



HERIOT WATT UNIVERSITY

21st century assessment Energy status of Denmark and Netherlands

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May 11, 2025

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1 Introduction

This assessment deals with the 21st century lecture and the aim is to compare two countries with an energetic point of view (production, consumption, policies).

First of all, I really wanted to study energy in Denmark. Often shown as a model in term of renewable energy, it's a country that I want to discover. I love culture from northern country of Europe and Denmark is one of them. In a second time, I chose to study Netherlands. I went in this country few years ago and I liked the culture and philosophy of people. I had the impression than people were aware about climate change and use to take bus or bike for example instead of taking their car each day. In these two countries, I have the feeling that there is a potential to develop renewable energy due to the geographical position in Europe. Finally, it could be countries where to make my future dissertation or a place where I could have a job one day.

In this assessment, I first chose to talk about the potential and resources available in Denmark and Netherlands concerning energy. Then I will talk about ways of consuming energy to realize energy needed in each field and I will finish by talking about energy production and future project in particular renewable energy production.

2 Geography and resources available

2.1 Denmark : leader in wind energy potential

With a population of 5,730,000 inhabitants and a superficial of $42,922\text{km}^2$, Denmark is one of the greenest countries in the world depending to the resources available on its territory. First of all, Denmark is one of the countries with the most of wind resources. As we can see on the figure 1, that is a map coming from EMD international [27], the full potential of Denmark in matter of wind power generation. This high potential is due to the fact that Denmark can be seen as a peninsula that juts into the North Sea and is thus more exposed to wind than continental countries.

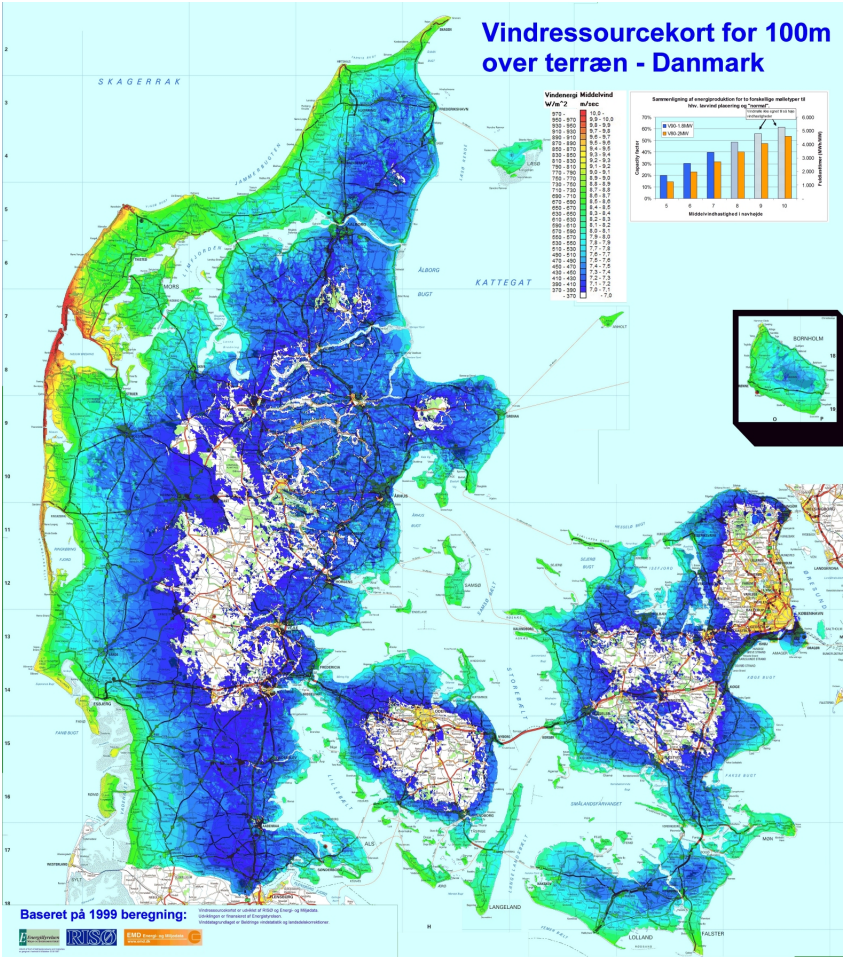


Figure 1: Wind map of the Denmark. Blue areas are areas least exposed to the wind ($400\text{W}/\text{m}^2$ possibly to generate) while the red areas, principally off the coast of Denmark are able to generate around $900\text{W}/\text{m}^2$.

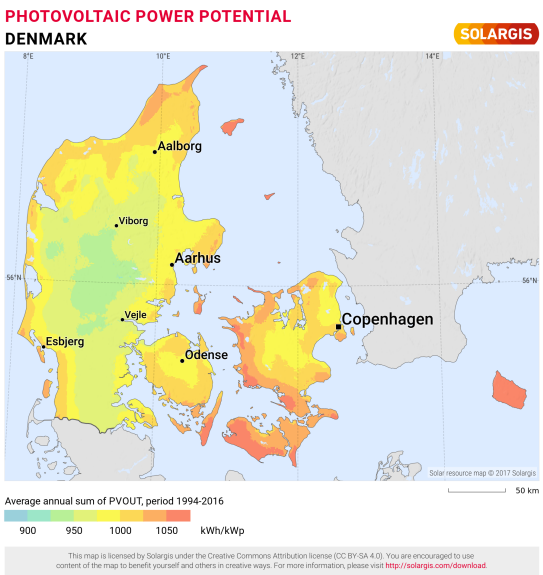


Figure 2: Solar potential in Denmark [23]

Concerning the solar potential of the danish territory, Denmark is not one of the country with the best solar exposition. However, we can find a areas in particular in the Lolland island where we can exploit a strong solar potential (see on figure 2). But we have to keep in mind that this value is nothing comparing to the countries with the higher solar potential in the world. Always according to Solargis, the areas with the less photovoltaic potential in South Africa are around $1400\text{kWh}/\text{kWp}$ and the the areas with the higher potential in Denmark is around $1000\text{kWh}/\text{kWp}$.

2.2 Netherlands : hub of European trade

With a population of 17,250,000 inhabitants and an area of $41,543\text{km}^2$, Netherlands is the main commercial gateway in Europe thanks to its geographical position. Rotterdam's port is the main trading place in Europe with huge amount of merchandise exchange (416 millions of tones in 2017). It's in this context than Netherlands has a major role concerning energy in Europe cause of this strategical position, where most of hydrocarbon to supply Europe are imported.

Netherlands historically draws its energy potential from gas fields, notably Groningen gas field. Discovered in 1959, gas resources in this location constitute a large amount of gas available in Netherlands. As we can see on the figure 3, majority of gas resources are located in the North East of the country. A large amount is also available off the dutch coast but more difficult to exploit.

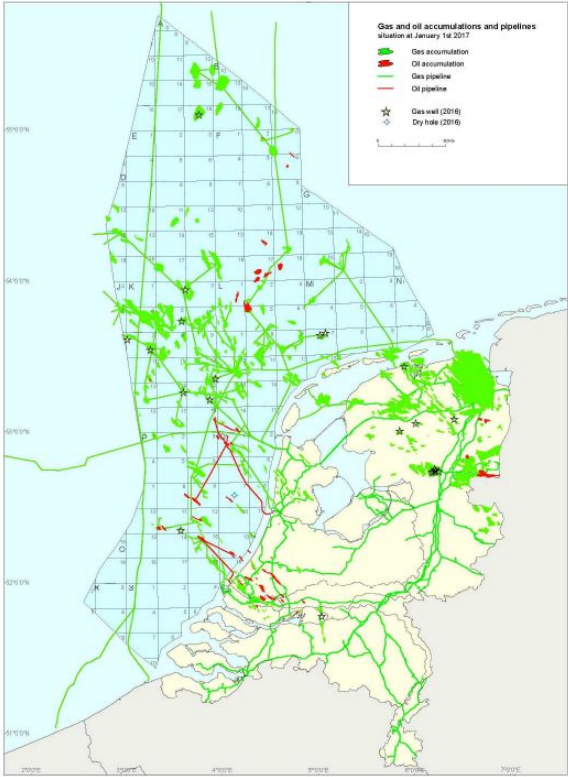


Figure 3: Oil and gas resources in Netherlands (Dutch government [11])

Concerning the wind potential, Netherlands is not a country exposed to wind inside its territory. The main part of potential wind farm is concentrated in the sea, off the dutch coasts. Concerning the solar potential, we clearly observe on the figure 4 that the west of the country is more conducive to exploiting the solar energy. While the north has a low solar potential, if we come near the dutch coast that we can exploit this energy more. But once again, this potential is very low comparing to countries of south of Europe or again south American and African countries.

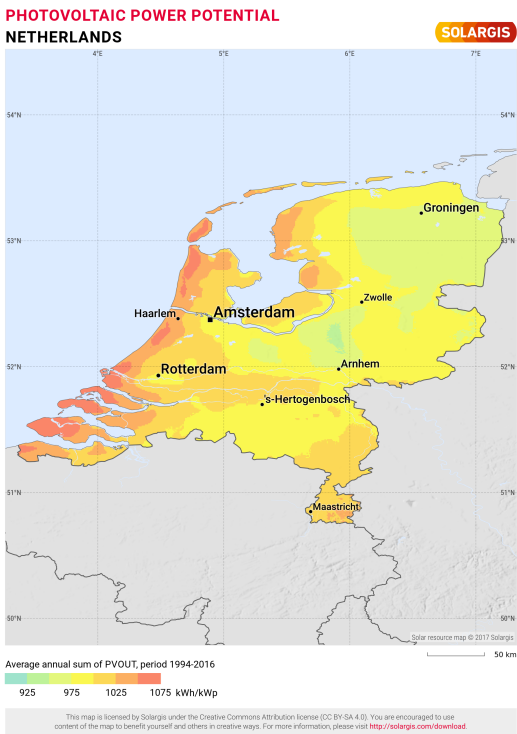


Figure 4: Solar potential in Netherlands [23]

2.3 Share of resources in the North Sea

The exploitation in oil and gas by these two countries fits into a context of management of these resources in the North Sea. According to Crystol energy[17], we can observe on the figure 5 the sharing of oil and gas in the North Sea. While Norway and UK are the main producers in therm of oil, both Netherlands and Denmark have particular exploitation sites. Netherlands concentrate half of gas resources of the North Sea and Denmark has some mixed field of oil to exploit.

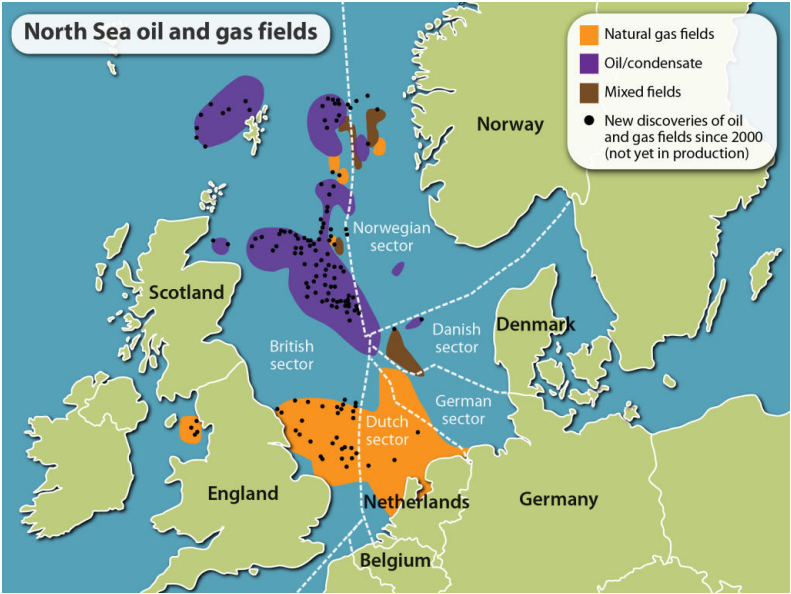


Figure 5: Sharing of oil and gas in the North Sea

3 Energy consumption

First of all, it's essential to know the energy consumption of these countries. It gives us an idea of what is needed by population, so will influence then the production of energy.

3.1 Consumption of electricity, oil and gas

3.1.1 Electricity

In a country where the population has grown of 800,000 inhabitants since 1970, it's naturally that the electricity demand in Denmark increased in the same way. According the figure 6, electricity demand has increased in the same proportion in transport, residential and commercial use.

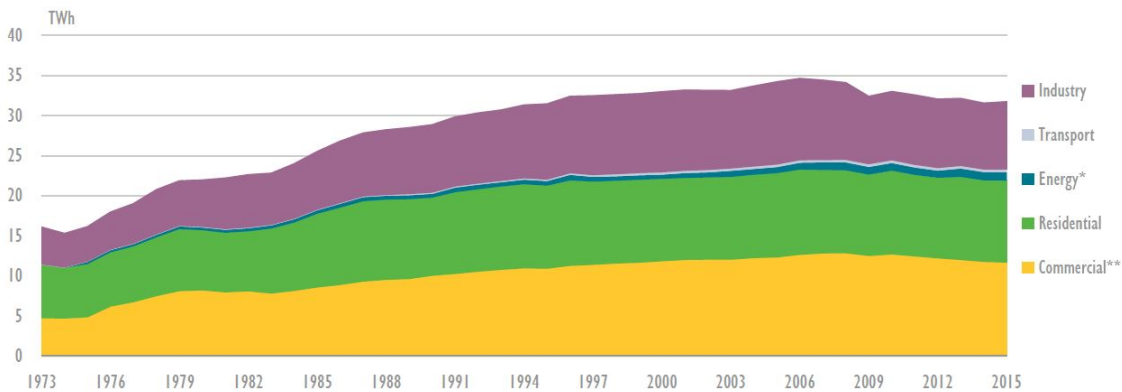


Figure 6: Danish electricity consumption by sector, 1973-2015 [5]

The dutch electricity consumption has known a even more accentuated increase since 1973. Netherlands is a more populated country than Denmark, and grew from 13 to 17 millions inhabitants since 1970, increase of population that increase, even more than in Denmark, energy demand. Figure 7 shows us that the electricity consumption is dominated by industrial and commercial applications. It's explained by the development of Rotterdam's harbour in particular between 1980 and 2000 where the transhipment incidence saw a sharp rise [20].

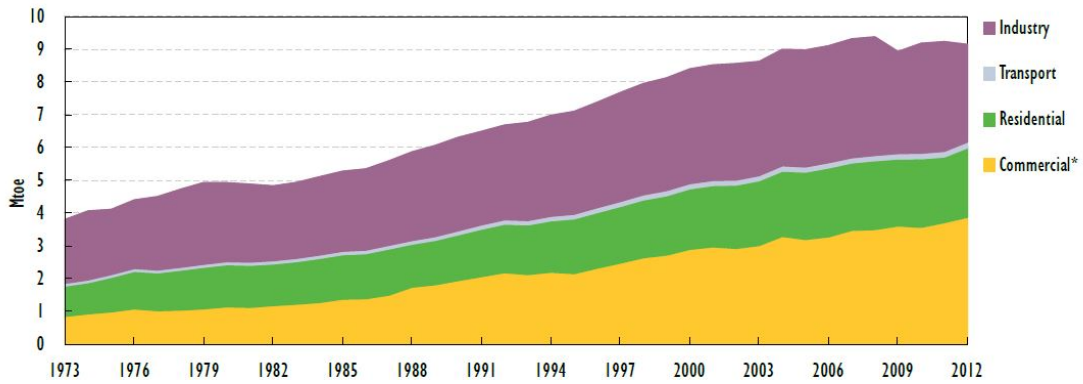


Figure 7: Dutch electricity consumption by sector, 1973-2012 [6]

On both figure, we can observe the impact of the financial crisis in 2008 on the industry electricity consumption, statistic which have stabilized since this date.

3.1.2 Oil

According to the figure 8, Oil consumption in Denmark is decreasing since the 70's. The transport sector did not decrease its consumption. It can be explained by the consumption of oil always necessary now days to transport merchandise and people. But according to the green transport policy agreement [12], the danish government wants to reduce by 20% emissions of the transport sector. For example, Copenhagen, the danish capital, wants to put into circulation 41 electric buses for 2019 and switch all buses by electric buses for 2030 [1].

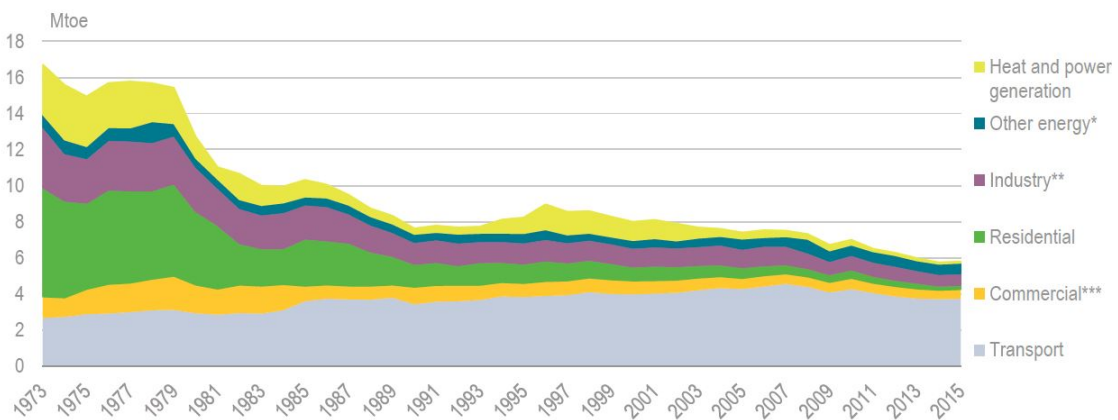


Figure 8: Denmark oil consumption by sector, 1973-2015 [5]

We'll see in the production part that this decrease, in particular in residential application is due to the change of way of production and consummation in Denmark. In Netherlands, we observe on the figure 9 that the consummation in oil, on the contrary, has increased in industrial application because of the development of the port activity.

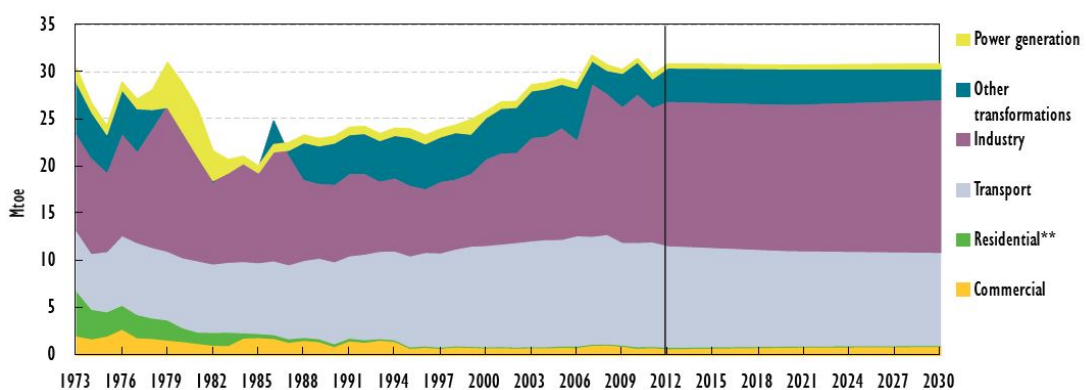


Figure 9: Dutch oil demand by sector, 1973-2030 [6]

3.1.3 Gas

Since the first licensing round in 1984 that allowed companies to explore and produce hydrocarbons in specific danish areas[16], exploitation of oil and even more gas exploitation has known an high increase. But since 2005, the gas demand declined of 35% and the government wants to decrease this gas consumption to 2.4 before 2025. This ambition is justified by the fact than enough renewable energy could be produced to replace gas using (see section 3).

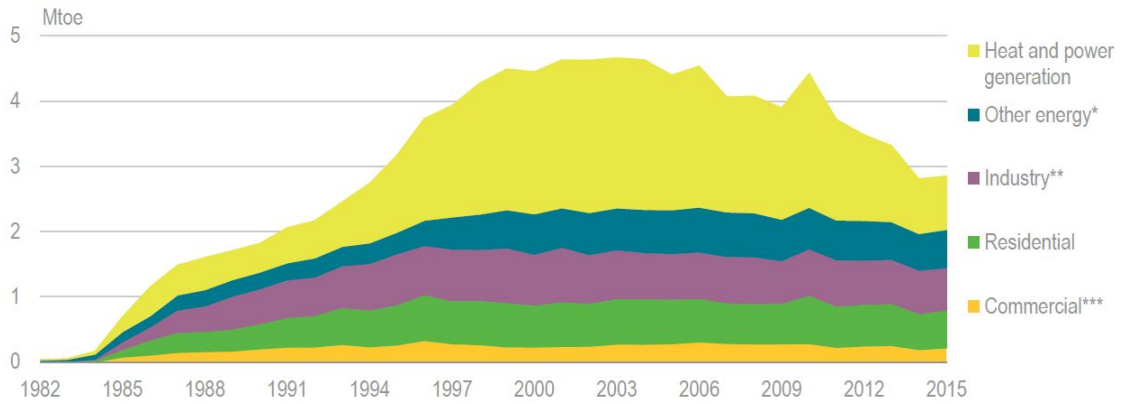


Figure 10: Denmark natural gas consumption by sector, 1982-2015 [5]

In Netherlands, situation is quite different because of the strategical production site in Groningen. In fact, almost every householder is connected to the gas network. The increase of demand in 2010 is linked to a particular cold winter that increase the gas demand for heating processes. Dutch government expect to decrease the gas consumption to 40 bcm until 2030. But the demand in gas will depend of the capacity of the country to produce energy coming from other resources.

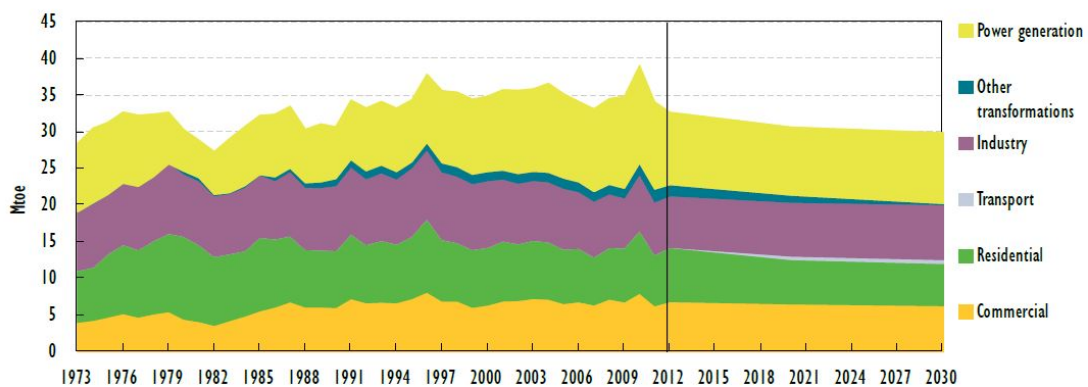


Figure 11: Dutch natural gas demand by sector, 1973-2030 [6]

3.2 Key sectors

3.3 Taxes

Consumption of energy resources is also linked to taxes in place on territories. By setting up these taxes, governments want to influence ways of consumption of industrial or consumers.

First, Denmark set up a tax in relation with hydrocarbon exploitation.[22]. The aim is to regulate exploitation of oil and gas resources. The tax takes into account construction, maintenance and services functions related to the exploitation of resources. Also, Denmark is the country in Europe where energy has the higher price. Electricity for example is taxed around 67% and cost around 0.3€ per kWh[4] and the price for one kWh of gas is around 0.09€ [18] (3rd more expensive in Europe). Comparing with Netherlands, we also find one of the higher prices in Europe for the gas but electricity is cheaper (around 0.16€ the kWh). The figure 12 representing VAT evolution in some European countries explains prices of energy in Denmark and Netherlands that have an high VAT rate. Evolution of energy price in Netherlands has dramatically changed since 1990's where the VAT was under 17% and the kWh of energy was around 0.1€

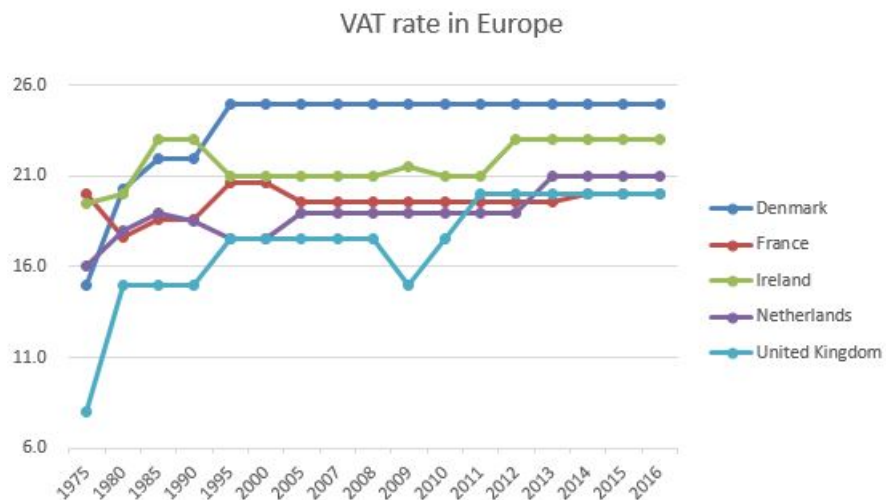


Figure 12: Evolution of VAT in Europe[25].

4 Energy production

In this section, I will compare energy exploitation in the two countries. We will see in this data the reflection of the policies applied by governments regarding the exploitation of resources in the territory or in terms of sustainable development.

4.1 Resources exploitation

According to the figure 13, we notice the self-sufficiency in electricity of Denmark since 2010. Since 1993, Denmark is also self-sufficient in oil. One part of this oil is used to generate electricity and a large amount is exported. Since 2012, the number of petroleum barrels keeps going up making it the third largest European oil exporter after Norway and UK with 3000 thousands barrels of petroleum in 2017. But this number is quite insignificant face to the to giant exporters like Russia or Saudi Arabia than export more than 5000 thousands of barrels in one day.

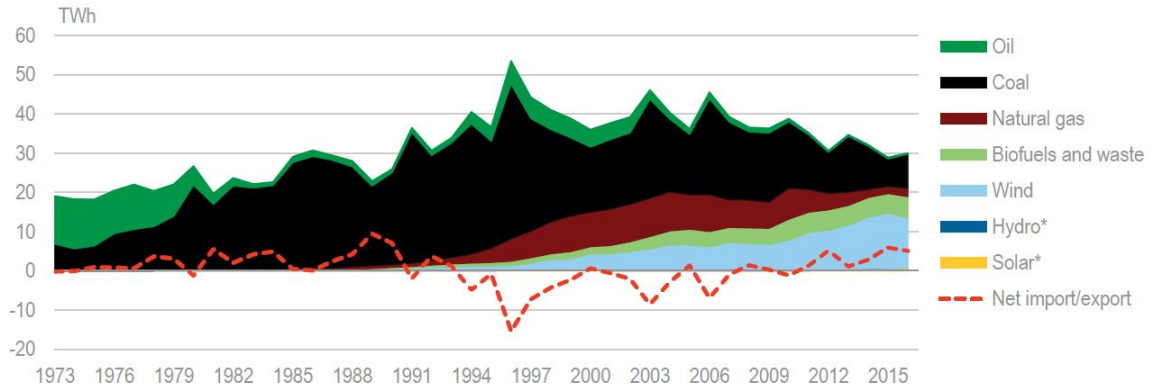


Figure 13: Denmark electricity generation by source, 1973-2016 [5]

As mentioned in the first section, the strong power of Netherlands is its resources in gas, in particular in the Groningen field. It's naturally that we found the natural gas as the first resource using to generate electricity (figure 14). The electricity generation with gas increased for 30 years but we will see in the energy policy subsection that the government want to change conditions of exploitation of gas.

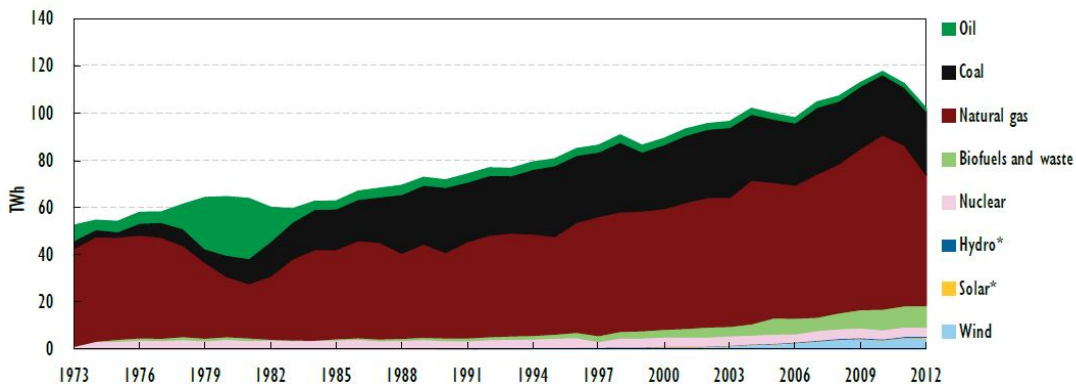


Figure 14: Dutch electricity generation by source, 1973-2012 [6]

In both country, electricity generation with coal takes a big part. According to the IAE, CO2 emission from coal per capita in Denmark and Netherlands are respectively 3.2 and 1.8 whereas the average is around 3.1 in the world. Here is one of the weakness showing by Denmark. But the government established a plan to reduce this number. In fact, the country wants to phase coal by 2030[3].

4.2 Oil and gas production

As I said previously, both Denmark and Netherlands are big producers of oils so both are exporting a large amount of oil and gas. Begun in 1972 in the North Sea fields, production of oil in Denmark is now includes 19 producing fields. Actual reserves in oil and gas are actually respectively around 135 million of m^3 and 59 billion of m^3 (2017 figure) [14]. Sweden is the main importer of Danish oil following by Netherlands where the oil production is only of 4 bcm a year. According the ENS (Danish Energy Agency), a reduction of oil production is expecting from 2021 because of the renovation of some installations[7]. The forecast also plan a reduction of the production from 2023 but Denmark should stay a net exporter in oil from 2032. That what we can observe on the figure 15, reserves are being exhausted, so that in 2045 Denmark will no longer produce oil.

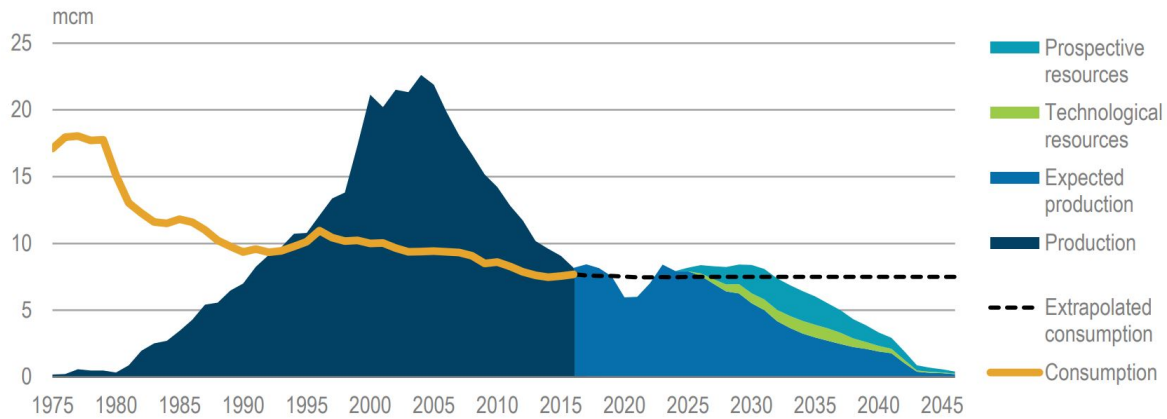


Figure 15: Denmark oil production forecast [5]

Concerning gas production in Denmark, it began in 1983 and there are now 17 fields producing gas in the country. Once again, Denmark is a net exporter of gas in Europe, principally to Sweden (48%), Netherlands(32%) and Germany(20%). A stop of the production on one of the main site should appear between 2019 and 2022 when installation will be rebuild.

Natural gas is the largest source of electricity production in Netherlands, representing 40% of the TPES (total primary energy supply). On the figure 16, we can observe the production and exportation of dutch gas. We clearly notice the large production of gas today around 80 bcm what makes it today the second largest producer in European Union. Moreover, this production represents twice the gas needed in the country that permits to Netherlands to export the surplus. These exportations are mainly destined to Germany, Belgium and Italy.

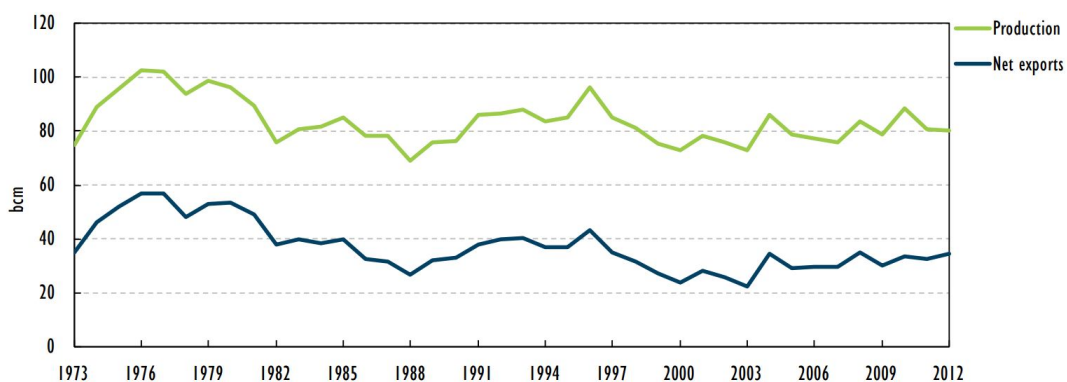


Figure 16: Dutch natural gas indigenous production and net exports, 1973-2012 [6]

4.3 Renewable energies

One of the specificity of Denmark is electricity generated by renewable energy. On the figure 17, we clearly see that electricity generated by the wind is most important that the other sources. Historically, necessity to adopt renewable way to produce energy finds its origin in the middle of 20th because of the effects of WWII and the oil crisis in 70's[15]. Denmark was in the obligation to import fuel resources to power the country and the raise of oil prices forced government to review its policy. It's at this date that first electricity taxes and first investments in renewable energy R&D appeared so that the first wind turbines are born in the early 80s which corresponds to the first years of production in the figure 17. Then, the second main policy appeared during the 90's with the "Energi 2000" plan, one of the plan without nuclear power. The government analyzes the danish situation and took the decision to reduce CO2 emissions by 20% and provide electricity by 10% with wind turbines by 2005. The last ambitions in term of wind turbines took place in 2009-2012. We clearly noticed on the figure 17 the rise of number of wind turbine since 2009, date from which government established a financial policy concerning the price of electricity generated by wind turbines. We can also observe some fluctuations on wind electricity production but these variations are because of the years with less wind potential that other or again of the variation of turbines number (when old one reach the end of their lifespan, we have to removed it).

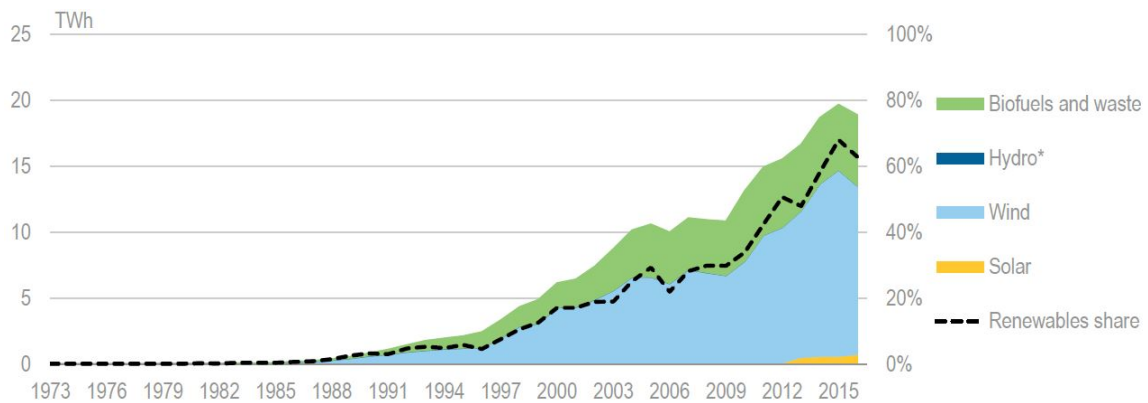


Figure 17: Danish renewable energy and waste in electricity generation, 1973-2016 [5]

In its climate change and energy policy[8], European countries have to reach the following objectives : reduce their greenhouse gas emissions by 20% (comparing to 1990 levels), have 20% of energy coming from renewable and increase by 20% energy efficiency. According to Eurostat[10], Denmark has already reached its objective but Netherlands is one of the countries the farthest of its one. And this very slow progression can be observed on the figure 18 where Netherlands reached its part of renewable energy in electricity production by only 5 % in 30 years. However, we can notice the high increase in biomass and waste production. It's linked to the stimulation of biomass energy by the government for different uses in particular to generate energy thanks to waste incineration to generate electricity. We can also underlined the fact that the country has a very poor electricity production thanks to wind turbines. This seems be in contradiction with the dutch reputation and its famous windmills but electricity generation with the wind only started in 2002 and didn't know an important growth since this date.

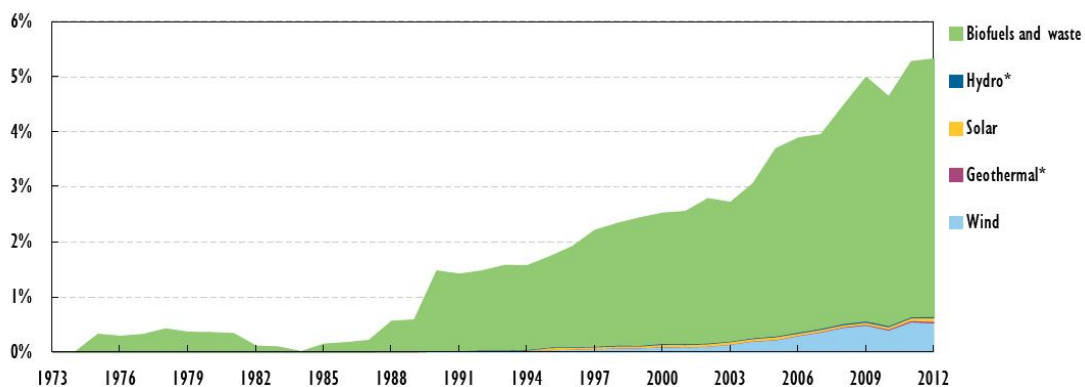


Figure 18: Dutch renewable energy as a percentage of TPES, 1973-2012 [6]

4.4 Energy policy

4.4.1 Climate change policy of Denmark

In December 2012, danish government set a plan called "Energy strategy 2050" also containing a "Climate change policy" to create a sustainable, green climate adaptation efforts in Denmark. [13]. The main parts of this action plan consist to help municipalities in green ecological transition. For it, the government provides advice and knowledge to help every citizen and politic power to promote Denmark as a model in green transition in Europe. In this project, it's also plan that Denmark will be independent in energy from 2050.

As mentioned in section 2, biomass in one of the main renewable source of energy in Denmark. In 2014, danish government investigated an analysis concerning bioenergy using and the conclusion was that measures needed to be taken be cause of climate change risks of the biomass. It results the Industry agreement on biomass sustainability[21] where government decided to regulate using of biomass (especially using of wood pellets and chips).

The most recent danish policy about energy regulation is dated from the last 2 October when the government decided to create a petrol and diesel ban plan[2]. With this text, the danish Prime Minister Lars Lokke Rasmussen wants to ban petrol and diesel cars from 2030 and hybrid one from 2035. Whereas France and Britain have decided to ban petrol and diesel cars from 2040, Denmark wants to go even further with this policy, leading the way to a green and sustainable system in energy in the country.

4.4.2 Netherlands and gas wind transition

Because of the exploitation of the deposit that causes soil subsidence, Netherlands has to review the operating rules of the Groningen's field gas. The dutch government has decided in February 2018 to cut production by half to 12 billion cubic meters per year [24]. The purpose is primarily the safety of people living near the production site. But there is also the issue of energy. Actually, 40 percent of energy in Netherlands is produced by gas. Cutting gas production, the dutch government has to find another way to produce energy.

GRONINGEN PRODUCTION FORECASTS

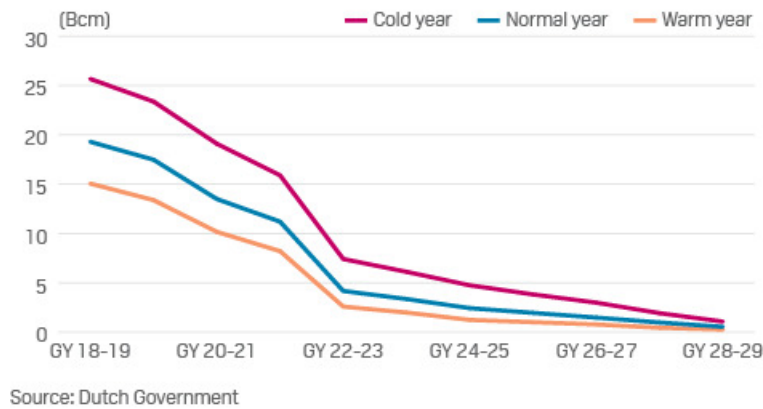


Figure 19: Forecast of gas production in Groningen. The purpose is to produce less than 10 Bcm before 2025 to close definitely the production in 2030[9].

One of the main project to overcome this lack is to build off shore wind farm. The country has the ambition to build the largest offshore wind farm in the world by 2027 using an artificial island of 2.3 square miles to support the installation. Leading by the TenneT company, the project should take place in Dogger Bank (figure 20), a site where wind has a strong potential. The purpose is to create a power hub able to supply energy to UK and Netherlands first and possibly to Germany, Belgium and Denmark in a second time.



Figure 20: Dogger Bank where we can find high wind speed and shallow water, perfect for the implantation of an artificial island [26]

It's an ambitious and complex project where innovative technologies have to be found to transport energy on a long distance or again to build this kind of island. But Netherlands used to face this kind of issues, living under the sea levels for centuries. An high economic value has also to be considered, the estimated cost of this project is around 1.5bn €.

By 2050, Dutch central government wants to reduce the Netherlands' emissions of greenhouse gases (like carbon dioxide (CO₂)) to zero. It plans to make 16 percent of renewable energy in all energy used in the Netherlands sustainable by 2023. This is outlined in the Energy Agreement for Sustainable Growth that the government made with 40 groups, including employers, trade unions and environmental organizations. The Energy Agenda sets targets for the years up to 2050. Energy Agreement for Sustainable Growth [19]

5 Conclusion

Regarding all these informations about energy in these two countries, we clearly see differences between Denmark and Netherlands, quite close geographically.

First, Denmark is a leader country in term of green development and renewable energy. It knew take risk early in history and took directions in green energy production when other countries chose to keep standard way of production.

Netherlands appears in Europe like a country using a lot of energy especially because of its numerous windmills and famous using of bike. But looking the production, wind is not the main energy source. Netherlands seams to be late it green energy exploitation despite the will to create wind farms in the future. In my mind, Denmark is an example in matter of renewable energy policy. This country got a potential in wind potential and knew how to exploit it. We do not reproduce in other countries what Denmark did cause it's simply impossible, each country does not have the same potential in matter of wind but we have to think like them, trying to find the best energy to use at the right place.

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