Is the Industrial Turn in Renewables Killing Denmark's Energy Cooperatives?

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Abstract. This study contributes to sustainability transitions research by taking an energy democracy perspective on important, comparative aspects of community energy development. Locally rooted wind energy cooperatives have played an important role in Denmark's clean energy transition but recently 4 out of 5 such projects have shut down. This development has been associated with a turn to large investor-driven industrial-scale renewable energy projects. The broader participation of cooperatives in other parts of Denmark's energy sector has received little scholarly attention. The purpose of this study is to provide a synthesis across different technologies and types of cooperatives showing the industrial turn's impact on the cooperative energy landscape. This paper builds on the identification of almost 800 energy cooperatives. Cooperatives remain a substantial part of the energy system in Denmark. They account for 26 percent of total turnover in the energy sector and are especially important in electrical distribution, district heating, biogas, and onshore wind power. Combining descriptive statistics and interviews with key actors in the field, this paper shows how the industrial turn negatively affects producer-owned wind and solar power cooperatives, and farmer-owned biogas cooperatives. Other types of energy cooperatives like district heating companies seem unaffected. A novel phenomenon is identified: The rise of energy mega cooperatives in the field of electrical distribution. These cooperatives have 100,000s of members and function as business groups with diverse activities in renewable energy generation and distribution. The study highlights a large potential for participation of retail- and housing cooperatives in renewable energy supply and suggests that comparative perspectives are needed to better understand the potential for democratizing Europe's clean energy transition.

Key words: sustainability transitions, energy democracy, community energy, energy cooperatives, grassroots innovation.

1 Introduction

There is global consensus on the need to act on climate change by decarbonizing energy systems. Sustainable energy transitions are rapidly evolving in many countries

and they are not only technical processes, but have major impacts on ecology, economy, politics, and governance (Solomon & Krishna, 2011; Markard, 2018). The transition to clean energy sources, like all sustainability transitions, is closely linked to social change and the potential for more emancipating energy futures (Gatto, 2022). The climate emergency has also increased societal interest in energy. Popular mobilizations such as “Fridays for Future” have influenced political agendas in some countries. Recent shocks such as the 2021-2022 energy crisis, and the Russian invasion of Ukraine, have had dramatic effects on European energy policy and increased the focus on carbon neutrality and energy security goals.

Sustainability transitions can be defined as “large-scale disruptive changes in societal systems that are deemed necessary to address grand challenges, such as climate change” (Krupnik et al., 2022, p.2). Recent social science approaches to energy research include themes such as the phase-out of existing technologies like coal and nuclear; influence of legal and technical contexts, or social norms, on the development of renewable energy; and ownership and socio-spatial conflicts over renewables. In this context, energy cooperatives have been identified as alternative niche actors with potential to contribute to a transformation of the existing fossil-dominated energy system in Europe. This is often linked to the emergence of decentralized, community-based local solutions to energy production and distribution (von Wirth et al., 2020). Germany and Denmark have been highlighted as places where democratic, bottom-up energy initiatives have been particularly successful. However, cooperatives and associated social movements now appear to be at a crossroads as large-scale commercial renewable industries are consolidating their positions (Mey & Diesendorf, 2018; Rommel et al., 2018). The structural change in governance, legal, technological, and other conditions to the advantage of commercial energy industries is a trend observed across Europe (Kirch Kirkegaard et al., 2021; Markard, 2018; Novikau, 2022), and can be described as an “industrial turn”.

Too little is known about the present role of cooperatives across technologies in Europe’s energy sector and the Danish case might well serve to shed light on emerging trends and potentials in the context of the industrial turn. The results presented in this paper is based on descriptive analysis of quantitative data and interviews with 10 energy activists, industry association representatives, and researchers from the fields of community energy and cooperatives (Kohl, 2022).

1.1 Research question

The research question is:

How does the industrial turn in renewables affects Denmark’s cooperative energy landscape?

The paper is structured as follows: In section 2, the background and context of energy cooperatives is described. In section 3, the theory is reviewed with a focus on conceptualizations of energy democracy, and the research methods are described. Section 4 gives an outline of the broad participation of cooperatives in Denmark's energy sector. In section 5, findings on the impact of the industrial turn on the cooperative energy landscape is presented and discussed, followed by conclusions in section 6.

2 Why cooperatives? Background and context

Energy cooperatives are part of a wider, emerging phenomenon across Europe of different kinds of local, citizen-based, and democratic energy initiatives, sometimes grouped together as "community energy" (Caramizaru & Uihlein, 2020; Ruggiero et al., 2021; Seyfang & Haxeltine, 2012). The REScoop federation of European renewable energy cooperatives lists 1,200 cooperatives as members (REScoop, 2022). In Denmark (population 5.9 million), there are hundreds of cooperatives with production or distribution of energy as a primary activity. The claims to fame of Danish energy cooperatives are as innovators and pioneers of wind power, and as generators of local participation and local economic development. This development began after the 1973 Oil Crisis where a shift in Danish energy policy encouraged local, innovative solutions to energy supply. This led to the rise during the 1980s and 1990s of community-based wind power "guilds", or cooperatives. Wind cooperatives initially benefitted from investment subsidies and a fixed price for each kilowatt-hour (kWh) produced (feed-in-tariff, or FIT) (Hvelplund, 2013). From the early 2000s, support schemes were gradually removed by governments who favored neoliberal, market-based policies. This led to a dramatic decline in community-based wind power (Kirch Kirkegaard et al., 2021). When the proliferation of wind turbines peaked in 2000 with more than 6,200 installations this was very much the result of local and community engagement in wind power. Even in 2008, when large commercial actors had well begun a takeover of the market, and the number of wind turbines had dropped to 5,200, around two thousand turbines were still owned by community-based cooperatives (Energistyrelsen, 2008).
Wind guilds are the best known and most studied example of renewable energy cooperatives in Denmark, but they are by far not the only cooperative component of the energy sector. Cooperatives can be defined as autonomous, jointly owned enterprises guided by a set of values (see ICA, 2022), and governed by a "one member, one vote" principle. Apart from this shared democratic principle, Danish energy cooperatives have diverse business models, they engage with different energy technologies, and are made up of groups of people with different profiles. First of all, cooperatives do different things in different ways. At one end of a fossil-renewables spectrum is a cooperative such as consumer-owned energy company OK that runs a network of 670 low-price gasoline stations and has around 11,500 members. At the

other end of the spectrum is the emblematic 8,000-member strong producer-owned offshore wind guild Middelgrunden, founded by environmental activists. The bulk of energy cooperatives, in particular district heating companies and electric grid companies, are neither all fossil, nor all clean energy, but are in a process of transition, with short- or mid-term decarbonization goals (Kohl, 2022).

Also importantly, there tend to be shared characteristics between the members within certain types of energy cooperatives, but not necessarily between different types of cooperatives. Thus, cooperative members are not necessarily "activists". Biowaste and biogas cooperatives are for example often founded by local farmers as producer-owned enterprises. Consumer-owned district heating, and electrical grid cooperatives, are, for legal reasons, open to all households in certain areas, resulting in more diverse membership. More activist-driven types of membership are seen in association-style cooperatives (often linked to local community development schemes), or multi-stakeholder cooperatives like eco-villages. Other membership profiles can be found in cooperatives that engage in energy production as a secondary activity, like retail or housing cooperatives. The diversity of Denmark's energy cooperatives is also reflected in the fact that they do not have a common umbrella association (like the DGRV in Germany) but tend to form part of business associations with non-cooperative firms working in their specific business area.

3 Theoretical and methodological framework

It is widely observed that the large-scale rollout of renewables that increasingly contributes to energy supply across Europe comes with a structural change in the institutional context of renewable energy projects. This includes a change in policies from support schemes like feed-in-tariffs, which benefit community-based projects, to market-based set-ups (Krupnik et al., 2022). This "industrial turn in renewables" occurs at different times in different places and can have dramatic effects on ownership modes. Kirch Kirkegaard et al. (2021) show how the original, local cooperative ownership of much of Denmark's onshore wind power shifted to distant and international corporate ownership, and link this to changes in four other entangled dimensions. First, a shift in policies and incentives like abandoning feed-in-tariffs and requirements of local ownership. Second, a change in turbine technology from small and mechanically simple turbines up to 500 kilowatts to large and complex ones of up to 8 megawatts. Third, a substantial increase in the size of the investment required. Fourth, a change in financing from low-risk, cheap mortgage loans to high-risk complex financing instruments. This is also essentially also a transition from environmentalist ideology to profit and capitalism.

Markard (2018) identifies this second phase of the energy transition as a challenge to existing technologies, organizations, and infrastructures. A decline of established business models comes along with intensified political and economic struggles of

actors like utility companies, industry associations, and grassroots. This increasingly puts social movements for decentralized control of energy systems under pressure (Mey & Diesendorf, 2018; Rommel et al., 2018). Such movements and environmentalists have coined and use the term “energy democracy” to describe their struggles against top-down approaches to decarbonization and the current centralized fossil-based energy system. In this context, energy democracy entails social ownership of energy infrastructure, public participation in decision-making, and a focus on environmental and social justice (see for example Climate Justice Alliance, 2022).

“Energy democracy” is also used as a theoretical concept by social science researchers to describe aspects of democratizing the energy system including fostering collective participation, transparency, grassroots innovation, and democratic forms of ownership and decision-making, usually related to renewables (see Wahlund & Palm, 2022; Szulecki & Overland, 2022). There is a growing critical and feminist inquiry of the actual functioning of grassroots and cooperative energy initiatives in regards to participation, gender, economic privilege, etc. (see Allen et al., 2019; Lazoroska et al., 2021). Paul (2018) suggests that “Energy democracy can be understood as an expression of a new spatial politics of energy transition, evident in the protests, civil disobedience, and alternative energy practices of civil society*”.* This paper focuses on “alternative energy practices” in Denmark, in a study aiming to better understand the impact of the industrial turn on cooperatives across a spectre of different technologies, by looking comparatively at a wider cooperative energy landscape.

Previous research has often focused on case studies of cooperatives, or a single technology, such as wind turbines, district heating or biogas. A methodological challenge in a comparative synthesis study like this one is that there is no central, official data on energy cooperatives in Denmark. The Danish Ministry of Energy does register – through the Danish Energy Agency – all renewable energy installations (see Energistyrelsen, 2021). However, this registration does not necessarily reveal the true form of ownership of the particular installation, as shown in detail by Gorroño-Albizu (2021) in the case of onshore wind farms. In general, ownership forms include private individuals e.g. farmers, and land- or home-owners, municipal, state company, cooperative, private investor-led companies, or a mix of these.

One main empirical source of this study is data gathered from desk research (descriptive statistics) on Danish Ministry of Energy publications. Another main empirical source of data comes from mappings done by the Danish Research Institute for Democratic Businesses (Demokratisk Erhverv) of 20,336 Danish cooperatives (DE 2022a, see also Jørgensen et al, 2019). The mapping compares accounting data from Statistics Denmark with data from Denmark’s Central Business Register to identify most cooperatives in all business sectors, including energy supply. The information from these two main data sources was summarized and collated to provide an overview of the general role of cooperatives in the energy sector.

However, this data alone often did not show exactly the participation of cooperatives in specific energy sectors, nor did it explain decreasing or increasing roles of cooperatives. Therefore, to provide a descriptive analysis of the quantitative data set, additional data was also gathered via semi-structured qualitative interviews, combined with conversations, and correspondences, with 10 informants. Six were community energy activists and/or cooperativists working with respectively REScoop Europe (European federation of citizen energy cooperatives), INFORSE (International Network for Sustainable Energy – Europe), BL Danmarks Almene Boliger (Danish Federation of Non-Profit Housing Providers), an eco-village, a wind guild and a biogas coop. Two represented industry organizations: Dansk Fjernvarme (Danish District Heating Association), and Biogas Danmark (Danish association of biogas stakeholders), and two were academic researchers on community energy and cooperatives.
Interviewees were selected to reflect both activist and professional perspectives on energy cooperative experiences, as well as different technologies and a diversity in organizational forms: district heating companies, wind guilds, solar cooperatives, grid companies, housing cooperatives and eco-villages. Interviews were conducted between January and May 2022. Data from interviews, together with some media sources, served to qualify the quantitative data gathered via desk research. This also allowed for the inclusion of concrete examples of cooperative initiatives in different parts of the energy supply spectre. Some of the initial results were previously used in a report on energy cooperatives for the Danish Business Authority (Kohl, 2022).

4 An introduction to the role of cooperatives in the energy sector

Cooperative ownership in the Danish energy sector hit the public and political agenda in 2018 around a controversy over the proposed sell-off of state-owned electric grid company Radius. Critics argued that Radius, which distributes power to households in the capital city Copenhagen, should be considered “critical infrastructure” and therefore not be sold to a private, commercial investor. After considerable public pressure, a parliament majority decided that Radius should instead be sold to regional consumer-owned grid cooperative, SEAS-NVE (Elkjær, 2019). In this way, consumer-owned utility cooperatives solidified their long-standing tradition of occupying key positions in critical energy infrastructure, although within a general context of neoliberal market reforms and privatizations in the Danish energy sector.
Social science studies have highlighted Denmark as a frontrunner in renewable energy transition with a high degree of local and public participation and ownership, often focusing on wind power guilds and district heating cooperatives (Gorroño-Albizu, 2021; Kooij et al., 2018; Mendonca et al., 2009). Decentralized, bottom-up initiatives are common also in other countries, but the Danish case is particular in that energy cooperatives like wind guilds emerged already in the 1970s linked to alternative social movements and anti-nuclear activism. In the case of grid cooperatives, some trace

their roots back to the introduction of public electricity in the 1890s where municipal companies dominated urban supply, and cooperatives dominated rural supply (Frederiksen, 2018).

Today, decentralized energy generation is spreading fast, and the Danish Energy Agency lists more than 100,000 small or larger electricity producing plants (Energistyrelsen, 2021). However, official energy statistics do not provide detailed descriptions of ownership constellations which makes it difficult to obtain precise and up-to-date data of the total scope of energy cooperatives (see also Gorroño-Albizu et al. 2019). The most recent survey from the Danish Research Institute for Democratic Businesses (2022a) estimates that "democratic enterprises" (see definition below) account for 26 percent of total turnover in the Danish energy sector. The relatively large contribution of cooperatives is mainly due to the activities of a handful of very large consumer-owned grid company business groups.

The following description sheds light on central fields and actors in the cooperative energy landscape, without pretending to provide an exhaustive picture. The main points are that cooperatives play key roles in distributing electricity to households and businesses, in producing and distributing heat, in generating onshore wind power, and in production of bioenergy, especially biogas. Many cooperatives also play roles in renewable energy supply as a secondary activity, for example housing cooperatives or retail cooperatives installing solar roof farms. Such energy generation projects are often developed together with the installation of other technologies that can potentially use electricity from renewable sources like heat pumps or charging stations for electric vehicles.

4.1 Definitions: Cooperative or democratic enterprise?

Energy cooperatives in Denmark seldom use the word *kooperativ* (cooperative) in their company name. That term seems to be associated with employee-owned cooperatives outside the energy sector. The classic legal organizational form of energy cooperatives is as an *amba* or *andelsselskab med begrænset ansvar* (limited liability cooperative), but a variety of other cooperative ownership models exists. In the following, cooperatives will be defined according to the Danish Research Institute for Democratic Businesses' definition of a "democratic enterprise". That is an independent business organization governed by a democratic assembly on the principle of one member, one vote - or at least 50 percent controlled and/or owned by such a democratic assembly – and with a relatively open membership (DE, 2022b). For a detailed discussion of the overlapping concepts of cooperatives and democratic enterprises see Hulgård et al. (2022).

4.2 The cooperative energy landscape

A 2019 mapping of all cooperatives in Denmark lists a total of 785 cooperatives in the energy sector (Jørgensen et al., 2019). The survey is based on data drawn from the Central Business Register and excludes very small, or unconventional, cooperatives. 737 cooperatives are listed in the category of "consumer-owned democratic companies" and are divided according to their business branch subcategory: Heat supply (328), production of electricity (312), electricity trade (43), distribution of electricity (31), construction of cable networks for electricity and communications (23). 48 cooperatives are listed in the category of "association-owned democratic companies", all in the subcategory of production of electricity. No energy-related cooperatives were listed in the category of "employee-owned companies". Three energy-related cooperatives were listed among the largest of the "consumer-owned democratic companies" defined by having more than 500 employees. All these three cooperatives would seem to play a marginal role to the discussion of clean energy transitions and the industrial turn in renewables. The first is the gasoline retail cooperative OK; the second is the energy and water metering company Kamstrup, owned by OK; and the third is electrical technology firm EL:CON, owned by grid mega cooperative NRGi.

In the following a grounded description is provided of the participation of cooperatives in different energy technologies and fields: 4.2.1 electric power distribution; 4.2.2 district heating; 4.2.3 bioenergy; 4.2.4 wind energy; 4.2.5 sun energy; 4.2.6 water energy; 4.2.7 geothermal energy; 4.2.8 eco-villages and energy communities; 4.2.9 energy research and development.

4.2.1 Electric power distribution

Electricity is traditionally delivered from producers to consumers through an electric grid, consisting of transmission lines (the highways of power), substations, and the distribution lines that connect with end-users in households and businesses. This traditional model of delivery is increasingly challenged by the expansion of decentralized renewable energy generation where some consumers are at the same time producers. In Denmark, the state-owned enterprise Energinet acts as transmission system operator (TSO) and owns the transmission network for electricity (and natural gas). Regional and local grid companies, also known as distribution system operators (DSO), own and operate the distribution network that leads power into people's homes.

Most of Denmark's around 40 grid companies are consumer-owned cooperatives (Energistyrelsen, n.d.). Among the largest are mega cooperatives like Andel (formerly SEAS-NVE), NRGi, Norlys, and Energi Fyn, who all have several hundred thousand members. Andel alone distributes around 40 percent of all electricity in Denmark and is owned by 400,000 households, corresponding to 1 in 7 of the country's 2,8 million

households. The major consumer-owned grid companies are in practice energy business groups with diverse activities including generation of renewable energy, natural gas supply, IT- and telecommunication networks, etc. Energy Fyn is an example of a regional grid mega cooperative with 200,000 members from the island of Funen that owns and operates 26 wind turbines, manages street lightning, develops fiber-optic cable networks, and distributes natural gas, besides the core activity of electric power distribution.

4.2.2 District heating

District heating is the dominant technology in heat supply and 64 percent of all households are connected to district heating networks. Networks are expanding steadily with around 20,000 new households connected every year since 2014 (Dansk Fjernvarme, 2020). As of December 2019, there are 323 cooperative district heating companies who together accounted for 34 percent of all district heating sold in Denmark (Forsyningstilsynet, 2020). There are also around 50 municipal companies and a few private firms. District heating is a transmission system that can be connected to any source of heat. District heating today is generated from renewable sources like biomass, biogas, wind, solar, and geothermal, as well as industry surplus heat, and fossil-based fuels like natural gas, coal, waste, and oil. District heating plants increasingly install technologies like heat pumps and electric boilers that can make use of electricity from renewable sources. The national district heating business association estimates that 52 percent of the heat supply is based on renewable sources (Dansk Fjernvarme, 2020).

District heating cooperatives outside large cities sometimes rely heavily on biomass such as straw from local agriculture. Solar heat plays an increasing role and at least 120 district heating companies have invested in solar installations. One example is the consumer-owned cooperative Dronninglund Fjernvarme that supplies heat to around 1,500 households. In 2021, 70 percent of local heat supply came from solar-powered heat pumps connected with a large interseasonal heat storage. The remaining 30 percent came from natural gas (Ingvardsen, 2022). Another widely used technology is biogas. In some cooperatives, the farmers who supply manure to the biogas production are represented on the board alongside district heat consumers. The village-based cooperative Energi Vegger features another organizational design where the 150 household members elect four representatives to the board, the municipal council appoints one representative, and farmers who supply manure can elect a board representative without voting rights. The Vegger energy cooperative is part of a wider rural cooperative ecosystem that includes a grocery store, a culture house, and sports facilities (Hulgård et al., 2022).

4.2.3 Bioenergy

As already mentioned, bioenergy in the form of biomass like straw, or wood chips and pellets, biogas, and to a smaller extent also biofuels, are used by district heating cooperatives. Biogas is also a rapidly growing component of gas supply to some 400,000 households and companies connected to the gas distribution network. In 2020, an estimated 60 percent of total biogas production came from 35 farmer-owned cooperatives. The rest came mainly from individual, farmer-owned plants, together with industrial plants (Personal communication with Biogas Danmark). According to the Danish Ministry of Climate, Energy and Utilities, the share of biogas in the gas network is expected to increase from 20 percent in 2021, to 70 percent in 2030, and to reach 100 percent in 2040 (KEFM, 2021). Biogas is also thought to have potential to contribute to decarbonization of the transport sector and in connection with emerging power-to-X conversion technologies.

4.2.4 Wind energy

Wind power accounts for half of Denmark's electricity consumption, and figures are rising. The development of offshore wind parks and offshore energy islands dominates the political and media agenda. Cooperatives in general play a marginal role in offshore wind development. Among exceptions are the Middelgrunden wind energy cooperative operating ten 20-year-old wind turbines near Copenhagen's coastline, and mega cooperative Andel's 90-turbine wind farm at Rødsand II with an installed capacity of 215 MW. Onshore wind turbines still account for most of total wind energy production: 10 TWh out of a total of 16TWh (WindDenmark, 2022), and has the advantage of being considerably more cost-effective than offshore turbines (Energistyrelsen, 2022). Gorroño-Albizu (2021) found that 68 percent of installed onshore wind energy capacity was "citizen-owned" in 2016, and out of this share between 11 percent and 38 percent was collectively owned, usually in the form of "wind guilds".

Not all guilds fulfil the criteria of democratic governance as defined by the Danish Research Institute for Democratic Businesses. An example of a guild that is not a cooperative is Prøvestenens Vindmøllelaug. This wind guild with 500 members was created because commercial wind power developers were formerly legally obliged to offer a minimum of 20 percent ownership in the project to residents within a distance of 4.5 km. According to this wind guild's statutes, members vote according to their number of shares. The European federation of citizen energy cooperatives, REScoop, estimates that most Danish wind guilds do function according to cooperative norms (personal communication with REScoop board member Erik Christiansen).

4.2.5 Solar energy

Solar energy is generally generated in two forms. One is as solar heat (solar thermal collectors) which is of increasing importance in the district heating sector, as earlier described. The other form is solar power generation via photovoltaics (PV). Today,

solar power covers only 4 percent of total electricity consumption, but the potential is far higher. Only few solar power cooperatives have been founded, mainly due to legal restrictions that complicate collectively owned projects. In 2005, environmental activists founded the Copenhagen Photovoltaic Guild which is operating two rooftop plants on buildings owned by the City of Copenhagen (Københavns Solcellelaug, 2022). Cooperative retail giant Coop amba, which was founded in 1896 and currently operates around 1,200 supermarkets, is increasingly installing industrial-size solar rooftop-farms, including the hitherto largest plant in Denmark (Energy Supply, 2020). There is also an increasing number of rooftop PV projects in the cooperative housing sector. Most of these projects are limited to providing lighting to common areas like stair halls and outdoor areas, but do not provide electricity to individual homes because of legal restrictions.

4.2.6 Water energy

Hydropower plays a marginal role in Denmark today but was previously very important. Cooperatives own most remaining historic hydropower stations. The largest is Gudenaacentralen, which covered a fourth of electricity demand in Denmark's largest province Jylland when it was inaugurated in 1921. Production is now around 14 gigawatt hours (GWh) (Gudenaacentralen, 2022). An emerging form of water energy is wave energy which is thought to have a potential role in future energy supply. One of the most important test centers facilitating innovation and research is run by Nordic Folkecenter for Renewable Energy, an education and resource center, founded as a cooperative by activists in 1983 (Bølgekraftforeningen, 2022).

4.2.7 Geothermal energy

Low-temperature geothermal energy is widely exploited by district heating cooperatives and housing cooperatives using heat pumps. High-temperature geothermal energy is still at an early stage in Denmark. Test facilities have shown that it is necessary to drill very deep to exploit high temperatures. In 2022, energy mega cooperative NRGi announced the take-over of a 20 percent ownership share in geothermal development firm Innargi. NRGi is based in the second-largest Danish city of Aarhus, and Innargi will develop a new project aiming to bring geothermal heat from a depth of 2 to 3 kilometers under the city. According to the plan, one-fifth of the district heating in Aarhus will sourced from high-temperature geothermal heat in less than a decade (Tornbjerg, 2022).

4.2.8 Eco-villages and urban energy communities

There is growing interest in eco-villages and their holistic approach to sustainability lifestyles. More than 20 Danish eco-villages are part of the national umbrella organization LØS, and many of them have developed integrated energy solutions, combining wind turbines, solar plants, heat pumps and other renewable technologies (LØS, 2022). Eco-villages are sometimes organized wholly or partly as cooperatives.

Examples include the cooperative village Karise Permatopia with 210 inhabitants. The village operates an 8.5 km long district heating pipe system based on a geothermal heat pump powered by a wind turbine. Local energy supply includes a charging station for electric vehicles. Currently, the village sells surplus electricity from own generation to the grid and at other times buys electricity. The vision is to become self-sufficient. Urban citizen energy communities are a novel phenomenon sparked by the adaption of EU's "Clean Energy Package" (EC, 2019) that gives citizens the right to generate, share, store and sell electricity. In this strategy, citizen energy communities are a key concept (Palm, 2021). A citizen energy community was founded in 2020 in Hvidovre municipality as a multistakeholder cooperative with participation of citizens, local businesses, and public institutions, together with the local district heating cooperative (EBO Consult, 2020). The purpose of this cooperative is to inspire and contribute to the clean energy transition in an urban area with some 6,000 inhabitants.

4.2.9 Energy research and development

Many cooperatives participate in innovation, research and development directly related to the above-mentioned fields and technologies. Also, gasoline retail cooperative OK is developing biofuels based on animal fat. An important actor in renewable technologies innovation is the grassroots-founded institution Nordic Folkecenter for Renewable Energy which is organized as an association-style cooperative with a democratically elected board majority (Nordisk Folkecenter, 2022). An example of an important employee-owned cooperative in the renewable energy landscape is the consultancy PlanEnergi. This cooperative has around 50 associated employees and has since 1983 advised developers of numerous renewable energy projects.

5 What are the effects of the industrial turn on energy cooperatives?

The industrial turn in renewables is often celebrated by Danish politicians who associate it with the massive investments in renewables by Danish state-owned energy giant Orsted (originally an oil and gas company) or with the export successes of Danish wind turbine manufacturers like Vestas. The fact that renewables are now contributing significantly to energy supply also influences a public discourse along the lines of "small was beautiful, but bigger is better". Community-based, idealist driven projects are increasingly seen as a thing of the past. The rise of industrial-scale renewable projects comes hand in hand with a crisis for especially wind, biogas, and solar cooperatives.

5.1 The rise and fall of wind energy cooperatives

The effects of the industrial turn on wind energy cooperatives are well documented. Wierling et al. (2018) found a stark decline in Danish wind cooperatives from around

1,000 to less than 200 in just ten years, a trend also observed by others (Bauwens et al., 2016; Gorroño-Albizu et al., 2019). This coincides with the dismantling since the early 2000s of incentives and support schemes that benefited community-based wind power development and is also influenced by the EU-mandated liberalization reform of the electricity sector (Kirch Kirkegaard et al., 2021). In 2018, a majority in parliament furthermore introduced a cap on the total number of onshore wind turbines, aiming to reduce the number of turbines from 4,200 to 1,850 by 2030 (Altinget, 2020). Consequently, many existing community-based wind guilds are left with few chances of developing new projects or renewing their aging turbines. Some studies indicate that rising local resistance against wind turbines might be explained partly by a loss of local community control and ownership over projects (Gorroño-Albizu, 2021; Kirch Kirkegaard et al., 2021). The wind farm at Hvide Sande harbor on the North Sea coast illustrates this dynamic, and also shows that there is still room for some innovative wind power cooperatives. Initially, local resistance stopped a private, commercial wind energy project here. Then in 2010, the local tourist association created a cooperative fund to finance developments in tourism and harbor infrastructure by profits from wind power. The fund retained 80 percent of ownership, and a local guild with 400 members took a 20 percent share. This version of the wind farm project did not generate strong protests. (Folketinget, 2012). Today, the local district heating cooperative has taken over the ownership of the wind farm.

5.2 A crisis in solar power and biogas cooperatives

The rise and fall of wind energy cooperatives contrasts with the lack of development of a significant cooperative movement around solar power. Solar energy cooperatives are common across Europe and a recent study from Germany shows that 80 percent of 835 energy cooperatives run photovoltaic solar installations (DGRV, 2021). In Denmark, a restrictive legal framework has prevented the emergence of more than a few experimental solar power cooperatives (see 4.2.5). Cooperative actors such as the social housing cooperative association BL, and REScoop, have identified as main obstacles the lack of the right to develop or operate internal grids across cadastral boundaries to create internal networks for production and consumption, and the lack of fair pricing (IDA Teknologivurdering, 2022).

The existing legal framework benefits the development of large-scale commercial solar photovoltaic projects but restricts the large-scale participation of housing cooperatives, eco-villages, and citizen energy communities. The (non)participation of the cooperative social housing sector seems particularly critical because of the potential of large-scale urban rooftop plants. BL is an umbrella association for 500 non-profit social housing cooperatives with around 1 million residents, and the association estimates that their estates could provide five to six percent of Denmark's total household electricity consumption from rooftop plants alone if legal restrictions were lifted (IDA

Teknologivurdering, 2022). Furthermore, there is a dimension of conflict between, on the one hand, the cooperative housing sector's call for control of their internal electric distribution networks between residential units, and on the other, the electrical grid cooperatives defending their regional monopoly as distribution network operators and owners of the grid that connects every household.
Biogas cooperatives face similar challenges to wind cooperatives. Incentives and support schemes are being removed, and large commercial investors with industrial-scale projects have in recent years increasingly dominated the field (Booker Nielsen, 2022) In these new biogas plants, it is often only the manure supply that remains organized as a farmers-owned cooperative, while ownership and operation of the energy production itself, often in the form of upgraded biogas, is in corporate hands (personal communication with Biogas Danmark).

5.3 A steady expansion of district heating

Data calculated by the author shows that the share of heat supply coming from district heating cooperatives fell slightly from 36 percent in 2016, to 34 percent in 2019. Nevertheless, cooperatives are actually increasing their district heating networks and total production, as well as innovating and diversifying their intake of renewable energy sources. Only the municipal companies, that dominate many large urban areas, are also expanding, and at a higher speed given high population density in their areas of operation. The overall number of district heating cooperatives has decreased slightly because of mergers between small rural cooperatives. In this sense it does not seem that the cooperative model for district heating is in crisis.

5.4 A remarkable rise of mega grid cooperatives

In the field of electrical distribution, there are two remarkable phenomena. The first is the transformation of some local grid cooperatives into regional mega cooperatives with hundreds of thousands of members. The accumulated capacity in these mega cooperatives and their appetite for developing new business operations has clearly made them potential players in fields like offshore wind parks and capital-intensive experimental development projects like high-temperature geothermal. This might also have implications for cooperative involvement in emerging technologies like wave energy. The other phenomenon is the public perception of grid cooperatives as being more benevolent, democratic, or trustworthy vis-à-vis mainstream commercial energy firms. This is reflected in the national parliament's 2019 decision to sell Copenhagen's electrical distribution network – not to the highest-bidding commercial investor – but to a regional grid cooperative. It is important to note, however, that the parliament made a U-turn on this issue after substantial pressure from the public and much debate on the energy democracy-related theme of critical energy infrastructure and democratic control.

5.5 Discussion of key findings

The findings presented in this study do not give a monochrome picture of the effects of the industrial turn on Denmark's energy cooperatives. It rather illustrates how diverse different technologies and organizational forms develop at the time being. It provides a snapshot of the current cooperative energy landscape without showing exact direction of future transformations nor disclosing the actors and power figurations that might influence political agendas tomorrow. A potential bias is that much qualitative data comes from sources like the Danish Research Institute for Democratic Businesses or community energy activists or energy cooperatives that might overemphasize the contribution of cooperatives in energy supply. Also, the potentially significant dimension of interactions and cooperations between municipalities and energy cooperatives is not explored here. The findings suggest that political will in the form of incentives, support schemes, or mandatory non-profit models, are very important for the flourishing of community-based or cooperative energy projects in onshore wind power, farmers-owned biogas, or district heating. Logically, neoliberal drives to liberalize energy markets by dismantling such schemes or introducing market-based solutions in specific sectors can have disastrous effects on parts of the cooperative landscape. It is also clear, that popular mobilisations can have a direct impact on the political and legal framework for cooperatives, as exemplified in the case of the sale of Copenhagen's grid company Radius to a cooperative. At the same time, market actors do not always behave as political decisionmakers would like them to. Despite attempts to open the highly regulated energy sector to more commercial actors, recent years have also seen the growth of mega coops and the takeover of previously privately owned power plants by municipalities. The general tendency of politicians to favour more market-based solutions affects different technologies and different organizational forms at different times. Following this, more sophisticated models describing the characteristics of the industrial turn might be relevant for some technologies, and not for others. For example, the model developed by Kirch Kirkegaard et al. (2019) describing the core elements of the paradigm shift in Danish wind power – policies and incentives, technology change, size of investment required, and change in financing – might have explanatory power also in the case of biogas, but not necessarily in the case of solar power. It can be argued that there is not "one industrial turn" in renewables, but many. Or that the term industrial turn is not at all adequate to grasp the complexity of the transformations described in this paper. The findings of this study seem to support a point made by Krupnik et al. (2022) that every renewable technology has its own unique associated political economy. This is evident in the way the industrial turn impacts some, but not other, energy cooperatives.

It is outside the scope of this paper to investigate how the transformation of some cooperatives into something almost resembling industrial actors may influence the way democracy functions in these new mega cooperatives. But the new cooperative

ownership regimes emerging in the context of renewable energy transitions seem like an important topic for future research. An exploration of actual and potential synergies in the wider cooperative eco-system, for example between social housing cooperatives and electrical grid cooperatives, also seems a promising theme.

6 Conclusion

This study shows that cooperatives play a substantial role in the energy system in Denmark and account for 26 percent of total turnover in the energy sector. Cooperatives play key roles in distribution of power and heat, as electric grid companies and district heating companies. Cooperatives also dominate the production of solar heating and biogas, and hold a large share of onshore wind power production. Additionally, coops contribute to research and innovation in emerging renewable technologies and organizational forms. The industrial turn in renewables has had a negative impact on farmer-owned biogas, and producer-owned solar and wind energy cooperatives. Wind coops have been most affected with four out of five wind cooperatives disappearing in a decade. Other forms of energy cooperatives are less affected, and some - like district heating coops - are thriving. A novel phenomenon is the rise of mega energy cooperatives, originating as local grid companies, with a variety of business activities. Several mega coops have more than 100,000 members, and the largest even has more than 10 percent of all households in Denmark as members. Large retail coops are also increasingly initiating large renewable energy projects. An untapped potential is identified in the large Danish cooperative housing sector where legal restrictions still stand in the way for a major buildout of rooftop solar. The findings suggest that comparative perspectives are valuable to better understand the potential for democratizing Europe's clean energy transition. The findings also have important consequences for the debate on scope and potential of grassroots innovations to develop sustainable energy systems, and particularly on the assessment of challenges and opportunities for the flourishing of renewable energy cooperatives.

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