Netherlands is deducted from the pink line in the graph from **Appendix A** is 9.8 TWh in 2020 and 18 TWh in 2023, corresponding respectively to 9800 GWh and 18000 GWh.
Comparing the expected wind energy production onshore and offshore by ECN shows that total of offshore production will exceed the total of onshore production around 2021, and by 2023 the differences have been enlarged by almost 3000 GWh.

In the Province of Groningen, before 2023, no new projects will be ready, this is due to the desire to have Gemini-West operating in 2024, starting with a tender begin 2020, and creating 700-1000 MW.
In a long-term strategy, the Province of Groningen turned to consultancy bureau BLIX Consultancy BV, in order to plot the potential of wind energy offshore in a research called “Offshore wind boven de Wadden” **[3]**. A rollout strategy for offshore wind energy has been chosen, which is between 2025 and 2029, every year 2000 MW of operational wind energy power is placed and constructed in the area around the existing Gemini wind parks and above the navigation channel.
This research included the determination of best locations for turbines, their cost, and employment opportunities for the Groningen citizens. Coming out of this research, the area above the Wadden can potentially have a power production of 11 GW, which is fifteen times the power delivered by Gemini, considered as one of the biggest wind parks in the world.
But the realization of offshore wind park Gemini has a relatively limited impact on the share of renewable energy in the Province of Groningen because only 3.3 % of the generated electricity will be allocated to the province of Groningen and also to their renewable energy mix.

V. Energy consumption projections

5.1. Projections for the Netherlands

MONITweb **[8]** is a website where the ECN policy studies can be found in the form of graphs on topics such as energy consumption, energy production and emission of greenhouse gases. The projections from the graphs made by the ECN for the energy consumption of all Dutch citizens is 250 petajoule (PJ) in 2020 and 310 PJ for 2023. Which respectively corresponds to 69450 GWh and 86100 GWh. **(Appendix B)**
Projections for onshore wind energy consumption is (42.1 PJ = 11694 GWh) in 2020 and (53.7 PJ = 14917 GWH) in 2023.
Projections for offshore wind energy consumption is (32.7 PJ = 9083 GWh) in 2020 and (65.6 PJ = 18222 GWh) in 2023. **(Appendix H)**

5.2. Projections by BLIX Consultancy BV (Groningen)

The current electricity demand in the Province of Groningen will rapidly grow due to the increasing consumption of data hotels, hydrogen production, ammonia production and Compressed Air Energy Storage (CAES). The electricity consumption from households and the current industry will not change as much and will in the nearby future have a smaller share in the total consumption in the Province of Groningen.
In this research, three future scenarios have been determined in order to propose full-scale projections for the future.

A. Scenario 1: Business as usual.
No significant growth or decrease in production and consumption. Only investments for which an investment decision has already been taken will be included. **(Appendix E)**

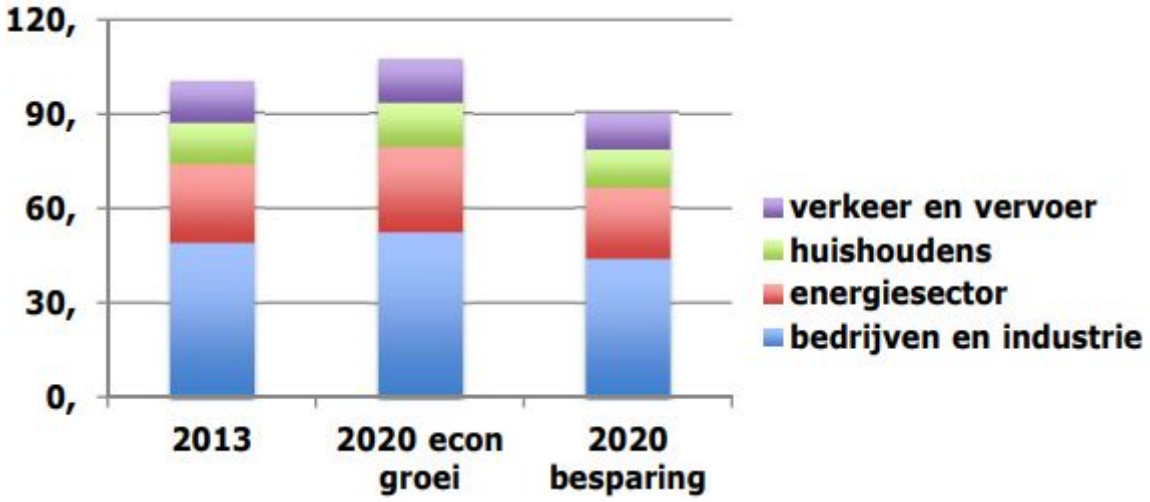
B. Scenario 2: Incremental Growth.
Additionally to scenario 1, the current production and the current and expected trends in energy consumption will be taken into account. “De Nationale Energieverkenning” will be used as a leading assumption base. **[9]**
“De Nationale Energieverkenning” has been written by several parties among which are governmental instances. On an annual basis, the NEV publishes the state of affairs concerning the energy production and consumption and provides an insight into the expected developments until 2035. **(Appendix F)**

C. Scenario 3: Green Transformation.
In this scenario, large-scale changes in a green manner will take place in the Eemsdelta Regio. Disappearing of old grey producers, interchanged for the implementation of all existing current green initiatives. In order to make transport

and industry more sustainable, renewable electricity is being used for the production of green hydrogen and green ammonia, among other things. **(Appendix G)**
Interpreted from this graph, is the projected consumption in 2020, which will be 6000 GWh and 11000 GWh in 2023 in the Province of Groningen. Scenario 3 will be used for the comparisons in future chapters because it is the only one with available data in this research.

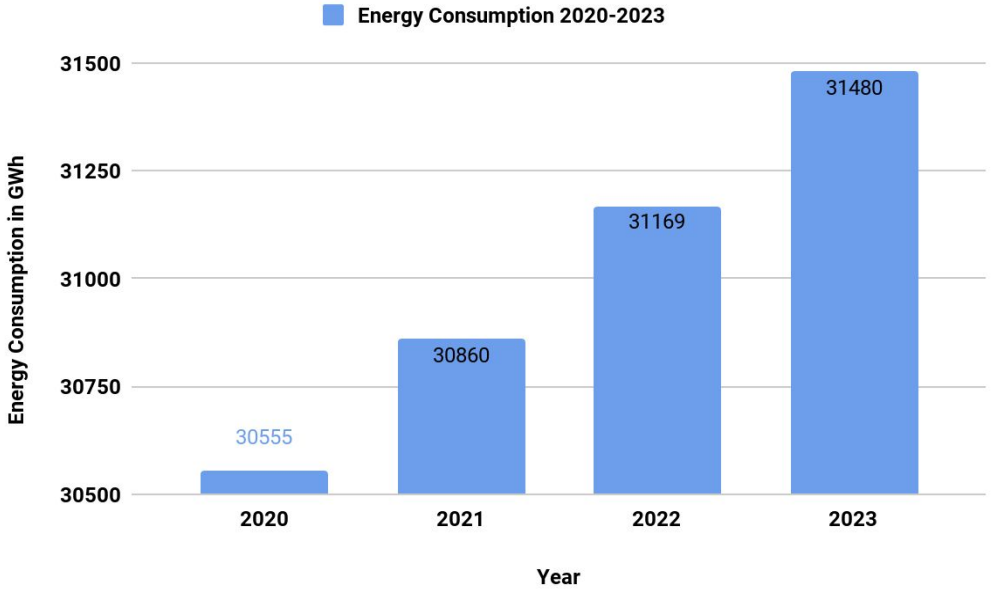
5.3. Projections Province of Groningen

The Province of Groningen has planned an energy transition, a plan made in 2013 in order to state and motivate their future plans with the province. In this report **[12]**, projections were made over energy use in 2020 as can be seen in the graph below.



Graph 5: Projected energy use in Province of Groningen by different sectors

In 2013, the total used energy in Province of Groningen was 100 PJ equal to 27778 GWh. And the projected energy usage in 2020 following the line of economic growth is 110 PJ, respectively 30555 GWh.
In 2023, it is expected that economic growth is good for an increase of 1 % per year, as seen in the graph below.

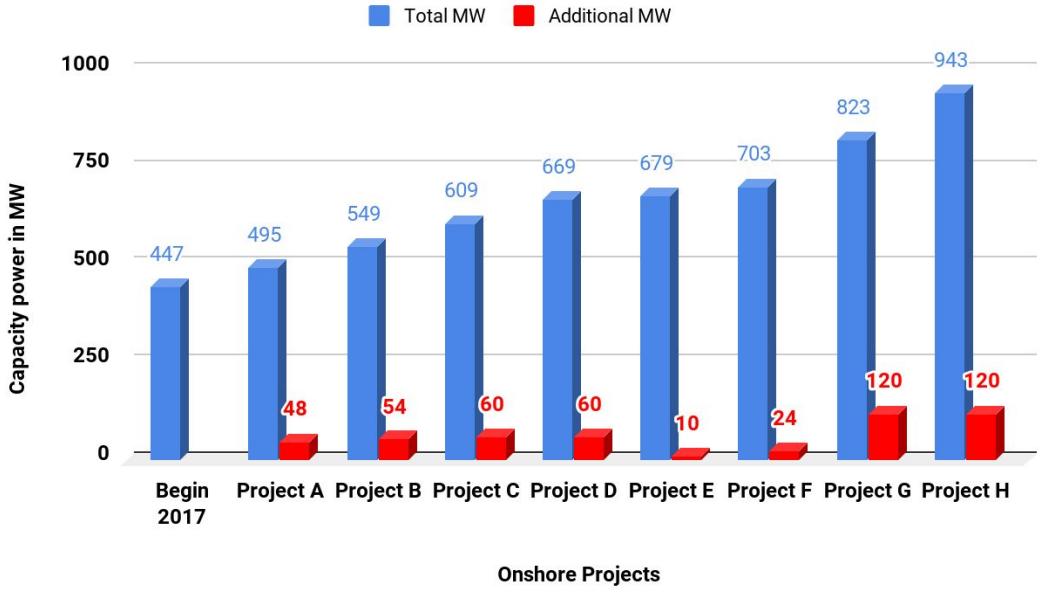


Graph 6: Project energy consumption Province of Groningen 2020-2023

VI. Comparing Wind Energy Targets and Future Infrastructure

6.1. Onshore

On 31st January 2013, the Province of Groningen agreed to an 855,5 MW onshore wind energy target reached before or on 31st December 2020. Which is almost an increase of 100%, compared to the wind electric power currently available on land, 447 MW. So in three years, 408,5 MW need to be installed through projects all over the Province of Groningen.
In Chapter 4.3, all 8 planned or ongoing projects are explained in detail and if all projects are developing as planned a total of 943 MW is reached at the end of 2020. Which would mean that the Province of Groningen will have reached their target and that the overall Dutch target of 6000 MW will become one step closer to being achieved.



Graph 7: Onshore Wind Power in 2020 In Province of Groningen

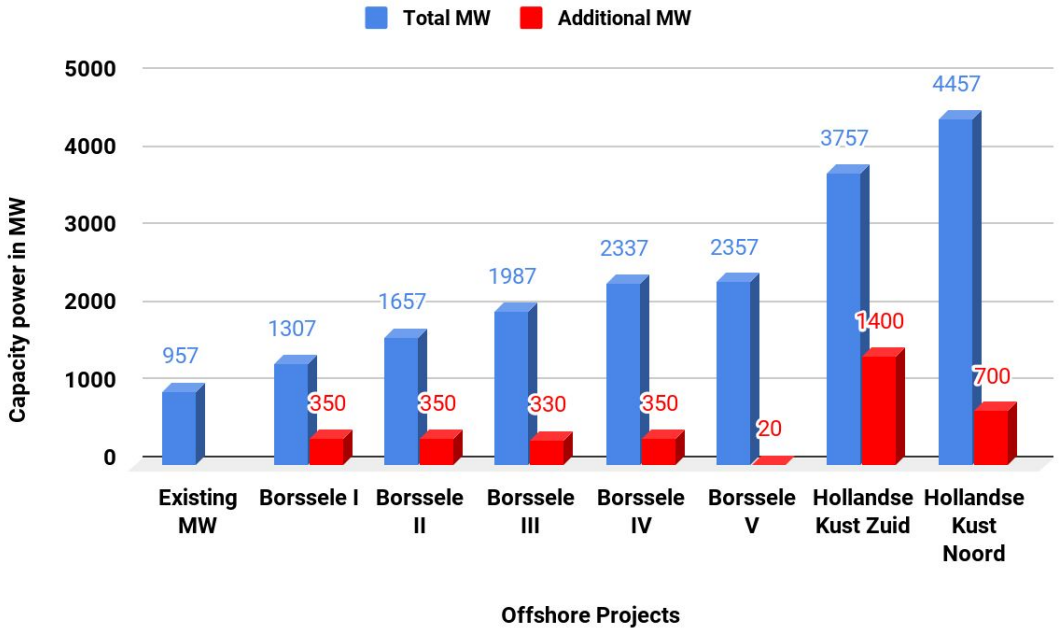
In Graph C, we can see how each project individually participates in achieving the needed power through wind energy. And can be concluded that if one project where to be delayed this would not influence the feasibility of the Province of Groningen passing the 855.5 MW line, only a delay in one of the two governmental projects (Project G and H) would jeopardize that.

6.2. Offshore

The Dutch Government created an overall target for offshore wind energy power of 4450 MW in 2023, in order to fulfill the 16% of the total used energy is coming from renewable sources.
In 2017, dutch offshore wind turbines power is 957 MW, which needs to be multiplied by 4.5 in order to reach the target. Exactly 600 MW of the in total installed 957 MW is coming from the Province of Groningen through wind park Gemini.

The Netherlands is composed of 12 provinces, from which 6 have a coastline and can possibly be a host of an offshore wind turbine park. With the creation of the second biggest wind park of the world, Province of Groningen took a leading role in offshore wind energy in the Netherlands, as witness is the research “Offshore wind Boven de Wadden” done by their order.

Further offshore wind power will not come from wind parks located above Groningen coastline, there are no concrete plans for additional wind parks on such a short notice. A tender in 2020 is planned for Gemini-West but in the most positive scenario, it will be up and running in 2024.
Since the received energy is divided between provinces and the Province of Groningen receives 3.3 % of the total produced offshore wind energy, the additional 3500 MW coming from planned projects along the Dutch coast, bringing the total offshore wind power at 4457 MW which is enough to reach the target.



Graph 8: Offshore Wind Power in 2020 In the Netherlands

VII. Comparing Wind Energy Targets and Energy Consumption

7.1 Onshore

Province of Groningen will in an ideal scenario have an onshore wind electricity power of 855,5 MW in 2020, while it is known that a 3 MW onshore wind turbine will produce around 6.5 mln kWh, respectively 6.5 GWh per year. So, in order to find the projected production of onshore wind turbines, we divide the total amount of ideal targeted power which is 855.5 MW but due to the fact that turbines cannot be installed in fractions, 858 MW will be used in the following calculations and divided by 3 MW and multiply it by the average energy produced by a 3 MW onshore wind turbine (6.5 GWh per year). Which leads to a projected total amount of produced energy of 1859 GWh per year, by onshore wind turbines in 2020.

$$(858 / 3) * 6.5 = 1859\ GWh$$

Comparing it to the projected consumption of the Province of Groningen will lead to the percentage, that onshore wind energy will cover the total consumed energy in 2020. In 2016, the total final used energy was 19 242,22 GWh **[15]**, which is a sum of the use of energy, both fossil and renewable energy sources by households, companies, institutions and traffic and transport. **(Appendix I)**
So primary energy use is not taken into account, which would have included the use of energy carriers for the conversion into other energy carriers (power plants) and deployment of energy carrier for making a product that is not an energy carriers in the chemical industry.
In 2020, the projected energy consumption is 30555 GWh and so the percentage can be calculated :

$$(1859 * 100) / 30555 = 6.1\ \%$$

So the onshore wind energy will deliver 6.1 % of the total projected consumption in the Province of Groningen if the target is met.

7.2. Offshore

The target for offshore wind energy has been set at 4450 MW in 2023 but used for calculation is 4453.2 MW in order to find an whole number. An offshore wind turbine of 3.6 MW produces enough energy to supply 3312 average EU households. In the Netherlands, an average household consumes 3400 kWh electricity per year. So in order to know which amount of electricity the Dutch wind parks produces per year in 2023, we perform the following steps :

Step 1 :

$$4453.2 \ / \ 3.6 \ = 1237 \ \textit{turbines with an average of} \ 3.6 \ MW$$

Step 2 :

$$3400 * 3312 = \ 11,260,800 \ kWh$$

Step 3 :

$$1237 * 11,260,800 \ = 13,929,609,600 \ kWh \ = 13,929.6 \ GWh$$

If the target will be achieved by the Dutch Government, offshore wind energy will produce $13,929.6$ GWh per year leaving aside improvement in wind turbines or production technology.
Part of the production by wind turbines at sea is also attributed to the Province of Groningen. There are no national agreements on who can claim this renewable energy so each Province receives a part of the wind energy produced at sea. The Province of Groningen has been awarded 3.3 % of all the offshore wind energy production.

$$13,929.6 * 0.033 \ = 459.7 \ GWh$$

We take into account the projected consumption the Groningen population in 2023 which is 31480.7 GWh as can be found in Chapter 5.3. Finally, divide the projected consumption by the project production in 2023 by offshore wind parks :

$$(459.7 * 100) \ / \ 31480.7 \ = 1.46 \ \%$$

In 2023, offshore wind energy will account for 1.46 % of the total consumed energy in the Province of Groningen.

VIII. Comparing Future Infrastructure and Energy Consumption

8.1. Onshore

In the scenario where all ongoing onshore projects for wind energy are coming through and finished in time, a total of 943 MW will be settled in the Province of Groningen. For the following calculations, 945 MW, which is order minimum project value that reaches the ideal target since we cannot install wind turbines in fractions.

To cover all of the energy consumption demand which is what essentially will need to happen in tens of years because the Province of Groningen wants for 2050 to have all energy consumed being produced through renewable ways. As seen in the previous chapter, a 3 MW onshore wind turbine will produce around 6.5 mln kWh, respectively 6.5 GWh per year. So, in order to find the projected production of onshore wind turbines

$$(945 / 3) * 6.5 = 2047.5\ GWh$$

Comparing it to the projected consumption of the Province of Groningen will lead to the percentage onshore wind energy will cover the total consumed energy in 2020. The projected electricity consumption in Province of Groningen is equal to 30555 GWh.

$$(2047.5 * 100) / 30555 = 6.7\ \%$$

Future onshore infrastructure will produce 6.7 % of energy consumed in the Province of Groningen in 2020.

8.2. Offshore

As written before the total amount of producing power from wind turbines offshore in the Netherlands is divided and the Province of Groningen receives only the percentage it has been awarded to, which equals 3.3 % of the total available power offshore 4457, used for the calculations is 4557.6 MW since we cannot install wind turbines in fractions, in 2023 if no more offshore wind farm projects arise. An offshore wind turbine of 3.6 MW produces enough energy to supply 3312 average EU households. In the Netherlands, an average household consumes 3400 kWh electricity per year. So in order to know which amount of electricity offshore wind parks produces per year, we perform the following steps :

Step 1 :

$$4557.6 / 3.6 = 1266 \textit{ turbines with an average of } 3.6\ MW$$

Step 2 :

$$3400 * 3312 = 11,260,800\ kWh$$

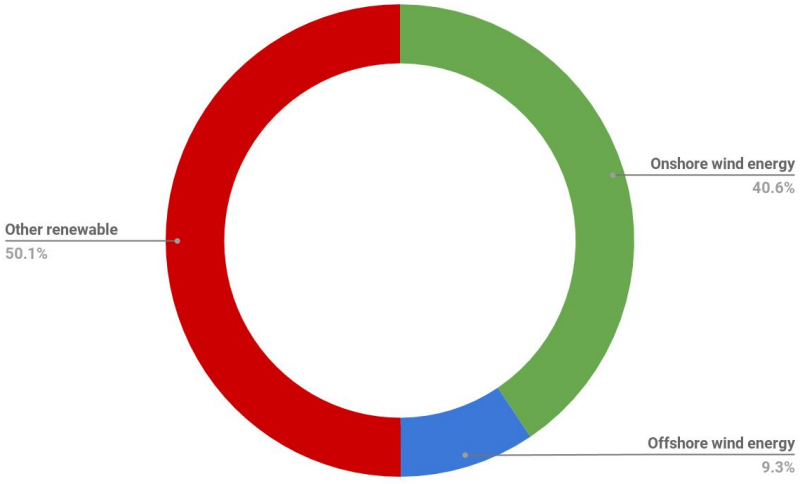
Step 3 :

$$1266 * 11,260,800 * 0.033 = 470,453,702\ kWh = 470.4\ GWh$$

The Province of Groningen will be awarded 470.4 GWh per year and since the targets for wind energy offshore has been set in 2023, we take into account the projected consumption of the Province of Groningen in 2023 which is 31480.7 GWh as can be found in Chapter 5.3. Finally, divide the projected consumption by the project production in 2023 by offshore wind parks :

$$470.4 / 31480.7 = 1.49\ \%$$

So if no more offshore wind projects arise or are finished before 2023, the offshore wind energy will account for only 1.49 % of the total consumed energy in the Province of Groningen. This percentage will rapidly increase if scenario 3 from the Blix Bv research is achieved, meaning an additional 2000 MW every year from 2024 until 2029. Adding together the percentage of consumed energy delivered by onshore and offshore wind energy production assuming that the total onshore wind energy power stays the same from 2020 to 2023. Percentage onshore wind energy consumed in 2023 would be 6.5 %, making a total of 8 %. With the target in 2023, of having 16% of all consumed energy coming from renewable sources, it would mean that the energy from other renewable sources such as biomass, photovoltaics should be 8 %. Below, a graph shows the percentage of each onshore and offshore wind energy production in the scale of the 16 %.



Graph 9: Percentage onshore and offshore on 16 % scale

IX. Subventions and Policies by Dutch Government

9.1. Subventions

9.1.1 Onshore

Due to the fact that wind energy projects are not profitable from the start, the Dutch Government is giving subventions to developers of wind parks through a regulation called 'Stimulering Duurzame Energieproductie' (SDE). Subventions through SDE stimulates the production of renewable energy and is focused on companies and (non-profit) institutions.
In addition, tax advantage is possible through Energie-investeringsaftrek (EIA). Meaning that developers who invest in wind energy can deduct 41.5% of their investment costs from their fiscal costs of their enterprise. The actual and direct benefit is dependent on the tax percentage. Finally, developers will pay less income and corporation tax.

9.1.2. Offshore

The Dutch Government is giving subventions to companies for the constructions of wind parks. Through a publicly open tender procedure, companies can register. The company that can build and operate the wind park for the least amount of subvention through electricity prices, receives the subventions as well as the constructions permit, which continuously promotes the idea of competition and drives the building price to the cheapest point. Directly leading to lower cost for the Dutch Citizen because it means fewer subventions. Until this moment, construction a wind park offshore is not profitable, this is due to the fact that cost made for pollution are not taken into account by the production of grey energy.
The Dutch Government will give 8 billion euro to the wind parks operators the upcoming 20 years. Aside of this subventions, another 4 billion will be used for laying the required infrastructure for the wind parks, such as power cables.
The Dutch Government and the sector agreed that the costs, in 2020 must have decreased to 40% compared to 2010. With this temporary investment of the government, the sector has more certainty, which stimulates large pre-investments and innovations.

In the long term, subventions will not be needed anymore due to the building up of a valuable economic sector and more sustainable energy in our energy mix. Three years ago, the expectations were that wind parks offshore would cost up to 18 billion euro in terms of subventions. Included in these costs, are the cables through the sea

to guide electricity back to land. In two years time, there has been a decrease of 50% in these costs, and the end is not yet in sight.

9.2. Policies

9.2.1 Onshore

As stated in chapter 4.3, the provinces of the Netherlands are authorized to establish the groundwork/construction or expansion for wind parks with a capacity to produce electricity from 5 MW - 100 MW, not including the latter one. Above 100 MW, the project becomes automatically a matter for the Dutch authorities.
In the Province of Groningen, for all new wind projects, a specific contribution is requested from the developers of the wind farm into Windfonds, of the amount of €1050,-/MW/year, to index annually.
This fund is intended to distribute the benefits and the burdens for the environment in an equal way. The contribution will be used in order to remove the solitaire wind turbines in the Province of Groningen and in reaching agreements in the temporality of the wind parks.
The Dutch Government and the Province of Groningen agreed to a wind park lifespan with a maximum of 30 years at their location. **[11]**

9.2.2 Offshore

The Dutch Government regulates all conditions in order to construct wind parks: their emplacement, the permits and the connection to the electricity grid. Additionally, the Dutch Government does research into the building of the plot, the winds speeds, and the water data. This in order to procure the best possible preparation for the construction of an offshore wind park. The Dutch Government has decided to regulate the distance from offshore wind parks to the coast in the form of the 12-mile zone (22.2 km), which prescribes that wind parks should be located around 22,2 kilometers offshore. However, with two areas of the South-Dutch and the North-Dutch coast, a narrow strip of wind turbines is added at a distance of 18.5 kilometers. A pending procedure, where the final decision on this matter needs yet to be taken. Further away from the coastline is not an option due to important shipping routes and the costs of longer cables to the coast.

X. Discussion

Onshore targets will be reached if all 8 pending projects proceed and are finished as planned by the Province of Groningen while the offshore target, reaching a wind energy capacity of 4450 MW in 2023 will be achieved mainly due to the projects along the coast in the Southern part of the Netherlands.
Since the Province of Groningen only receives 3.3 % of offshore wind production, the increase offshore wind power cannot compete with the increase in energy consumption from the Groninger citizens, companies, energy and transport sector of the Province of Groningen. It is recommended that future wind park projects should be focused on land. Concentrating on wind energy onshore is the best viable option or re-negotiating a higher percentage offshore wind energy.

In order to keep up with the current developments in different industries in the Province of Groningen such as the construction of data hotels and a growing industry around Groningen Seaports, the municipality of Groningen and the province of Groningen, in response, have offered the development of offshore wind farms in the area above the Wadden Islands.
Looking at it from the province perspective, new offshore wind parks are bringing extra employment opportunities through the construction and maintenance of the wind farms and it becomes attractive for companies to settle in the area vicinity. Also, the Groninger citizens have no opposition possible since the wind farms are not located near their houses, so no noise or view complaints.

While those are important points from a province its perspective, when evaluating the numbers it would be more profitable and have a bigger impact on renewable energy consumption to invest in new onshore wind parks. This can be done through the construction of large onshore wind parks or offering subventions to owners of wind turbines on their land, extra from the subventions given by the Dutch Government. And taking into account the current development due to the drilling of natural gas done by the NAM, leading to earthquakes, destroying buildings and causing serious safety issues all over the province. The Groningen citizens can either choose between the risk of earthquakes or having wind turbines compromising some parts of their landscape causing neither safety issues or destruction.
Offshore wind energy production would have only advantages compared to natural gas drilling and onshore wind energy causing neither safety issues or landscape destruction but due to the low percentage of energy received from offshore wind energy, and until now it can’t compete on energy production level with the previous energy sources. This will not be a permanent condition since offshore wind energy will be one of the main arrows of Dutch renewable energy.

XI. Conclusion

After conducting this research, the following outcomes can be concluded. All ongoing projects have been mapped and a full-scale picture has been presented, leading to conclude that both onshore and offshore targets will be achieved in 2020 and in 2023. Achieving both targets is a small step in reaching EU-targets, which shows a leading role for the Province of Groningen in the Dutch renewable energy landscape.

Complementary to the increase in energy consumption of the Province of Groningen, both onshore and offshore wind energy percentages will increase up to respectively 6.1 % and 1.46 %. With good conditions for high wind speeds and a sparsely populated land, the province of Groningen has all needed factors to benefit a maximum from wind energy. Inevitably, a growing industry comes with an increase in energy consumption. Energy consumption which is planned to come totally from renewable energy in 2050 and will make Groningen the first province to fully operate with renewable energy.

XII. Recommendations for further research

It is important to take with all calculations and numbers, the influence of wind speed into consideration. Wind speeds are variable from day to day, and while there are studies done before the choosing the emplacement of wind parks, it can never be totally accurate. Some media and scientific researchers are proposing a theory of decreasing wind speeds in the Northern Hemisphere due to climate change and that it will result in changes in the wind resource over the next 50-100 years.

Wind, large-scale air circulation depends on the temperature differences between the warm equator and cold polar regions. As global warming continues, scientists expect the temperature difference between the equator and the poles to shrink, because the Arctic is warming at a rate twice the global average. Less of a temperature difference between the equator and the poles is likely to mean slower average wind speeds. However, wind speed will not change uniformly across all regions and some regions could experience an increase in average wind speeds. **[16]**

If found true, it would have a major impact on the wind energy industry. But every story has two sides and so researchers from the University of Colorado, have concluded that:” expected technological advancements and consequent cost reductions will likely outpace the projected changes in the wind power potential”. Since today’s installed wind power turbines have a design lifetime of 20-25 years, they will be replaced by modern technology long before the effects of climate change have an impact on their profitability.

As well as lifetime, the power/capacity of a new single wind turbine differentiates from wind turbines what was installed several years ago. For example, offshore wind park Princess Amalia has wind turbines with a capacity of 2 MW while newer wind parks as Gemini have 3 MW which makes a huge difference overall. Between the construction of both wind parks is 10 years, so wind turbines capacity development could be researched further. The potential offshore wind energy production in the total surface of the North Sea is estimated at 250 GW: 25.000 wind turbines with a capacity power of 10 MW. **[13]**

So, further research could be looking into the lifetime, technological developments of wind turbines, the impact of climate change on average wind speeds and the potential of the North Sea.

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http://monitweb.energie.nl/.aspx/Statistic/2

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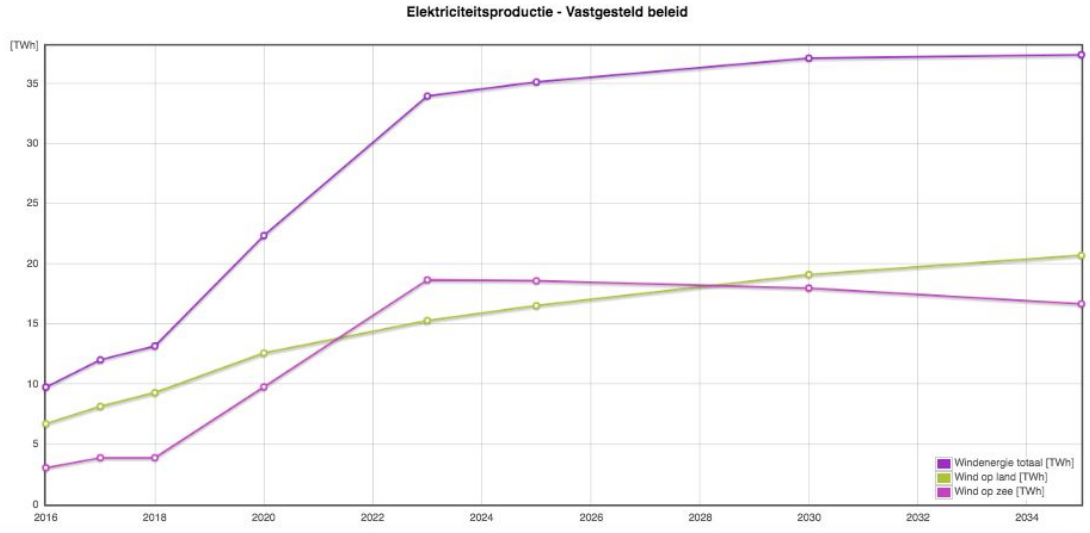
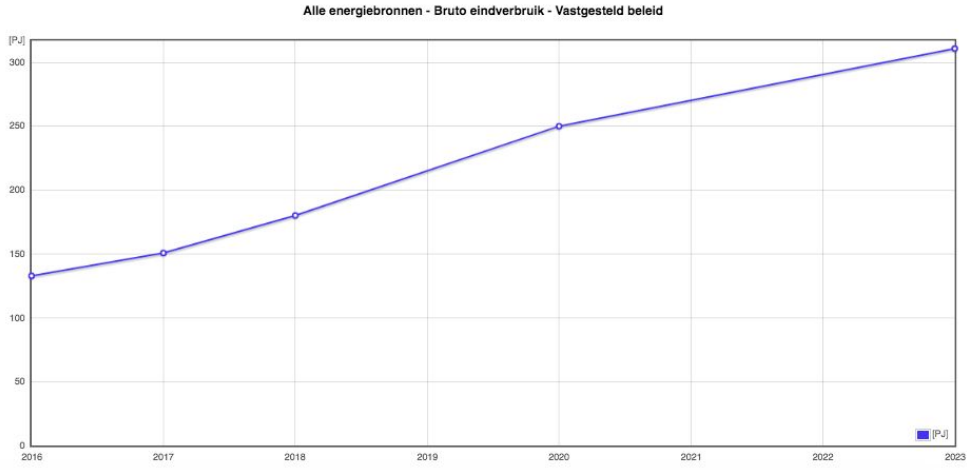
Appendixes

Appendix A.



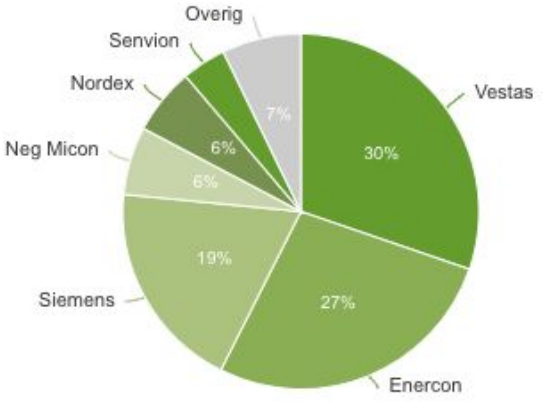
Graph A. Netherlands Wind Electricity Production 2016-2035 (http://monitweb.energie.nl/)

Appendix B.



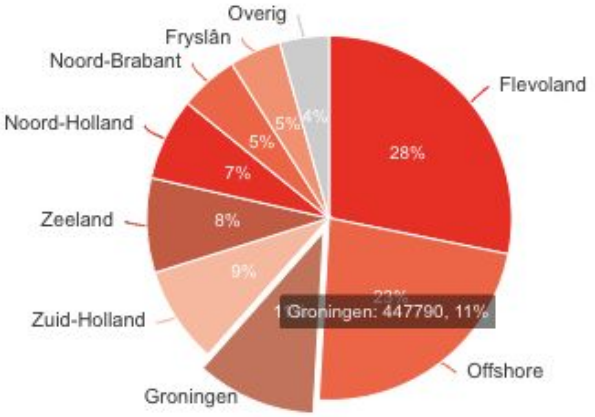
Graph B. Netherlands Energy Consumption 2016-2023 (http://monitweb.energie.nl/)

Appendix C.



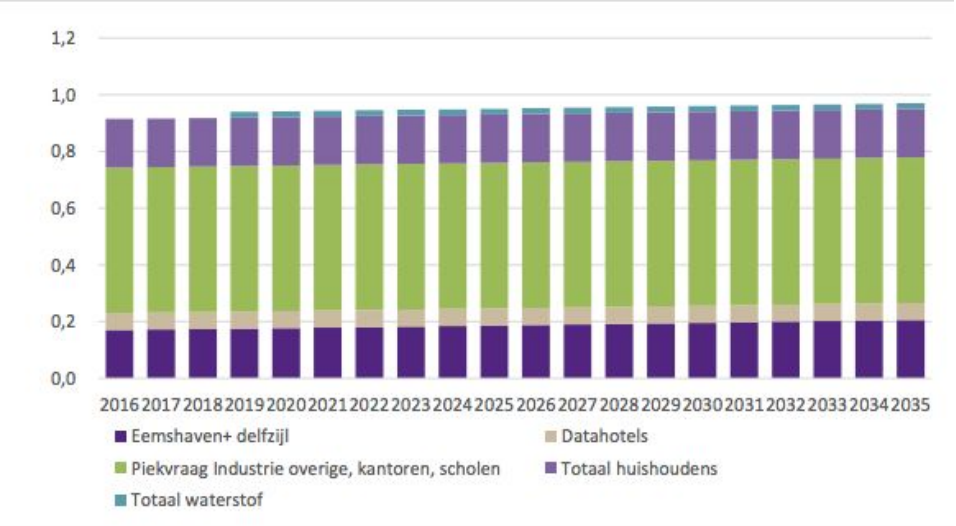
Graph C. Power Delivered by Manufacturers in 2017 (www.windstats.nl)

Appendix D.



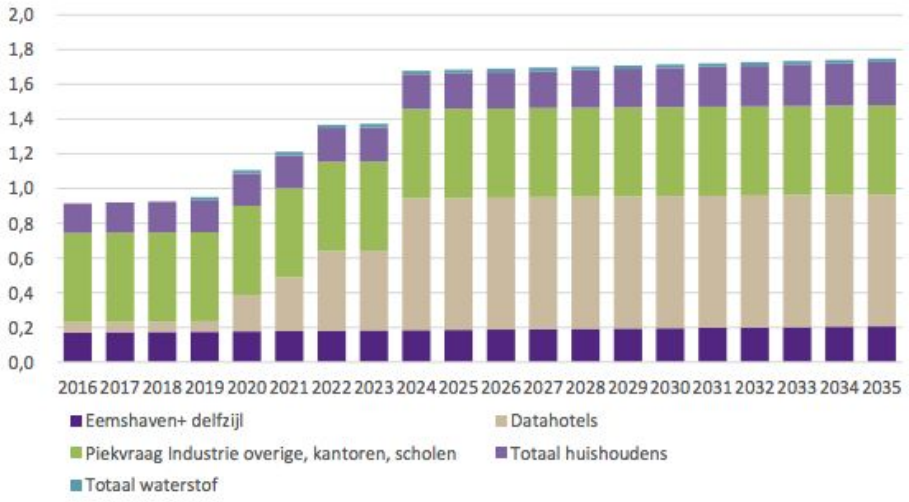
Graph D. Delivered Power per province 2017 (www.windstats.nl)

Appendix E.



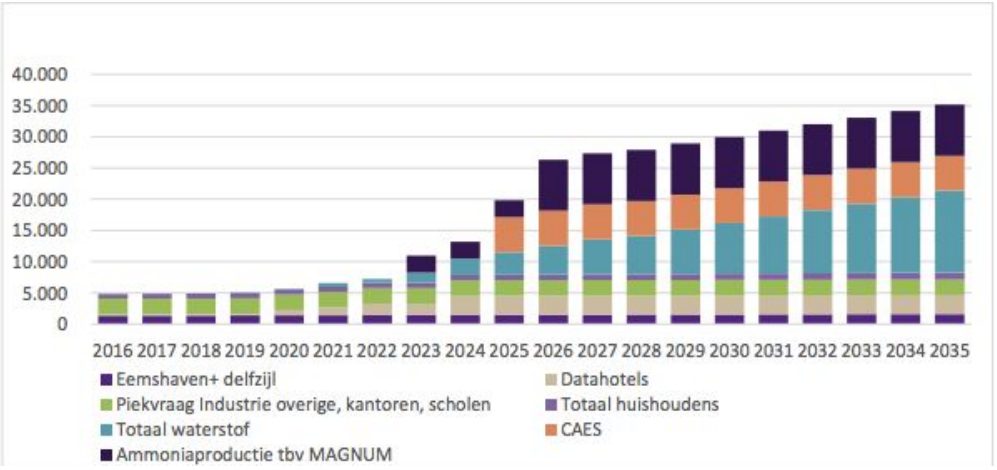
Graph E. Electricity Consumption according to Scenario 1 (BLIX Consultancy BV)

Appendix F.



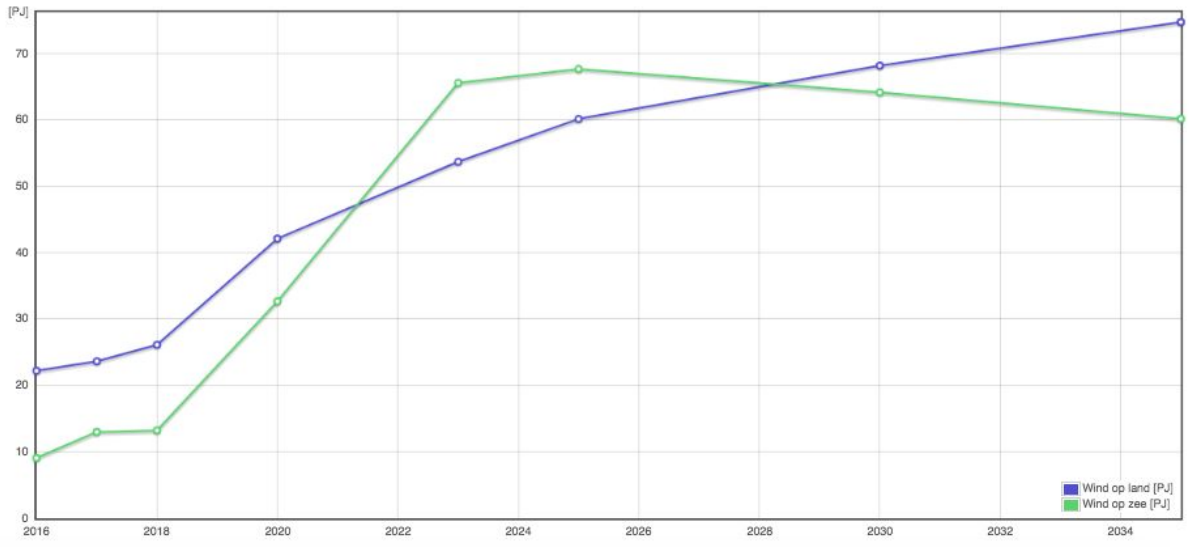
Graph F. Electricity Consumption according to Scenario 2 (BLIX Consultancy BV)

Appendix G.



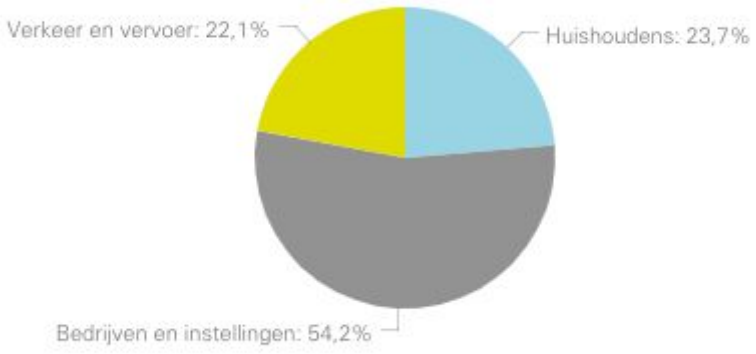
Graph G. Electricity Consumption according to Scenario 3 (BLIX Consultancy BV)

Appendix H.



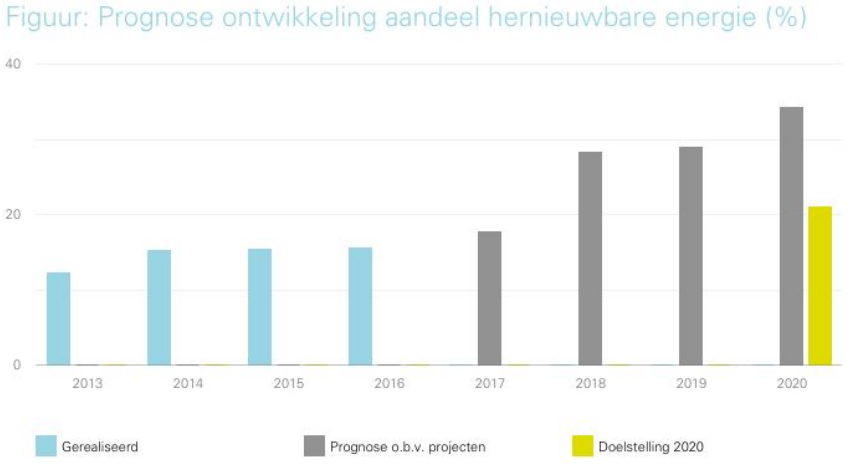
Graph H. Netherlands Energy Consumption of onshore and offshore wind energy 2016-2035

Appendix I.



Graph I. Percentage contributing to final energy use (Energie monitor Provincie Groningen).

Appendix J.

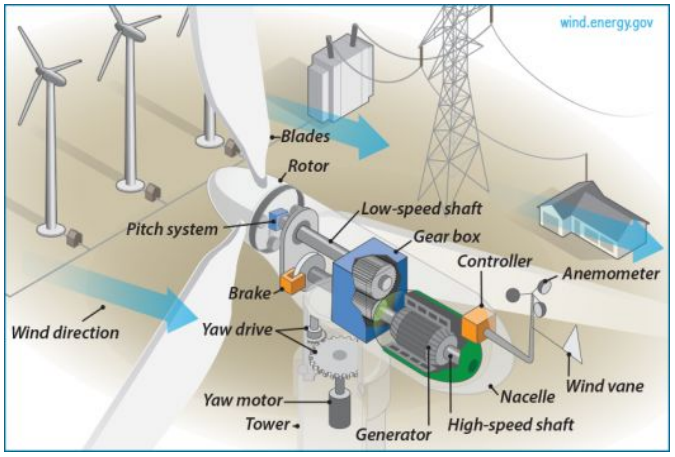


Graph J. Projections percentage renewable energy used (Energie monitor Provincie Groningen).

Appendix K: Energy Production and Lifetime

Modern wind turbines generate energy due to the turning of the blades through the wind. This movement is being formed into electricity. Nowadays, most of the wind turbines have three blades around a rotor. The rotor is connected to the main shaft, which spins a generator to create electricity. The illustration below provides a detailed view of the inside of a wind turbine, its components, and their functionality.

The shaft height of the wind turbine or windmill, as well as the diameter of the blades determine the output to a large extent. As the wind turbines get higher, fewer windmills are needed to achieve the same production because higher wind turbines provide more electricity. Other factors involved in the output of electricity are the types of turbines and local wind speeds.



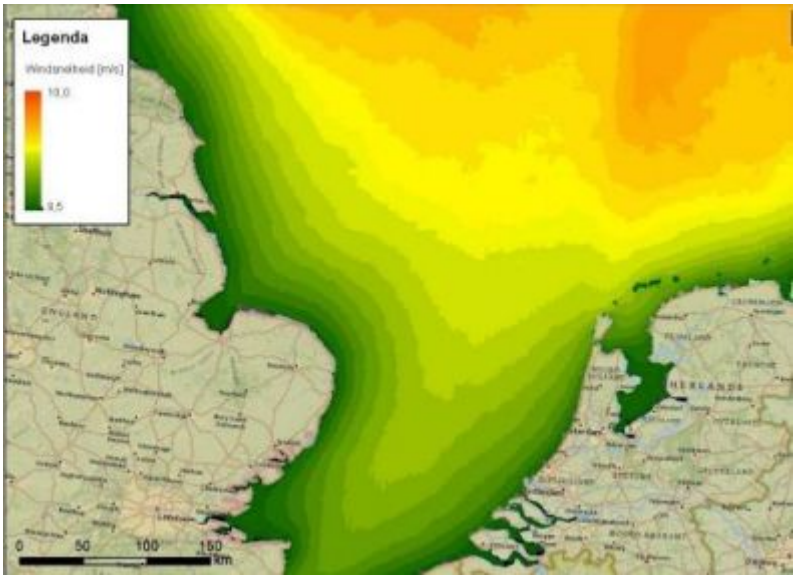
Wind Turbines Components

The ability to generate electricity from wind turbines is measured in watts. Watts are very small units, so the terms kiloWatt (kW = 1,000 watts), megawatt (MW = 1 million watts), and GigaWatt (GW = 1 billion watts) are most commonly used to describe the capacity of wind turbines. The current wind turbines minimal capacity power is two MW.

An average onshore wind turbine with a capacity of 3 MW can produce more than 6.5 million kWh in a year, enough to supply 2000 average EU households with electricity. An average offshore wind turbine of 3.6 MW can supply more than 3,312 average EU households. Electricity production and consumption are most commonly measured in kilowatt hours (kWh). A kilowatt-hour means one kilowatt (1,000 watts) of electricity produced or consumed for one hour.
Windmills begin to turn from wind power 2-3 and deliver full power from wind power 6. The first half year, the energy output is close to the electricity used during construction of the wind turbine. From there it will deliver green energy for 20 up to 25 years.

Appendix L: Wind yield method

The wind speeds increase the further going in the north direction on the North Sea. As can be seen in this picture below.



Average wind speeds above the North Sea (Source: Pondera)

Below through a Weibull distribution, often used for wind profile estimations, shows wind speeds calculated with three parameters: average wind speeds over the years, a scale factor A and a form factor k.