MSc Program
Environmental Technology & International Affairs

Wind Power: Bounds for the different development stages of the industry in Mexico, the United States and Denmark

A Master's Thesis submitted for the degree of
"Master of Science"

supervised by
em. Univ.-Prof. Dr. Günther Brauner

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Vienna, 30.05.2019

Affidavit

I, **STEFANIA ISLAS MUEDANO**, hereby declare

1. that I am the sole author of the present Master's Thesis, "WIND POWER: BOUNDS FOR THE DIFFERENT DEVELOPMENT STAGES OF THE INDUSTRY IN MEXICO, THE UNITED STATES AND DENMARK", 91 pages, bound, and that I have not used any source or tool other than those referenced or any other illicit aid or tool, and
2. that I have not prior to this date submitted the topic of this Master's Thesis or parts of it in any form for assessment as an examination paper, either in Austria or abroad.

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Signature

Abstract

This thesis will demonstrate the advantages and challenges of increasing the support and investment in the renewable and clean method of wind energy production, in Mexico, Denmark and the United States. A comparative analysis will show the facts that surround this industry in the selected countries, the advantages and limitations of this field, that have resulted in different levels of development in time and finally depict possible limits and trends. A legal or financial analysis is not part of this thesis given the variable market costs and changing regulations, important factors which would reduce the endurance and usefulness of this particular study. The focus of this thesis content is to highlight the disposition of the wind energy sector, which is to provide clean energy, employment, to reduce the global environmental polluting emissions that negatively impact ecosystems due to the daily abuse of the scarce fossil fuels as a source of energy to feed modern life's way of living.

Keywords: Wind energy, grid installation, sustainability, energy security, renewable energies, development, Mexico, US, Denmark

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List of Abbreviations

AWEA- American Wind Energy Association

AZEL- National Atlas of Zones with High Potential for Clean Energies (Mexico)/ Atlas de Zonas de Alto Potencial de Energías Limpias

BAT- Best Available Technology

BCSE- Business Council for Sustainable Energy

BWEC- Bats and Wind Energy Cooperative

CDM- Clean Development Mechanism

CEC- Clean Energy Certificate

CENACE- National Centre for Energy Control (Mexico)/ Centro Nacional de Control de Energía

CFE- Federal Electricity Commission (Mexico)/ Comisión Federal de Electricidad

CO- Carbon Oxide

CO_2- Carbon Dioxide

CONAPO- National Population Council (Mexico)/ Consejo Nacional de Población

CRE- Energy Regulatory Commission (Mexico)/ Comisión Reguladora de Energía

DKK- Danish Kroner

DOE- Department of Energy (United States)

EIA- Environmental Impact Assessment

EO- Earth Observations

EPG- Electric Power Generation

ETIP- European Technology and Innovation Platform

EU- European Union

EUR- Euros

GDP- Gross Domestic Product

GHG - Greenhouse Gas

Gt- Giga tones

GWh- Giga Watt per hour

IEA- International Energy Agency

IPP- Independent Power Producers

IRENA- International Renewable Energy Agency

ISO- Independent System Operator

km- Kilometres

km^2 - Squared kilometres

kW/ kV- Kilowatt/ Kilovatio

LIDAR- Light Detection and Ranging

m- Meters

m/s- Meters per second

Mt- Mega tonnes

Mtoe- Million Tonnes of Oil Equivalent

MWh- Megawatt per hour

NASEO- National Association of State Energy Officials (United States)

NH_3- Ammonia

NOAA- National Oceanic and Atmospheric Administration

NOX- Nitrogen Oxides

NREL- National Renewable Energy Laboratory (United States)

PPA- Power Purchase Agreements

PV- Photovoltaic

RES- Renewable Energy Sources

SE- Ministry of Economy (Mexico)/ Secretaría de Economía

SEMARNAT- Ministry of Environment and Natural Resources (Mexico)/ Secretaría de Medio Ambiente y Recursos Naturales

SENER- Ministry of Energy (Mexico)/ Secretaría de Energía

SRE- Ministry of Foreign Relations (Mexico)/ Secretaría de Relaciones Exteriores

Sist- System/ Sistema

Tmca- average annual growth rate/ tasa media de crecimiento anual

TSO- Transmission System Operator

TWh- Terawatt per hour

UK- United Kingdom

UN– United Nations

UNFCCC- United Nations Framework Convention on Climate Change

US- United States

USD- United States Dollars

USWTDB- United States Wind Turbine Database

VOC- Volatile Organic Compounds

WETO- Wind Energy Technologies Office

WWF- World Wide Fund for Nature

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I would like to thank my supervisor for his expert and objective lectures, wise input and useful content guidance for the investigation of this Master Thesis.

I would like to thank my family for their support, and I acknowledge their huge economic effort done along so many years for funding great part of my studies. I would like to thank my Father for his financial backing and responsibility example, my Mother for teaching me how to study and being perseverant, and my Brother for competing with me to be the best.

I would like to thank my Grandmother and my Aunt for their much appreciated emotional support, without which I would not have survived these two years separated by continental distances from those whom I love the most.

"International wisdom says that the least expensive and most environmentally benign unit of energy, is the unit that is not consumed or produced in the first place."[1]

World Energy Council, 2019

[1] World Energy Council, "World Energy Issues, Monitor 2019", 2019, (p.189)

1. Introduction

This study's motivation is grounded on the urgency to find solutions to the already visible global environmental harm, which is primarily caused by anthropogenic activities for the purpose of satisfying modern societies' industrial and consuming interests. World polluters have managed to generate seriously alarming pollutant concentrations in tropospheric habitats, destabilizing the homeostasis of the planet, which on a daily basis continues to deal with acidification and damage to its ecosystems' and wildlife's health. Recurrent energetic production is related to the massive consumption of non-renewable resources and this study focuses on the natural availability of wind, as a renewable resource which can act as a buffer for the induced impacts of the energy industry.

A thorough review of relevant literature and statistics provided by national and international institutions provided the necessary grounds to justify the thesis of this research. Considering that Mexico, the United States and Denmark are similarly surrounded by water bodies on the East and West sides of their territories, and that their strong wind energy potential is organically given, this makes them interesting candidates where the focus of the generation of wind energy for supplying electricity to households and power industries could result in an international business advantage. Nevertheless, each of these countries has a different capacity for energy production, given their different historical experiences, national priorities and natural or economic resources, grid capacity, qualified labour force, installed and available technology.

A deep questioning and answering type of analysis of the reasons which explain the marked differences and future potential in the development of the wind energy industry in Mexico, the United States and Denmark, based on their geographical, political, economic, and energetic backgrounds and possibilities.

Research's main question: Is an intercontinental wind energy plan possible between these countries, considering their different energetic business needs, experiences, legal frameworks, political priorities and economic profiles, for the purpose of expanding globally the wind energy model for electricity supply? The hypothesis is that an intercontinental wind energy power plan is possible between countries, because the wind industry involves an interconnected globalised market. Technology and knowledge are transferred across countries, and this fundamental exchange network is the one which will ensure intercontinental cooperation plans.

The argument behind the possibility of this plan to happen is based on the imminent global increase of electricity demand, the international interests to reduce fossil fuel emissions, the technological advances which help reduce costs, and the existing interest of clean energy companies to expand their business through international projects and cooperation contracts.

This investigation followed a comparative analysis method between the current and future wind energy industries in Mexico, the United States and Denmark.

The relevance of this investigation is driven by the need of reducing pollution emission levels which affect climate change, the need of cleaner energy supply through the investment on alternative energy sources, the transfer of knowledge and technology across countries and the potential job creation opportunities this would bring. The different wind potential on each country is considered as well as their possibilities and limitations.

The wind industry has been developing its expertise around the world at different levels, with different efforts and different resources. In this thesis, the author made a reflection trying to find the reasons behind a slower or faster pace of development in specifically three different countries around the world, and identified the need to categorize their development in stages, to identify advantages and disadvantages in the process. The intention is to understand the guidelines that help analyse each country's wind energy situation objectively for the purpose of supporting its strategic development and trying to increase its possibilities to its maximum potential according to their local situation and category stage.

Mexico, the United States and Denmark were respectively categorized in beginner, intermediate and advanced levels of the wind industry development. It was defined in this way by looking carefully in their advantages, acute problems and robust preoccupations. Each country has a different focus for their efforts, a different political or financial engagement, and this is due to their national interests, but as well there is a direct relation with their dissimilar time-accumulated experience or intensity of devotion towards the industry.

Evaluating different country's development stages is useful for big scale analysis. Comparing and contrasting is a practical way of acknowledging the possible paths a country could be faced with in the future. Nonetheless, it is crucial to bring to light that a solution or result in one country will never be a solution or will never have the same result for all the other countries, due to their very different and unique circumstances that differentiate them.

The situation faced in one country and the solution taken to deal with it should not be considered to be applied in another country, as they all have different political and legal frameworks, environmental conditions, different ways of working and different decision-makers. Notwithstanding, distinguishing its advantages in good time will help decision-makers take full advantage of the region's particular conditions before the competition increases even more and becomes more difficult to keep the pace. By knowing the paths other countries took in the past could be a functional way of planning future scenarios, avoiding the repetition of mistakes, getting access to the best suitable technology and achieve a high proficiency in the wind industry's development. Countries which characteristics fit in the proposed levels 1 and 2 are to be considered in this Master Thesis as beginners. Countries in level 3 are to be considered intermediate. Countries in the levels 4 and 5 are to be considered advanced.

Table 1 Categorization Proposal: Wind Industry's National Development

Level	Characteristics
1	- Initial development stage, not significant production of wind energy, however, the wind potential has been identified and a plan to harvest it is on the run. At least one wind project has been started. Support is given to the local professionals and considers importing technology and experts for passing on the know-how and learning from other countries experiences.

Beginner	- Government or private investments are funding the research and development for a national wind industry. Accepting international project developers into the country without substantial constraints. National energy policy supports renewable energies, without compromising the welfare of indigenous communities, archaeological sites, wildlife or natural ecosystems. Starts building the industry in solid bases to avoid a future collapse.
2 Beginner	- Although in a young stage, wind energy is already feeding the grid. A learning curve has started to show the areas which need to be strengthen and decision makers count with committed teams for fixing the gaps that may challenge the potential development. Wind potential is better identified with wind mappings, and national manufacture can support part of the demanded technicalities. - National energy policy is evolving to improve the legal framework and setting rules of procedure to orderly evolve and facilitate, within the legal margins, a scope's expansion. Existence of a national authority or authorities in charge of regulating the new market and ensuring its development. Government is establishing supportive institutions and guidelines for the creation and extension of wind parks. Public and private investments in the wind industry have significantly increased. - Recording progress and having long-term plans with clear future scenarios. Having a national wind energy plan with targets and directing funds to support them.
3 Intermediate	- Wind energy represents a significant share of the national energy consumption. Updating software, processes and strategies to ensure efficiency improvements and functional infrastructure. - Renewable energy institutions support wind energy and publish studies and periodical reports to improve the identified deficiencies and propose solutions. A holistic national programme supports the coordination of authorities and stakeholders. - Special teams are working to solve logistics, site selection and improving wind models. Significant increase of jobs related with the

	wind industry. Having education and training programmes for supporting future skilled workers. - Grid expansion and investment in the national electrical transmission network system. National and international funds and investments working to boost the wind energy potential
4 Advanced	- Reduce dependence of technological and mechanical imports by having several national related manufacturers. Logistic solutions developed innovation of machines and transporting tools, improvement of methods, use of remote sensing tools to identify risks and impacts. Constantly updating reports. Constant renovation of wind facilities to ensure the use of the most efficient infrastructure and best available technology. - Providing education and training programmes for supporting skilled workers abroad and emerging wind industries in other countries. - Finding legal, economic and fiscal framework improvements. Being more selective with high quality project developers interested in investing in national wind energy projects. Involvement in international projects, sharing of knowledge and technology.
5 Advanced	- Manufacture products for the wind industry with exportation capacity. Improve or create new models and custom-built instruments. - Remote monitoring and controlling. Being a leader or role model. - Having half of the national share of electricity consumed being provided by wind energy suppliers. Modernizing and innovating the wind industry, in technology and solutions. Exporting ideas and selling or commercializing with the acquired knowledge. Digitalization and automation of processes.

Source: Own representation

2. **Mexico**

Mexico is located in a most valuable point connecting North America with Central and South America. On the East and on the West, with a total of 9,330 km of coastline, it counts with access to the Pacific Ocean, the Gulf of Mexico and the Atlantic Ocean (CIA, 2019). Mexico is the second largest energy consuming country of Latin America, and according to the United Nations database, in 2020 their population will be 133,870,000 inhabitants growing at a rate of 1.06 % each year (UN, 2017). More people mean more energy consumption, especially in modern times, with a lifestyle and industries highly dependent on electricity use for almost every aspect of any daily production cycle. Given Mexican natural rich availability of wind resources it makes sense to broadly diversify their actual sources for energy supply, which today is largely dependent on the combustion of fossil fuels, primarily gas followed in importance by coal and oil (IRENA, 2015, 13).

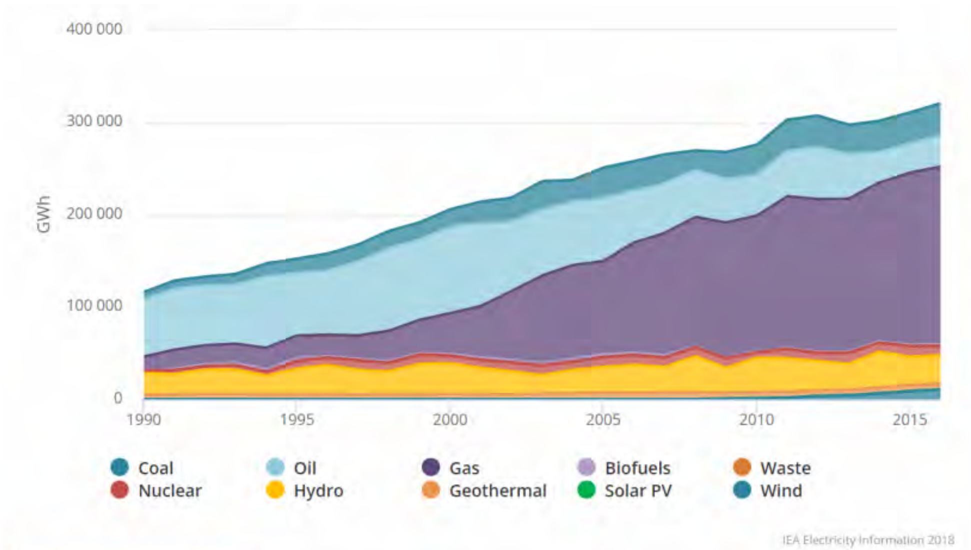


Figure 1 “Electricity generation by fuel. Mexico 1990-2016” Source: (IEA, 2018)

Compared to other countries, Mexico has ample land availability, comfortable working climate conditions, and very good wind quality; its wind market still has opportunities to be covered by investors, nationally and internationally. If solar power and wind power team-up in the future and their potentials are well developed, they could provide almost 60% of the clean energy of the country

(IRENA, 2015, 3). Onshore wind power could provide 92 TWh in the year 2030, requiring annually 1.7 GW of wind capacity installations[2] (IRENA, 2015, 3).

In the Figures 2 and 3 of the International Energy Agency, we can see that renewables already play a role for the Mexican energy supply, but wind, has still a very modest 3.2 % participation, being gas the leader of supply, followed by coal, oil and biofuels. From the renewable resources, hydropower is the leader.

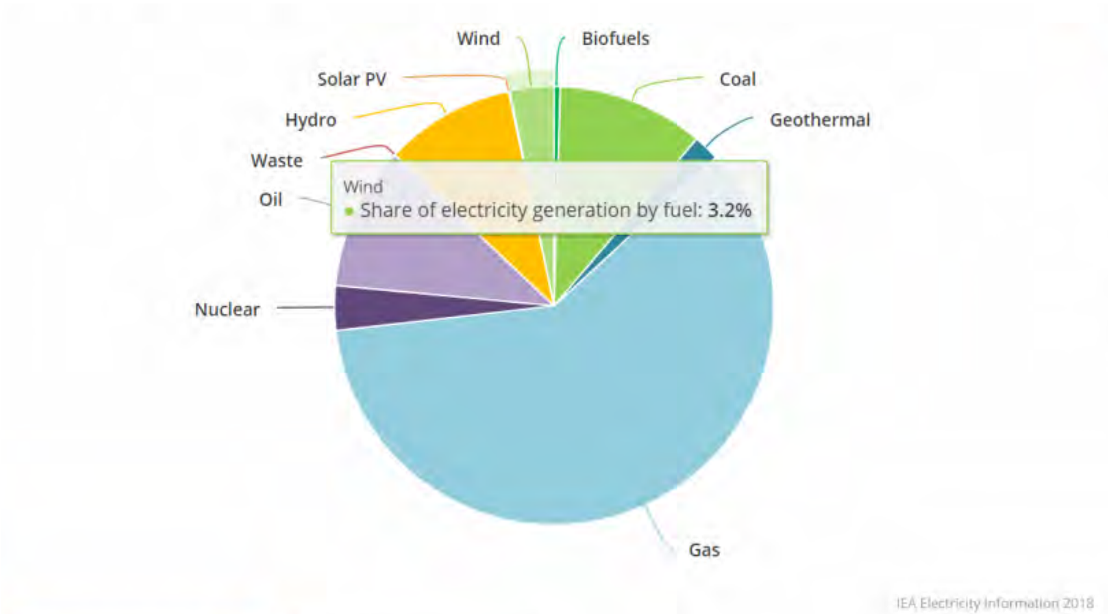


Figure 2 “Share of electricity generation by fuel. Mexico 2016”
Source: (IEA, 2018)

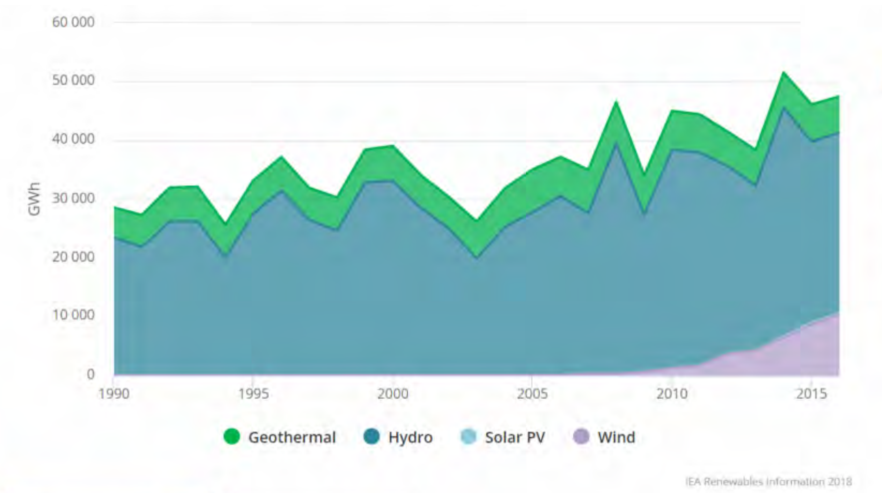


Figure 3 “Electricity generation from renewables by source. Mexico 1990-2016”
Source: (IEA, 2018)

[2] See Annex 1 table for the Electricity units in Watts.

2.1. Wind Energy Market

As proven with the Predict Wind model map below (Figure 4), Mexico's geography is convenient for the wind industry, given both its flanks at East and West count with important wind intensities and intra-terrestrial regions are often ventilated. The black arrows indicate the wind's direction and the colours in certain areas indicate the specific wind's intensity at the moment of the study. The red areas indicate the strongest winds, in this location the model box marked being 59.3 km/h, fading weaker into yellow and green for medium intensities, and the colours blue to purple indicate very low wind intensities.

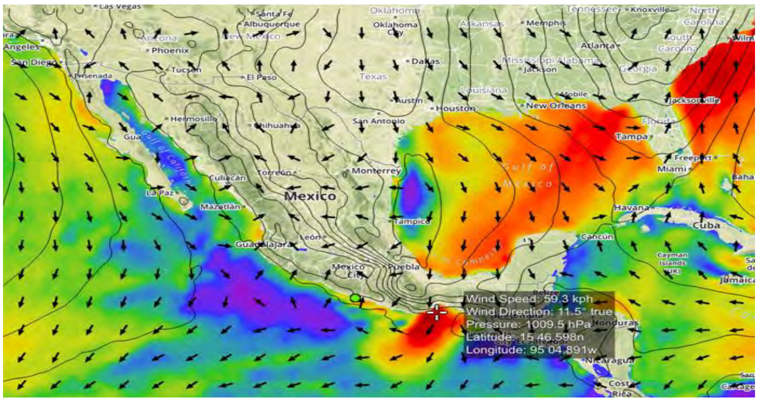


Figure 4 "Wind Mexico" Source: (Predict Wind, 2019)

For having a better naming precision, we will refer to the areas as the regions presented in the Ministry of Energy map below (SE, 2018, 18). Mexico has been strategically divided into 10 regions to better manage the national electrical system. They are referred as:

1. Central
2. Oriental
3. Occidental
4. Northwest
5. North
6. Northeast
7. Baja California
8. Peninsular
9. Baja California Sur
10. Sistema Mulegé

Figure 5 "National Electric System Regions"
Source: (SE, 2018)

According to the National Atlas of Zones with High Potential for Clean energies (AZEL, for its Spanish name), a tool which allows to highlight the most wind intense locations, we are able to present in Figure 6 the wind-relevant areas on land. The country has high potential in the Baja California Peninsula on the North West, also along its central landmass territory, as well as in the coasts of the Gulf of Mexico in the East, in addition to the Yucatan Peninsula located in the East, and particularly good potential in the South coast of the Pacific Ocean. According to Figure 6, the best potential is that located in the (2) Oriental region, (5) North, (6) Northeast, (7) Baja California, (10) Sistema Mulegé, and (8) Peninsular regions.

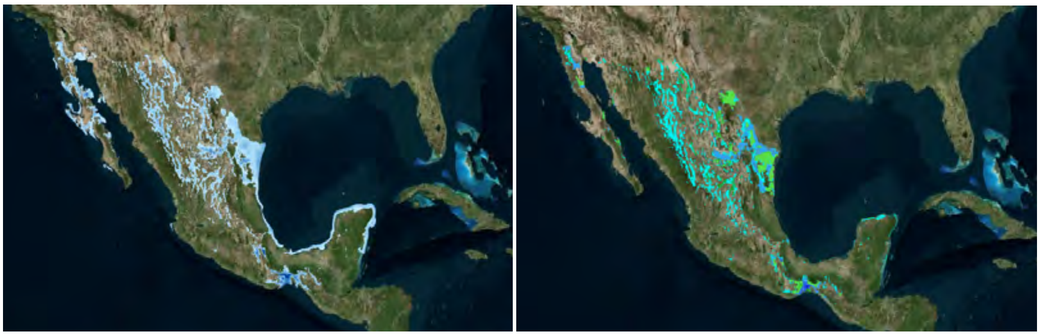


Figure 6 "National Atlas map: areas with high wind potential"
Source: (AZEL, 2019)

On the National Atlas map on the left, marked with dark blue it is illustrated where high wind potential has been identified, ranging between 11.5 m/s (or 41.4 km/h) marked in darker blue and 6 m/s (or 21.6 km/h) in lighter blue. On the map on the right the green zones are those qualified with high potential, in darker green the usable wind could generate up to 126 GWh/y by 10 km^2, although the most probable exploitation could potentially generate around 50 to 75 GWh/y by 10 km^2, and the wind energy plant potential being around 50 %.

Therefore, as the Mexican National Centre for Energy Control (CENACE) illustrates, the most relevant zones for investments which count with high potential for wind energy production are those highlighted in Figure 7 (SE, CENACE, 2018, 79).

Figure 7 “Zones with high wind energy potential” Source: (SE, CENACE, 2018)

In the southern territory of Mexico, as illustrated in Figure 8 below, a special geographical condition results in the most powerful wind current passage Mexico counts with. Convenient it is for trade to have the shortest landmass in the territory that keeps distance between the Pacific Ocean in the West and the Gulf of Mexico in the East, separated by a length of around 200 km; it also generates very strong winds. The most important area in the South is named Isthmus of Tehuantepec, located in the federal state of Oaxaca, where one of the most powerful wind projects of Latin America has been installed. The map on the left below draws attention to this area’s strongest wind regions, and on the right, the shortest distance between oceans is also drawn.

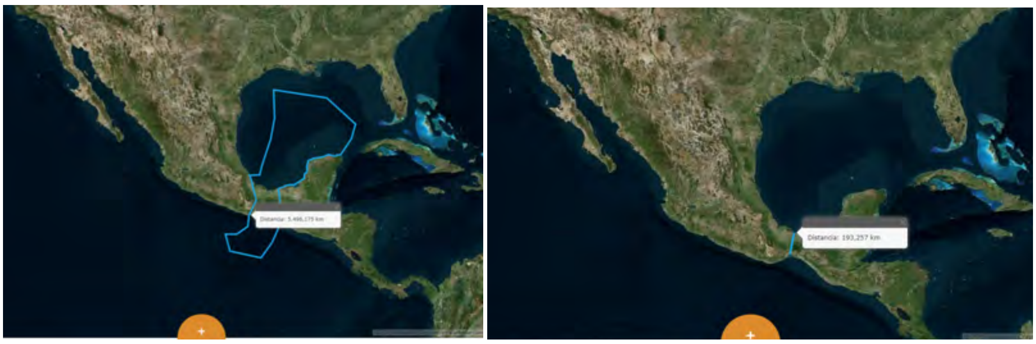


Figure 8 “Istmo de Tehuantepec I” Source: (AZEL, 2019)

In the next illustrations of Figure 9, we can better visualize the region. On the map to the left we can observe the most involved states. Subsequently, on the Juchitán area zoomed-in sketch to the right, the white areas delimit the operational wind parks to the Pacific coast; the pink areas delimit the ongoing projects, and the grey area marks the halted ones.

Figure 9 “Istmo de Tehuantepec II”
Source: left (BBC, 2017), right (GeoComunes, 2019)

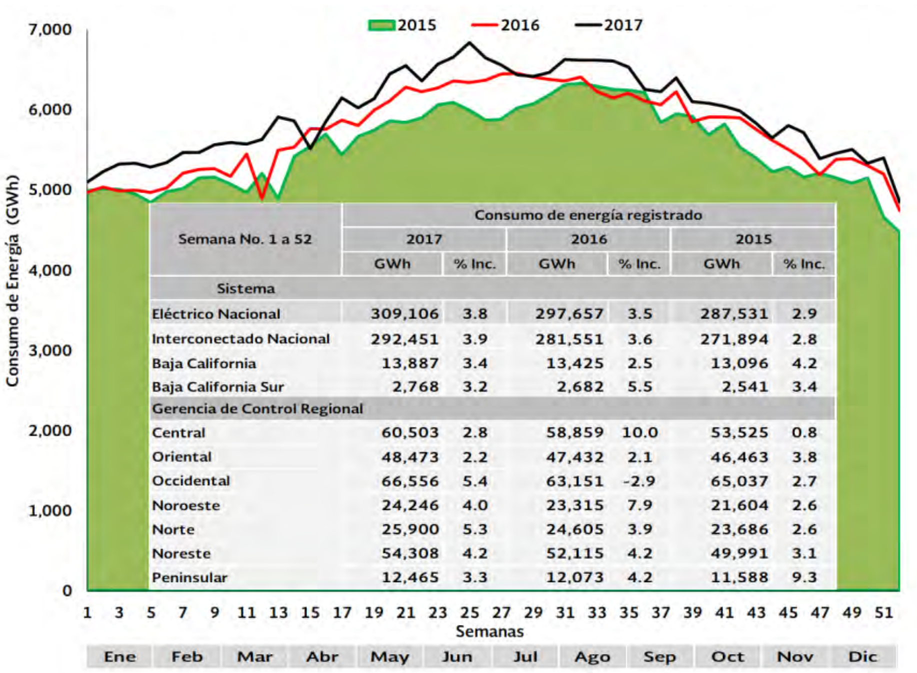
What could also be influential for wind parks to function is not only wind supply. As mentioned before, in this area there is wind surplus, but other factors influence the productivity of wind parks. In this case, it is known that local communities were not comfortable with the installations, and that some framework weaknesses influenced in the suspension of projects. Although rural communities are not in the same living conditions as in the great cities, they jealously protect their lands against what they could feel it is a threat for wellbeing. Aspects like this are to be considered in any country during the planning stages. Local communities, archaeological sites, natural ecosystems, between others, including population densities and their electricity demand.

It is therefore interesting to bring to light the importance of each onshore region as their differences in electricity consumption may define priority projects. In 2017, the National Electric System recorded an electric consumption increase of 3.7% resulting in 309,727 GWh in the country. Climate change is bringing within an increase of electricity demand for heating and cooling devices around the world. In the case of Mexico, the regions consumption ranked:

1) Occidental, 66,696 GWh
2) Central, 60,685 GWh
3) North East, 60,685 GWh
4) Oriental, 48,583 GWh
5) North, 25,949 GWh
6) North West, 25,949 GWh
7) Baja California Sur, 13,825 GWh
8) Peninsular, 12,498 GWh
9) Baja California Sur, 2,622 GWh
10) Sist. Mulegé, 152 GWh

Data Source: (SE, CENACE, 2018, 59)

Table 2 “Behaviour of the electric power consumption of the national electric system 2015, 2016 and 2017” Source: (SE, CENACE, 2018)



Semana No. 1 a 52	Consumo de energía registrado					
	2017		2016		2015	
	GWh	% Inc.	GWh	% Inc.	GWh	% Inc.
Sistema						
Eléctrico Nacional	309,106	3.8	297,657	3.5	287,531	2.9
Interconectado Nacional	292,451	3.9	281,551	3.6	271,894	2.8
Baja California	13,887	3.4	13,425	2.5	13,096	4.2
Baja California Sur	2,768	3.2	2,682	5.5	2,541	3.4
Gerencia de Control Regional						
Central	60,503	2.8	58,859	10.0	53,525	0.8
Oriental	48,473	2.2	47,432	2.1	46,463	3.8
Occidental	66,556	5.4	63,151	-2.9	65,037	2.7
Noroeste	24,246	4.0	23,315	7.9	21,604	2.6
Norte	25,900	5.3	24,605	3.9	23,686	2.6
Noreste	54,308	4.2	52,115	4.2	49,991	3.1
Peninsular	12,465	3.3	12,073	4.2	11,588	9.3

Table 2 shows the electricity demand during the 52 weeks of the year (from 1 to the left to 51 to the right) (SE, CENACE, 2018, 45). In this table it is compared the change of energy consumption during three years among the regions (during 2015, 2016 and 2017). The lowest consumption is done in the winter months of December, January, February, and March (January in the left and December in the right). The increase of electricity demand starts from April, May and June, reaching the highest levels in July due to the high summer temperatures (in the middle of the graph). Hotels, business buildings and modern houses or domestic apartments count with modern cooling systems. Electricity demand starts to slowly go down again in August, rising a bit in September, and decreasing in October and November, closing the cycle.

The Mexican consumption behaviour has seen increments during the last years, as expected the increasing tendency continues in time. The most energy demanding months are those of warmer weather, from April until September, being July the most energy intensive, suggesting that the warmer regions consume electricity for cooling, additionally from households, hotels, food and drink, hazardous materials and delicate medicines need either very cold or freezing temperatures.

The graphs in Figure 10 draw the average differences of consumption during the yearly seasons. In the North, North East and North West (left graph), and in the South (and the rest of the regions) (right graph); the summer season is depicted with the red line on a working day, light green on a non-working day. The grey line represents the winter season on a working day, and dark green in a non-working day (SE, 2013, 74). In general, the electricity is needed since 5 am when people wake up, then after 2 pm (14 hrs) is when the electric demand increases more, and later on decreases when offices tend to close at 9 pm (21 hrs), increasing again when people arrive at home.

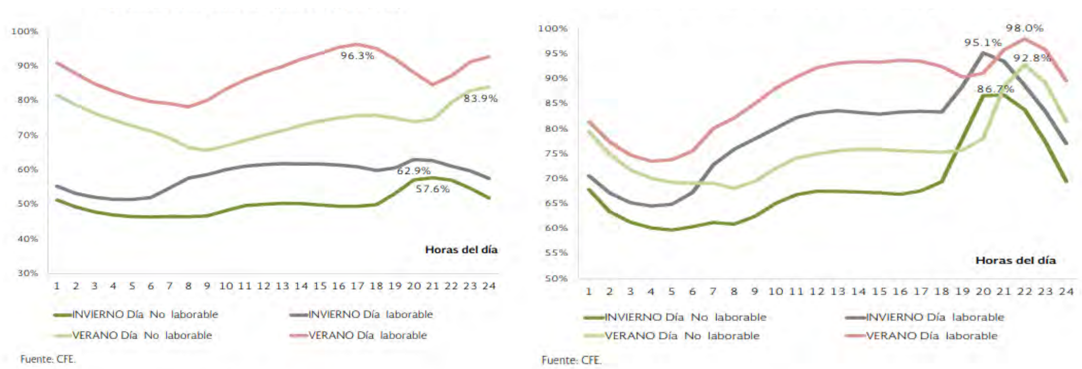


Figure 10 “Typical curves of the hour load with respect to the maximum demand” Source: (SE, 2013)

In the graph of Figure 11: “Real demand profile, 2017”, the demand differences in the northern regions between winter (in red) and summer (in green) are more clearly identified. (SE, 2018, 73)

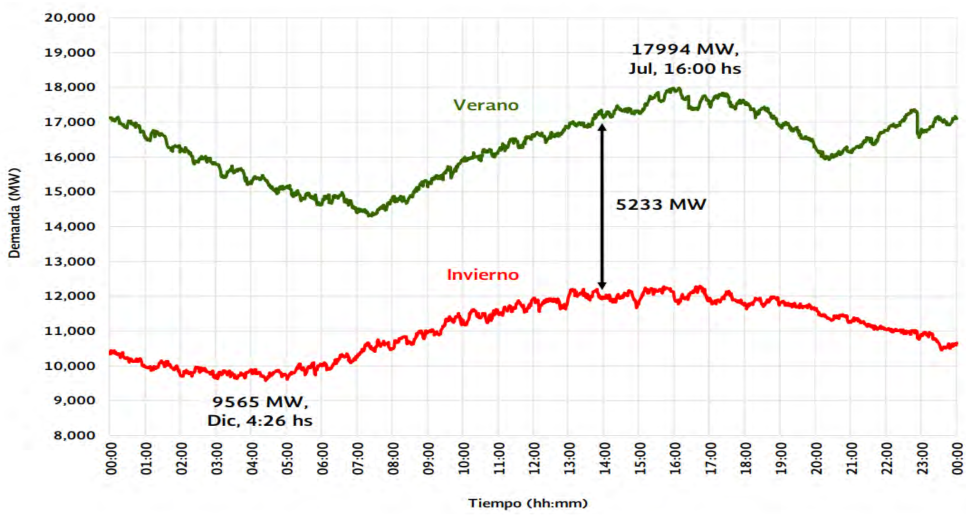


Figure 11 “Real demand profile, 2017” Source : (SE, 2018)

According to the International Energy Agency (IEA) graphs below we can distinguish the historical increase of electricity consumption in the country, since 1990 until 2016. We can observe that the last data informs that the electricity consumption per capita is around 2.29 MWh, leading to a total electricity consumption of 280.62 TWh, and compared with the wind electricity generation, we can notice than clean wind energy provided for 10,378 GWh, in comparison with 59 GWh a decade before. A very sharp increase in a very short time.

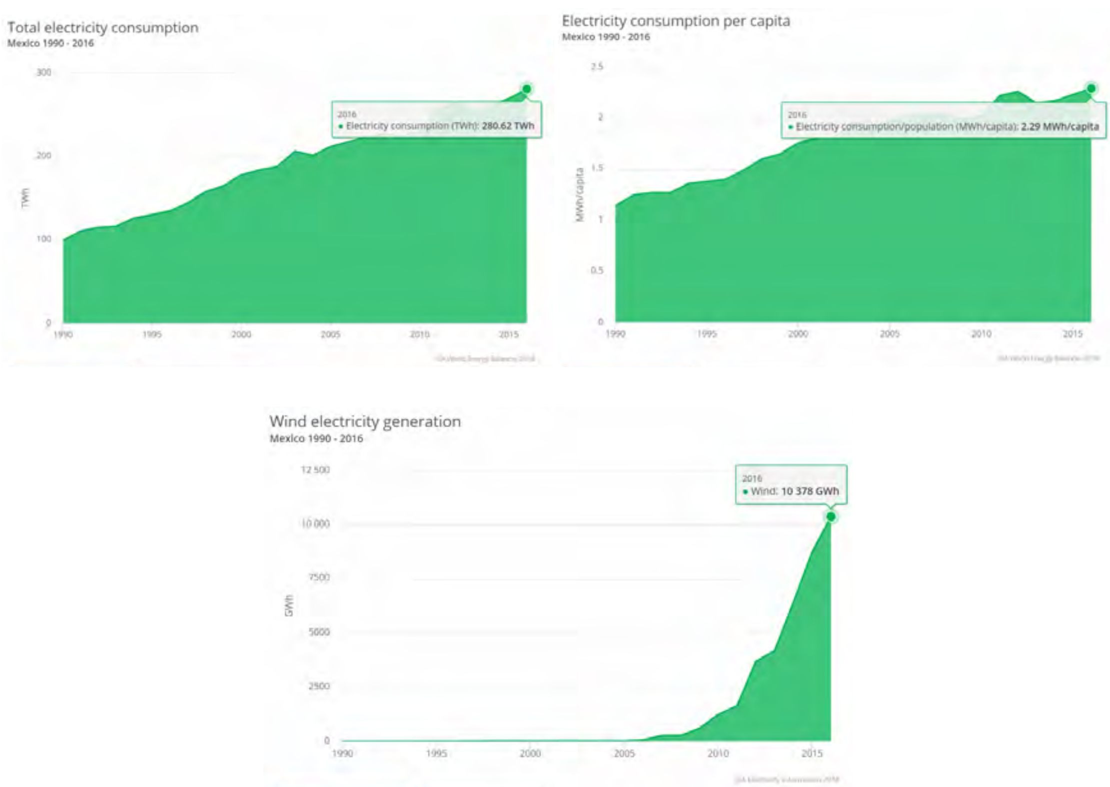


Figure 12 “Electricity Consumption. Electricity Consumption per Capita and Wind energy generation. Mexico 1990-2016” Source: (IEA, 2018)

The Mexican energy demand tendency has been increasing in the last years, reaching historically high levels. The total electricity consumption in 2017 was 309,727 GWh. Nevertheless, the jump in production of the last 10 years of wind electricity has generated as well historically high levels in the country, and in the future it will continue to increase.

According to the 2018 World Energy Council’s study, “Energy Trilemma Index”, which evaluates national energy sustainability systems around the world; Mexico rates on a global scale on place 58 of the 125 studied countries, positioned between Ukraine and Russia, reflecting its efforts in the integration of equilibrium between energy security, energy equity and environmental sustainability[3] (World Energy Council, 2018, 54).

Recent official government efforts have been carried out to make a more sustainable energy economy, like the Energy Reform of 2013, which opened up the Mexican market for international investments to modernize the energy sector, including the endorsement of clean energy production (Gobierno de la República, 2014). Ideally, foreign direct investments will multiply in the future to impulse the potential that Mexico has and benefit the energy market economy.

To counterpart these efforts, the Ministry of Environment and Natural Resources (SEMARNAT for its Spanish name) created a specialized agency to safeguard national interests, hand in hand with the Ministry of Economy (SE), a Consulting Council was also created, and the Ministry of Energy (SENER) created a Commission for regulating energy and a National Commission on Hydrocarbons. The coordinated venture aims for a national future of yearly production of 38 % of national electricity from cleaner sources, equivalent to 280 TWh by 2030, 50 % of energy produced by clean sources in 2050 (REN21, 2018, 190), and reduce coal's demand by 62 %, natural gas by 21 % and oil by 6 %. Economically this would be reflected in 9 % savings in electricity production, which are 7.2 USD per MWh, and annually 1.6 billion USD considering also savings from health complications related to pollution and reduced CO_2 emissions (IRENA, 2015, 1).

According to the National Centre for Energy Control (CENACE) the sectors that consume the most electricity are the medium-sized enterprises consuming 36.8 %, the great industries consume 26 %, residential users 23.5 %, commercial sector consumes 5.9 %, agricultural pumping 4.6 %, and services 3.3 % (SE, 2018, 18). All of this represents an opportunity field for wind-generated electricity, having the opportunity for reaching 42.2 million Mexican users.

[3] World Energy Trilemma Report 2018, defines in p.54:
-Energy Security -Effective management of primary energy supply from domestic and external sources, reliability of energy infrastructure, and ability of energy providers to meet current and future demand. ---Energy Equity -Accessibility and affordability of energy supply across the population.
-Environmental Sustainability -Encompasses achievement of supply- and demand-side energy efficiencies and development of energy supply from renewable and other low-carbon sources.

According to the International Renewable Energy Agency (IRENA), succeeding hydropower, Mexico has wind energy as the second most installed capacity of renewable energy resource in the country (IRENA, 2015, 3), which is still not yet in its full capacity, reflecting the huge potential available for future technology deployment and energy provisioning. The maps beneath show the principal electric centrals in 2017 (left) and permit holders for electric centrals (right).

Figure 13 "Principal Electric Centrals" Source: (SE, 2018, 18)

As stated in IRENA's 2030 Analysis for Mexico: "Many existing projects have been developed using project financing, a scheme used by most IPPs [Independent Power Producers] to minimize costs and reallocate investor risks. Project developers owning such projects have undertaken power purchase agreement (PPA) contracts under the self-supply scheme with large well-established companies that benefit from high credit ratings. This facilitates access and thus far has lowered the cost of financing for wind power generation. Such contracts also tend to be designed to limit project investor liability." (IRENA 2015, 16) With this we see more clearly the expansion of wind projects.

The Mexican transmission system is very well linked, nationally, and internationally. Nationally, the transmission system is clearly identified in regions, and only Northern Baja California and Southern Baja California have an isolated system. Internationally, according to the IRENA information, there is an installed transmission line of 103 km of 400 kV with Guatemala, capable of exporting 200 MW and importing 70 MW (IRENA 2015, 23). As well, Mexico has a 65 MW connection with Belize, and 11 more connections with its main consumer, the United States (36 MW Texas and 800 MW California) (Ibid.). Figure 14 marks in red the maximum flow (MW), in grey the transmission limit and in yellow the extra limit hours of energy control.

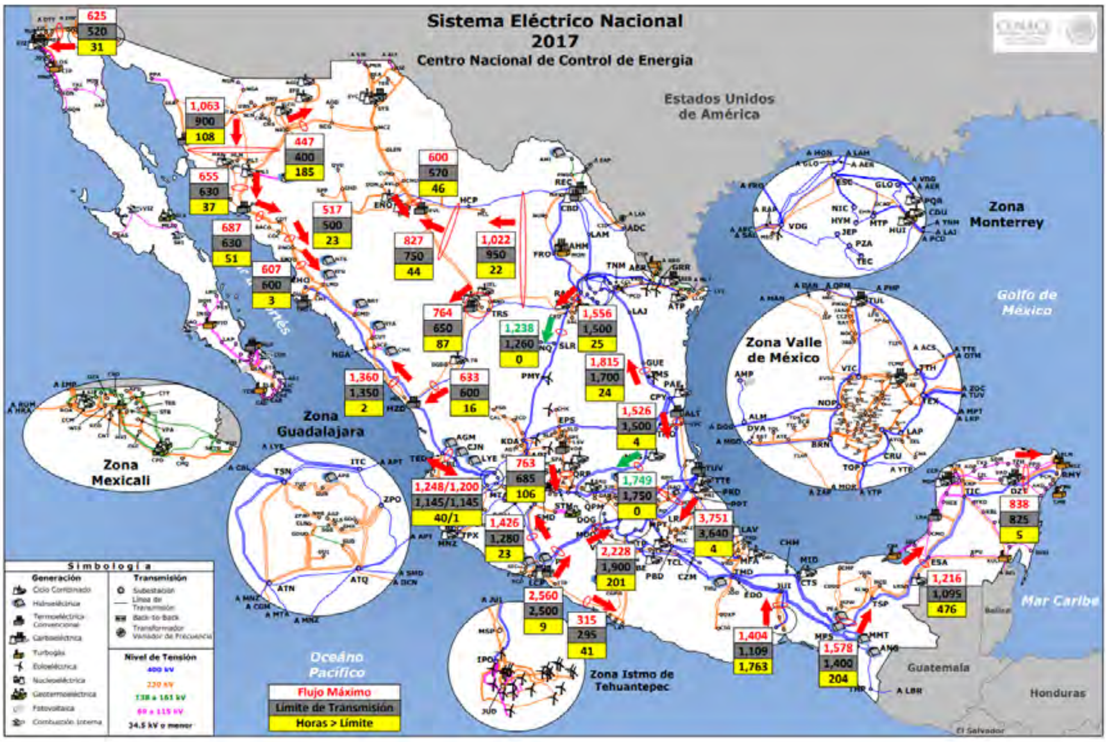


Figure 14 “National Electric System-Generation and Transmission”
Source: (SE, 2018, 53)

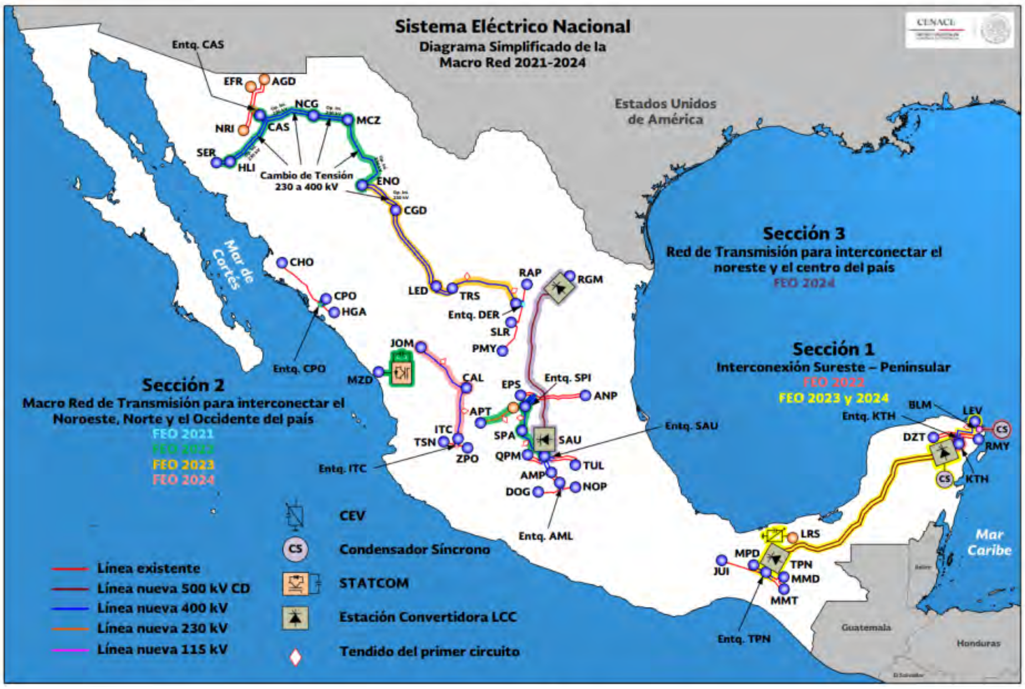


Figure 15 “National Electric System, Network 2021-2024”
Source: (SE, 2018, 80)

Figure 14 contains very detailed information about the National Electric System, updated in 2017. Including locations of different generation systems, and the transmission that connects them, as well as the tension levels they can manage. In Figure 15, the future transmission plans are coloured in light blue for 2021, in green for 2022, in orange for 2023 and in pink for 2024 (SE, 2018, 80).

These structural plans are a good base in which shareholders could rely for assuring that their investments will be supported by national transmission improvements. The expansion of the network will support the growing renewable industries, and we can realize that they are planned to be located in the regions where we previously mentioned wind energy has its better potential and substantial electric demand.

The National Centre of Energy Control (CENACE), which is an independent system operator (ISO), bases these plans making an analysis of statistical data, on energy balances, of future projections based on current hourly demands, planning different scenarios and considering the national energy policy. They use statistical models to calculate what is needed to prevent blackouts, considering annual forecasts, and regional forecasts. (SE, 2018, 58)

Figure 16: “Gross consumption forecast of the national electricity system 2018-2032- Planning scenarios, high and low”, shows the Ministry of Energy scenarios for the future projections from the year 2018 until 2032, being the uppermost line the highest possible average growth rate of gross electric consumption (3.5 % increase up to 500,000 GWh by the year 2032), middle line shows how far the expected plans go (up to 475,000 GWh), and the last line shows the lowest gross expected demand (2.5 % increase up to 440,000 GWh).

Figure 17: “Regional forecast of gross consumption 2018-2023 and 2018- 2032, planning scenarios”, shows the future planning scenarios per region, made by the CENACE with reference in the year 2017. The upper box number is for the increased average annual growth rate (%) scenario 2018-2023 and the box beneath adds one decade to the analysis, showing the 2018-2032 expected scenarios.

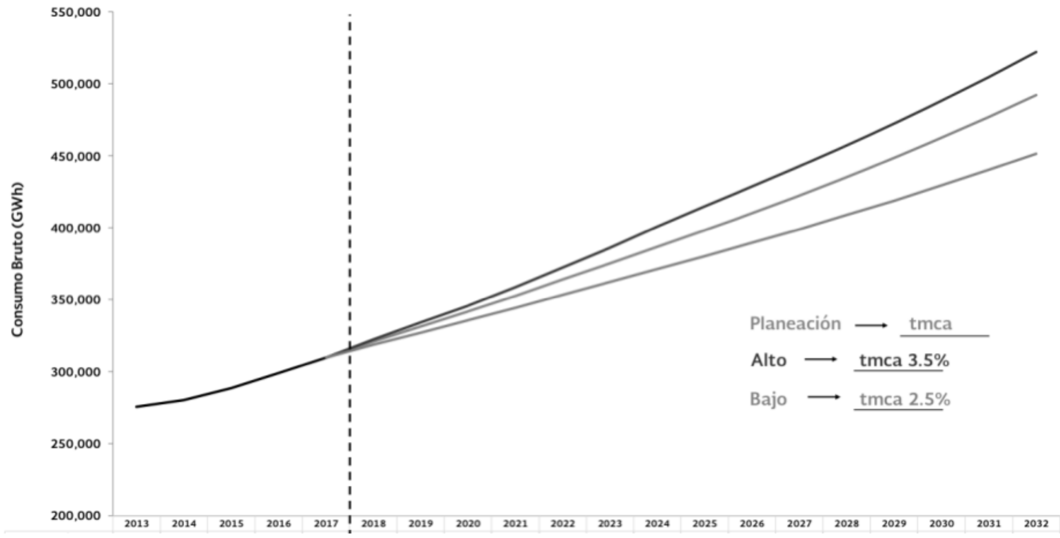


Figure 16 “Gross consumption forecast of the national electricity system 2018-2032- Planning scenarios, high and low” Source: (SE, 2018, 64)[4]

Figure 17 “Regional forecast of gross consumption 2018-2023 and 2018- 2032, planning scenarios” Source: (SE, 2018, 65)

Among the socioeconomic benefits that the supply of wind energy brings, is the avoidance of pollutant emissions that different industries generate (Figure 18), which affect environmental and human health, and which today are the related cause of around 47 % of the country’s total deceased. The economic savings in 2030 could round between 3 and 5 % of the country’s GDP, and reach between 4.6 billion USD to 11.6 billion USD savings by reducing the emissions 17 % (IRENA, 2015, 3).

[4] tmca= average annual growth rate (tasa media de crecimiento anual)

The impact and purpose of the wind power could be used in Mexico in the industries with largest electricity consumption, namely, the automotive, aluminium, tobacco, mining, rubber, water bottling, paper, chemical, cement, fertilizers, and steel (IRENA, 2015, 20). Moreover, wind energy should benefit the powering of households, especially to the close to 50 % of the rural communities who have no access to it (IRENA, 2015, 22).

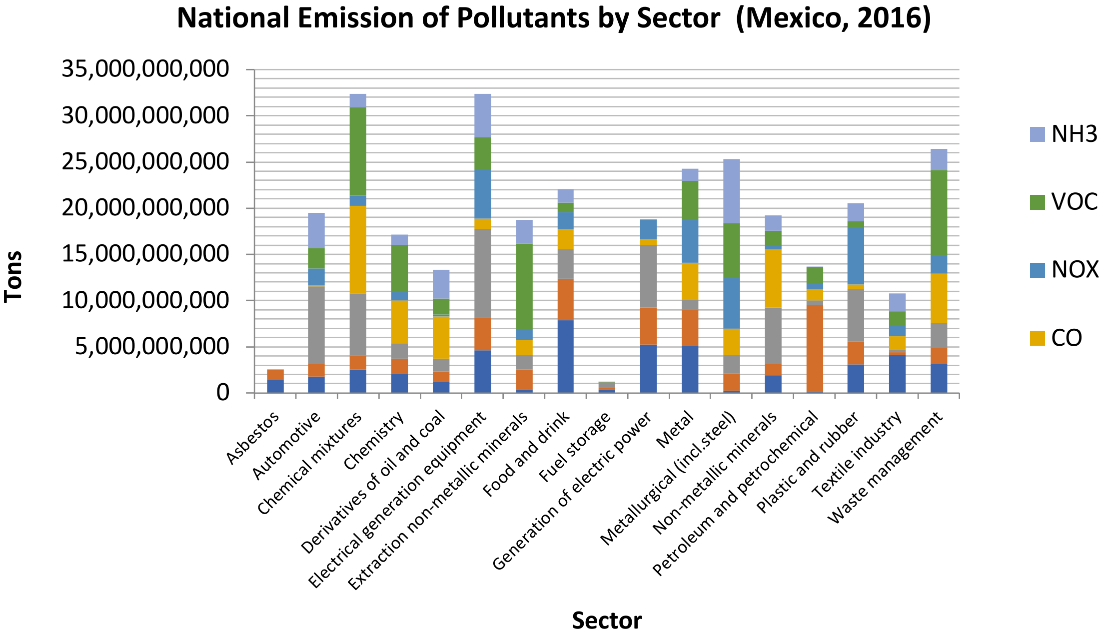


Figure 18 “National Emission of Pollutants by Sector. Mexico 2016”
Data source: (SEMARNAT, 2016)

According to the National Council of Population 27 % of the Mexican population lives in isolated communities, and 15.2 % live close to a city, wind energy can provide more power and support for the growth needed to improve their quality of life and local development by providing jobs to nearby settlements (CONAPO, 2017, 45). Figure 19 marks in red the localised isolated communities with populations smaller than 2,500 inhabitants. The green are those close to a highway, in blue are those close

Figure 19 “Isolated communities. Mexico 2014”
Source: (CONAPO, 2017)

to a mixed community. In brown are marked those close to a city, and in yellow those who belong to a city.

2.2. Advantages and limitations

Mexico's geography is advantageous for the wind industry, and nearly 60 % could be successfully harvested (IRENA, 2015, 49). The national policies that are periodically evolving will end up providing in time better cornerstones. Currently, there is a Clean Energy Certificate (CEC) system, similar to the one managed in the European Union, which obliges some parties to certain emission quotas along periods of time, which can be traded and obtained by registering reductions of greenhouse gas (GHG) emissions, which is an advantage for the companies who provide clean energy to supply those parties (Ibid., 33).

Mexico has a diplomatic talent like almost no other nation; it counts with 14 ratified agreements with countries around the world which aim to protect the environment and 84 agreements for technological and scientific cooperation (SRE, 2019). This certainly means that international companies of renewable energy can most probably find their country having special relations and benefits when signing an agreement for the development of the wind industry in Mexico. At the present time, in the case with the United States, 3 agreements exist, and in the case with Denmark one agreement exists.[5] For the funding, institutions like the World Bank, or the Inter-American Development Bank, as well as other international funds, focus on endowments for clean energy projects, especially in developing countries.

"Cities are largely bound by national frameworks and infrastructure systems. Yet effective cooperation and coordination of policies and initiatives between different levels of governance can enable change at the local level. It can unlock finance, capacity building and technical support, data, and can create new mandates to accelerate the transition to a sustainable energy future" (IRENA, 2016, 8)

[5] For the consultation of the bilateral treaties, visit the Ministry of Foreign Relations database: https://aplicaciones.sre.gob.mx/tratados/consulta_nva.php.

Some essential requirements for the wind's energy industry expansion in Mexico are the establishment of clearer operation rules to facilitate the amplification of the scope of the wind industry, transparent environmental impact assessments (EIA), social acceptance of projects, respect for indigenous lands and archaeological sites, better skilled and more professional work-force, fair legal processes, modernizing and enabling more and better access to grid infrastructure, ensuring a functional and proficient value chain, improving the capacity building, improving response times, distribution and reparation efficiency, relevant information availability and the implementation of financial incentives.

The above mentioned for the reduction of investor's risks and consequent increased aspirations for their integration into the market. Most of the needed investments are for power generation (56 %), for distribution (21 %), for transmission (12 %) and for maintenance (11 %) (IRENA, 2015, 24).

Mexico still has to overcome some of the most important limitations that could impact the industry in a large scale. The effective rule of law needs some improvements in practice, the government's intentions are set on the energy policy to fulfil its responsibility to meet electricity demand at the lowest cost; however, the efficiency and the effectiveness of the Mexican legal framework nonetheless needs qualitative improvements, which mostly depend on the government officials desirable improved education on the field they are and will be working on. Additionally, the future projects are to be authorized by the Energy Ministry (SENER) (Ibid.), in coordination with other two institutions, the National Centre for Energy Control (CENACE) and the Energy Regulatory Commission (CRE- Comisión Reguladora de Energía), which will reduce the simplicity of the authorization processes.

Another challenge is to be able to connect more efficiently the distances between the areas with high wind potential and areas of electricity demand. The long-term planning of the national authorities seems to be making progress, however a limitation to the industry would be if these plans are not successfully executed.

For the purpose of wind energy being successfully transmitted to the consumers, a system's modernization plays a crucial role. According to IRENA's 2030 study, “a Transmission System Operator (TSO) would consider three divers for grid expansion: renewable interconnection, market condition improvement and supply security” (Ibid., 64).

This is done by improving its integration and expansion of grid and mini-grid, for meeting the congestion challenges of the variable power flows, designed across the national energy demanding regions, a right that until now has been exclusively given to the Federal Commission of Electricity (CFE). Up to the year 2017, according to their Annual Report, 830,000 km of distribution network are currently installed across the country (CFE, 2017), but for the future electricity demand increase, an expansion even larger will be needed to have more congestion flexibility to avoid any blackout risk, which requires additional yearly investments of 300,000 million USD for backup generation capacity of 6 GW (IRENA, 2015, 64).

Another challenge will be to meet the low carbon obligations set on national hard law, given that even if renewable supply increases, user demand increases as well. According to IRENA’s prognosis, the renewable power generation in 2030 will only represent 19.3 % of the sources, even if the national targets pointed clean energy supply up to 35 % by 2024, to 40 % by 2035 and 50 % by 2050. Fossil fuel plants, which have long lifetimes, or the imports of gas will continue to be the main energy providers until those non-renewable resources’ stocks expire.

2.3. Expected Scenarios

Short-term:

In a short-term period of time, the lack of qualified labour force, such as engineers and wind energy or clean energy specialists, will be a throwback that will defy project developers. The reason behind this is the rather low quantity of experts approachable in a national level. In Mexico there is a very good potential for efficiency at lower costs than other countries, given the hard- working culture that exists there, but this might not be enough to achieve improvements in a long term if there is a different level of training or education than that of other developed countries on the clean energy industry. Clean energies are at a young stage of development in Mexico, and so, the trained individuals up to now might not be enough to explode its full potential. To consult the basic needed skill areas within the wind industry please consult Annex 2.

This lack of qualified workforce has the likelihood to lead to a poverty trap: beginning a tendency of importing the workforce from abroad and not allowing the local communities to get involved in the projects. In a situation where the locals are not qualified enough, importing human capital is a good short-term solution. Nevertheless, for avoiding falling in a vicious circle, those international professionals should also be aware that they should share their knowledge in the country they are working. Better trained people create stronger teams; well-qualified teams carry on better results.

The companies involved in the wind projects should plan for considerably intensive trainings to improve the professionalism of the Mexicans who will be then the future workers in the wind parks, or renewable energy projects. Organizing trainings and courses will be an investment for future savings. As experience could show, technology transfer is not enough for development; also, the knowledge transfer is relevant and a priority for keeping the pace with the global advancements, which could even result in local innovation for international improvements.

On the other hand, the energetic dependence on the imports of fuel from the United States would be reduced if wind energy flourishes hand in hand with other renewable sources of energy. Cleaner sources could partly support the energy market and save spending in fossil fuels. The knowledge that fossil fuels are not an everlasting source of energy to satisfy this increasing energy demand, hand in hand with investigations of scientists, academia, media communication and environmentalists, collectively they have harvested the interest and concern for the future's energy availability and global well-being.

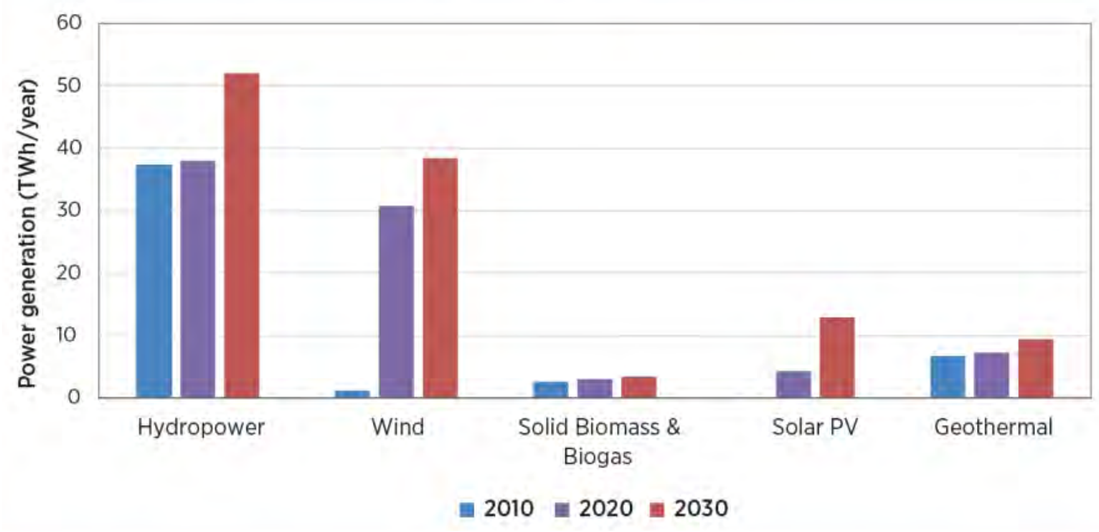


Figure 20 “Reference Case, Renewable Power Generation Growth 2010-2030”
Source: (IRENA, 2015, 47)

Modern generations are having a slight increase of conscience of their consumption habits, which will reflect in making the future businesses’ energy consumption more conscious as well. This will be reflected more action taken to support the modernization and promotion of policies and technologies for renewable sources in the country, including wind energy.

Long-term:

As depicted on the earlier maps, Mexico has vigorous winds onshore and offshore; nevertheless, the investment target and Mexico’s future wind industry will probably focus on onshore, and not on offshore, which in practice is somewhat more complex and considerably more costly. The former, given that the Mexican wind industry is still under a young development growth stage (according to our proposed table, in level 2), more experience would be needed, more qualified trainings would need to be done, and even if this is manageable in the long term its coasts are yearly heavily visited by locals and by tourists. Offshore wind energy generation, apart from being more costly and dependent of constant maintenance, it generates a visual invasion of the landscape, which in the popular Mexican coasts will not be extensively accepted.

In Figure 20, from IRENA Energy prospects for Mexico, wind power will be the second largest source of renewable power generation by the year 2030, reaching almost 40 TWh a year. The power generation for buildings could be its main area of application, as these increases almost 40 % of energy demand by 2030, or for the industry sector, which may increase its renewable energy use by around 35°% (IRENA, 2015, 47), and wind's clean energy could partially provide for this demand.

The socio-economic benefits are reflected in jobs related to the industry, which could rise, from 48,000, according to IRENA's studies, up to 175,000 (direct and indirect by 2020-2030) (Ibid., 58), clearly improving the value added of the country, stabilizing GDP's growth, and improving life quality of those working directly or indirectly with wind energy. If more local workers receive the needed trainings, the employment increase will be even greater. Mexico's CO_2 emissions could be reduced up to 70 % by 2030 (Ibid., 57). And savings from the fossil fuel industries could save up to 4.2 billion USD (Ibid., 58), each year, or reflected on a 5 % of energy saving potential (Ibid., 67).

3. United States

The United States is the largest country of North America, located in an advantageous position bordering Mexico in the South and Canada in the North, and with extensive 19,924 km of coastlines along the Pacific and Atlantic oceans (CIA, 2019). According to the United Nations database, next year their population will be 331,432,000 inhabitants, more than double that of Mexico, and it will keep growing at a rate of 0.70 % each year (UN, 2017). An increased population, which will continue to emit contamination to the atmosphere, an exponential increment just as the 2.5 % increase emission of greenhouse gases, more specifically 6,574°Mt which took place in 2018. This emission increase broke the downward tendency of emission reduction the country had had since 2005 given the impact of recent political changes. Their energy demand has also increased; this is correlated to their economic growth and increasingly fierce weather circumstances which lately result in excessive energy use for adjusting indoor conditioning regulators.

Nevertheless, in the World Energy Council's Trilemma Index, the United States globally rates on the 14th place for energy sustainability (World Energy Council, 2018, 54), a position between Canada and Israel, a reflection of its "strong performance in facing new energy transition challenges" (Ibid.,6). Their efforts supporting renewable energy sources have also been reflected in a 5.1 % increase of clean energy harvested at a national level, while in 2018 coal consumption was reduced 4.9 % to represent 27 % of the total share of energy produced in the country (BCSE, 2019, 1). Figure 20 shows the electricity content by fuel, figure 21 the renewable electricity generation and figure 22 the tendency in ten years from 2009 to 2018.

Renewable energies bring more certainty to investors, because even after being harvested, the resource is not depleted, like in the case of fossil fuels, which scarcity condition alters their price every second. In the case of wind, its value added is the stability it brings to the energy market, and the certainty of energy supply, this fact providing certainty definitely opens-up space for focusing on solving different problems.

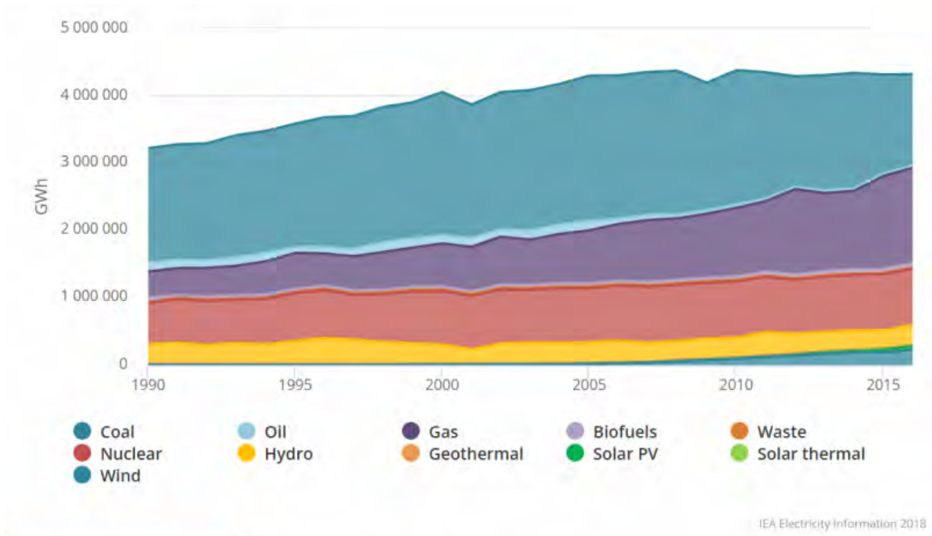


Figure 21 “Electricity generation by fuel. US 1990-2016” Source: (IEA, 2019)

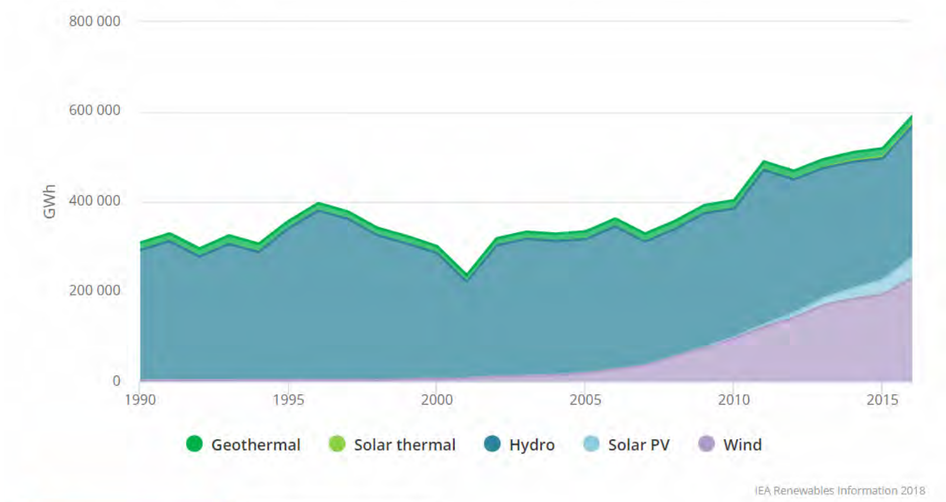


Figure 22 “Electricity generation from renewables by source. US 1990-2016”
Source: (IEA, 2019)

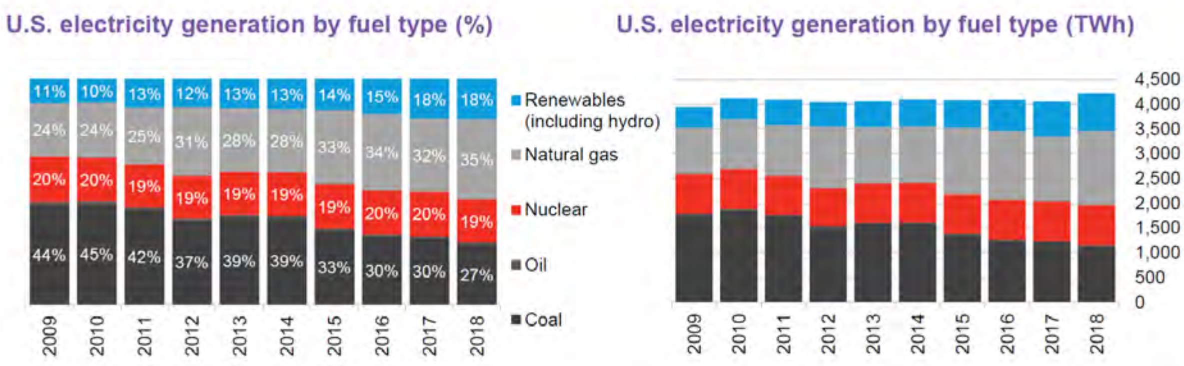


Figure 23 “US Energy overview: electricity generation mix. US 2009-2018”
Source: (BCSE, 2019, 18)

3.1. Wind Energy Industry

The geography of the United States has a lot of benefits, including the exchanging wind from the Pacific coasts. As we can notice in the Predict Wind models in Figure 24, the strongest winds are in the offshore north, but there is also a depiction of a lot of potential onshore, which is also cheaper to harvest. The strongest winds are tinted in red, rounding 54.1 km/h (15 m/s) at the moment of the study, fading into orange and yellow as the wind intensity is reduced, and the softest ones are in blue turning to purple. The small black arrows extended along the model indicate the varying wind's direction.

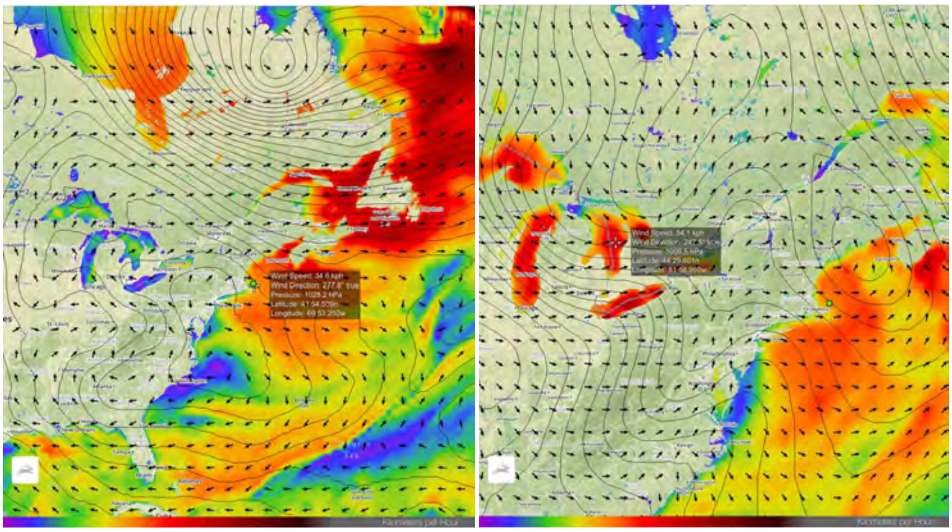


Figure 24 “Atlantic coasts of the US” Source: (Predict Wind, 2019)

The models above have the wind speed indicators, wind direction, pressure, and latitude and longitude information at the moment of the study; they vary with day and season and are constantly changing. However, stable tendencies are registered, like in the maps in the next page, borrowed from the National Renewable Energy Laboratory (NREL), which are helpful to indicate the areas with more vigorous and constant wind power.

In the map in Figure 25 on the left, the red areas experience the strongest offshore winds, located in the north coasts of the US territory; the yellow areas indicate the weaker regions. In the map on the right the darker blue areas indicate good potential areas for onshore wind farms, mainly located in the central and west inland territories of the US.

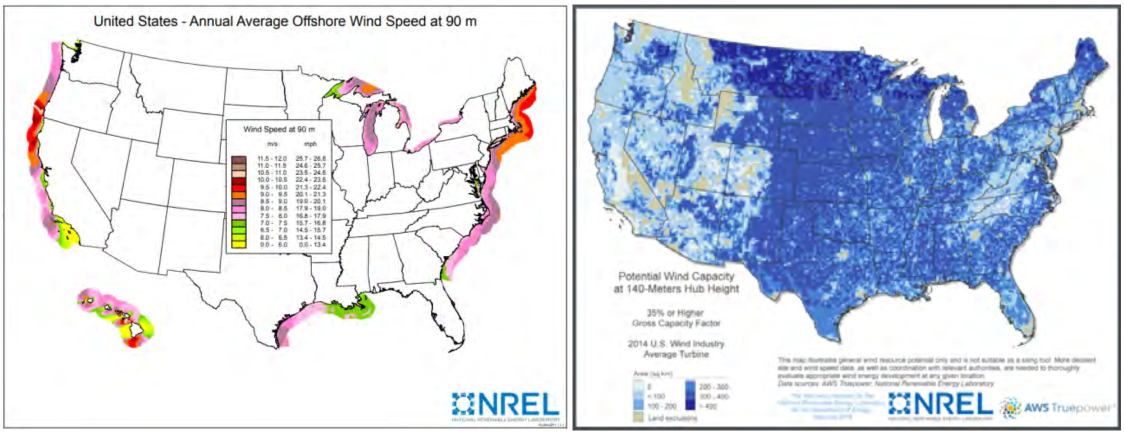


Figure 25 “US annual average wind speed” Source: (NREL, 2019b, c)

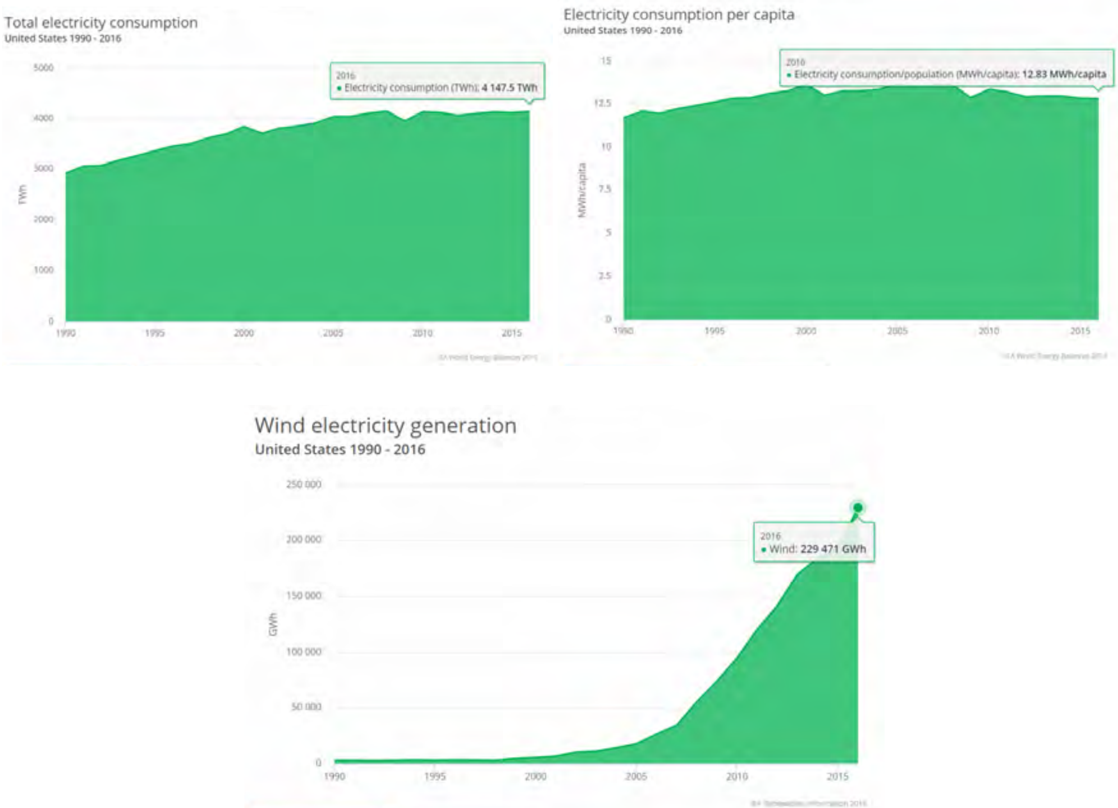


Figure 26 “Total electricity consumption. Electricity Consumption per Capita” and “Wind electricity generation. US 1990-2016” Source: (IEA, 2018)

According to the Business Council for Sustainable Energy (BCSE), the national GDP grew 2.9 % and their energy consumption 3.3 % (BCSE, 2019, 8) alarmingly calling for a diversification of their energy sources by noticing that their energy demand is larger than their domestic growth. A country with such a big demand has to plan accordingly. With the information provided by the International Energy Agency (IEA) in Figure 26, we found out that in 2016 the electricity consumption per capita in the United States was 12.83 MWh. which somehow makes analysts notice that even if there is better efficiency from modern electric devices, the electric consumption has not been reduced, it has almost been maintained along the years, and this is because even if the devices have better efficiency, people are using them more intensely, taking away the possibility of reducing emissions by reducing their demand. In Figure 27 each relevant site for electricity consumption is marked with circles; the big circles represent the largest electricity consumption demand (surpassing 300 MWh/y) and the small ones the least electricity demand, (under 1 MWh/yr). Figure 28 shows the share of electricity generation by fuel.

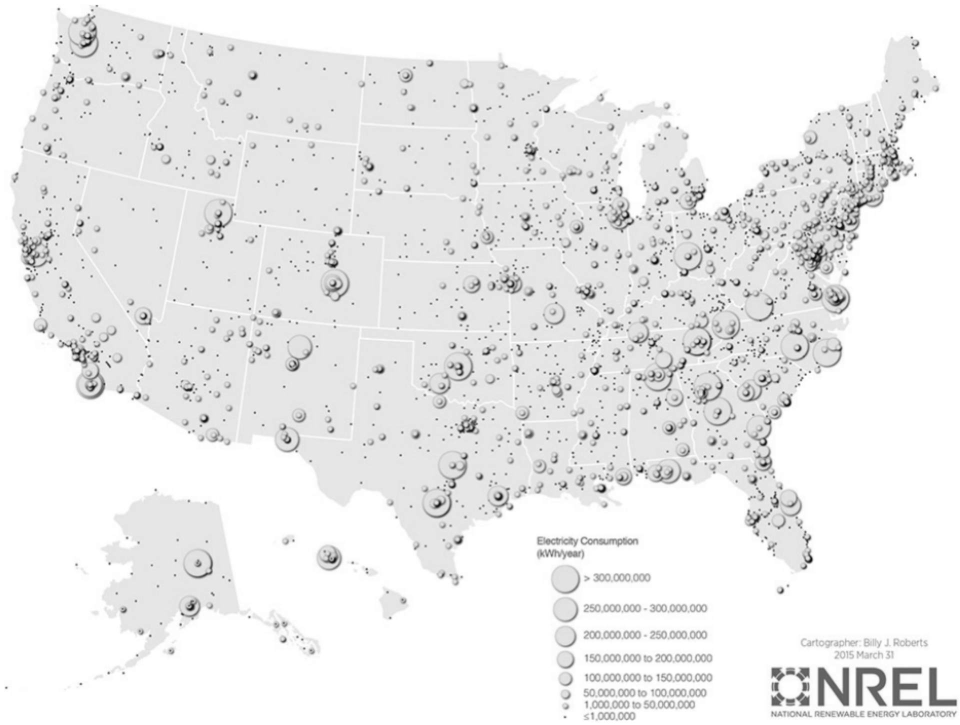


Figure 27 “Geographic distribution of Electricity Consumption at Federal Facilities” Source: (NREL, 2019d)

So, if consumption is not going to decrease, sources must be diversified. The US energy industry has identified a 10% wind potential to be provided to US Energy in 2020 (DOE, 2018b, 4), and supports it widely, by providing funding and investing in their wind’s energy research and development. According to the Business Council for Sustainable Energy (BCSE) 2019 Factbook, “wind is the largest single source of zero-carbon power-generating capacity in the U.S. Total wind installations are essentially level with nuclear in terms of capacity” (BCSE, 2019, 7).

Their prognosis is that they will be zero-carbon emitters by the year 2045, confident of their situation of having a handful of companies who participate in new projects. This prognosis remains to be seen, as business interests and political support could change over time, and not precisely towards a more encouraging spirit in the direction of renewable energy.

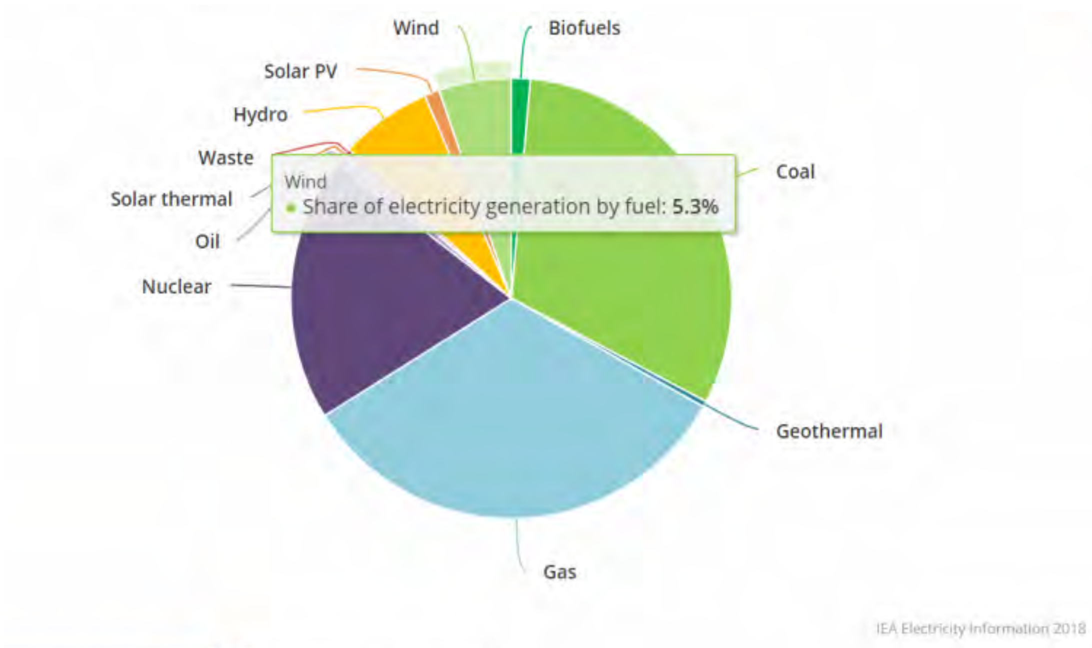


Figure 28 “Share of electricity generation by fuel. US 2016” Source: (IEA, 2018)

The US will achieve with the research and development efforts done by the National Offshore Wind Research and Development Consortium, and other constituencies, a supply of energy from offshore wind power, with the goal of maximising the gathering of close to the 86 GW of capacity (DOE, 2018a, 2).

In Figure 29, “Offshore Wind Regions”, each of the relevant offshore coasts are marked in shades of grey, the darker the shade the stronger their wind net capacity factor (%), with a share of the total offshore wind potential. The North Atlantic is the strongest candidate for offshore wind, with 33 % of the plausible 86°GW, the South Atlantic and Pacific Coasts have very similar futures, with their respective 22 % and 20 % of the predicted total offshore capacity, the Great Lakes region has a 15 % capacity, and the Gulf Coast has a 10 % capacity. (DOE, 2018a, 5)

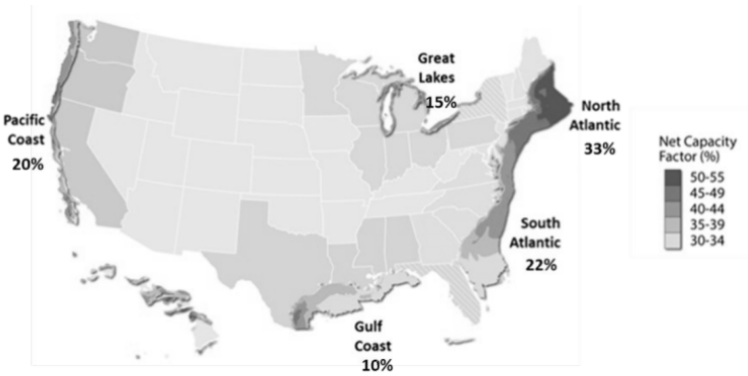


Figure 29 “Offshore Wind Regions” Source: (DOE, 2018a, 5)

The expected 2030 offshore installations will have different wind turbine models, those previously tested with fixed-bottoms down to 50 m, and the developing floating wind turbines down from 60 to 90 mts. The reason behind this is that 1,200 GW of offshore wind in the United States could be produced in very deep waters, which means plentiful of wind resources for energy supply, but also more technological challenges for their balancing (DOE, 2018a, 7).

New materials and safety mechanisms need to be developed in order to ensure long-term safe installations. These projects demand resources, unique assembling machines and transportation to get further into the ocean more often. Here comes the relevance of remote sensing and monitoring, to reduce the need for long and time-consuming visits. Instead, with satellite data provided to avoid costly and overwhelming time offshore, unnecessary physical travels to outlying locations. Though maintenance is always needed, drones are being developed to substitute the need for some check-up expeditions: “Drones typically offer quicker, more accurate and cost-effective inspection work of wind turbines and blades than conventional methods” (Wind Power Engineering, 2019).

The US Department of Energy (DOE) destined 20.5 million USD in 2017 for safer innovation, and to reduce risks, teamed-up with outstanding project developers, the final sum was elevated in 2018 to 41 million USD, specifically targeted for offshore wind, for technology development, for site studies, for optimizing operation and supply chain solutions while at the same time reducing costs of electricity transmission and distribution (DOE, 2018a).

The efforts go beyond funding and beyond importing technology from wind industry leaders or more developed nations. Different local requirements delineate what needs to be innovated, new customized technology has to be developed, as the ocean depth and sea bed is not similar, geophysical studies with tailored methods are being constructed. Furthermore, the regional regulation is different, the companies are not the same, the climate and ocean have a different behaviour, and the harbours have different loading capacities, and they were not all specifically designed to fit the wind turbines needs, such as, large capacity and space; wide enough spaces able to manoeuvre huge blades. A whole new supply chain is unfolding from the needs of this industry.

The investments do not stop there, and will not stop soon, as just in March 2019 additional 6 million USD were destined to wind energy research projects, to improve blade designs, to reduce the energy loss, to improve real-time and forecast models considering weather variability, and to reduce animal casualties by predicting their risk by locations, responding with a solution by emitting ultrasonic acoustic signals to keep them at a safer distance from the large blades of modern turbines (DOE, 2019c). In Figure 30, we can see how the wind turbine design has evolved over the last decade, and therefore, the space occupied by them has become a matter of concern for harbour managers, and as well for the protectors of the flying fauna.

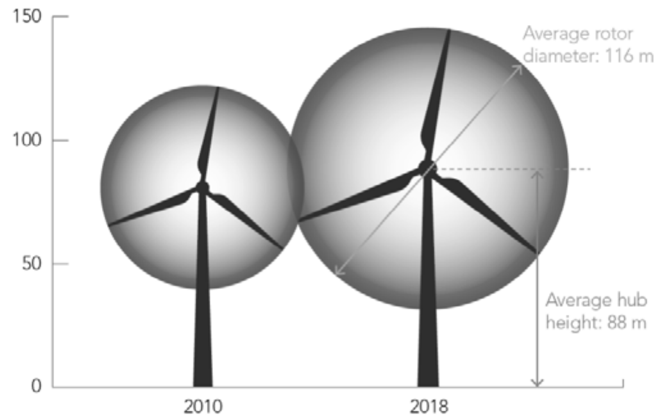


Figure 30 “Evolution of the ‘Average’ Utility-Scale Turbine”
Source: (AWEA, 2018, 5)

In the US Wind Turbine Database, all the onshore or offshore projects could be found in a detailed demeanour. Name and year of projects, their capacity in MW, the quantity of turbines, their height, and location, could be found in this interactive tool. For instance, in the database map of Figure 31 we have a sample, which shows in green highlighter a specific project unit in Mojave, California. Each spot in the ground is a wind turbine, and each colour is a different project, with all the detailed information and other close-by projects in the right tab of the dark screen, in case the researcher wants more information about them. These instruments are very useful for the analysis of atmospheric, environmental impacts and wildlife influence that surrounds them. The knowledge is also shared online, with reports, studies and papers published available to the public, enhancing a wider participation of the interested society.

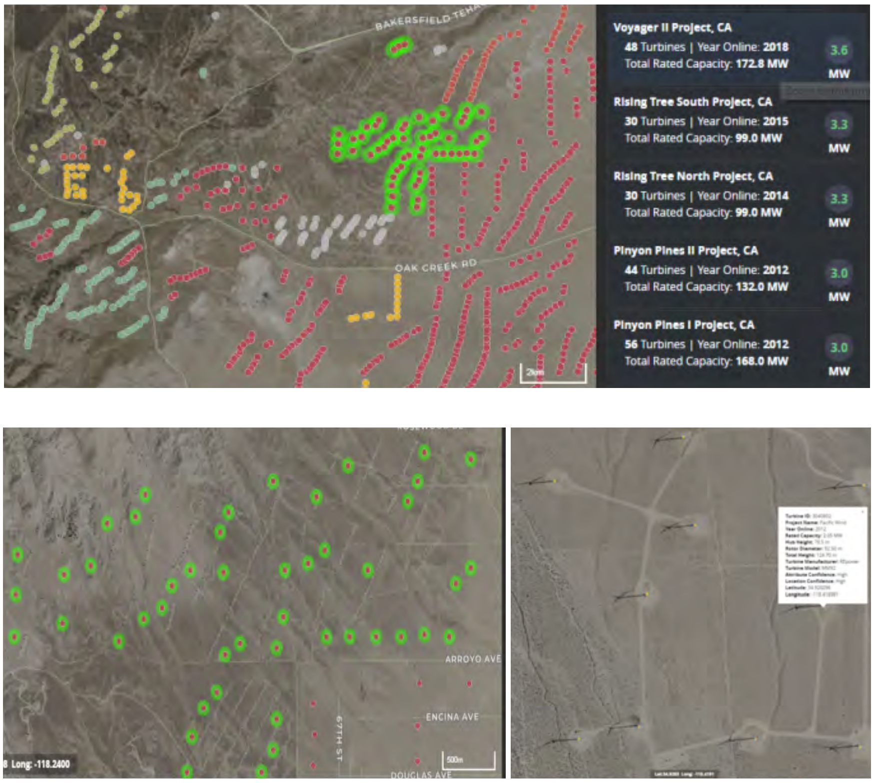


Figure 31 “US Wind Turbine Database” Source: (USWTDB, 2019)

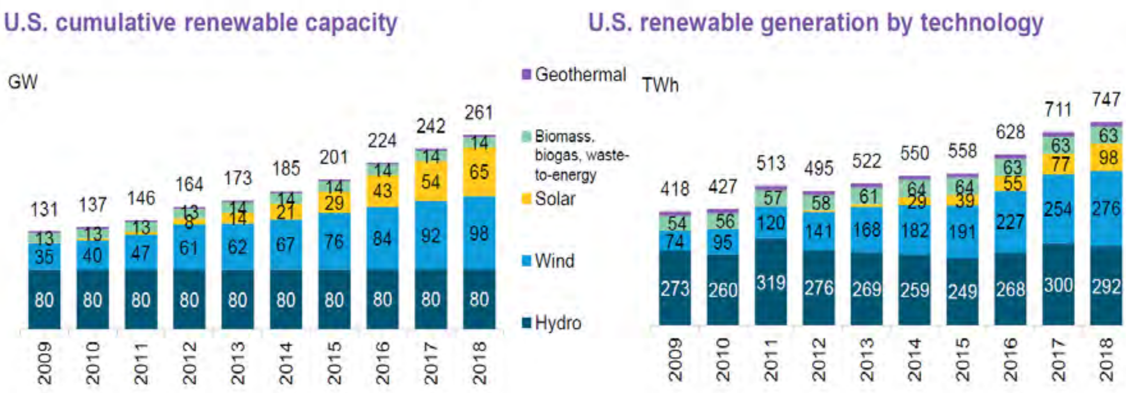


Figure 32 “US Energy overview: Cumulative renewable energy by technology” Source: (BCSE, 2019, 22)

In the graphs in Figure 32 we can see how wind has gained territory in the energy sector. In the graph to the left we can see how in almost 10 years US wind energy managed to almost triplicate its cumulative capacity. Wind energy is the second most important source of renewable energy after hydropower in the US.

The wind sector has been generating more energy year after year, as shown in the graph to the right, only out-placed by hydropower but exceeding the energy generation of solar, biomass, and geothermal. This is just another confirmation of its remarkable potential that distinguishes wind energy among the other renewable sources.

These positive results have not been easily achieved. Investments have been done, and costs paid. However, supported by cautious coordinated policies, an achievable objective which has been proved to be attainable is that the costs of production are continuing to decrease. This is the reason why the wind sector had in 2018 an installed capacity of 98 GW which in 2018 produced 276 TWh, remarkable 29 TWh more than the previous year; in fact, larger compared with the solar installed capacity of 65 GW and a respective more modest generation of 98 TWh.

With this grounds, 158 companies had already in 2018 set a change in their energy sources, to become 100 % renewable energy consumers (BCSE, 2019,41), by adapting their building installations and contributing in this way with a switched demand inclined in preferences for cleaner sources, a demand that will inescapably increase with time.

To promote and support this enlargement, the US government grants recognition to those companies who meet specific requirements: The Energy Star Certification, which improves a company's reputation for good energy use. It is attributed to good quality energy efficient buildings which manage to save economic resources spent in clean energy and play an important national role in reducing the emissions generated by their industries (Energy Star, 2019). In a large scale the impact is huge, and it could be reflected in slowly converting entire states into 100 % clean energy consumers, this is what the future will witness, just as Hawaii and California have planned to do by the year 2045 (Deloitte, 2018, 4), and of course influencing other impressed states to follow.

For this tendency to continue, the investment needed in the update of the transmission systems needs not to be forgotten, to ensure maximizing its value, ensure the supply and avoid risking energy security towards instability, hand in hand with quickly digitalizing hurdle administration, to make progress in the performance and tracking processes with the best available technology (BAT) and collecting real-time data for analysts to handle. Digitalization is certainly a part of the future of all industries ahead.

According to their forthcoming plans, the prognosis is that the US will continue supporting its investment for independent transmission developers in 2020 with 21.7 billion USD, and in 2021 with 20.9 billion USD (BCSE, 2019, 37). The Business Council for Sustainable Energy (BCSE), judges that the later benefits are almost 4 times greater than the instant costs, cheering investors up with positive calculated prospects.

Another growing concern is the storage of energy, which needs additional investment support for the improvement of their battery technologies, hoping that in the future the lithium-ion battery or another one has a relevant improved capacity. Wind Europe’s database for wind and storage, allowed for a quantification of the current projects in several countries.

In the graphs in Figure 33, we can see displayed how many wind energy projects a country has and the capacity of the related projects, which will in the near future be supporting in this way the growing clean energy industries.

The United States has 13 projects, 12 for battery storage, and one for flywheel storage (operational: 185.6 MW, contracted 20 MW). Denmark has three projects, two for battery and one for power to gas storage (3.5 MW and 1.3 MW respectively). Other engaged countries are Greece (50.08 MW), Germany (35.1 MW), the UK (25.1 MW), China (23MW), Spain (13.5 MW), Ireland (7.2 MW), Canada (6 MW), Portugal (6 MW), South Korea (4 MW), Netherlands (3.2 MW), Australia (2 MW), France (2 MW), Italy (2 MW) and Japan (1 MW). Almost all are betting for battery storage, a few others for pump hydro as well as flywheel, and only Germany seems to have hopes for the hybrid battery’s future.

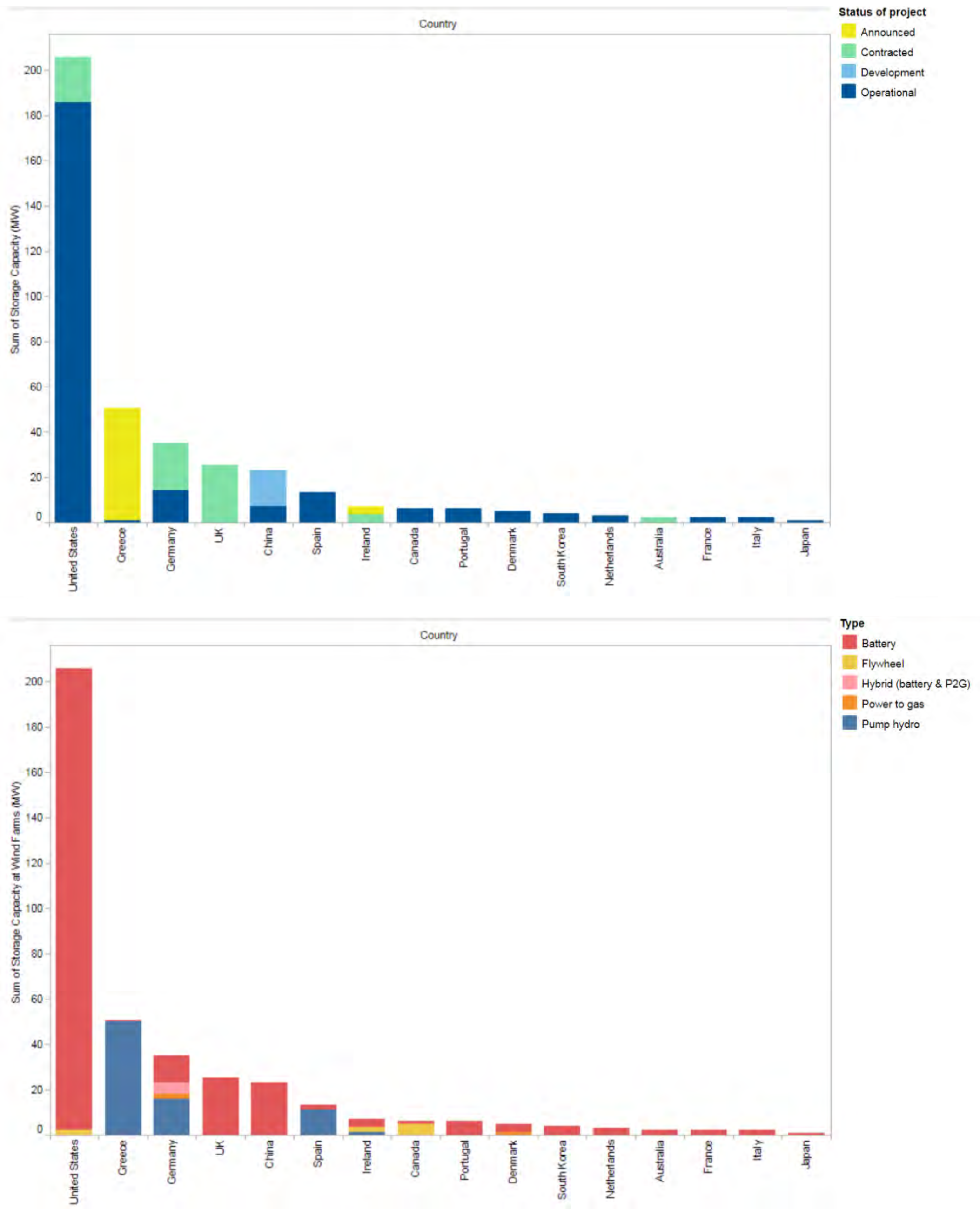


Figure 33 “Wind & energy storage co-located projects”
Source: (Wind Europe, 2019)

As global economic growth is related to energy independence and to the growth of energy efficient sources, we refer now to the relation of it to the national population. It is in every country’s interest to increase local employment, for the sake of national economic development. The socio-economic benefits in the United States (Figure 34) are reflected in the 111,166 jobs registered in 2018 related to the wind electric power generation (EPG), which is significantly higher compared with other renewable energy industries (NASEO, 2018, 68). The opportunity areas for job creation along the value chain, identified by the

International Renewable energy Agency are: “project planning, manufacturing, installation, grid connection, operation and maintenance and decommissioning”; “supporting processes, such as policy-making, financial services, education, research and development, and consulting” (IRENA, 2014, 10).

According to the American Wind Energy Association, all the 50 states that make up the country benefit from the wind industry, which supports other 24,000 of indirectly related jobs as well (AWEA, 2018, 3). Each of the wind projects requires different adjustments; however, they could take between 5 to 10 years or more to be completed, which ensures short and long-term jobs provided by the national and international companies involved.

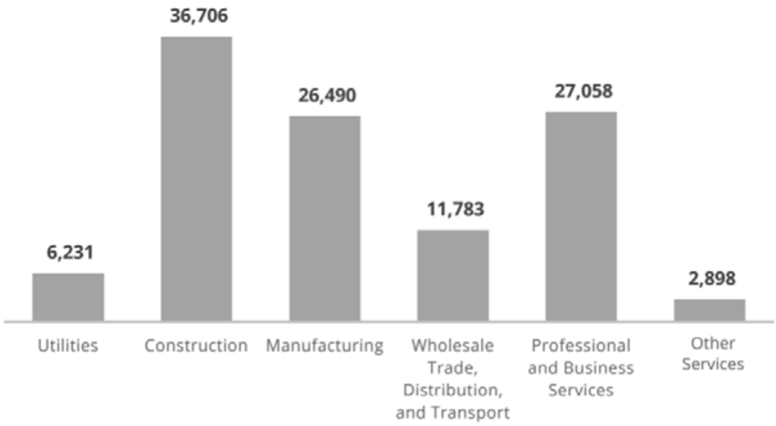


Figure 34 “Wind Electric Power Generation- Employment by Industry Sector”
Source: (NASEO, 2018, 68)

We can notice that the US wind industry already is in a further stage than that of Mexico. Focusing into solving other than basic details for improving what was previously constructed in a solid base. They are studying new areas with wind potential, finding solutions for logistic problems, improving the supply chain flaws, improving the reliability and safety of the processes and by responding to their concerns of lack of trained workforce by trainings and technical education with sufficient infrastructure and generating with this an internationally competitive industry (NREL, 2017, ix). Certified workers are to be expected by 2030, skilled and trained with the best programmes, experts and experience, ensuring the customers an improved service provided by better prepared and larger teams, gender-equal, and increasing entrusted confidence in their service.

By having more inclusion in the sector more opportunities arise. In Table 3, we can see the 32 % female participation versus the 68 % male participation in the wind electric power generation in the United States for 2018, an opportunity area to make social improvements in the near future.

Table 3 “Wind Electric Power Generation- Demographics, Q4 2018”
Source: (NASEO, 2017, 70)

Demographics	Wind		National Workforce Averages
Male	75,403	68%	53%
Female	35,763	32%	47%
Hispanic or Latino	23,015	21%	17%
Not Hispanic or Latino	88,151	79%	83%
American Indian or Alaska Native	1,359	1%	1%
Asian	11,206	10%	6%
Black or African American	8,466	8%	12%
Native Hawaiian or other Pacific Islander	1,532	1%	>1%
White	75,582	68%	78%
Two or more races	13,021	12%	2%
Veterans	10,956	10%	6%
55 and over	16,574	15%	23%
Union	5,320	5%	11%

Figure 35 “Wind Electric Power Generation- Expected Employment Growth by Industry”, Source: (NASEO, 2017, 69)

The working positions range from production to manufacturing, installations and repairs, administration, management and sales (NASEO, 2017, 59), between others, especially in the sectors depicted in the previous graph.

Coordination between authoritative and supportive institutions is evolving, people working in the planning, regulations and operations, are communicating what needs to be fixed to expand the transmission capacity and be able to support the expansion with sufficient back-up technology and process' adjustments. Each time, investors in the US are facing fewer risks. Balances are done to predict perils and to avoid casualties. Strategic improvements are being discussed with shareholders to maximize the latent benefits, and several future opportunities are being considered to expand the transmission system (NREL, 2017, 11).

In their visualisation of the future improvements and developments needed they had set targets for the years to come, detailed in the Department of Energy report: Wind Vision Roadmap 2017. In the near future of 2030, they expect to fulfil a defined list of essential actions and wind energy employees are working towards achieving them (DOE, 2018b, 5). Namely, improving predicting times for wind forecasting in minutes, hours, days, seasons; improving the understanding of the wind variations that occur in a year, including those expected by concurrent climatic appearances, like the Enso-Cycle[6] (National Weather Service , 2019), and prepare safely to confront them.

Efforts are also engaged into developing models to predict weather and wind patterns; innovate in remote measurement systems, to collect long-term data with the established monitoring systems, to improve the data sets for extreme wind and wave events; to create data archives and support the creation and update of maps and models which consider wind power, turbulence, speeds and other influencing details.

Several companies worldwide are actively working on satellite and remote sensing technologies to improve the imagery and achieve impeccable representations and models. Even if modelling costs are high today, the tendency of their price is also decreasing, and having access to their information certainly reduces the risks and costs for investors, reflecting the savings in more competitive prices for their energy in the market.

Other future actions due to 2030 are the improvement of the turbine aerodynamic and taller design, updates for computational tools to support with the quantitative studies, which can impact on the technology efficiency and quality. As well,

[6] Enso-Cycle: "A constant change in the warming and cooling weather pattern happening in the Pacific Ocean which modifies the weather and results in storms which affect the countries with Pacific Coasts" (National Weather Service, 2019).

showing working opportunity areas, like promising projects to support the next generation for stronger and lower-in-costs technology.

All of the efforts in the United States bring together loads of ideas from people around the world working together towards the same objective, so for this reason, international collaborations continue to be part of the future plans of the United States. All the ambitioned actions mentioned above can only go hand in hand and coordinated with stable and reliable rules of procedure, secure operating conditions, and stricter certifications to regulate that everything evolves in the correct direction. Their idea of evolution is to be able to lead the industry by 2050, by teaming up the best experts to offer wind products and alternatives with innovative US' designs along the entire supply chain.

The United States plans for a future competitive industry, by developing original manufacturing technology not only for domestic demand, but also for large-scale international commercialization. They recognize the importance of ensuring safe installations. Ensuring maintenance and monitoring of the workplace is always important for timely turbine replacements, increasing infrastructure's safety and reliability by reducing risks and costs due to failures. For 2050 they are already working on the identification of flexible curves of supply to prepare for high-congestion flexible solutions, higher capacity resources and suitable technologies to be able to respond to future energy demands (DOE, 2018b, 36).

Their Wind Roadmap Actions reflect how much project developers, policy makers and investors consider the importance of the awareness of the cost-benefits of managing a full supply chain. This importance comes from the need to increase efficiency between diverse but complementary industries and finally create a competitive wind industry. Naturally, this comes together with a longing increase of economic support. For instance, an interesting synergy is mentioned by the analysts, which teams-up the aerospace, automotive, oil and gas industries together (Ibid., 23), for the production of first level materials and customized instruments to widen the wind's industry capacity, to establish networks and to strengthen the country's infrastructure.

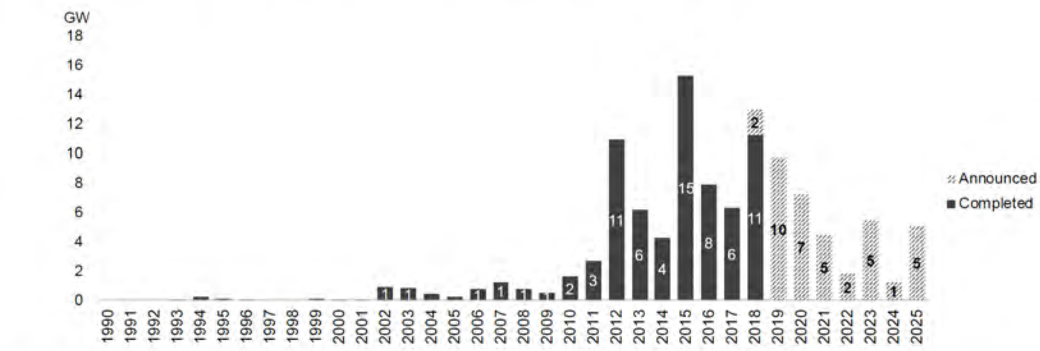


Figure 36 “US Energy overview: Completed and announced coal-fired plant retirements” Source: (BCSE, 2019, 19)

The joint efforts with the fossil fuel industry may seem confusing, but instead of competing, they should be joining forces to work together as they unconsciously and indirectly do so by being the main international actors who keep powering the world with their produced energy. It is to be remarked, that the companies involved in the energy sector have in their financial planning the annual retirement of coal-fired power plants (Figure 36), for instance 17GW for the period 2019-2020, and 18 GW more until 2025 (BCSE, 2019, 19). For this reason, instead of picking a competitive atmosphere, a well-disposed merge of efforts could be more positive for their societies.

By 2050 the US intends to work better with the public and environmental impacts. They have set actions to be followed to reduce the environmental damages by avoiding more and by reacting faster.

For instance, in the Department of Energy Wind Vision Roadmap, the actions to reduce wildlife impact include the improvement of the understanding of the wind industry’s relation with the environment, namely migration patterns and others, by generating and sharing information to better understand the impacts and avoid dangerous starting points, minimize the damages and compensate for them with stronger mitigation strategies. They have categorized with an increased priority the access to funding for wildlife research and funding for public impact research (DOE, 2018b, 50).

Environmental impact assessments and public monitoring will continue to revise the risks and affectations to the areas where wind farms or power plants are installed, and make efforts to reduce them in quick timing to reduce the harm. For instance, the Energy Department, calculates an avoidance of 12.3 Gt of greenhouse gasses are to be avoided with wind energy's operation, as well as saving 260 billion water gallons (DOE, 2019b).

Their special team in the Energy Department, called the Wind Energy Technologies Office (WETO), aims to ensure environmental security by reducing man-made impacts; it "works to understand and mitigate barriers to wind power deployment by conducting research and development activities" (DOE, 2019a). They have been funding projects in collaboration with environmental organizations, and they come from laboratories, universities, local governments, industries and non-profit organizations. The WETO supports research and innovation to "develop cost-effective technologies that can minimize wildlife impacts at land-based and offshore wind farms" (DOE, 2019a). They have results from studies and actions are taken to produce ultrasonic signals to ward off bats, prairie chickens, as well as studies on the impacts of the speed of the wind turbines in relation with eagles sharing airspaces with them. In the projects' map of Figure 37, we can realize how widespread is becoming the innovation urge for wind technology, as it shows by location the number of projects active or completed in the United States.

Figure 37 "Wind Energy Technologies Office- Projects Map"
Source: (DOE, 2019d)

Around 50 of these projects are focused on environmental impacts and siting. They evaluate camera systems to minimize eagle and bat fatalities, smart detection strategies, ultrasonic acoustic manufacture, wildlife's habitat use and displacement, stereo-optic imaging, flying wildlife interaction avoidance towards wind turbines, analytical impact assessments, migration in coastlines, sensor monitoring, collisions, mitigation strategies, between others (DOE, 2019d).

Governmental efforts are supported by the concerned subgroups, like the Bats and Wind Energy Cooperative (BWEC) who work towards that same aim in a setting of cooperation. Other institutes work creating models involving weather variables and integrating all the information together to develop protection measures to enable a risk reduction based on better informed decisions.

3.2. Advantages and limitations

The United States has very good and increasing experience in the wind industry, resulting in more efficient learning curves and helping to identify the pivotal issues that need to be worked on to improve their current developing status. This is the reason why, the United States will continue to be a leader for the wind industry, as its fast advancements supported by strong investments will continue to flourish. A challenge will be to keep this level of interest, not only reflected in the future local or international investments, but also with respect with their human capital.

Education and training should be permanent to ensure continuity among generations. Energy demand will increase, and wind power will continue to power turbines. The urge of the industry to grow or to achieve its highest potential should be maintained in time. In case the United States achieves their maximum potential development point, motivation and investments should not be halted. Additional innovations are going to be needed and will help increase technological efficiency and general quality improvements to previous designs.

Another challenge that will persist in time is energy conservation, related with the improvement of the energy effective distribution when and where it is demanded, changes in patterns of energy use by industries and households, energy efficiency improvements or quality decadence by electric equipment, coping with an increased demand associated with a consecutive technological dependence. The current recycling of materials should not be set aside, this has to continue and improve as much as possible. Further logistical challenges will have to be conquered as well, akin to figuring out the transportation for onshore and offshore of the excessively voluminous blades (ultra-large rotors of 200 or more meters), which will have greater presence in the future.

An evident nuisance for the offshore wind industry of the United States is the threat of smashing hurricanes in their Atlantic coasts and Gulf of Mexico (RCG, 2018, 6), due to the inconveniences and potential damages to the turbines, difficulties for maintenance, the challenges that deep water's seabed represent, the waves' strength tumbled against the installations and soil and turbulent weather conditions; and lack of work-force on site, all are meant to be superseded.

Some other drawbacks, identified by the World Energy Council in its 2019 Report, could limit the development of this thriving renewable solution. For instance, the greatest impact is done by the voluble government's policy, which brings uncertainty for investors. Another inconvenience they consider relevant is the US role in the regional integration, their trade barriers with neighbouring countries, between others, so as to have the power to hinder a handful of efforts (World Energy Council, 2019, 189).

3.3. Expected Scenarios

Short-term:

Compared with Mexico, the US has different struggles than that of a young industry. Its development has jumped to more than that of an intermediate level. According to our table it belongs to level 4, higher than the expected development when this investigation was started.

An additional alternative that has been arising is floating wind technology, unattached like the usual offshore, and with similar potential than the traditional. The US is supporting the future wind industry in a way that it is one of the top leaders to follow in a global level. Decision makers have identified crucial working areas, which with the determination and seriousness which they are being confronted will result in a magnification of improvements.

One of the future solutions for some of the problems has seemed to be pointing towards preparatory simulations, remote monitoring with "advanced sensors, artificial intelligence, and turbine-based robotics to initiate remote repairs, the use of drones and autonomous vessels, and self-healing concepts to reduce manual repairs" (RCG, 2018, 15).

Long-term:

When a country like the United States invests so many financial resources for the purpose of innovation, an expected long-term challenge would be a shortening of the lifetime of certain technologies, early expiration of equipment, decommissioning of both types of plants: renewable and non-renewable. The United States needs to make sure that when decommissioning renewable energy plants, they do so in the correct moment and for the correct reasons. They should recycle all possible material and do not dispose the whole machinery too early, to ensure that the grey energy surrounded by these processes is less than the energy earlier or later produced.

This country's offshore and onshore wind energy potential is being seriously considered by investors, so much that it could become the nation with the most installed wind capacity due to its national energy needs and ample territory. Their area is noticeably wider than that of other leaders in the same industry, and with this natural advantage it will achieve to harness wind parks of considerable importance and power.

Grid operators will need to analyse and take care of the grid capacity at every level and take care of every detail, for being able to support the increasing energy demand that will circulate around the country, and to take it to the most and least demanding regions. Innovation in good quality and more efficient electric networks is indispensable to support the energy production and ensure full energy distribution and minimize the risk of transporting losses and blackouts.

4. Denmark

Denmark is a strong country with intense winds of Northern Europe, located in a very convenient position bordering in the South only to Germany, and connected to Scandinavia by the Northern Sea, which covers its surrounding 7,314 km of coasts (CIA, 2019). According to the United Nations database, next year their population will be, 5,689,000, and it will keep growing at a rate of 0.38% each year (UN, 2017). In the World Energy Council's Trilemma Index, it globally rates on the 1st place for energy sustainability, followed by Switzerland and Sweden (World Energy Council, 2018, 54), which involves the overall best results for energy security, energy equity and environmental sustainability.

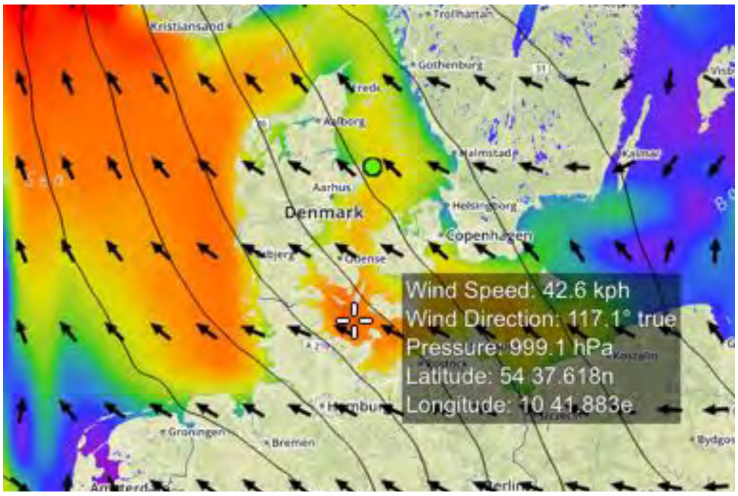


Figure 38 "Denmark" Source: (Predict Wind, 2019)

According to the International Energy Agency, wind is the strongest renewable source of Danish energy, and all renewable sources together produce more energy than fossil fuels for this country. Its leadership is well illustrated in Figures 40 and 41. Wind produces a fascinating 41.9 % of the total electricity (Figure 39), followed by 29 % of coal, 13.3 % of biofuels, 7.1 % comes from gas, 5.1 % from waste energy, 2.4 % from solar photovoltaic, and the most modest 1.1 % from oil sources. Wind energy is provided since the 1990's for an exponential increase of demand. A tendency well forecasted and well received. On the other hand, coal's combustion was periodically reduced since the 1990's, to mark the beginning of an era for renewable outburst.

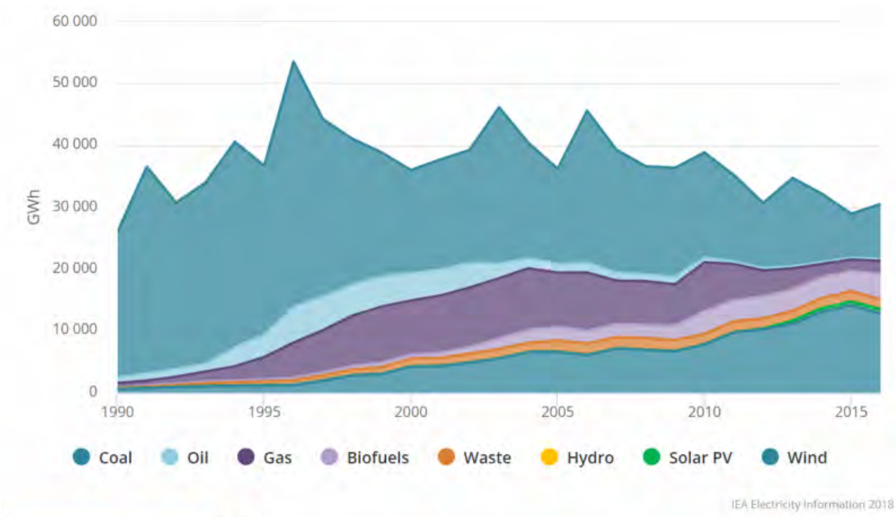


Figure 39 “Electricity Generation by Fuel. Denmark 1990-2016”
Source: (IEA, 2018)

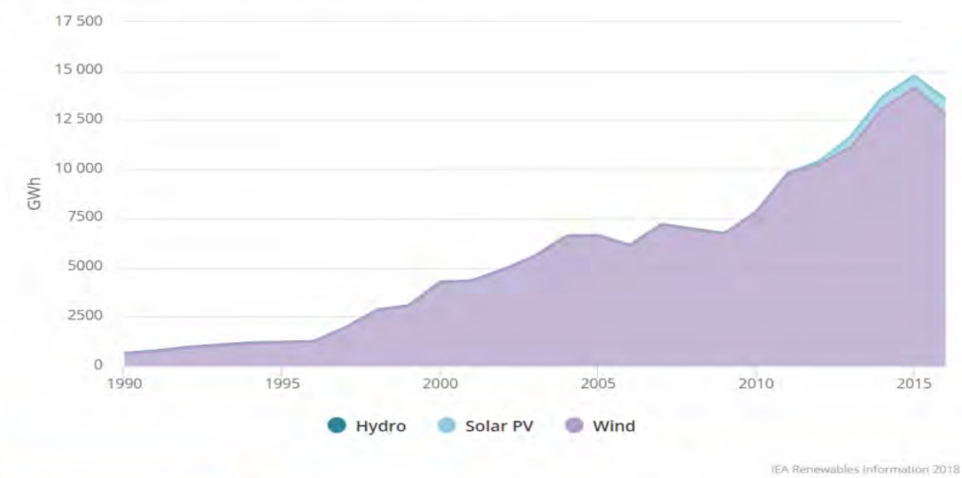


Figure 40 “Electricity Generation from renewables by source. Denmark 1990-2016” Source: (IEA, 2018)

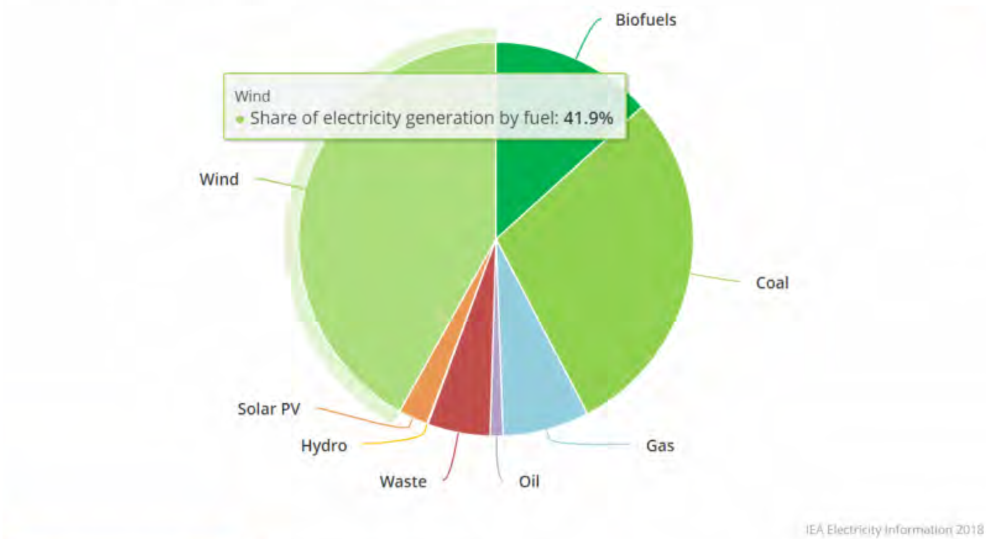


Figure 41 “Share of electricity generation by fuel. Denmark 2016”
Source: (IEA, 2018)

4.1. Wind Energy Industry

Denmark has the Baltic Sea to the East, and the North Sea to the West; a very interesting and related geography to Mexico and the United States, surrounded by water. The Predict Wind model in the previous page illustrates the areas with strongest winds in red, fading into yellow for strong winds. The information box in Figure 38 informs of the wind speed at the point with 42.6 km/h (11.8 m/s). Denmark barely has a coast with smooth winds; very few regions in the north are depicted in a weaker green, which is not a still atmosphere. The dark arrows indicate the unceasingly variable wind's direction at the moment of the study.

Even if Denmark has a very small territory compared to the US or Mexico, it has taken advantage of its coasts and surrounding shallow waters. From this aspect comes their splendid offshore development. They have had political support for more than three decades and had resulted in making of Denmark one of the ultimate wind's energy leaders in modern times (Danish Ministry of Energy, 2018b, 5). According to our development table, it ranks in level 5. The Danish Ministry of Energy, proudly publishes that their country has the best world's energy system (recognized in 2017 by the World Energy Council), best investment conditions (recognized in 2017 by the World Bank) and best green entrepreneurship (recognized in 2017 by the World Wide Fund for Nature (WWF)) (Ibid.).

Since the 1990's according to the Danish Energy Agency "offshore wind farms have been built because power companies were given political orders to do so" (Danish Energy Agency, 2015, 7) and today they have around 61 MW of offshore wind turbines connected to the grid, and 220 MW of onshore, according to information of Wind Europe (Wind Europe, 2018, 10). Denmark recognized the steadiness of offshore wind long before onshore could have been seriously considered in some other countries. Their business perception has allowed for profits for already decades by now. In Europe, the only countries running offshore development include Denmark with 61 MW, Belgium with 309 MW, Germany with 969 MW, Spain with 5 MW, Sweden with 3 MW, and the UK with 1,312 MW (Ibid.).

The developers who started earlier, have already had decades of accumulating utilities, of benefits from a wind industry that very few dared to substantiate, and investing the profits into new developments. Even in their latest Energy Agreement of 2018, they commit to “further build Denmark’s international positions of strength with a focus on renewable energy, energy efficiency improvements, research and energy regulation” (Danish Ministry of Energy, 2018c, 2) for what they refer to as a “green transition”.

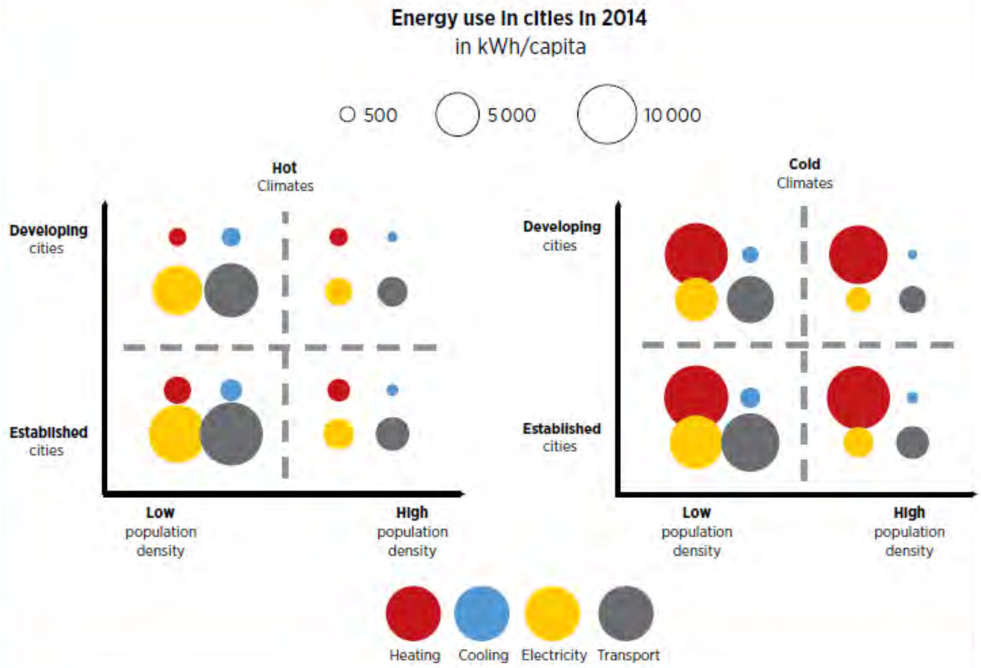


Figure 42 “Energy use in different city types, 2014” Source: (IRENA, 2016, 7)

Denmark generally faces cold weather conditions; it requires energy to produce electricity just like other climates in other regions, but it specially needs more energy for heating in winter and cooling in summer (Figure 41). This is also one of its motivations to encourage the development of cleaner sources.

In 2018 a target was set in the Danish Parliament: to reach a 55 % of renewable energy share in the energy market by the year 2030, but 100 % share in the electricity sector (Danish Ministry of Energy, 2018c, 2). Targets as high like this need a sufficient back-up and they will do so with projects of more than 2 billion Euros (15 billion DKK) and by adjusting their taxation system to benefit the lowest income group and by modifying tax rates by different demand hours for an attractive facilitation of the execution of the proposal.

For each year, the Danish Ministry of Energy, has committed to invest almost 70 million Euros (500 million DKK) to feed a rich renewable energy reserve starting on 2025, and to meet their target of reducing CO_2 emissions for 1.5 million tonnes.

In fact, they aim for a zero-emission by 2050 (Danish Ministry of Energy, 2018c, 2). The Ministry of Energy expects that these developments soon allow for a removal of state subsidies from offshore wind and phase-out coal electricity production by 2030. Danish decision-makers are eager for global leadership, and are clearly making efforts to accomplish this aspiration.

Even though it has never been an easy business, Denmark recognized the high energy demand of its people, and realized that fossil fuels were an impermanent and volatile source of energy. Denmark was three decades in the future not long ago. Their vision took them to be the role model for clean wind power production, then and today.

After seeing all the clean energy produced, an ethical question arises: if energy is being produced with cleaner sources, does that mean that the energy consumption could increase without remorse? Could energy be consumed infinitely? Danish electricity consumers could have been asking themselves that same question each time they plug in an electric device. The beauty of renewable energy resources, such as wind and solar energy, though having diurnal and nocturnal variations and seasonal transformations, is that they are harnessed and utilised without the need of environmental exploitation. They are harvested without depleting their source. Renewable energies, like solar and wind, have the capacity to fulfil our basic energy needs, and the rest of the demand could be claimed and arguably be sole caprice. However growing is the consumption of renewable energy, tightly wrapped in a cleaner human conscience; the statistics for Denmark show an unexpected tendency: electricity consumption per capita is currently lower than it was ten years ago (Figure 43). This means that the clean energy revolution in the country went beyond technology; it went also into a responsive human level of understanding of how to manage self-consumption habits, an upgrade of criteria, updating standards of an education for energy consumption after a revealing personal experience with nature’s harms, and improving behaviours by exemplifying on how to evolve from a primitive lax conscience.

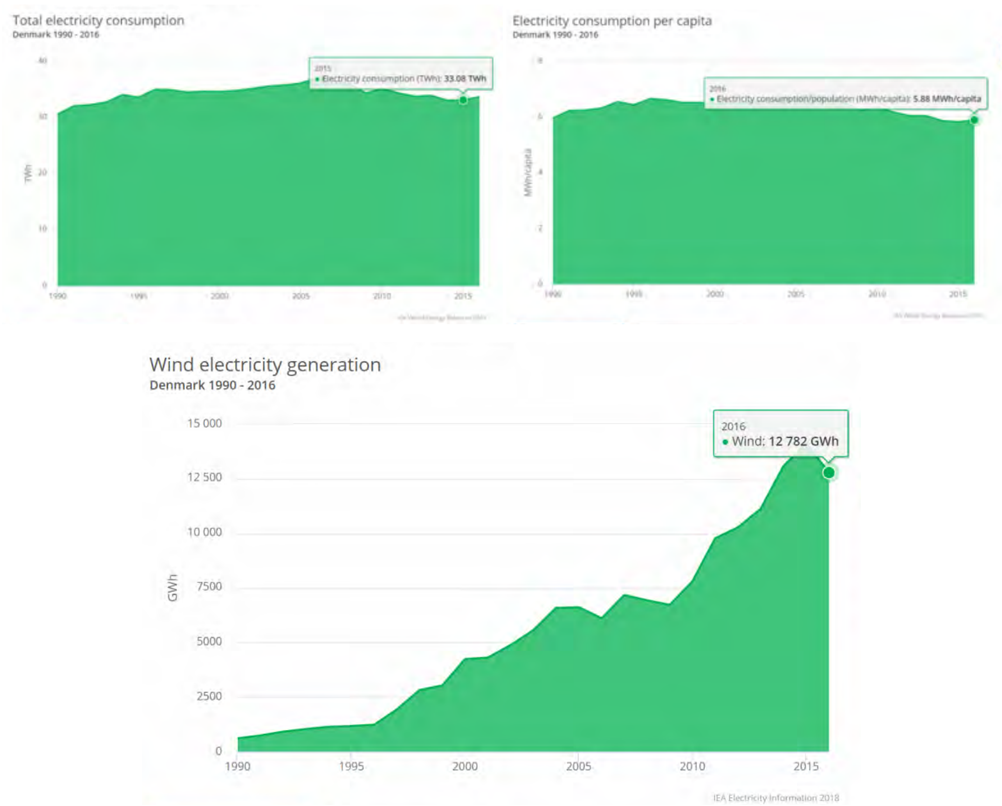


Figure 43 “Total Electricity consumption. Electricity consumption per capita” and “Wind electricity Generation. Denmark 1990-2016” Source: (IEA, 2019)

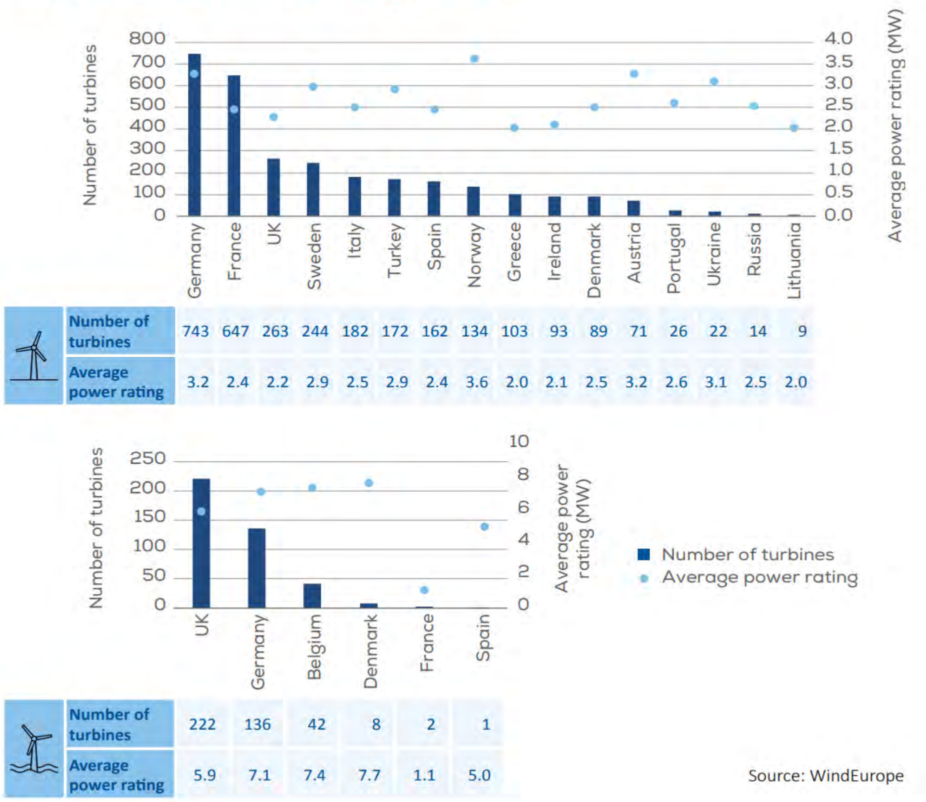


Figure 44 “Number of turbines installed in 2018 and their average power rating” Source: (Wind Europe, 2018, 20)

From Figure 43, we can notice that even though the energy consumption has not increased, the wind electricity generation has been only ascending and boosting at impressive rates for almost two decades. According to the IEA information for 2016, Danish electricity consumption per capita was around 5.88 MWh, and the wind electricity generation around 12,782 GWh.

The European Union, community of which Denmark is a member, plans to have almost 30 % of the community's electricity demand provided by wind energy by 2030 (Wind Europe, 2017, 19). Today wind energy provides 14 % from which Denmark provides 41%, Ireland 28 %, Portugal 24 %, Germany 21 %, Spain 19°%, and the UK 18 % (Wind Europe, 2018, 17). Although, according to Wind Europe's files, the future wind capacity forecasted to 2030 will have more than one leader in installed wind energy capacity. Denmark will still play an important role. The leaders are expected to be Germany, with 85 GW capacity by 2030, France with 43.4 GW, the UK with 37.5 GW, Spain with 35 GW, and after some other countries, Denmark with 9.3 GW. But let us not be distracted by the Danish small share, but the quality and understanding of its product.

As we can see from the Wind Europe graphs (Figure 44), it is not about the quantity of turbines installed, but about the power they can generate. In it we can see how even if Denmark installed about 90 turbines, minimal amount compared to Germany of around 750 or France around 650, Denmark still produces a lot of MW with less but highly efficient technology. With less than 100 turbines Denmark generates 2.5 MW, a bit more than France with 647.

The Danish wind industry is at the edge of innovation and development. Not only technologically, but as well in its legal framework and acquisition processes. They are more experienced than some of the other countries, and can afford being more selective with whom they work along in their wind projects. The planning procedures for future projects start several years before their execution, so that when a future investor makes an offer, it is completely informed of every detail that will mean costs or opportunities for its capital.

Their research and innovation include all aspects of the industry, but also all aspects of the materials, designs and functioning of the wind turbines. This enormous market comprehends the extraction of raw and processed materials, development of blades, nacelles, towers, mechanical components, electrical systems, cables and foundations, improvements in operation and management and installation and maintenance of stations (European Commission, 2016, 36).

Denmark’s setting provides certainty to the interested parties, who know that if they develop a project in an offered location in Denmark, a holistic country’s policy support is guaranteed, an advantage not many countries could offer. For instance, some of their next three offshore upcoming projects for 2021, 2023, 2024-2027 will have 800 MW capacity each, adding to the largest offshore wind farms in Europe, installed at a distance from 8 to 15 km off the coast, far enough for the purpose of reducing the visual impact to ensure a communitarian local support (Danish Ministry of Energy, 2018c, 3).

Denmark also guarantees previously well elaborated and transparent Environmental Impact Assessments (EIA), realized with anticipation to mark the importance and vitality for a contract to consider this aspect before signing anything else. This is a solid start which renewable energy projects around the world could consider implementing. They are to be reimbursed by the developer if they accept the conditions, and in this way corruption is avoided by all means before a project even starts. They use environmental monitoring programmes, which help identify natural currents, water salinity, ocean tides, threatened species, habitats and migration patterns of animals in an area.

The Danish Ministry of Energy plan is to smoothly remove half of their onshore wind turbines from 4,300 to a maximum of 1,850 in 2030, and swift their priorities towards larger offshore wind energy, “to improve the conditions for affected landowners” whose properties’ value was negatively impacted and reduced (Danish Ministry of Energy, 2018c, 5). The map in Figure 45 illustrates the locations of the current offshore wind farms in Denmark.

On the other hand, the oil and gas industry will inevitably have market repercussions, as the energy demand in Denmark is projected to favour renewable energy, as depicted in Figure 46. For the year 2040, the oil and gas industry will have their lowest demand scenario in the century (tumbling to 5,000 million tonnes of oil equivalent (Mtoe)) whilst renewable energies industry will have its greatest demand in the century (rising above 9,000 Mtoe).

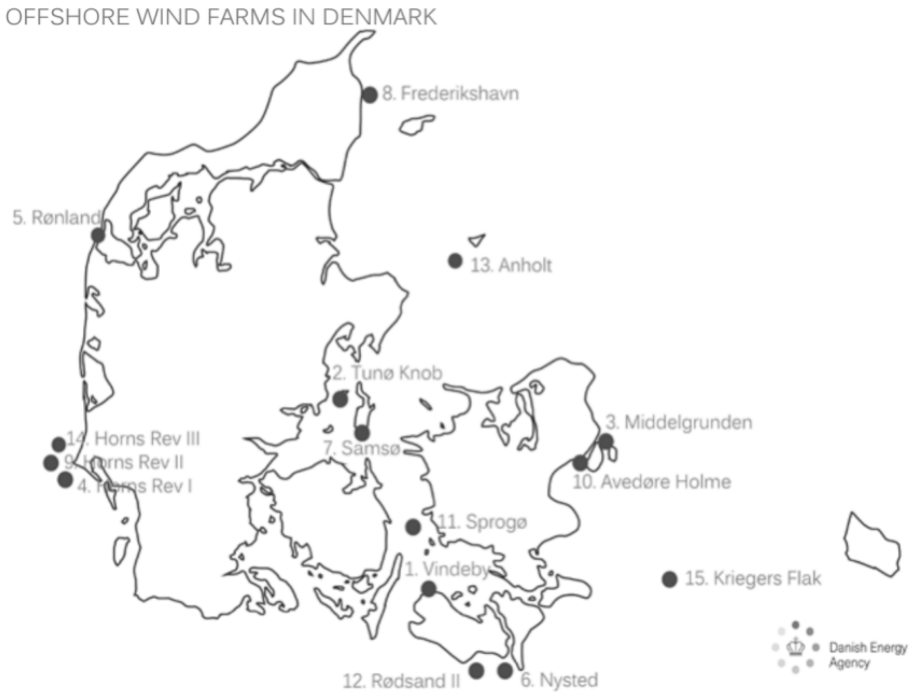


Figure 45 “Offshore Wind Farms in Denmark”
Source: (Danish Energy Agency, 2017, 8)

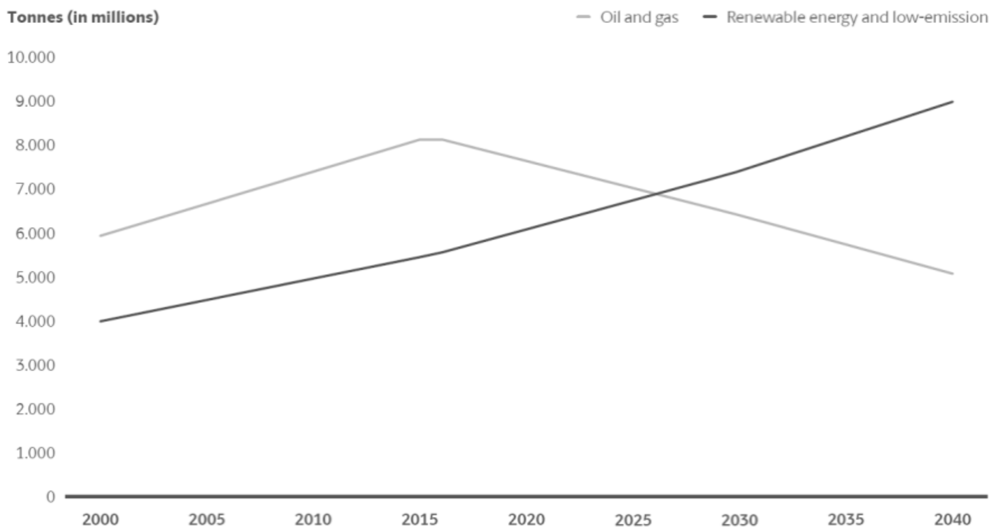


Figure 46 “Energy demand (Mtoe) between now and 2040”
Source: (Danish Ministry of Energy, 2018b, 22).

Technically answering our previous ethical questions; energy can be generated and consumed within the limits bordered by the grid scheme. Energy storage and transmission systems are the limiting variable, not so much the wind itself. If Danish population wished to consume all the wind energy, they could harvest it would be conditioned to the turbine efficiency, transmission effectiveness, installed capacity, designed connectivity networks, and storage capacity.

4.2. Advantages and limitations

Denmark also faces impediments for a fluent clean energy development, and the Ministry of Energy is targeting to better control subsidies to ensure the industry's independence (although not fully independent as it belongs to the European Union and should coordinate policies with other EU countries), update policy regulations, reduce the restraints of the tax structure, ensure energy supply and update the related business models (Danish Ministry of Energy, 2018b, 10). In the short-term they will establish testing facilities (Danish Ministry of Energy, 2018b, 21) for achieving broader clean energy solutions, as well they will realize more precautionary inspections to the operating farms to improve deficiencies and fix failures at an early stage to avoid future complications. In this way Denmark is turning limitations into industrial advantages.

Each type of wind's energy mechanical generator has some imperfection drawbacks (European Commission, 2016, 42), with the offshore installations, speciality of Denmark, some disadvantages arise. According to the European Technology and Innovation Platform on Wind Energy the huge and heavy offshore turbines' foundations take plenty more time to be built given their more complex design and given their size, they are difficult to transport. They can only be installed in certain type of resistant seabed, which is able enough to hold them. They require a lot of protection from the inescapable exterior climatic conditions, which end-up bringing more costs, taking- up more time and resources, and a lot of noise is generated while being installed, between other complications and inconveniences.

A challenge to counterbalance the above mentioned is the ongoing development of floating offshore wind farms, expected to keep stability even in deeper waters while also being efficient. Materials and structures still need to improve in weight, strength, durability, sustainability and affordability (European Commission, 2016, 50).

In Figure 47, the Ministry of Energy depicted the current and future subsidies proposal. This helps investors plan ahead with no doubt and certainty of the financial environment that probably expects them in the years to come.

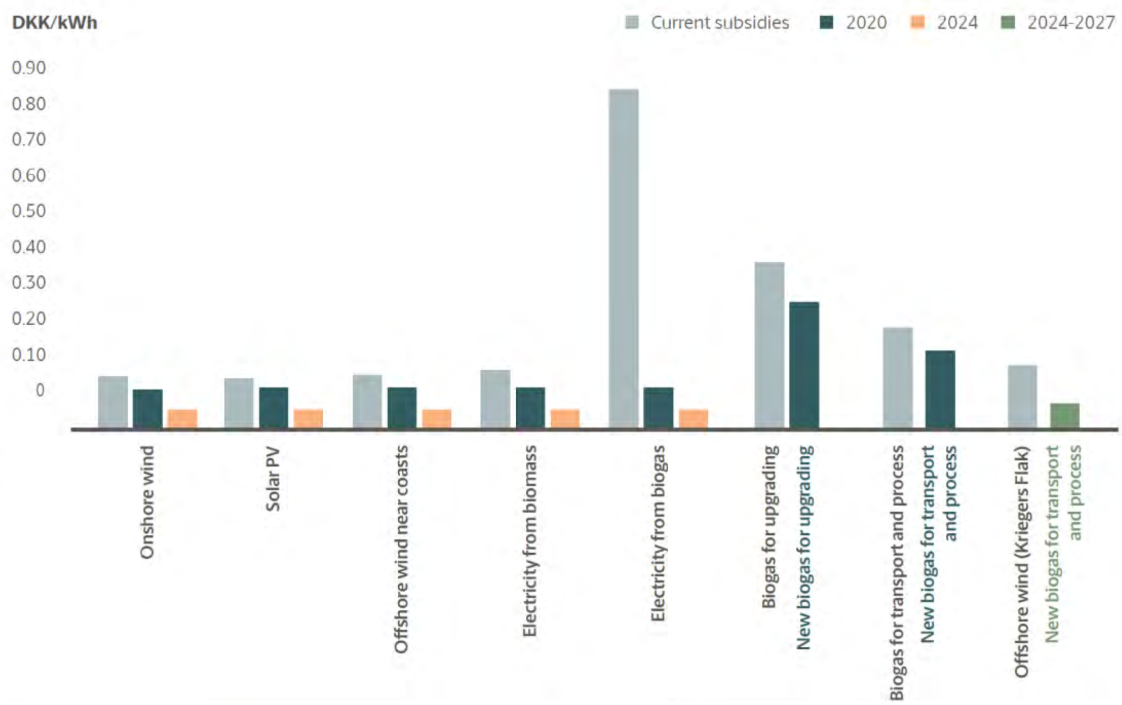


Figure 47 “The government’s proposal for a new subsidy system”
Source: (Danish Ministry of Energy, 2018b, 14)

Currently, the subsidies for onshore wind projects are carefully distinguished from those for offshore wind projects near the coasts, and in a separate category is the offshore wind park Kriegers Flak. We see that the Ministry proposed a sequential decrease in subsidies for almost all of the category projects until 2024. Only biogas for transport and process will have subsidies after that year until 2027.

The planning of future financial scenarios and announcing ahead the support the government will provide result in a competitive advantage for Denmark, ensuring market stability, certainty, and transparent information availability to the public and to investors. On the other hand, an arguable constraint that could prevent the fast-increasing tendency to continue would be the announced reduction of subsidies, which in their initial stage were one of the supporting causes of the great wind industry expansion. Nevertheless, with a strong wind commercial environment already luring companies for decades, the financial expenses could withstand from the established wind enterprises themselves, since they are not beginners in the industry as other developing countries, and they could, or with collaboration, already finance at this stage their projects.

According to the Danish Ministry of Energy, Denmark counts with international partnerships concerning export and cooperation arrangements for clean energy innovation and research on cost-efficient technologies, referred to as bilateral cooperation with public authorities on transformation of the energy sector (Danish Ministry of Energy, 2018b, 23). In the export scheme, they manage deals with the UK, the US, and Germany. In the cooperation scheme, they deal with Mexico, South Africa, Ethiopia, Indonesia, India, Vietnam, China, Turkey, and Ukraine. This reflects the openness and globalized profile of the wind energy industry, the opportunities provided across countries and the possibilities for transnational plans for growth and development along the supply chain to improve clean energy delivery to future generations.

4.3. Expected Scenarios

Short-term:
Denmark will continue to work on improving dominance on processes that ensure the best practice at a global level. In a short-term, their evolution of the energy transmission capacity from a surplus area to a deficit area will demand quick responses from planners and engineers, with interconnectors that allow the needed flexibility for switching operators' commands (IRENA, 2017, 86).

Connectivity will be strengthening not only locally, but internationally. Having strong electricity connections with other countries is part of a globalized energy market, which can have advantages like extensive energy supply options, but also disadvantages, like foreign energy dependence and possible lack of reliability in the other systems' operators. Nevertheless, in the case of a black-out, foreign energy supply supports flexible and secure repowering of critical areas with sufficient congestion, and international ownership of grid will support the expansion of energy capacity to avoid such situations in the first place.

What we refer to as flexibility is what the European Technology and Innovation Platform on Wind Energy described in their Strategic research and innovation report and we include European analysis because of Denmark's membership in that Union. According to their report, there are five sources of flexibility: grids, markets, flexible demand, flexible generation, and storage (European Commission 2016, 23). For grid flexibility they call for an improvement in the interconnection capacity, distribution and transmission networks. For flexibility in the market sources, a good planning day ahead is essential to be able to respond to the population's demands, which for domestic and industrial scenarios are also to be considered. For generation flexibility, it is essential to consider more than one source, not only wind, but the other ones involved which could add to the provision, such as hydropower, gas, etc. And for storage flexibility, different methods have to be put in together, including batteries, hydro-pump, also compressed air energy storage, power to gas or power to heat and thermal storage.

Long-term:

The Danish government's efforts work towards fulfilling smart energy plans, digitalization of data, digitalization of problem solving, and improvement of energy storage (Danish Ministry of Energy, 2018b, 24). It is true that automation improves the speed of work and reduces costs, but the long-term picture shall be carefully observed. Automatic mechanisation and digitalization bring-up another risk worthy of careful planning. On the first place, dependence on digital commanding, which in the case of blackout or failure, a chain reaction of system errors could be detonated. On the other hand, even if their population increases in a low rate and eventually to an almost negative rate (according to the general global tendency according to the UN statistics)[7], there would be expectations of having the same employment needs as today, maybe even with a wider variety.

However, if such a strong digitalization of processes evolves, a long-term risk is that fewer workforces are going to be needed, perhaps for planning humans could do the thinking, perhaps not: perhaps the people involved in the operation will still be needed, or perhaps drones could substitute them. The project workers would probably lose their jobs because machines could eventually replace them.

This risk is imminent in a lot of industries, not only in this one, and it could be just a matter of time until it grows until being usual. However, it is up to the engineers

[7] Consult Annex 3 for the UN average annual rate of population change (percentage)

and involved decision makers, to decide how much autonomy the process could have, in order to ensure enough human involvement and adequate employment. There exist digital solutions to certain problems, but there will also be only human solutions to certain mechanical problems. If the wind industry is developed to an almost autonomous level, job losses in the sector could increase, turning a labour-flourishing sector, into a small sphere of software owners and producers for fixing, maintaining or replacing turbine parts. A balance shall be met.

Storage solutions, not only in battery technology but with improved creative methods are a present and future concern. One of these alternative methods for energy storage is pumped-hydropower, which takes the excess energy produced from wind turbines on very windy days to distribution lines on high demand regions. This technology helps to use the energy in a productive way when it is not used.

It works by pumping-up water from low to high altitude reservoirs (Figure 48), released down again when wind energy generation is low but still energy demand is high. The wind energy, which was not consumed finds a new life, with a synergy of technologies, it helps storing energy without the need of batteries, and water damps can be emptied in days with lower wind intensity, and back up when excess of energy allows the cycle to continue. The long-term solutions brought-up will include not only one way of renewable energy production, but they will mix different technologies, just like wind and solar to pump hydro. Cooperation among different countries will thrive for achieving the same aim: affordable power, grid stability, energy availability and energy security.

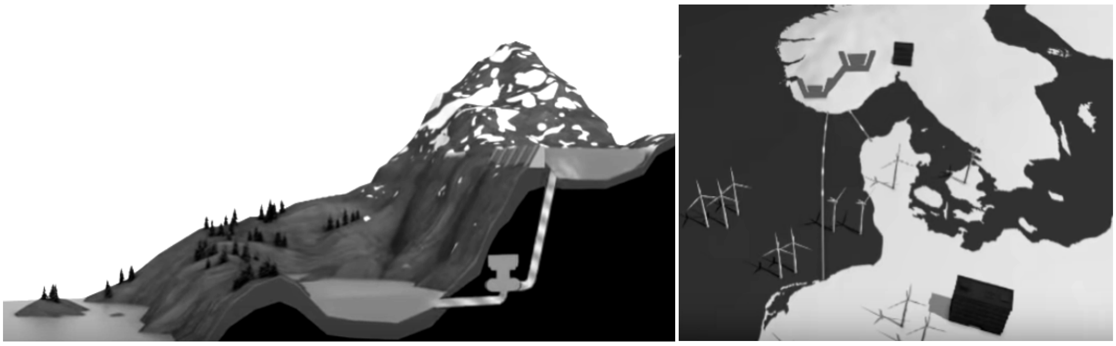


Figure 48 “Pumped-storage hydropower” Source: (Statkraft, 2014)

5. Conclusions

Each of the countries analysed in this thesis count with different experiences and development stages. On the one hand, Mexico is currently at a young stage of its wind industry's development, and it could be referred to as beginner with high aspirations and capabilities. The United States is in an intermediate level, given its' more complex and detailed wind industry system, and Denmark has an advanced level of development in the wind industry given its expertise and dominance of the wind energy sector. The proposed levels are not trying to give any certain status to the country, rather guide its project managers into a more organized planning. Comparing and contrasting situations in other countries could help steer decisions into certain directions based on the experiences of the application of certain technologies in other places.

It is difficult to classify a country by its development stage when day by day advancements or setbacks are confronted. Each of proposed categories or development levels is a provisional position for a period of time, as economic difficulties can slow down the course of action; national growth and share of GDP dedicated to other industries, lack of coordination between authorities, or a strong and influential political figure could disrupt or hold back financial and policy support towards cleaner energy enlargement. Economic resources play a crucial role; if a country does not have the financial means to fund these expensive projects, their potential cannot be fully exploited.

Energy prices are continually dynamic, costs, taxes and subsidies influence in a stronger way than the good will or aspirations of an investor. Several national unavoidable constraints as natural or archaeological locations could not and should not be sacrificed nor surrender in the feet of renewable energy developers. Environmental protection is the main priority. So, the transition between clean energy development levels can recklessly range from slowly going forward to rapidly regressing backward.

Mexico is still trailing its wind development, it´s pace will be slower than the other two studied countries. For now, it does not have the necessary experience and financial resources to ensure an energy security independent of fossil fuels. It has not yet enough financial resources destined to this end as wind farms development is not a political or national priority. The governmental short-term situation tends to favour local industries and coal combustion technologies.

The country will struggle to acquire an updated know-how and the necessary workforce, local technology or grid capacity to develop wind technology at a better pace. Mexico is at a young phase of the development of its wind industry, and in its foreseeable future development it will continue to be only a supportive alternative for the energetic sector, as its maximum wind energy production is not going to be enough to satisfy the country's growing energy demand, so other sources of renewable energy, like hydropower and photovoltaic, are still going to be needed.

Nevertheless, as other countries like Denmark and the US are interested in sprawling wind energy generation, and through the existing bilateral agreements between governments and private enterprises. The investment in other countries, like Mexico, is feasible and will probably face boosting environments propagated by wealthier countries, especially if funding support from international organizations and institutions favour technology innovation and knowledge transfer to developing countries. The aforementioned, will also require a low risk environment, with political, fiscal and institutional support.

Due to its geographical location, close to one of the most developed countries in the wind sector, it has considerable possibilities of growth if the correct strategy is coordinated with national actions. The magnification desire of many companies worldwide supports a tendency of foreign direct investment, especially in countries with potential to generate clean energy in a near future, which inevitably will be heavily dependent on it. A business niche is expanding. For these reasons multilateral plans between countries and institutions or intercontinental development campaigns are feasible and much desired. Namely, the Clean Development Mechanism (CDM) of the UNFCCC[8] that works with international projects, targeted on developing countries commenced by more developed ones, and through them tackles greenhouse gas emissions to meet Kyoto Protocol targets. Of course, this is delimited to those signatory countries only.

[8] For more information on the Clean Development Mechanism (CDM), access: https://cdm.unfccc.int/.

The United States' wind industry will probably be somewhat halted by political and social support in the short-term, due to the more than ever unpredictable situation of their transient government. In the long-term, the United States might retake the path of general political support towards renewable energies as the business is profitable and shielded from fluctuating prices, in contrast to the fossil fuel sector. What's more, wind energy support is favourable to guarantee their consumption interests due to their huge energy demand and much needed diversification of sources. All support relies as well in other interests, such as national security. The ways they utilise these renewable tools for guaranteeing energy supply to achieve this strategic goal and energetic independence are related in the investment for development of cleaner energy sources, such as wind power. This will carry on evolving to a next level of wind energy development.

Even though the Unites States is the northern neighbour of Mexico, which could be interpreted on plain sight as both countries having a similar wind power potential - still their geography, weather conditions, technological, economic and legal development has considerable differences. A contrasting characteristic might be the economic support coming from their governments towards the expansion of cleaner energy production, which in the United States has been encouraging important research in the wind energy sector, creating an impulse to the industry that separates both their standing points.

Even though Mexico and the United States have access to great coastal winds on the East and West, their onshore development is completely different due to social, economic, scientific and technological constraints. Mexico needs more experience in the industry to construct the necessary bases for a stronger industry that could cope with the short-term or long-term complications, costs and challenges offshore wind installations represent.

If the circumstances continue the way they seem to be flowing in today's surroundings, it could be expected that Denmark will continue developing and investing in offshore wind farms given their economic advantage and hands-in experience. Their global leadership may be dwarfed by other strongly emerging countries; nevertheless, their technology's quality and independence from fossil fuels will still make out of them an exemplary country for specifically wind energy generation.

What can be pictured is that Denmark’s past is somewhat similar to Mexican’s future, but with more modern technologies. The US present wind industry is in some way part of Denmark’s present as well.

In every market there are leaders and followers, competitors and innovators. The question and issue to solve with emerging markets in developing countries is how quickly they could meet the latest trends without a great delay so it becomes a technology of the past. Apart from learning through knowledge sharing, followers can come-up with improved ideas to share with those with whom they learnt from.

The greatest risk that developing countries face when training only a small group of workers and not creating enough bases for the establishment of a wide and steady long-term growth, is that those trained could later become experts and while not finding a local opportunity to further develop or apply their capabilities, they will look for opportunities somewhere else, most probably in countries where the industry is more broad. Those workers could have been the promising future for a developing country, but they tend to flee where their ideas have more tools to be shaped. This phenomenon is better understood as brain drain, and it is not a revealed newness.

A possible path towards a stable renewable growth involves a complete planning of emission targets, renewable energy share, investments, regulations and barriers, trainings and possible production and consumption scenarios. These analyses should comprehend short and long-term interactions. Considering seasons, installed network capacity, space and time, costs of operation and installation of transmission systems and currents and voltages for grid preparation. Nevertheless, the installation of wind parks and their energy backup operating systems should not disturb, damage, or inflict unconformities to local communities. Respect of the social demands or concerns of which technologies are acceptable and where are well received. There is no going back to the conventional sole dependence of fossil fuels; nevertheless, the most ethical methods should be considered and implemented to promote wind or other renewable energy development.

The state has the responsibility to empower their population, to produce social development, technological advances and economic growth. If the state fails to offer this, those with valuable ambitions will take their innovative ideas somewhere else. Promoting science and technology goes further from the training courses. Renewable energy is not a concern of the creative companies, but a lifestyle taught in a country, and it could only be embraced by long-term conscience reflection and taught education.

Understanding the connection with the processes that we depend on in a daily basis, like electricity production, reduces sceptical attitudes due to a lack of understanding of the origin of the product we are consuming until its end point. Each decision of energy consumption today is taken mechanically, tomorrow, these decisions are going to be taken consciously, understanding the impact of every demand.

Environmental protection and energy security are the most important concern of recent times, and the only way to apply solutions is by sharing knowledge, technology and education, as it has never been done before. We not only need scientists and engineers. This renewable energy revolution needs a holistic involvement of every person who needs and consumes electricity as a way of life. It shall be understood that life as we know it depends on that.

A challenge to overcome an informed public, hand in hand with data availability, analysis capability, and policy making to ensure hands-on action and that the information is actually used for improving awry situations. This is one of the reasons why transatlantic cooperation is to be encouraged; primarily, to share information and technology.

A huge part of the needed information for innovation could be provided with the vital support of modern technology. Satellite imagery is able to clearly depict trends of environmental stress and environmental behaviors that definitely make an impact on the potential for the installation of renewable energy technologies. Remote sensing is able to hint the cloud formation and the tendency of direction that atmospheric winds could take them forward, and this is crucial for defining where a wind power plant could be established.

Living in the 21st century, we have witnessed how advances have proven that some unimagined technological benefits would help shape the future societies that will coexist in the world, and from there comes the importance of global environmental monitoring. The information that is mostly lacking is to know which countries have which capacities and at which level is their real potential for renewable energy installations.

The possibilities of each region are best understood with the support of Earth Observations (EO), for indicating their solar exposure, distinctive heat ranges, the intensities of atmospheric wind tendencies, water bodies behavior around a region and geothermal possibilities for renewable potential. If countries have access to this information, they would be able to take better decisions on long-term energetic investments for the wellbeing of their country.

Acknowledging the potential, they could have for Renewable Energy Sources (RES) they would be better adapted for meeting their future generation's energetic needs without compromising the welfare of the ecosystems in our world. For instance, the compromised stability of the earth, how it is in the case with the very polluting extraction and combustion of fossil fuels which contribute to the damaging greenhouse gases (GHG) that deplete the ozone layer and disturb with powerful consequences the global climate.

Earth Observations can be done through satellite imagery, sensors and digital simulations, also previously referred to as remote sensing. It uses electromagnetic radiation which helps in monitoring the earth's atmospheres in space and time for assessing damages caused by natural disasters, predicting geothermal activity, tracking and forecasting water phenomena, or anthropogenic emissions impact on global warming or environmental acidification.

Of course, an adverse aspect is that a real advanced specialization is needed for being able to analyze remote sensing data, and there is not yet a huge supply of trained individuals able to work on this analysis, very advanced education and good intellectual skills, summed up with the availability of the latest instruments and software which is needed and thus this not easily accessible neither affordable for all.

A trained person would need to know not only how anemometers work, but also the use of LIDAR technology (Light Detection and Ranging), which can measure peculiarities such as wind speed, wind streams, uneven terrains, it "(…) is a method that uses light in the form of a pulsed laser to measure ranges (variable distances) to the Earth. These light pulses—combined with other data recorded by the airborne system— generate precise, three-dimensional information about the shape of the Earth and its surface characteristics" (NOAA, 2018).

As this technology depends on the latest satellite technological developments it consequently is extremely costly, especially for developing nations, who would need the information the most. Nevertheless, with time and innovation advancements, remote sensing is expected to become less expensive and more affordable in a long-term scenario. As well, it is significant to underline that all attempts made to comprehend the behavior of nature are normally done with the most affordable or Best Available Technology (BAT), and that there are very sturdy weather and natural forces that constantly make the measurements difficult to obtain, for fully understanding or predicting.

In the case for wind power generation and according to a Renewable Energy journal publication "(…) remote sensing profilers take measurements over a much larger measurement volume, sensing the wind speed at different heights by assuming horizontally homogeneous flow within the circular scan of each vertical level. As profilers, ground-based remote sensors shall be compared with mast profilers measured by cup anemometers. In this context, the evaluation should be extended from point measurements to profile measurements including variables of interest like wind speed and direction shear." (Sanz, et.al. 2013: 200).

Earth observations and remote sensing results are so different from each location that it is relevant to clarify that results for one place could not be generalized or transferred between countries, thus each region should have its own local monitoring analysis to result in precise calculations according to specific local geological and atmospheric characteristics. A coastal region in Mexico will have a totally different monitored wind behavior compared to a coastal region in Denmark. Taking this into contemplation, developed and developing countries should not consider borrowing data from other countries and should not try to adapt it to theirs, as results for terrain, turbulence, radiation, height, wind speed or direction, air density and stability are unique to each location.

Wind's energy could be harvested into power without affecting the global wind stocks, because it is a natural condition of atmospheric differential temperatures that does not stop to react until thermal equilibrium is accomplished. This is what makes it a renewable energy. Renewable sources are a good support to reduce the modern need for combustion of fossil fuels, which extraction and emission consequences are now of a global scale with damages that will continue to affect the ecosystems for hundreds of years to come.

An additional benefit for harvesting the wind's energy is the ability to later provide power to isolated communities or big energy consumers, the creation of jobs, (some, short-term, others, long-term), the attracted investments that will impulse a region, and the implicit energy availability and energy security for the population. The latter is related to the upcoming increase of independence from the carbonised fossil fuel energy generation and therefore a more stable and forecasted supply of cleaner energy due to the reliance on sustained renewable energy sources owing to its scarce volatility.

The installation of wind turbines needs well planned investments for adequate technology, investment in smarter grid management depending on diurnal and nocturnal demands, in the overall grid capacity and intercommunication, energy transmission and storage to provide certain percentage target of clean energy supply.

Another big challenge that requires detailed and careful planning is the development of the infrastructure that will be able to provide a solid ground for the increase of energy generation, transmission, storage and distribution. Investments in infrastructure go hand in hand with investments in innovation and development, improvement of skills, regulatory framework, compatible programme managements, and technology deployment.

But a basic foundation of those is a mature and efficient market, which rules and legal framework are coherent and complied and which obstacles are not meant to slow-down the renewable energy industry, but to avoid future complications. Government support, credits and subsidies, as well as funding are indispensable in the first stages. International cooperation for promoting the globalization and the best available technology (BAT) is crucial for having an up-to-date technology and strategies, when transfers of technology and knowledge are done across countries the industry's development is more homogeneous and may advance at a similar pace.

The conflictive interaction with the carbonized sources of energy could shift its focal point, as all industries tend to evolve, and are susceptible to taking different paths for the aim of achieving a place in the market. This decarbonising evolution of the energy sector could be supported by those already involved in it, with the problem-solving knowledge and networking expertise with harvesting and distribution familiarity. At each level, institutions and governments shall contribute to ensure a fair market competition and a viable working environment of cooperation and promote serene negotiations.

In general, each country depends on the rather classically unsteady local government's ambitions towards a cleaner energy production, or a steady one, based on their energy intensity from which they depend on, their outlined long-term plans, other regional or international economic interests, prominent business or political inclinations and their vision for the expansion of the existent renewable energy technology. The update of existing legal and fiscal frameworks, the creation and handling of new regulations, the capabilities of the institutions designated to support a stable amplification of the industry, and the prioritisation of certain issues in their prospective agendas will mark the regimen of this evolution. Notably, political and economic support is vital, because with it technological applications are able to go beyond limitations. Nonetheless, internationally, the energy market also has the power to bring nations together.

Institutional care will be fundamental. To avoid an institutional deterioration is vital to allow the involved teams to keep corruption out of any possibilities, ensure that solid foundations and updates guarantee the quality and durability of the framework system. Trainings are a cornerstone to keep a skilled workforce informed of developments and devising needed updates in older and possibly less efficient processes.

Development will continue to flourish due to technological updates and harsh competition amongst the companies dependent on the industry, which will be interested in being the best option for big customers. Special care has to be taken to avoid a splitting of focus and generate in this way a division of tracks, which could stop the joint progress of the whole endeavour. Nevertheless, if the current track is to be improved, the learning curves should be taken into consideration to take the most convenient path to continue fostering the innovation of the best available technologies and broaden the business' opportunities.

After demonstrating the different efforts of Mexico, Europe and the United States, based on their different priorities, approaches and needs of energetic supply, we can expect a relatively slow jump in the investments on wind energy (or wind farms), given the grid obstacles and installation costs. Other competitive options to invest in renewable resources could distract the attention from wind, namely solar PV, and the lack of space for turbines or adequate infrastructure for the transport and installation of wind farms, capital priorities, and perception of a low and slow payoff of the wind industry.

Nevertheless, a positive impact on environmental local conditions is certain, after supplying energy from a clean source and substituting fossil fuels that seriously damage nature. Wind energy also has some negative effects on the environment, like invasion of land or animal casualties, however, they are smaller in dimensions compared to the emissions and damage made by other energy sources, and technological innovations are being developed to reduce these impacts to the minimum and ideally to eliminate their repercussions.

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Annex 1

Electricity units in Watts		
Abbreviation	Name	Value
daW	Decawatt	10^{1} W
hW	Hectowatt	10^{2} W
KW	Kilowatt	10^{3} W
MW	Megawatt	10^{6} W
GW	Giga Watt	10^{9} W
TW	Terawatt	10^{12} W
PW	Petawatt	10^{15} W
EW	Exawatt	10^{18} W
ZW	Zeta Watt	10^{21} W
YW	Yottawatt	10^{24} W

Annex 2

Table 4 “Skills areas within the wind industry” (adapted from the original Source: (European Commission 2016, 57))

“Skills areas within the wind industry”	
Academic research, design and R&D - Loads and aerodynamics - Consultancy - Electrical/grid (inc. software) - Wind turbine technology	Finance - Wind energy finance - Project finance - Corporate finance
Project engineering - Electrical/power engineering - Civil engineering - Mechanical engineering - Commissioning - Maintenance	Manufacturing engineering - Electrical / power engineering - Quality control - Diagnosis - Metal fabrication - Machining - Mechanical and electrical fitting - Testing
Project management, project development and multidisciplinary skills - Project management - Energy resources assessment - Spatial planning/ consenting - Policy regulatory analysis - Project development and project management - Legal experts - Communications	VET (Vocational education and training) - Service and maintenance - Installation and commissioning - Introduction to wind energy - On-site safety (eg. Global Wind Organisation training platform) - Fire fighting - Tower climbing - Rescue - First aid
Business development - Direct sales - Marketing - Communications	

Annex 3

Table 5 “Average annual rate of population change (percentage)”

Source: (UN, 2017)

Average annual rate of population change (percentage)																	
Location	2015 - 2020	2020 - 2025	2025 - 2030	2030 - 2035	2035 - 2040	2040 - 2045	2045 - 2050	2050 - 2055	2055 - 2060	2060 - 2065	2065 - 2070	2070 - 2075	2075 - 2080	2080 - 2085	2085 - 2090	2090 - 2095	2095 - 2100
Denmark	0,38	0,40	0,37	0,31	0,24	0,20	0,19	0,19	0,20	0,20	0,20	0,19	0,16	0,13	0,09	0,08	0,08
Mexico	1,23	1,06	0,89	0,74	0,60	0,47	0,35	0,23	0,12	0,01	-0,09	-0,17	-0,24	-0,30	-0,36	-0,40	-0,42
USA	0,71	0,70	0,66	0,57	0,49	0,42	0,39	0,38	0,38	0,37	0,34	0,30	0,26	0,22	0,19	0,18	0,16