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Denmark
A Case Study for a Climate-Neutral Europe

Thibault MENU

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Abstract

In recent years, Denmark has steadily emerged as a leader and role model in the global green energy transition. Its greenhouse gas (GHG) emissions since 2010 have been reduced at greater pace than those of the European Union (EU) average. This transformation is all the more impressive, given that the country used to be a significant oil and gas producer which also relied heavily on coal for power generation. From its highly publicized success in offshore wind, to its ambitious goal of cutting GHG emissions by 70% by 2030 - which would put Denmark as a European and global frontrunner, with only Finland being more ambitious and planning to be climate neutral already by 2035 – as well as its pioneering green energy policies, the country has transformed itself into a beacon for low carbon technologies and public policies. The country has a record high share of renewable energy sources in power generation, with wind in the lead. Given the recent announcements and climate goals set by the Von der Leyen Commission, Denmark serves as an interesting case study for other European and world nations alike on how to embark on their own energy transitions. This paper assesses whether the country is really successful in accelerating even more than its European peers in its decarbonization process. And if so, what is so special about Denmark and what can be learned from its transformation?

Policies range from well-publicized successes, such as the country's ability to nearly rid itself from coal in its power mix in less than thirty years by increasingly developing its wind power potential, in leading the offshore wind segment and championing repowering, but also its lesser-known achievements, such as the diffusion of combined heat and power (CHP) and district heating across the country. Another success point of the country's strategy relies in promoting energy efficiency in the industrial sector as well as its use of energy taxation for enhanced decarbonization, even in challenging sectors such as transportation.

Questions remain open, especially concerning the sustainability credentials of biomass, a fuel which is a key component of the country's energy mix, but also the future role of natural gas, which has an important balancing role in power generation, given the country decision to rid itself of oil and gas (O&G) production by the middle of the century.

To a large extent, the Danish success story so far can be linked to a combination of socio-political factors including:

- a high level of stability and predictability in energy policy stemming from Denmark's long historical tradition of broad energy agreements,
- a cross-sectoral and holistic approach to developing the nation's energy policy involving a high level of participation from various public and private actors,
- a willingness to back innovative technologies, combined with generous public policy schemes in order to bring them to market-level competitiveness. Next frontiers will consist of large-scale carbon capture and sequestration projects, as well as low carbon energy islands.

However, it would be somewhat reductive to simply equate Denmark's success story to these previously mentioned factors. Indeed, the Scandinavian nation also benefits from certain geographical dispositions which are great assets for its path to decarbonization. For one, the country is ideally placed to develop variable renewable energy sources, most notably wind power given its topography and its strong wind resources. On top of this, Denmark also benefits from an incredibly reliable and interconnected power grid thereby making renewable energy integration into the wide energy system all the easier. In addition, the fact that its power grid is one of the most interconnected in Europe entails that excess renewable energy production can quickly be exported when the wind blows, just as imports can hastily be called upon when wind is found to be lacking. Finally, from a more socio-political perspective, the relatively flat social structure of Danish society as well as the country's high level of institutional trust, makes policymaking and policy implementation simpler as well as more effective than in other European states.

As such, although this paper identifies important lessons to be learnt from Denmark's decarbonization strategies, the context as well as the particular characteristics of the country in which these were implemented should nevertheless be considered when seeking to establish similarly successful carbon reduction policies.

In any case, Denmark is still far from coming close to achieving its objectives and will have to accelerate its decarbonization on all fronts: the country's current total primary energy supply still relies for 60% on fossil fuels.

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Introduction

As the fight against climate change inescapably moves up the priority ladder across the globe, carbon neutrality has become the focal point of policymaking in the EU. The Von der Leyen Commission announced in late 2019 its highly ambitious objective of making Europe the world's first carbon neural continent. This announcement would quickly be followed by the European Commission (EC) overarching and long-touted Green Deal. Accelerated decarbonization is now the order of the day, with debates on carbon reduction strategies raging amongst Member states, whilst simultaneously terms such as system integration and just transition are steadily invading the lexicon of the EC's policy papers. With the target set and the EU's policymaking apparatus in full swing, the eternal question lingers. How do we get there?

This paper seeks to partially resolve this conundrum by exploring the impressive story that is Denmark's successful strategy at putting itself on track to reduce its greenhouse gas emissions by 70% by 2030 – when in comparison the EU is about to agree on a -55% EU-wide target – and become a climate neutral society come 2050. As such, this paper seeks to delve into the various policies enacted and the different factors behind Denmark's transformation as a champion in the fight against climate change.

Divided into three main parts, the first section of this paper covers the most successful policies pursued by Denmark to reduce its carbon footprint over the last two to three decades. These policies range from well-publicized successes, such as the country's ability to nearly rid itself from coal in its power mix in less than thirty years by increasingly developing its wind power potential, but also its lesser-known achievements, such as the diffusion of combined heat and power (CHP) and district heating across the country. Furthermore, this first section also investigates the main success points of the country's strategy in promoting energy efficiency in the industrial sector as well as its use of energy taxation for enhanced decarbonization, even in challenging sectors such as transportation.

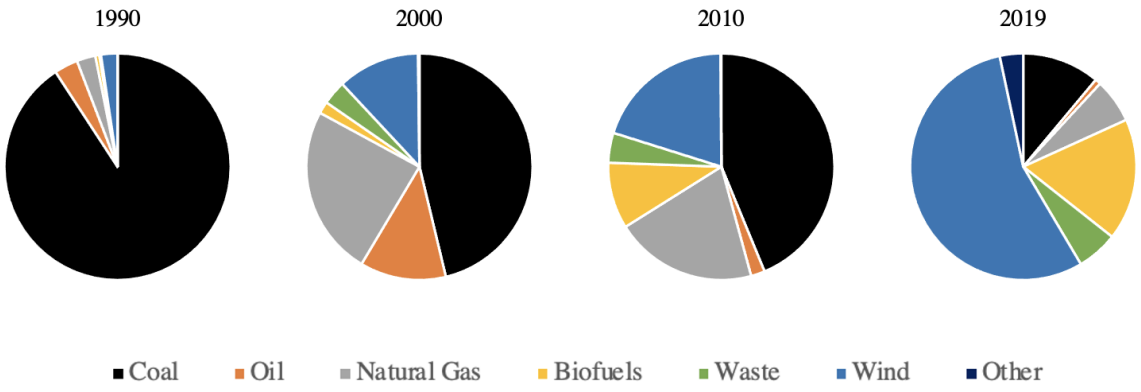
The second section of this paper explores Denmark's more recent announcements to achieve its decarbonization ambitions. This includes looking at the country's post-COVID-19 recovery strategy, its recent decision to pass one of the world's most ambitious climate laws, and its decision to end O&G exploration and production come 2050.

Finally, the third and last section of this paper takes a glimpse into Denmark's future energy policy – both the hopes it draws and the potential hiccups it may experience along the way. On the one hand, this involves looking at some of the country's most recent decisions concerning green hydrogen production, as well as the somewhat futuristic energy island projects that Denmark has decided to construct in the North and Baltic Seas. On the other hand, some questions remain open, especially concerning the sustainability credentials of biomass, a fuel which is a key component of the country's energy mix, but also the future role of natural gas given the country decision to rid itself of O&G production by the middle of the century.

The Danish energy transition achievements so far: a story of decarbonization and decentralization

Over the span of three decades, the Danish power generation system has undergone a remarkable transformation. In the beginning of the 1990s, domestic electricity production was dominated by fossil fuels, notably coal, which accounted for 90% of total power generation. Yet, by 2019, coal would have been largely relegated to a marginal position, accounting for only 11% of power generation.[1] In addition, the country's coal phaseout, despite being legally mandated by 2030, is expected to take place by an earlier date as both the country's leading energy company Ørsted and the leading Danish district heating utility Fjernvarme Fyn have announced accelerated coal phaseout plans.

Evolution of Denmark's Electricity Mix 1990-2019



Source: IEA Data.

This major three-decade long transformation can be divided into two main phases. In the first fifteen years starting in 1990, the primacy of coal was initially being challenged by both oil and natural gas resulting from a peak in domestic production in the North Sea. The growth of oil and gas in power generation, however, would prove

1. IEA, "Electricity generation by source, Denmark 1990-2019", January 2021, available at: www.iea.org.

to be a temporary phase as the country rapidly ramped up its renewable energy capabilities. Indeed, although renewables had already started to account for an increasing share of power generation since 2000, between 2000-2019, the share of power generation coming from renewables grew from 17% to 78%. This has driven a major decline in GHG emissions, surpassing since 2010 the average decline level in the EU: in 2020, GHG emissions were about 30% lower than in 1990.[2]

As such, the following section will delve into Denmark's success at becoming a renewable icon and pushing carbon reduction strategies via district heating, ambitious energy efficiency measures and energy taxation policies.

The Danish wind energy success story

In the aftermath of the oil crises of the 70s, Denmark went about a major reshuffle in its energy policy, with a strong focus on developing domestic O&G resources in the North Sea, converting centralized thermal plants from oil to coal and pushing for a diversification of energy sources towards nuclear and renewables. Initially, however, support for the development of renewables only came via energy taxes on electricity prices to provide financial support for public research.

Between the 1980s and the beginning of the 1990s, the Danish government took a more proactive approach to the development of renewables. As a result, wind power started benefitting from a range of policies and reforms which helped spur its development, including: i) public investment subsidies covering up to 30% of installation costs (gradually phased out as the industry matured), ii) the introduction of a "fair price" for wind power, under the form of a wind power purchase obligation for utilities set at 85% of the electricity retail price,[3] and iii) refunds on the Danish carbon tax (introduced in 1992) as well as a partial refund on the energy tax.[4]

Moreover, political and socioeconomic conditions were also important factors in boosting the role of wind. The rise of a strong anti-nuclear movement ("Organisationen til Oplysning om Atomkraft" or OOA) resulted in the Danish Parliament excluding its use in future energy planning in 1985, making wind an ideal candidate to diversify away from fossil fuels. In addition, by the mid -

2. European Commission, "Country fact sheet: Denmark", *EU Climate Action Progress Report 2020*, available at: https://ec.europa.eu.
3. This would be replaced by a fixed feed in tariff with the price fixed at 85% of the utility's production and distribution costs.
4. IRENA, "30 Years of Policies for Wind Energy: Lessons from 12 Wind Energy Markets", January 2013, available at: www.irena.org.

1990s, the government had set ambitious renewable energy targets, at 12-14% of total energy consumption by 2005, which would rise to 35% by 2030, and set up a central national authority in charge of implementing renewable energy policies, the Danish Energy Agency.

A remarkable phenomenon in the emergence and success of wind in the Danish energy landscape is the birth of local wind cooperatives. Spurned by favorable tax incentives and an environmentally conscious population, wind cooperatives began to increasingly invest in community-owned turbines. By 2001, these cooperatives would include more than 100,000 families and were responsible for 86% of all turbines installed in the country, providing the renewable energy industry a strong domestic market to depend on and ensuring that local communities benefit directly from wind power development, via lower energy taxes and profit sharing from electricity sold to the grid.[5]

Despite experiencing a strong growth rate during the 90s, wind energy would go through a prolonged slump in the mid -2000s. In the midst of the electricity market liberalization, the newly elected government decided to abandon the existing Feed-in Tariff (FIT) scheme in favor of a renewable portfolio standard (RPS) mechanism, with a system of tradeable green certifications to stimulate competition and encourage renewable energy players to increase their competitiveness. Under the RPS, the remuneration mechanism was composed of the market price plus a capped premium. In addition, the new scheme no longer guaranteed interconnection as had previously been the case. The result was a rapid decline in added wind power capacity, as the new premium was too low to be attractive and existing incentives for repowering old turbines provided for a more lucrative alternative. Moreover, the low rates and complexity of repowering resulted in the absence of any cooperatives being founded between 2003-2008 and many cooperatives selling their assets to commercial actors.[6]

This stagnation would end in 2009 following a strong revival of political support for wind energy in the midst of the COP15 in Copenhagen, the reform of the Promotion of Renewable Energy Act and the rise of offshore wind power. The new policy mechanism for wind energy was based on a new environmental premium on top of the market price, as well as an additional compensation price for balancing costs. This new support scheme for wind energy, managed by the Danish Energy Agency, allowed for greater revenue stability for producers whilst the cost of these subsidies was passed on to the

5. The Danish domestic wind market would prove crucial for local industry players to weather the downturn in exports to the Californian market at the end of the 1980s.
6. IEA-RETD, "Cost and Financing Aspects of Community Renewable Energy Projects. Volume II: Danish Case Study", March 2016, available at: http://iea-retd.org.

consumer under the form of a Public Service Obligation (PSO) tariff (similar to the German EEG). For more than a decade the PSO would remunerate various renewable energy projects around the country and support the industry. However, in 2016, in response to concerns by the EC that the PSO levy distorts competition between domestic and foreign producers, the government agreed to gradually phase out the PSO between 2017-2022, in a bid to reduce consumer electricity bills and simultaneously minimize the uncertainty faced by energy developers concerning the, up till now, unknown fate of the PSO. Beyond 2022, funds for renewable energy projects will be directly included in the Danish government budget and not be part of consumer household costs. In addition, the government will also seek to curtail the number of existing onshore wind turbines and focus on repowering existing ones as a result of growing resistance from citizens and the explosion of the offshore wind industry. Repowering is, indeed, a growing component of Denmark's wind strategy, especially considering that almost half of its wind fleet is over 15 years old. Its nearest rival with respect to that particular characteristic is Germany where only one fifth of the wind fleet is above 15 years of age.[7] However, it is worth noting that repowering is already an established practice in Denmark, as the country has already gone through three distinct repowering "waves" (2000-2003, 2008-2011 and 2013-2016), the latter two of which being incentivized via public support schemes. As a result of these policies, by the end of 2017 more than 84% of turbines installed prior to 1994 had been removed for a total of 3,200 dismantled turbines come 2018.

Another sector of the wind industry in which Denmark has made great strides is offshore wind. As the pride of the Danish energy industry, offshore wind has its own specific characteristics which have greatly aided in its development. Indeed, it benefits from two development procedures: the "open door procedure" and a tendering procedure. The former invites unsolicited applications in areas not covered by the tendering procedure, whereas the latter is carried out in a designated area. Both procedures however are financed under the same mechanism of a contract for difference scheme. Moreover, a particular characteristic of the Danish tendering model is the Danish Energy Agency, which acts as a one-stop authority for potential offshore wind developers[8] thus greatly reducing the administrative burden faced by developers. Finally, nearshore wind farm projects also have the particularity of being subject to consumer participation

7. R. Lacal-Arántegui, A. Uihlein and J. M. Yusta. "Technology Effects in Repowering Wind Turbines", *Wind Energy*, December 2019, available at: https://onlinelibrary.wiley.com.
8. Agora Energiewende, "A Snapshot of the Danish Energy Transition", November 2015, available at: www.agora-energiewende.de.

schemes, meaning that at least 20% of the project's total value must return to local citizens.

As a result of decades of favorable public policies, supportive financial mechanisms and industrial innovation, Denmark has become the symbol of wind power and in recent years offshore wind. To top this, local involvement via wind cooperatives and a proactive bureaucratic apparatus has helped spur the development of wind as the core power generation source in Denmark. As a result, in the space of just two decades, wind went from generating 12% of the country's electricity in 2000 to over 48% by 2019,[9] of which 30% came from onshore wind and the remaining 18% from offshore wind power.

District heating & CHP: decentralization & diffusion

Although not as widely publicized as Denmark's success in wind power, district heating and CHP can be considered as the second pillar of the country's energy strategy and have also played an important role in its quest to decarbonization. The initial expansion of CHP in city-wide district heating networks in Denmark was originally predicated on the goal of minimizing the country's dependance on foreign oil imports via a nation-wide oil to coal switch, in a bid to ensure security of supply. Denmark's first energy policy plan laid out the importance of building a diversified supply system with the objective of having two-thirds of collective heat consumption met via collective heat supply by 2002. In order to meet this goal, the Danish state delegated much of its authority to local municipalities whilst simultaneously investing in decentralized CHP plants, straw fueled demonstration plants and transmission networks. This would eventually result in investments in CHP systems and transmission networks totaling 15 billion between 1975-1988.[10] Yet, the focus of this first transformation was thus built upon ensuring security of supply.

However, as time went by, environmental concerns started to play a growing role in climate policymaking and began influencing more heavily the country's energy strategy. In the 1990s, a new planning system was introduced following an amendment in the country's Heat Supply Act. The objective was to promote the development of decentralized CHP whilst simultaneously reducing Denmark's CO_2 emissions and ensuring the economic viability of its

9. "Wind Energy in Europe 2020 Statistics and the Outlook for 2021-2025", *Wind Europe*, February 2021, available at: https://windeurope.org.
10. H. C. Mortensen and B. Overgaard, "CHP Development in Denmark: Role and Results", December 1992, available at: www.sciencedirect.com.

expanding gas network. The subsequent conversion of heat-only boilers to CHP would take place through a series of phases throughout the 1990s. Firstly, large coal -fired district heating units with access to the natural gas supply would be converted to gas -fired CHP. Secondly, medium sized gas -fired district heating units were converted to CHP whilst those without natural gas supply access were mandated to convert to biomass. Finally, the aforementioned policy was extended to small -scale district heating units, with those unable to access the gas network obligated to use biomass. Moreover, this widescale public policy conversion was accompanied by generous subsidy schemes to promote the conversion to more environment-friendly fuels and the establishment of a triple feed-in tariff system, which would remunerate CHP operators on the basis of their provision of peak, mid-load or low-load electricity and grant them an energy premium on top, which provided the monetary impetus to develop CHP. As a result of these pro-climate policies and energy efficiency measures, the CHP market experienced significant levels of investments. Indeed, between 1990-1997, three quarters of new capacity brought online consisted of small, decentralized CHP plants fueled by natural gas or biomass.[11]

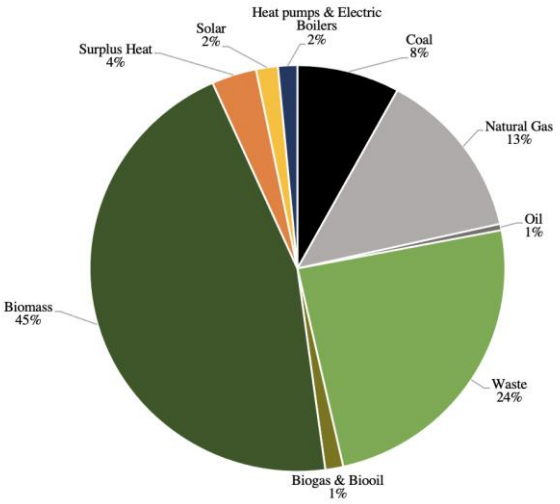
By the early 2000s, the country's CHP potential had by and large been entirely utilized. One notable change however, following the liberalization of the power market in 2003-2004 as well as the abandonment of the triple tariff system, has been the gradual decline of local CHP plants in power generation. This evolution took place despite the introduction of a subsidy support scheme for decentralized gas-fired CHP plants operating in the electricity market which ended in 2018. As a result, that same year, Denmark had the second highest share of CHP in total gross electricity consumption in the EU at 37.6%, behind only Latvia at 45.7%. To put this in comparison, the EU average was at (only) 11.2% that same year.[12] In addition, Denmark also boasts a high share of renewables in its CHP production at 53.7%, almost twice the EU28 average of 29.4%.

Overall, as a result of persistent governmental and local policies spanning over more than two decades, Denmark has one of the highest shares of district heating use in the EU, with 63% of its citizens being supplied in heat via this system, compared to approximately 20% of the EU population.[13] In addition, more than two thirds of this district heat was used in cogeneration, making Denmark the European country with the highest share of electricity

11. M. Lehtonen and S. Nye, "History of Electricity Network Control and Distributed Generation in the UK and Western Denmark", June 2009, available at: www.sciencedirect.com.
12. Eurostat, "Energy Data", 2019, available at: https://ec.europa.eu/eurostat.
13. N. Bertelsen and B. V. Mathiesen, "EU-28 Residential Heat Supply and Consumption: Historical Development and Status", *Energies*, April 13, 2020, available at: www.mdpi.com.

produced from CHP. On top of this, around 70% of the fuel used for heat generation originates from renewable resources such as biomass and sustainable waste – a figure which is likely to grow given the country's desire to become fossil fuel independent by 2050.[14]

Danish heat production by primary fuel in 2019



Source: Danish Energy Agency statisitcs.

However, not everything is so rosy on the CHP front and its future is relatively uncertain. The impressive growth of wind power in Denmark's energy mix and the rise in interconnectors capacity to Germany and the other Scandinavian states has had adverse results on the economics of CHP, resulting in the need for CHP plants to occupy a new position in the Danish energy sector by acting as a source of backup power for wind and/or using the existing heat storage capacity. According to various studies, the preeminence of CHP – specifically small-scale CHP units – in the structure of district heating generation in Denmark is nevertheless likely to take a hit, especially in the long run. As a result, come 2035, heat pumps and electric boilers are likely to account for almost 20% of heat generation and up to 35% by 2050 (incidentally replacing CHP as the main source of heat generation).[15] Moreover, another interesting technology which is growing in importance for district heating is thermal solar which is envisaged to represent 15% of heat generation by 2035. A number of drivers explain the expected expansion of heat pumps, electric boilers and solar district heating in the future Danish heating system. Indeed, a major indirect incentive for the development of solar district heating is the requirement for all district heating utilities to reach a certain amount of energy savings every year or else buy

14. Danish Energy Agency, "Annual Energy Figures 2019", 2020, available at: https://ens.dk.
15. EUKI, "Good Heating Practices from Denmark and Germany", December 2018, available at: www.eukih.de.

credit from another utility which has generated these "energy saving points" by exceeding its energy savings target. These credits are quoted on their own stock market which resembles a carbon cap & trade system. As a result, investments in solar district heating can generate valuable credits for the utility willing to develop solar thermal.[16] On top of this, a reduction in electricity taxation as well as the gradual phase -out of the PSO will increase the economic case for heat pumps and electric boilers. Finally, it should also be noted that Denmark has instituted a legal obligation to consider socioeconomic cost as the main investment criteria for heat pumps in district heating.[17]

Additionally, the rise in the number of large -scale and power-hungry data centers throughout Denmark provides an opportunity to use the excess heat as an energy source for district heating. Big Tech companies such as Apple, Facebook and Google have already announced plans to connect their datacenters to the local district heating grid.[18]

An energy efficient industrial sector

The third pillar of Denmark's decarbonization strategy, energy efficiency, has been a core focus area of Danish energy and environmental policy. In the industrial sector in particular, energy distribution companies have been involved in energy savings at the end user level since the early 1990s. Again, Denmark can be seen as a pioneer in this field considering the fact that its EEO (Energy Efficiency Obligation) scheme is one of the oldest in Europe along with the one put in place by the United Kingdom (UK) more than twenty years ago. Originally, the energy savings effort of Danish energy distribution companies was limited to performing energy audits and providing advice to their customers. However, this mode of operation would be radically changed by the introduction of the first EEO scheme from 2006 onwards, which shifted the focus from information and awareness campaigns on the importance of energy saving towards the implementation of such measures.

The current EEO scheme which stems from the Energy Savings Agreement of 2012 is a voluntary agreement between the Ministry of Climate, Energy and Buildings and the grid and distribution companies operating in the electricity, natural gas, oil and district

16. D. Tschopp *et al.*, "Large-scale Solar Thermal Systems in Leading Countries: A Review and Comparative Study of Denmark, China, Germany and Austria", July 2020, available at: www.sciencedirect.com.
17. B. Zühlsdorf *et al.*, "Industrial Heat Pumps, Second Phase IEA Heat Pump Technology (HPT) Programme Annex 48 Task 1: Danish Report", 2019, available at: https://orbit.dtu.dk.
18. Euroheat & Power, "Apple, Facebook and District Heating", August 17, 2017 available at: www.euroheat.org.

heating business. The current agreement which runs from 2012 to 2020 is renegotiated every three years with respect to its terms and conditions. Moreover, the Danish State does not provide direct funding for the implementation of this policy. Rather, the EEO is financed via the energy bill of end-consumers.

It is worth noting that the annual energy savings target set in the current EEO has tripled since its inception, going from 2.95 PJ/yr (petajoule per year) between 2006-2009 to 10.1 PJ/yr (c. 2.5% of energy end use) since December 2016. However, this last figure of 10.1 PJ/yr used to be 12.2 PJ/yr as per the agreement in 2015 but it was somewhat revised downwards due to concerns regarding the increasing costs incurred on third parties.[19] By and large, the EEO has led to very positive results for Denmark, with the country often exceeding its own energy savings targets. Since 2006, a majority of these savings (approximately 45%) have come from the industrial sector, with a further 30% coming from private households.

The Danish EEO has been praised for its flexibility, simplicity of administration and straightforwardness in technical accounting terms for energy savings. This success can partly be attributed to a plethora of factors:

- the country's long history of energy audits and energy savings advisory, provided by local distribution companies resulting in standardized reporting templates and methodologies,
- setting mandatory targets for the industry sector at a far earlier stage than other countries,
- allowing for innovation by providing freedom of choice when it came to choosing which measure to implement.

As such, the Danish EEO scheme exhibits high levels of acceptance amongst the general population and obligated parties whilst having low administrative costs.

As a result of all these measures, by 2016, energy intensity – already the third lowest amongst European countries – had decreased by a fifth since the turn of the century. Total final consumption has returned to its 1990 level following a period of growth in the 1990s, stabilization across the 2000s and finally decrease in the 2010s, all the while experiencing positive population growth and a more than two-fold gross domestic product (GDP) increase.[20]

19. EUKI, "Energy Efficiency Obligation Scheme in Denmark", September 3, 2018, available at: www.euki.de.
20. IEA, "Policies of IEA Countries: Denmark 2017 Review", November 27, 2017, available at: https://webstore.iea.org.

A tax driven decarbonization

Energy taxes have also played an important role in pushing Denmark's energy transition. The country is after all one of the front runners in integrating environmental considerations in their tax structure, having incorporated one of the world's first carbon taxes – added on top of the existing energy tax on coal, gas, oil and electricity – in 1992, introduced a tax on natural gas and sulfur as early as 1996 and pioneered the use of CO_2 emissions trading for the power sector in 2000. These taxes were significant in providing the necessary government revenue to fund energy efficiency programs and research and development (R&D) in renewables. In 2016, taxes on energy products accounted for 2.2% of Denmark's GDP, one of the highest levels amongst Organisation for Economic Co-operation and Development (OECD) countries.[21] It should be noted, however, that Denmark's current carbon tax of 177 Danish kroner (DKK 177 – c. €24) per ton of CO_2 equivalent (tCO_2e) has been described as insufficient by the Danish Council on Climate Change to meet the country's 2030 climate objectives. Indeed, the council, which evaluates and consults the country's climate policies, has argued that a uniformed carbon tax should be applied to all sectors and should be gradually increased to reach DKK 1,500 (c. €195) by 2030.

Taxation is also heavily used in the transportation sector to push the diffusion of electric vehicles (EVs). Indeed, EVs are exempt from vehicle registration fees and pay only a fraction of the required registration tax for vehicles. Internal combustion engine (ICE) vehicles, on the other hand, bear the brunt of these registration taxes as new owners are subject to vehicle registration taxes of up to 85% of the taxable value of the car, for cars worth up to DKK 185,000, and 150% for the value above that threshold.[22] Moreover, the country also imposes significant road fuel taxes via gasoline and diesel excises. However, according to a working paper of the International Monetary Fund (IMF), the current Danish retail gasoline and diesel prices represent barely half of what is needed to account for the environmental costs and high fuel taxation levels have been proposed by the country's automobile commission in 2020. To put this into comparison with other European countries, Denmark has the ninth highest gas tax at €0.63/L (liter), compared to an average EU28 level of €0.55/L, and the fourteenth highest diesel tax in the EU at €0.43/L, whereas the EU average is at €0.45/L.[23] On a separate note,

21. OECD, "OECD Environmental Performance Reviews: Denmark 2019", November 14, 2019, available at: www.oecd-ilibrary.org.
22. IMF, "Climate Mitigation Policy in Denmark: A Prototype for Other Countries", November 12, 2020, available at: www.imf.org.
23. Tax Foundation, "Gas Taxes in Europe", July 9, 2020, available at: https://taxfoundation.org.

it is worth mentioning that the Danish government has decided to implement a distance-based toll on heavy duty vehicles starting in 2025. In addition, it should be pointed out that taxation is only one side of the coin when it comes to decarbonizing the Danish transportation sector. Indeed, the government has recently embarked on an ambitious public support program to increase the number of EVs (including hybrids) from 20,000 to 775,000 come 2030.[24]

24. Reuters, "Denmark Agrees Deal to Have 775,000 Electric Cars by 2030", December 4, 2020, available at: www.reuters.com.

Denmark at the forefront of decarbonization ambitions

A post-COVID green recovery strategy

Denmark sees itself as both a model and pioneer of green growth. In this vein, the government presented the first part of its climate action plan as early as May 2020, in the midst of the COVID-19 crisis.[25] This climate plan, which aims at reducing the country's GHG emissions by 70% compared to 1990 levels by 2030, lays out six main components to accelerate the energy transition:

- Shifting from individual offshore wind farms to energy islands/hubs. Two energy islands, an artificial one in the North Sea with a capacity of at least 10 gigawatts (GW) and one in the Baltic Sea of 2 GW have recently been greenlit.
- Investing in future -oriented green technologies to complement renewables. Carbon capture and storage is of particular interest for the government. A pool of DKK 400 million (c. €52 million) will be allocated for Carbon Capture and Storage (CCS).
- Pushing a green transformation in industry via greater use of renewable energy and improved energy efficiency. A subsidy pool of DKK 900 million (c. €117 million) will be set aside for increased electrification and energy efficiency in the sector.
- Increasing energy efficiency and digitalization in buildings, both industrial and residential. Strengthening energy labeling schemes and smart technologies will be deployed to better inform decision makers. The state, however, will also be an active participant by allocating DKK 30 billion (c. €3.9 billion) for public housing renovations.[26]
- Removing O&G from the heating sector and replacing it with green district heating and electric heat pumps. In a bid to promote this policy, taxes on "green heat" will be lowered whilst those "black heat" will be raised. In addition, the government will suspend the legal requirement on producing heat and electricity

25. Danish Ministry of Finance, "Fact Sheet for the First Part of the Climate Action Plan" May 20, 2020, available at: https://fm.dk.

26. Public Housing is a cornerstone of Danish society as they house approximately 1 million Danes (c. 17% of the overall population).

simultaneously, push for greater sustainability requirements on biomass and set aside DKK 2.3 billion (c. €300 million) to replace oil and natural gas boilers with green heat.

- Moving towards a climate neutral waste sector come 2030, with a requirement of 80% of Danish plastic to be sorted out pre-incineration. A move aimed at reducing incineration and imports in a bid to move towards a circular economy.

An ambitious climate law to become carbon neutral

In the summer of 2020, the Danish parliament approved one of the most climate ambitious laws worldwide. This new climate law, approved by 8 out of the 10 political parties (85% of the seats) in parliament, contains two legally binding targets. In the short term, Denmark's GHG emissions are to be reduced by 70% compared to 1990 levels by 2030, which is a much stronger target than what the EU is currently preparing to set for itself (-55%). To put this into perspective, this means reducing GHG emissions from 54.8 $mtCO_2e$ in 2018 to 23.1 $mtCO_2e$ in 2030 resulting in an annual reduction rate three times higher than that which had been previously envisaged.[27] The Act itself, however, does not establish sectoral emission targets or how national targets are to be achieved. In the long-term the country is bound to reach climate neutrality by 2050,[28] in line with the Paris Agreement objective i.e., keeping the global increase in average temperatures below 1.5°C. Additionally, the 2020 Climate Act requires the government to come up with a ten-year perspective climate action plan, in line with the country's climate objectives, at least every five years. These plans will be both influenced and reviewed by the Danish Council on Climate Change (Klimarådet), the country's independent expert body tasked with advising on energy transition policy and making recommendations to the Danish parliament. On top of this, the government will have to secure, on an annual basis, a parliamentary majority to approve its climate policies and strategies at both a national and international level. With respect to this latter point, the Act stipulates that Denmark must work actively for the realization of the 1.5°C degree target by publishing an annual status report on its bilateral energy partnerships with large GHG emitters, its efforts to reduce emissions from international aviation and shipping and finally the impact of Danish climate finance in developing countries.

27. M. Hall, "Denmark's Phase-Out of Upstream Oil and Gas: Effective Climate Policy or Symbolic Gesture?", *The Oxford Institute for Energy Studies*, December 2020, available at: www.oxfordenergy.org.
28. The Danish Climate Act does not apply to Greenland and the Faroe Islands.

Failure to obtain parliamentary approval would in the short-term lead the government to have to propose additional efforts and, if a majority of parliament is still unconvinced, this would result in theory in a vote of no-confidence.

The challenge is huge: Denmark's current total primary energy supply still relies for 60% on fossil fuels, down from 78% in 2010. Its electricity mix is composed as follows: 55.2% wind, 17.4% biofuels, 11.1% coal, 6.3% natural gas, 5.9% waste, 3.3% solar and finally 0.8% oil. Past trends in the evolution of the country's electricity mix have shown sharp progress in reducing fossil fuels in power generation, making Denmark a champion in phasing out coal, yet the challenge is to decarbonize the entire economy including transportation, industry, and agriculture. In addition, the country must also incorporate the challenge of increasing reliance on electricity imports from its Scandinavian neighbors (3.7 TWh – terawatt-hours – from Sweden and 7.5 TWh from Norway in 2020) as its power mix comes to be largely, if not entirely, dominated by renewable energy sources.

Danish oil & gas exploration and production: the end is near

Following a political agreement in December 2020, the Danish government has agreed to cancel all future O&G licensing rounds in the North Sea – a *de facto* banning of exploration in its waters – and committed to ending all O&G production by 2050. This deal also cancels the country's latest and eighth licensing round. Given the country's position as the largest O&G producer in the EU (following the UK's departure), this announcement is highly symbolic and illustrates its commitment and status as a front runner in the energy transition.

Although symbolic, this decision should nevertheless be contextualized as to its potency. Indeed, although the largest EU O&G producer, Denmark's production (c. 103,000 b/d – barrels per day – in 2019) pales in comparison to its neighbors, Norway (c. 1,437,000 b/d) and the UK (c. 1,019,000 b/d).[29] Furthermore, it should also be noted that economic factors also played a key role in this latest announcement as lower oil prices, higher production costs and dwindling reserves – Danish oil production peaked in 2004 and gas production in 2005 – have led to interest waning in recent oil block tenders. Indeed, the country's eighth licensing round was already under pressure following Total's withdrawal from the tendering process in October, leaving a single contender in the race.

29. BP, "Statistical Review of World Energy 2020", June 17, 2020, available at: www.bp.com.

Nevertheless, the Danish government's decision to phase out oil and gas production by 2050, as well as to cancel its ongoing tender, is expected to cost state coffers approximately DKK 13 billion (c. €1.7 billion) in lost revenues.[30] However, all is not doom and gloom on this front as Denmark has its eyes on the future. The coupling of the country's offshore wind resources and its competences in the natural gas sector make it an obvious candidate to be one of the pioneers in carbon free hydrogen production in Europe. Another avenue of opportunity for the Danish O&G sector is likely to be CCS given the country's potential for CO_2 sequestration in the North Sea.

30. Reuters, "Denmark to End Oil and Gas Hunt in North Sea in 2050", December 4, 2020, available at: www.reuters.com.

Hopes & Potential Hiccups: An Eye to the Future

Tomorrow looks exceptionally green

Electricity consumption is expected to increase by approximately 3% annually in the coming decade due in particular to the (anticipated) increase in the deployment of large data centers, the increased electrification of the heating sector as well as, to a lesser extent, the rise of EVs in road transport. As per the projections of the Danish Energy Agency, data centers are expected to account for 15% of total electricity consumption by 2030, compared to 13% for heating and only 3% for transportation.[31] All this increasing electricity demand will be met by renewable electricity supplies that could reach 100% by 2026-2027 (except imports). Naturally, this growth rate is contingent on the expansion of the offshore wind farms included in the Energy Agreement of 2018, the deployment of commercial solar photovoltaic and the repowering of onshore wind turbines. Another sector where renewable energy is likely to grow significantly over the coming decade is district heating. Indeed, a similar trend to the one seen in the electricity sector can be observed in the district heating, one where the share of renewable energy is expected to increase from c. 45% in 2018 to 60% by 2030.

There is one sector where the share of renewable energy is currently lagging: transportation. In 2019, the share of renewable energy in transportation was approximately 9%, that is one percentage point under the EU renewable energy directive of 10% by 2020. This shortfall, however, is expected to be addressed with a greater use of electricity in rail transport as well as increasing numbers of electrified vehicles. Biogas, as well as biofuel blending in petrol and diesel, are expected to contribute only to a very limited extent. Nonetheless, in the absence of any new significant measures in this sector, the share of renewable energy in transportation is projected to reach 19% by 2030 (five percentage points above the RED II target).

Overall, the expansion of renewable energy throughout all these sectors is expected to result in Denmark reaching a total of 54% renewable energy in its energy mix come 2030, up from 41% in 2018.

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31. Danish Energy Agency, "Denmark's Energy and Climate Outlook 2019", October, 2019, available at: https://ens.dk.

Biomass sustainability in government crosshairs

As has been historically the case when dealing with energy matters, Denmark has already taken a proactive position to address the sustainability criteria for biomass use ahead of the upcoming EC review on the use of bioenergy. In October of 2020, the Danish government along with eight of the ten parties holding seats in parliament agreed on stricter legislative requirement surrounding the use of biomass in heat and electricity production.[32]

The agreement stipulates that all biomass consumed must be from legally felled trees, which are to be replaced via replanting. Moreover, it also specifies that imported biomass may only come from countries where forests are not in decline and/or from forests managed sustainably. Starting in 2021, this agreement will initially cover industrial plants with a capacity higher than 20 MW, before progressively covering all power, heat and industrial systems of more than 2.5 MW. In addition, the forthcoming legislation will ensure that emissions in the biomass are kept at low levels.

In the short run the agreement seeks to guarantee the sustainability credentials of biomass as a climate friendly transitional fuel to replace coal whilst other alternatives are pursued in the long run. Given the importance of biomass in the Danish energy system, this framework provides a foundation on which to tackle the sustainability issues attached to its use. This new framework, which replaces a voluntary industry agreement from 2014, sets firm sustainability criteria for preserving carbon stocks and carbon sinks in source forests, and demonstrates Denmark's decision to take a holistic view on tackling its decarbonization strategy.

Energy islands & hubs or the future of Denmark's renewable energy system

The Danish Parliament has recently given the green light for a project aimed at creating the world's first artificial energy island, to be located in the middle of the North Sea (80 kilometers off the west coast of the Jutland peninsula). It will cover an area of approximately 120,000 square meters and, in the first phase of development, will be connected to circa 200 offshore wind turbines for a capacity of 3 GW, a figure which is expected to reach 10 GW in the future.[33] As such, the

32. K. Taylor, "Denmark Proposes pPathway for 'Sustainable' Biomass", *Euractiv*, October 7, 2020, available at: www.euractiv.com.
33. Danish Energy Agency, "Energy Islands", 2020, available at: https://ens.dk.

island which is planned to be established by the early 2030s will play the role of both an energy hub to accommodate the growing number of offshore wind turbines in the North Sea, as well as a storage facility since the island will play host to a number of energy storage and Power-to-X systems. Overall, the project should cost up to DKK 210 billion (c. $34 billion) and is expected to be developed on the basis of a public-private partnership whereby the Danish government would be the majority shareholder, with a 51% stake, whilst the remaining shares would be held by the private sector.[34] However, this is not Denmark's only energy island project. Indeed, the country is planning a second albeit smaller (non-artificial) energy island in the Baltic Sea, on the Danish island of Bornholm. The island will serve as an offshore wind hub for a capacity of 2 GW and will potentially act as an interconnector between Germany and Denmark following an agreement between the two countries respective TSOs to investigate the benefits of building such an electricity connection.

These two infrastructure projects – the largest infrastructure investment in Danish history – testify to Denmark's willingness to innovate and take a proactive approach to tackling the energy transition. The country, which is home to both Ørsted and Vestas, has already shown its ability to develop pioneering renewable energy technologies. Perhaps a future characterized by large-scale artificial energy islands and green hydrogen technologies in the middle of the sea is not as futuristic as it may sound.

Corporates moves towards green hydrogen

A few days before the unveiling of the EC's green recovery program in May of 2020, a group cross-sectoral Danish companies – including Ørsted, AP Moller-Maersk, Panalpina, DFDS, SAS and Copenhagen Airports – announced the creation of a green hydrogen partnership aimed at developing an industrial scale electrolysis-based production facility around Copenhagen to produce sustainable fuels for maritime, air and road transport. In its first phase, the project will translate into a 10-MW electrolyzer to be online by 2023. A figure which is expected to rise to 250 MW by 2027 and reach full capacity or 1.3 GW by 2030.[35] The project will be powered from nearby offshore wind farms and supply a variety of actors in renewable hydrogen to be used by Copenhagen's city buses, renewable methanol for Maersk transport vessels and renewable jet-fuel or e-kerosene for airplanes.

34. L. Hook, "Denmark Reinforces Green Commitment with 'Energy Islands' Plan", *Financial Times*, May 20, 2020, available at: www.ft.com.
35. A. Franke, "Danish Companies Plan 1.3-GW Green Hydrogen Project to Fuel Transport", *S&P Global Platts,* May 26, 2020, available at: www.spglobal.com.

Furthermore, the country's leading power supplier Ørsted has also taken its own proactive role in developing green hydrogen technologies. Indeed, in January of 2021, the company and other industry partners announced a final investment decision on the H2RES project, an offshore wind -powered 2-MW electrolyzer due to come online in late 2021.[36] This project, however, pales in comparison to Ørsted's partnership with BP to develop a 50-MW electrolyzer at the oil majors Lingen refinery in Germany.[37].

The state has also taken a proactive role in funding green hydrogen projects. In 2019, the Danish Ministry of Climate, Energy and Utilities revealed that it had decided to invest around EUR 19 million in two large-scale renewables -powered energy storage projects. These two Power-to-X projects, dubbed GreenLab Slice PtX and HySynergy, are expected to be implemented between 2020 and 2025.

What future for natural gas?

The combination of the shutdown of the Tyra field[38] for redevelopment purposes and complications in the commissioning of the Hejre field has put pressure on the Danish gas system. For the duration of the Tyrashutdown, Denmark will not have any gas exports and increasingly depend on imports from Germany to bridge the short-term gap between internal production and supply. Overall, however, the refurbishment of the Tyra field is expected to have a negligible impact on the country's energy security. The return to production of the Tyra facility will allow Denmark to reach self-sufficiency again and resume its position as a net natural gas exporter.[39] In the long run, given the country decision to become fossil fuel independent by 2050, it will be interesting to follow the country's ability to juggle its domestic energy needs with environmental policy objectives, all the while ensuring its energy security and independence from energy imports. Note, however, that the contribution of biogas to Denmark's security of supply is becoming increasingly significant. Indeed, production of upgraded biogas is expected to reach 30% of gas consumption by 2030 compared to approximately 15% today.[40]

36. Ørsted, "Ørsted Takes Final Investment Decision on First Renewable Hydrogen Project", January 20, 2021, available at: https://orsted.com.
37. K. Wiggins and O. Aliaj, "BP and Orsted Plan Green Hydrogen Project", *Financial Times*, November 10, 2020 available at: www.ft.com.
38. Tyra is Denmark's largest natural gas field with more than 90% of national gas production processed through its facilities.
39. Danish Ministry of Climate, Energy and Utilities, "Denmark's Integrated National Energy and Climate Plan", December 2019, available at: https://ec.europa.eu.
40. Danish Ministry of Climate, Energy and Utilities, "Denmark's Integrated National Energy and Climate Plan", December 2019, available at: https://ec.europa.eu.

Despite being self-sufficient in natural gas production, Denmark is nevertheless entangled in various geopolitical considerations around two main gas pipeline projects i.e., Nord Stream 2 and the Baltic Pipe, as well as their related energy security implications. On the one hand, the Nord Stream 2 saga, although not crucial for Denmark's own energy security given its self-sufficiency in natural gas production, nevertheless provoked a fierce debate within Danish society on its geopolitical consequences. Despite reticence from a majority of the country's political class and civil society, the DEA issued a permit for construction of the pipeline in the Danish Exclusive Economic Zone (EEZ) in October 2019, in accordance with its technical evaluation and the country's legal framework. However, it is worth noting that the country, and by extension the DEA, nevertheless engaged in a form of filibuster which resulted in substantially delaying the Nord Stream 2 and further complicating its timetable.[41] On top of this, United States sanctions and additional threats have proven to be a substantial obstacle.[42]

On the other hand, the Baltic Pipe which stretches from Norway to Poland via Denmark, despite being less contentious than the Nord Stream 2 project, has its own geopolitical considerations. Indeed, the project would allow for further diversification in natural gas imports for Poland and thus help lessen its dependency on Russian imports as well as strengthen overall European energy security. In this vein, the project was recognized as a Project of Common Interest by the EU and received funds from the latter. Similarly, to the Nord Stream 2 pipeline, the Baltic Pipe project has also received questioning in Denmark, although this was based on environmental concerns and not political controversy. In addition, it is worth noting that the construction of this pipeline, if operational early enough, may result in easing the pressure on the Danish gas supply during the Tyra field redevelopment.

41. S. Wood and O. Henke, "Denmark and Nord Stream 2: A Small State's Role in Global Energy Politics", January 2021, available at: www.sciencedirect.com.
42. S. Elliott, "Nord Stream 2 Tight-Lipped on Danish Pipelaying Plans, German Progress", *S&P Global Platts,* December 15, 2020, available at: www.spglobal.com.

Reforming the EU ETS: a Danish perspective

Another area where Denmark has made important strides are those sectors covered by the Emission Trading Scheme (ETS). Indeed, Denmark's GHG emissions from sectors falling under the scope of the ETS have decreased more sharply than the EU average. However, this decline is attributed to other policies affecting these sectors, such as the support for renewable energy sources and various policy instruments put in place to stimulate energy efficiency measures, particularly in the industrial sector. As a result, the Danish government has argued for a structural reform of the EU ETS, specifically with respect to the existing surplus in allowances in a bid to send stronger price signals to the market. Without such a reform, participants of the climate debate in Denmark have also argued that the country's efforts in renewables and energy efficiency would fail to benefit the climate as the freed carbon allowances would simply be used elsewhere.[43] Simultaneously, however, the Danish Council on Climate Change (Klimarådet) – an independent body of experts that advises the government – has argued against an outright cancellation of a portion of Denmark's surplus carbon allowances, a strategy currently pursued by Sweden, arguing that such a strategy will have only limited short-term effects in terms of GHG emission reductions. Rather, the focus should be on expanding the development of renewable energy sources which, the experts argue, will lead to higher GHG emission reductions and at lower cost. Similarly, in most scenarios drawn up by the Council, the use of national emission reduction measures as opposed to the cancellation of carbon allowances has more cost-effective results in the short run, in order to lower non-ETS sector emissions.

43. The Danish Council on Climate Change, "The Inflated EU Emissions Trading System: Consequences of the EU ETS and Surplus of Allowances for Danish Climate Policy", March 2017, available at: https://klimaraadet.dk.

Conclusion: Lessons from Denmark

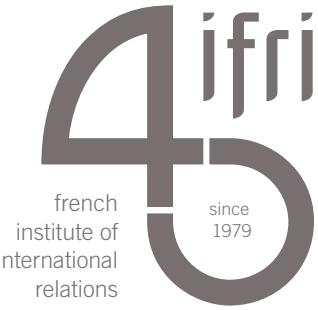
Denmark's long historical tradition of broad energy agreements has been a central pillar of both the country's energy policy and its environmental transition. These agreements have provided a bedrock of stability and predictability for investors whilst simultaneously ensuring a continuous transformation and transition of the energy system despite governmental handovers. In addition, the Danish political system is characterized by a high level of compromise, allowing for a greater level of continuity between the country's successive energy agreements despite potentially having different political parties in power. To top this off, by consulting with various stakeholders including industry actors, non-governmental organizations, political parties, experts and local communities, this collaborative policymaking attitude allows for a transparent and constructive approach, thus garnering high levels of stability and public acceptability. However, compromise is not synonymous with maintaining the status quo. Indeed, the country has shown itself to be a pioneer in developing renewable energy technologies and not shying away from pursuing ambitious renewable energy targets. This has allowed the country not only to substantially transform its power generation sector but also be seen as role model in the global fight against climate change.

Another specificity contributing to the success of Danish energy policy is the manner in which it is conceptualized, that is by pursuing public policy making in a holistic manner and by taking into account the synergies, interactions as well as potential knock-off effects that different policies and regulatory tools may have on the energy sector and economy at large. This cross-sectoral approach allows for a greater level of integration between the electricity, heat and transportation sectors which is crucial to successfully implement policies to transition to a renewables-based energy system.

Finally, decentralization and local involvement have also played an important role in the country's energy transition, notably in the development of renewable energy sources. The promotion of local cooperatives and/or consumer participation in renewable energy projects has allowed for a greater share of ownership as well as acceptability amongst the population, as they can directly enjoy the fruits of their investments. Of course, this model of decentralized development has somewhat diminished with the move away from

generous FIT schemes and, in the case of onshore wind turbines, growing complaints over their increased deployment. Nevertheless, it provided and still provides an effective platform to develop these technologies and spread their acceptability as a feasible alternative to fossil fuels.

All in all, Denmark own history of decarbonization can serve as a useful case study for the EU as it embarks on accelerating its own green transformation. It shows that ambitious measures such as the ones proposed in the Green Deal can bring about a substantial change in Europe's climate performance if these are backed by holistic and generous public policies, a wide long-ranging and systemic consultation of all societal stakeholders and finally a willingness to back technological innovation even if the benefits take years to materialize.



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