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Diploma thesis

An Analysis of Energy Policy of Denmark: Decentralisation and Community Ownership

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Annotation

The main aim of the thesis is to analysis the past fifty years of energy policy in Denmark to gain insight on how Denmark has become one of the European leaders in decarbonising its economy and developing renewable energy resources. A thorough review of academic articles, government and international institutional reports, and books on decentralised energy and climate change were essential for the research required for this work and make up the literature review section. The analysis and results section is divided into three parts that cover the three phases of the Danish energy transition and analyses the different government policies implemented during the different stages and how well they were in achieving the government's goals.

- Phase one: Adding renewable energy production into energy system.
- Phase two: Seeking solutions to the intermittency of renewable energy technologies when renewable energy production is between 40-50%.
- Phase three: Seeking storage solutions in an 100% renewable energy system.

The research led to some important insights that may be useful for other states seeking to decarbonise their economies within their own contexts and some policy recommendations conclude the paper.

Introduction

The current design of the energy system in most countries has been based on fossil fuels. This has made the energy system very flexible and reliable because large amounts of energy can be stored in liquid, gaseous, and solid forms via fossil fuels. However, it is widely acknowledged that a transition to cleaner, renewable energy sources are needed to mitigate the impacts of climate change and protect the environment. This is the beginning of an energy transition from traditional fossil fuel-based systems to systems based on variable renewable energy sources (VRES) that will involve both technical and regulatory challenges. This technological change and the use of VRES is leading to the decentralisation of the energy sector due to the distributed nature of VRES with their large-scale integration of into the electricity supply necessary for the future renewable energy system. Therefore, sooner or later such distributed production units will need to contribute to the task of securing the balance between electricity production and consumer demand.

This transition will require new policies and changes in incentive schemes for generators and the associated grid infrastructure as well as the transformation of some governance mechanisms, be these institutions, market design and network rules, and of course the politics behind them. Creating a system that can efficiently integrate these new technologies implies a change in energy governance. The traditional regulatory frameworks have been designed to secure the reliable operation within a centralised power system, but new systems will require a fundamental change to meet internationally agreed decarbonisation goals. In this sense, governance is a decisive factor for the successful transformation of the energy system and can act as an accelerator or decelerator of the transformation.

This paper will examine Denmark's experience in the energy transition with a key focus on the technological, economic/financial aspects of the energy decentralisation model and the legal/regulatory frameworks necessary to achieve the international agreed aims of decarbonisation. It will further examine the citizen/community ownership structure of the Danish model that has shown quite significant success in the lowering of electricity prices as well as citizen acceptance of the energy transition policies. Citizen empowerment and participation are considered strategic for the EU's energy transition. Citizen ownership of energy would be the highest form of citizen participation.

Aims

The large energy companies left over from the fossil fuel era have been specialised in coordinating the global allocation and distribution of fossil fuels. However, the transition to renewable energy implies a physical and economic decentralisation which will reduce the need for global and international coordination. This leads to a change in the characteristics of transactions in the new energy system and brings up questions about how the political process is influenced by different market actors and the tension between them. It is with this in mind that this paper seeks to understand the dominant discourse taking place in Danish society regarding the chosen energy system pathway in terms of technology as well as ownership aspects to achieve societal goals.

This paper will focus on the technical and organisational consequences of the transition from fossil fuels to mainly fluctuating renewable energy sources. In the Danish context, it will consider questions such as: can this change be managed within the traditional centralised model where excess power can be exported and where production plants are mainly owned by the former fossil fuel companies; or alternatively, whether the transition will rely on a decentralised model with smart energy systems and flexible energy consumption by integrating the entire energy system including power, heat, and transportation, accompanied with energy conservation? Furthermore, should this decentralised system be organised by cooperatively owned power plants synchronising supply-side investments? These are the contemporary questions shaping the development of the Danish energy system and I believe the answers can be very insightful for other countries behind Denmark but seeking pathways for their own decarbonisation, particularly within the European Union's framework Green Deal.

Denmark was chosen due to its leading role within the EU in implementing decentralised and community-based energy infrastructure beginning in the 1970s. Denmark's long-term experience in implementing renewable energy projects in localised small-scale settings make for an interesting case study especially with regards to citizen and community participation in its energy transformation. Therefore, the main research question is set as:

"Is it possible for an EU member country to replicate the policies, laws and processes of Denmark in order to decentralize energy production and consumption?".

Furthermore, I will seek to answer the following three sub-questions related to the main research question:

1. Does decentralized energy offer benefits to local citizens that centralized energy does not?
2. What kind of citizen ownership models have been implemented in Denmark?
3. Has Denmark been successful in developing decentralized energy?

Methodology

The analysis of the Danish energy system and government policies has been done through a thorough review of documents from international organisations, Danish national institutions, company reports, books on decentralised energy and academic articles. All these documents include policy statements, reports, statistics, technology descriptions, legally binding agreements and non-binding ones, reviews of the state-of-the-art renewable technologies and specific articles related to the Danish experience in implementing decentralised renewable technologies.

The international organisations provided context for the problems of climate change, CO2 emissions and other environmental problems that call for the introduction of renewable technologies as well as legally binding regulations and statistical information. The books I have used describe the processes of the energy transition from the traditional fossil fuel paradigm to the new renewable energy one. They helped with the theoretical understanding of the climate problems and discussed many possible pathways to take to achieve decarbonisation and focused on the shift towards decentralised energy systems.

The many academic articles I have reviewed cover four important aspects -technological, financial, regulatory, and community ownership- and are mostly related to the Danish experience. The focus was on technologies used in Denmark, but some others were discussed including some future possible technical solution regarding storage, for example. Other papers included some more technical articles mainly concerned the use of research into the ways that regulations shape the implementation, longevity, and acceptance of the energy transition and here many Danish government documents were also utilised. The synthesis of government documents, policy statements and progress reports with the academic research is the main method used in compiling the Results and Discussion section.

Furthermore, the analysis of the regulatory regimes established in Denmark is key to the understanding of their experience which concerns the different financial and economic incentive mechanisms for enabling the transition as well as their problems regarding disincentives and so articles describing these mechanisms have been used.

Results and Discussion

Phase 1: the niche deployment of decentralised renewable energies; feed-in tariffs (FITs) and incentive schemes; support for the renewable technology industry.

The 1970s oil crisis made it clear to some policy makers that the energy sector could no longer be left to just market forces and that a national energy strategy and regulatory framework were necessary to guarantee energy security.

The first strategy set out to redirect energy consumption, mainly by replacing oil (imported) for coal (regionally source). The strategy also called for the expansion of combined heat and power (CHP) plants that use waste heat from the production of electricity to heat homes and buildings. Later, with the establishment of the United Nations Framework Convention on Climate Change in 1992, the growing awareness of environmental degradation and climate change led to another change where sustainability became the determining issue. Power production from decentralised CHP increasing from 1% in 1990 to more than 30% by 2001 of total electricity consumption, and with around 60% of these CHPs organised as cooperatives and owned by the residents of small towns and villages.

In 1992, subsidies for electricity production from wind turbines were introduced, as well as state support for the completion of the district heating network and to promote the decentralised cogeneration and utilisation of bioenergy. The support for wind turbines was in the form of a fixed feed-in tariff, as at the time there was not an electricity market and generators received a constant price for generation.

It was also decided at this time that shares in wind turbine ownership should be local and distributed to many owners and so two important financial incentives were set up to facilitate this. The first was a tax refund of 0.27 Danish kroner per kWh and the other was a 30% reimbursement of the turbine's purchase price for private citizens who installed wind turbines. Owners had to live within a 9 km radius from the turbine, and by the mid-1980s between 120,000 and 140,000 citizens had become local wind power shareholders.

These state interventions and incentive mechanism helped to contribute to the development of the wind turbine industry and reduce investment costs. The Danish wind industry began to export its technologies beginning again in 1992 and by 2000 had achieved a 30-40% reduction in the cost of wind power electricity. In the latter part of the first phase, the share of wind powered electricity production grew to 13 per cent of total electricity consumption and wind turbines were now ready for large-scale

deployment with large turbines of about 2-3 MW of capacity. Renewable energy in the total energy mix reached over 7% of total energy production by 2000 while the economy continued to grow.

Phase 2: renewable energy rises to become a major player in the energy supply industry; moves towards a market-based system; new governance framework to encourage the new flexibility requirements.

Phase two can be characterized by the need to integrate renewable energy technologies and by changes in ownership structure of the energy system. At the turn of the millennium, onshore decentralised wind development slowed considerably due to market liberalisation, as well as the feed-in tariff support system for wind energy being replaced with a market premium subsidy. Henceforth, producers were paid the market price for their generation plus a premium on top.

Furthermore, an important change occurred in 2000 when the local ownership restrictions were halted and since 2008 there has only been the obligation to offer 20% of the shares at cost price to local residents from developers. It is estimated that 52% of the total existing installed wind capacity in Denmark in December 2016 contained a citizen ownership model and increases to 67% when excluding large offshore wind farms. With changes in legislation and incentive systems, more exclusive and distant citizen ownership models emerged. The Danish Energy Agreement of 2018 shows a preference for large offshore wind power projects designed around a tender process. This suggest that Denmark will experience changes in the ownership structure of turbines moving into the third phase dominated by large investor ownership.

The state required a non-profit regime, where the profit would remain in the electricity company and could not be used outside the electricity area for other purposes. This was also the case with locally owned wind turbines and CHP plants. The dominance of citizen ownership in the Danish DH/CHP is the direct result of profit generation being prohibited (i.e., the non-profit rule), which makes investments in DH/CHP systems unattractive for commercial investors and attractive for consumers who benefit from lower energy bills. Citizen ownership has been represented either in the form of municipal companies or consumer owned cooperatives and represents a 96% of all DH and CHP units. However, in 2004 the non-profit public regulation regime was replaced with an income frame regulation, where the public energy inspectorate each year announces an income frame for the specific electricity supplier.

In 2015, 68% of all district heating (DH) was produced in cogeneration with electricity in combined heating and power plants (CHP). This saves a significant amount of fuel compared to separate generation of heating and power.

In the second phase, renewable energy technologies make up to 40-50% of the electrical energy supply and so the development of an integrated energy system that can handle large amounts of intermittent electrical energy supply is required. In Denmark, the long-term development of district heating systems offers the opportunity for the integration of the electricity and thermal energy systems. The widespread use of CHP is one of the key reasons why it has been possible to increase energy efficiency and reduce carbon emissions over several decades.

Phase 3: renewables are now the dominant player within a flexible, well integrated energy system; energy storage becomes a priority, new market designs.

In the first two phases of the energy transition, the pace and types of development of renewable technologies was to a large extent determined by the national governance framework working in coordination with all the stakeholders. In the third phase, electrification occurs in new sectors such as heat and transport which require a governance framework that needs to enable the co-existence and integration of different systems.

It is with this in mind that the Danish system with a large share of CHP based district heating can be regarded as a system well suited for the integration of renewable energy. CHP units should be operated such that they produce less when VRES electricity input is high and more when it is low. Denmark is now at a stage where the integration of thermal and electric energy is a must since wind power is becoming the dominant supplier of electricity. This is done by investing in industrial and household heat pumps and heat storage systems all powered by VRES.

Danish wind power produced 46.5% of total electricity production in 2020 with the largest share of this coming from onshore wind turbines. However, the Energy Agreement of 2018 aims to shift wind power production to large offshore sites and in 2020 the Danish Parliament approved the creation of two “Energy Islands” in the North and Baltic Seas that will quadruple Denmark’s total offshore wind energy capacity. Furthermore, it will fund charging stations for electric vehicles and help the industrial sector decarbonize by increasing the use of renewable electricity and biogas.

To create a rational economic basis for wind power is to increase its market size by integrating electricity and heat and transportation. It is very important to involve the new flexible technologies such as CHP, heat pumps and the electrification of transport (batteries and electrolysers) in the grid stabilisation tasks, which may function as back-up electricity suppliers when wind power is insufficient to meet demand through vehicle-to-grid (V2G) technologies. New technologies enabled by digitalization

offer partial solutions not only to the intermittency of wind power generation but can also help to conserve energy. Battery technologies development are being driver by the EV industry but once batteries have degraded to some 80 per cent of their capacity, they may no longer be suitable for vehicle usage, but may still be suitable to stationary storage where size and weight are no longer critical factors in decentralized municipal stage facilities.

Research Question

"Is it possible for an EU member country to replicate the policies, laws and processes of Denmark in order to achieve the same goal of decentralizing energy production and consumption?"

This question at first may seem at have an easy answer. EU states all operate under the same regulatory regime and so replicating Denmark's policies should be straightforward. Furthermore, decentralized energy generally means renewable energy since solar photovoltaic panels and wind turbines are scattered across residential rooftops and dispersed on acres of farmland and the decentralization of energy supply means utilizing technologies that are in smaller capacity units and where their geographic distribution is wider than the traditional fossil fuel large generating units. It is as a system moving from a one-way, top-down, supply orientated operation of a few, large conventional fossil fuel power plants to an integrated system that is bi-directional, and demand focused with multiple, varied power generating units of all sizes. Therefore, while the answer to the research is seemingly "yes", an analysis of the answer is quite a bit more complicated.

The main steps when designing national energy plans are relatively straightforward but not necessarily simple. As each state has its own conditions, a logical place to start would be to evaluate the different technologies available and decide which would perform the best within the constraints of the state. Another key part of planning is assessing what phase of the energy transition the state finds itself in and what is its current energy mix. States with no or little renewable energy can begin implementing their chosen technologies without regard for its intermittency as the energy produced will not lead to load balancing tasks but states with large amounts of electricity from nuclear or hydro may begin at phase two if they produce more than 20% of electricity demand.

Another key consideration for lies in the ownership structure of DH plants, solar and wind turbine installations, and decentralised storage solutions. Giving local stakeholders ownership of renewable infrastructure also gives them a stake in the game and would increase local acceptance for their implementation. If policymakers have designed plans that take all of this into consideration, then

the next stage of creating the legislation and regulations to achieve the plans aims should encounter less opposition and technological difficulties that have costs in both financial and societal acceptance terms.

An important step for Denmark was the creation of the Danish Energy Agency that coordinates government policies across different ministries and engages with stakeholders when designing and implementing government policy. This has helped with the continuity of long-term planning. Many learnings can be used in other countries, but the timing and initiatives must be adapted to local circumstances. The role of stability in long-term policy decisions cannot be overstated. When long-term policy goals are set, the regulatory framework needs to reflect this. The regulatory framework should be designed to de-risk projects in order to achieve policy goals.

Sub-questions

1. Does decentralized energy offer benefits to local citizens that centralized energy does not?
2. What kind of citizen ownership models have been implemented in Denmark?
3. Has Denmark been successful in achieving its decentralized energy goals?

The citizen ownership models saw that local citizens have benefitted from the decentralised onshore wind turbines and DH/CHP units. Starting with citizen owned DH/CHP units, we have seen that they represent 96% of heat energy demand and comprise of 388 decentralised units either as a municipal company mainly in large cities (60% of demand supply), or consumer cooperatives in smaller settlements (36% of demand supply). Ownership policies for DH and CHP are generally the same and these policies have been mainly constant and changes in economic and legislative incentives have affected technology implementation rather than the ownership mainly in the conversion of DH to CHP. This is importantly co-dependent with the Danish non-profit public regulation which in combination with an efficient consumer ownership regime meant that any profits were given back to the consumer via a price reduction.

Consumer ownership of Danish DH/CHP has put pressure on the management and decision-making of DH/CHP companies, leading to lower heat prices for consumers and a continuous development of the systems by adopting the best available solutions in the market. Local ownership therefore gives benefits to locals through their agency in the decision-making process of DH/CHP companies and by having lower energy bills.

The case of wind turbine ownership is not so clear. The second half of the first phase saw the rapid expansion of citizen owned wind turbines which contributed to a large onshore wind capacity installation. The local ownership structure that saw increased growth since the 1990s is individual citizen ownership of households and farmers represented by prosumers who generally installed small wind turbines and sold the excess electricity to the grid. This was facilitated through government support schemes (subsidies) and ownership regulation that turbine owners had to live within a 9 km radius from the turbine. This has since changed and now the main local ownership regulation is that a 20% of the shares at cost price must be offered to local residents from developers. The non-profit and local ownership rules certainly gained local acceptance as demonstrated by the rapid development of wind turbines close to their homes and saw benefits as seen in electricity prices below the EU average in 2017. This also achieved one the EU's priorities in including citizens in the energy transition. However, as argued in the discussion about the third phase, these benefits are under threat due to the now open competition in European energy markets and Denmark's move towards larger offshore wind farms which require the capital to develop that local actors may lack.

Whether Denmark has been successful in achieving its decentralised energy goals has perhaps already been answered from the above discussion about the other research questions. Lower energy prices, reducing the energy intensity of the economy, citizen acceptance, participation and ownership all point to the success of Danish decentralised energy. Already in 2015, 42% of total electricity consumption was supplied by wind power (52% of this is decentralised and citizen owned).

It is the opinion of the author that the future 100% renewable energy future will have to have aspects of decentralisation and centralisation. In Denmark, the key technologies so far have been wind turbines and DH/CHP units. Moving forward new technologies will need to be implemented, some decentralised (household battery storage, vehicle to- grid, heat pumps, rooftop solar, etc.), and some centralised (offshore wind farms, electricity to-gas, etc.) and the ability of governments to include local stakeholders, NGOs, and businesses in the development of national energy plans will remain key to achieve the sustainable energy future.

Conclusion

Every state has its own conditions, histories, and culture that will affect the implementation of renewable energy systems but the analysis of Denmark's experience as a first mover allows political and economic decision makers from other states to prepare for the different phases of the energy

transformation by thinking from phase three backwards to leapfrog or to allow the three energy phases to co-exist. For states beginning their energy transformation, the ability to analyse the future difficulties with full energy system integration may well allow policymakers to avoid mistakes and implement solutions even before the future integration problems arise.

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