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Critically reviewing and conceptualising citizen ownership

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The past, present and uncertain future of community energy in Denmark: Critically reviewing and conceptualising citizen ownership

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ABSTRACT

Important progress has been made in the understanding of citizen ownership. However, confusion persists about distinct characteristics of different models and particularly about the concept of community energy. Moreover, quantitative understanding of the contribution of citizen ownership to energy transitions is limited. This study advances the knowledge of citizen ownership by describing the empirical characteristics of citizen ownership of wind turbines and district heating systems in Denmark in the period of 1975-2016. The methods comprise statistical analysis, literature review and contact to experts in order to identify, quantify, describe and categorise Danish citizen ownership models. The results show the significant importance of citizen ownership to investment in and implementation of decentralised sustainable energy technologies. Modifications of institutional incentives have led to multiple and diverse citizen ownership models, whose main distinctive characteristics are related to geographical scope, type of profits and distribution of benefits. This observation is valid also for other countries, which makes the citizen ownership categories developed in this study relevant for international research on the topic.

1. Introduction

A drastic reduction in global CO_2 emissions is crucial to mitigate global warming. Achieving this target requires that the carbon intensity of energy systems, including transport, is reduced significantly. The EU is committed to an energy transition that should bring greenhouse gas emissions down by 80–95% compared to 1990 levels by 2050 [1]. Citizens' empowerment and participation are seen as strategic to meeting the EU's energy targets [2].

According to Arnstein's ladder, forms of citizen participation range from *no participation*, to *tokenism* and *citizen power* [3]. In the energy transition, citizen ownership is the highest level of citizen power as it confers the control over the decision-making process and its outcome. Citizen ownership of energy (often referred to as *community energy*) has been associated with multiple qualities that may support energy transitions and address some social challenges [4–9]. A particular quality of citizen ownership compared to other forms of citizen participation (e.g. *consultation*, *placation* or *partnership* [3]) is its potential to develop grassroots innovations, which shall not be expected from the dominant market players [6].

Citizen ownership has attracted remarkable attention internationally and literature on the phenomenon is rapidly increasing. However, there is a lack of consensus on the meaning of community energy [5,10]. In fact, its current "ambiguous" utilisation [11] hinders policy design because it overlooks the diverse characteristics and qualities of the several citizen ownership models grouped under the label of community energy [11,12]. This is problematic because differing and ambiguous definitions of the concept may lead to unintended political consequences, such as large distant investors fitting the definition of "citizen project" [13] or ineffective ownership measures to address e.g. local opposition [14].

Moreover, there is still a lack of studies that have counted the number of citizen-owned energy projects [9,15–18]. Most countries do not systematically monitor the evolution of the ownership of energy companies and infrastructure —a few exemptions are Scotland [19] and Denmark (only for district heating systems) [20]. Consequently, the data recorded about the ownership of energy companies and infrastructure is very limited and likely insufficient to discern different ownership models without tedious data collection and complex data analysis procedures — as illustrated in this paper. The shortage of such quantitative studies curtails the understanding of (1) how different factors (e.g. institutional incentives) influence ownership of energy (including the creation of intended and unintended ownership models) and (2) how ownership influences the energy transition. Advancing this understanding is necessary in order to evaluate the appropriateness of new renewable energy (RE) policies (e.g. tender schemes) against the

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background of e.g. EU's goal of greater citizen empowerment. Specifically, a clearer understanding of citizen ownership and key differences between the multiple citizen ownership models is indispensable to successful policy design. This paper intends to contribute to these efforts by studying the empirical characteristics of Danish citizen ownership.

The focus is on the ownership of wind turbines and district heating (DH) systems and the analysis covers the period of 1975-2016. The paper adds on the quantitative knowledge presented by Mey & Diesendorf [17] and Wierling et al. [16] as it provides an updated estimation of the overall ownership of wind capacity in Denmark. Furthermore, the study builds on previous work done to advance the understanding of citizen ownership (e.g [10–12,21–23].) in order to build up citizen ownership categories. Hicks & Ison [12] argue that "context and motivations [..] form the foundation of a project and influence decisions made in other areas, leading to a range of outcomes". Those decisions include choices about e.g. activity, technology, scale of project, governance structure, legal form, financial models, distribution of benefits, level of engagement of local community, etc. [11,12,21–23]. As a result, citizen ownership is very diverse. Moreover, van Veelen's analysis about Scottish local ownership of energy [11] shows the ability of citizen ownership to adapt to changes in contextual factors and address new motivations. These observations are the reasons for analysing two different technologies and sectors from a long-term perspective. The approach taken in this study makes it possible to understand the relation between institutional incentives and citizen ownership evolution while keeping a focus on the key characteristics that differentiate the identified citizen ownership models.

The research questions are: (1) what kinds of citizen ownership models have been implemented in Denmark?, (2) what share of the wind capacity and DH demand has been citizen-owned?, (3) what are the main characteristics of the implemented citizen ownership models? and (4) which categories could help better understand the heterogeneity of citizen ownership in Denmark?

Section 2 introduces the theoretical approach of this article, describes the background of the understanding of citizen ownership and community energy and explains the methodology applied to answer the research questions. Section 3 answers research questions 1–3 and section 4 answers research question 4. Finally, section 5 concludes with a discussion of the results and recommendations.

2. Framework and methods

2.1. Ownership of energy systems and energy transitions

Fig. 1 provides a simplified understanding of how ownership of energy systems and energy system transitions are interlinked, dependent on institutional incentives and embedded in a process of what Hvelplund [6] calls *innovative democracy*. *Innovative democracy* has been developed based on Danish history, and occurs when the political process related to the energy transition is influenced by market dependent actors (e.g. consumers, technology providers, international energy corporations, municipal companies, wind cooperatives, etc.), *and especially,* by market independent actors (e.g. NGOs and the public debate). The former, together with their representative associations, advocate for their private interests within the energy transition. Market independent actors more directly advocate for energy transitions that could meet the goals of society. The (dominant) discourse within an energy transition influences the perception of what can be rational and legitimate solutions, both in terms of technology and actor participation [24]. The combination of the implemented energy system transition and ownership determines if and which of the goals of society are met and to what extent. Fig. 1 may represent the EU and its Member States, as well as possibly other industrialised countries. The influencing power of different actors may vary significantly over time and from country to country based on market shares of actors, organisational capacity of networks and democracy levels, among others [24].

The energy system transition (what technologies are implemented and in which quantities) and the ownership of energy systems (who owns how much of what technology) are dependent on legislative and economic incentives (or restrictions) determined by the political process. However, they are not the only determining parameters for the implementation of a given technology or ownership. First, technological options are constrained by available resources [24]. Second, technology implementation and ownership possibilities are related [6,9]. Yildiz [9] estimated that 47% of the installed decentralised RE capacity was owned by citizens in Germany in 2012. The same year, citizens owned 50.4% of the German onshore wind capacity, which did not have distinct economic or legislative incentives for different types of owners. As revealed by the estimations presented in Section 3.2 in this article, citizens in Denmark have also contributed to a larger onshore wind capacity installation than large energy investors in periods with no ownership discriminatory incentives for this technology. This may indicate either higher investment attractiveness of this technology for citizens (as supported by the financial considerations presented by Yildiz [9] for Germany), higher implementation success rates (e.g. because of higher local acceptance) or a combination of both. In contrast, the percentage of citizen ownership in centralised RE technologies (e.g. large hydropower plants and offshore wind farms) is insignificant [9].

As energy systems transition from centralised and fossil fuel dominated towards decentralised energy systems based primarily in RE, the value added of the different parts of the energy supply chain experience significant alterations that may undermine the market power of the large incumbent energy companies [6]. Or, said in another way, the value added of the business models of large and distant incumbent energy companies —based on economies of volume for fuel purchase and economies of scale for capital investments— is diminished in decentralised RE systems as a consequence of the characteristics (e.g. very low fuel costs) of these systems and their proximity to users. Therefore, decentralised RE systems pose a threat to market shares of large fossil fuel incumbent energy companies, who are likely to advocate for technological pathways that will lead to centralised low carbon energy systems and for economic and legislative incentives that will deter citizen ownership [6].

From the above reflections it may be deducted that the concern about ownership is a strong underlying component in the debates about the energy transition —possibly camouflaged under biased discourses about appropriate technological choices. On the other hand, the reflections highlight the need to involve different types of investors in the energy transition in order to realise the necessary investments in different types of technologies [9]. In this regard, further empirical data on ownership of different technologies is needed to support the decision-making process of the energy transition to low carbon systems [9] and to evaluate the appropriateness of different legislative and economic incentives.

2.2. Understanding citizen ownership and community energy

Citizen ownership has commonly been studied in relation to RE and as an alternative to the traditional energy companies, whether private or state-owned [5,25]. *Community energy* is a long disputed concept, which has been used to refer to several types of citizen ownership [5,10–12,23]. A non-restrictive understanding of the concept has been considered positive to the extent that it has facilitated multiple configurations of citizen ownership [10]. However, an ambiguous understanding entails the risk of encompassing and supporting actors, processes and outcomes that are not consistent with the characteristics often associated with community energy and consequently of not obtaining the expected benefits [12,26].

The structured literature review presented by Brummer [5] on community energy reveals that "although a vague accordance can be assumed, some definitions vary in key aspects". Brummer points out

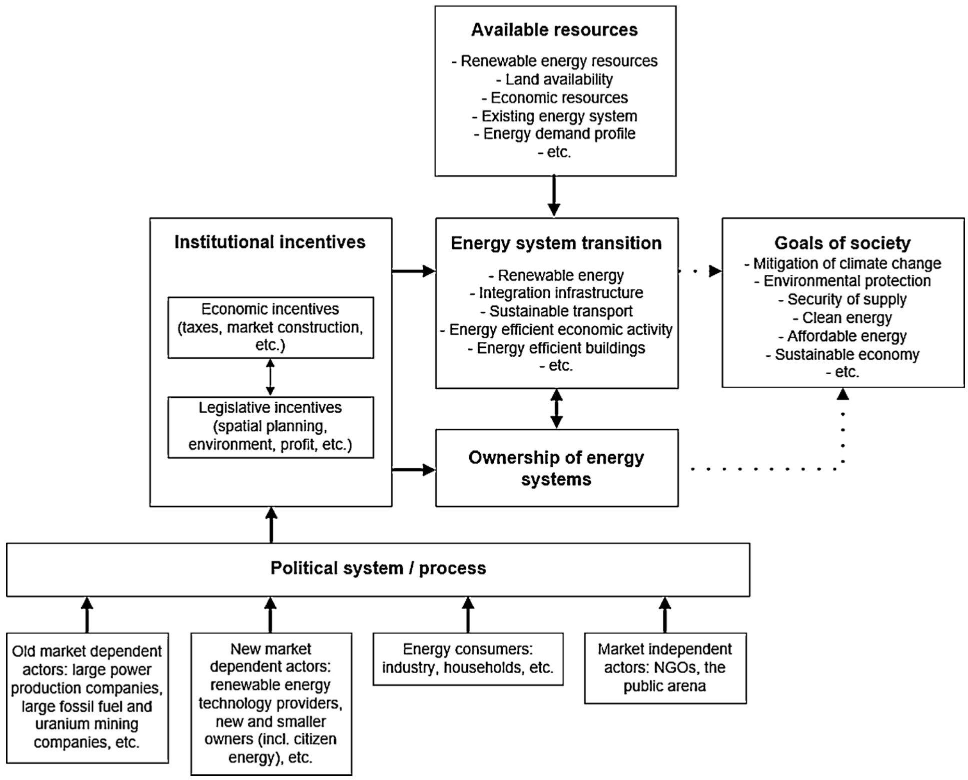


Fig. 1. Theoretical approach, understanding of ownership of energy systems and energy transitions in Denmark and the EU. Inspired by Hvelplund [6] and Kooij et al. [24].

that the largest discrepancies arise from the diverse meanings conferred to the term *community*. Both *communities of localities* and *communities of interest* as well as several different characteristics and elements have been associated with the term [5,23]. Interestingly enough, individually owned energy projects have also been labelled as community energy [27]. Using the same concept to refer to so diverse citizen ownership models creates confusion and overlooks important differences between the multiple models. On top of that, different terminology is commonly used in other countries in relation to community energy or citizen ownership [25], adding to the confusion. In Denmark, for example, it is common to refer to *community ownership*, *local ownership* and *consumer ownership* [8,17,28,29], whereas the boundaries between them are blurry.

It is not the intention of this study to discuss the understanding of community energy. Instead, it is acknowledged that several forms of citizen ownership exist and that they deserve greater attention than received up to now. Besides, it is argued that some of the heterogeneity within the meaning of community energy is due to a lack of vocabulary to refer to the many and relatively new citizen ownership models.

The goal of this study is to advance the understanding of the differences between citizen ownership models and their relevance for the energy transition by analysing the creation and evolution of these models in Denmark. The scope of the study is limited to the outcome (i.e. geographical spread, profits and distribution of profits) and does not include the process (e.g. project initiator, motivation, communication, decision-making, etc.). However, it is acknowledged that the outcome is dependent on the process. Given the relevance of the process to understand key differences between citizen ownership models, future research should complement the results presented in this article.

2.3. Methodology

The research questions are answered by (1) scoping of implemented citizen ownership models, (2) quantification of citizen ownership, (3) description of ownership models and presentation of illustrative examples and (4) development of citizen ownership categories. The methods comprise statistical analysis of secondary data (for wind turbines), literature review and contact to experts (the Danish Energy Agency (DEA), EMD International A/S (EMD), Danish Wind Turbine Owners' Association (DWTOA) and Nordic Folkecenter). The research questions are limited to wind turbines and DH systems and exclude other technologies (e.g. photovoltaics or biogas plants) and infrastructure (e.g. electricity distribution grids). DH systems comprise "a network of pipes connecting the buildings in a neighbourhood, town centre or whole city, so that they can be served from centralised plants or a number of distributed heat producing units" [30]. DH is an energy- and cost-efficient technology for collective heating in local areas with sufficiently high demand densities [30]. This technology has the potential to play an important role in future energy systems by increasing energy efficiency and providing opportunities for utilisation of local heat resources (incl. waste heat, solar energy and geothermal energy) and cross-sector integration (i.e. electricity-to-heat) [30]. The delimitations in technology choices enable a simplification of the research and its outcomes while keeping an overall understanding of citizen ownership in Denmark, as concluded in the initial scoping of Danish citizen ownership models.

The statistical analysis of ownership of wind turbines is limited to the company or person registered as the owner of the wind turbine. Only one owner or ownership category is registered per turbine in the accessed databases. However, wind turbines are often owned by several shareholders, which may in fact be several companies with different ownership models. For example, the three wind turbines in Hvide Sande are owned by Hvide Sande Nordhavn Møllelaug I/S, which is owned by a local foundation (80%) and local residents (20%) [29]. Despite that, only the umbrella company (i.e. Hvide Sande Nordhavn Møllelaug I/S) is registered in the database as the owner of the wind turbines. This means that various ownership models may be hidden under one umbrella company, which reduces the level of detail of the analysis. All

Table 1
Identified citizen ownership models for wind turbines and DH systems in Denmark. In the case of wind turbines, the ownership may be a combination of several ownership models except for wind turbines owned by prosumers. Ownership combinations may comprise citizen ownership models and large investor ownership models. [7,8,17,34,38].

Citizen ownership models	
Wind turbines	**DH systems**
Prosumer	Municipal company (local)
Individual ownership (local and distant)	Consumer cooperative (local)
Cooperative (local and national)	
Guild (local and distant)	
Municipal company (local and distant)	
Consumer cooperative (local and national)	
Foundation (local and national)	

existing and decommissioned onshore and offshore wind turbines are included in the analysis independent of their size.

The statistical analysis of ownership of DH systems is limited to the company responsible for the entire system operation and supply to end users (hereafter the DH company). This means that the ownership of the multiple heat producers who provide heat to the DH grids is out of scope for simplification reasons. All DH systems are included in the analysis independent of their size or heat sources. Nowadays, fuel sources in Denmark include fossil fuels (mainly natural gas and coal), waste heat and RE such as biomass, biogas, solar thermal energy or geothermal energy [30,31].

Ownership data of DH systems was collected via literature review. Ownership data of wind turbines was obtained from two databases and completed with literature review. The databases were sent by email by DEA (Doc_DEA) and EMD (Doc_EMD), a Danish software and consultancy company in charge of recording ownership of wind turbines until 2003. The former provided the name of the companies registered as owners of the wind turbines and the latter the category of ownership that was registered for the wind turbines. Note that there was no description of the categories registered by EMD and that it was up to the wind turbine owner to choose one (personal communication). As a result, the choice of category was rather subjective. In fact, it has been observed that, in some cases, the same owner registered different wind turbines under more than one category. This subjectivity is comparable to the current vagueness about the understanding of community energy and illustrates some of the problems that arise from lack of explicitness and free interpretation.

The many turbines and turbine owners and the lack of information about the ownership category after 2003 made it necessary to adopt a systematic approach and required a simplification of the list of citizen ownership models found in the scoping. First, *citizen ownership* (who own 10 wind turbines or less) and *large investor ownership* (who own more than 10 wind turbines) were differentiated. The parameter was provided by DWTOA, who revealed that in May 2017 only one of the 242 members in the internal category *small shareholders* owned more than 10 wind turbines (personal communication). DWTOA is representative of multiple forms of wind turbine ownership in Denmark and therefore their input was assumed to be valid to differentiate the two main simplified categories. In October 2018, the association had about 3000 members —which include companies and private owners of wind turbines— and represented approx. 29,000 wind turbine owners; this is 3057 wind turbines and 3659 MW of installed wind capacity [32], i.e. approx. 70% of the total installed capacity in the country at the end of 2016 (Doc_DEA).

In order to add detail, the category *citizen ownership* was divided into *individual ownership* and *collective ownership*. When data limitations impeded the assignment of those subcategories, *unidentified citizen ownership* was assigned. The systematic approach to assigning the simplified ownership categories to the wind turbines includes corrections of the pre-assigned categories, i.e. *citizen ownership* and *large investor ownership*, as well as ownership data comparison between the two databases. The data match is done using the wind turbine identification number. For further details of the procedure followed to assign the ownership to the wind turbines see Appendix A., Fig A1.

The systematic approach and the limitations of the data imply that the results are not fully accurate, but provide approximate figures that contribute to improving the insight on the ownership of wind turbines in Denmark. One of the great limitations for a comprehensive analysis of citizen ownership is the impossibility to find out whether the main owner is local or not. Therefore, the database analysis is completed and contrasted with evidence found in the literature review. Additionally, illustrative examples of the different citizen ownership models are presented to provide a higher level of detail. The data on some of the illustrative examples was given by Nordic Folkecenter, a Danish NGO working on the promotion of democratic renewable energy since 1983.

The citizen ownership categories are built on key differentiating aspects of the identified citizen ownership models. The key aspects are limited to outcome characteristics and do not consider process characteristics, which are out of the scope of this study. Future research should include other technologies, infrastructure and energy services as well as the process characteristics of different citizen ownership models to complete the research presented in this article.

3. Citizen ownership in Denmark

3.1. Implemented citizen ownership models

Table 1 lists the identified citizen ownership models for wind turbines and DH systems. The diversity of ownership models is higher for wind turbines. The primary reason lies in the significant modifications of the legislative and economic incentives for wind turbines [8,33–35], which have created the possibility for new organisational models, leading to an ongoing rearrangement and development of new ownership solutions. In contrast, policies for DH systems have been more constant [7,36] and changes in economic and legislative incentives have affected technology implementation [30,37] rather than the ownership [7]. Besides regulations, the long lifetime of DH systems and the linear relation between the size of DH systems and number of consumers (payers) might also have influenced the steadiness of citizen ownership within DH systems. In comparison, wind turbines have a shorter lifetime, which implies shorter —and potentially more diverse— ownership cycles. Moreover, the areas with the best wind resources in Denmark tend to have low population densities, which might limit the potential of local citizen ownership in a context of increasingly large wind turbines due to capital availability/needs.

3.2. Citizen ownership of wind turbines

The statistical analysis (see procedure in Appendix A) reveals that only 86 out of 3549 owners have more than 10 wind turbines in Denmark. Among those only six citizen collective owners and six citizen individual owners are found. The analysis estimates that 52% of the total existing installed wind capacity in Denmark in December 2016 contained a citizen ownership model (see Table 2). The percentage increases to 67% when deducting the large offshore wind farms, summing 1141 MW and built as a result of political orders given to energy companies or granted via tender processes [36,39]. The five large

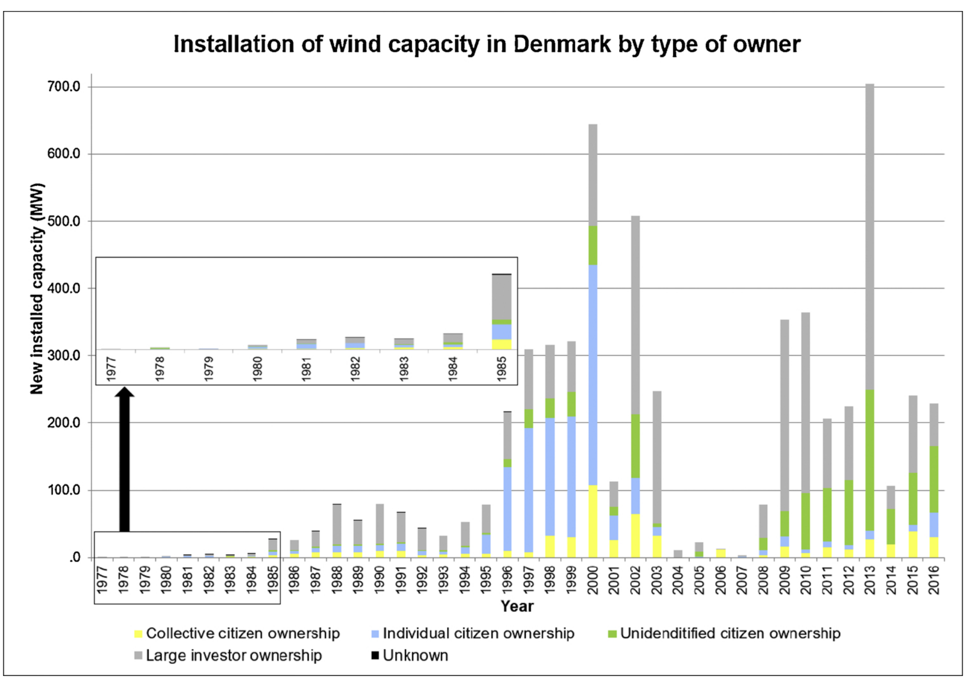
Table 2
Summary of ownership of wind turbines in Denmark in December 2016. The values are calculated by applying the methodology presented in Appendix A., Fig A1.

General data	Quantified ownership categories	Ownership of installed capacity (MW)	Ownership of installed capacity (%)
Existing wind turbines: 6,099	Citizen ownership	2,747	52
	Individual ownership	1,212	23
Decommissioned wind turbines: 3,051	Collective ownership	507	11
Existing companies: 2,942	Unidentified citizen ownership	1,028	19
Closed companies: 607	Large investor ownership	2,499	48
Wind energy produced 37% of the final electricity demand in 2016 and 43% in 2017 [40]	Unknown	0	0
	TOTAL	5,246	100

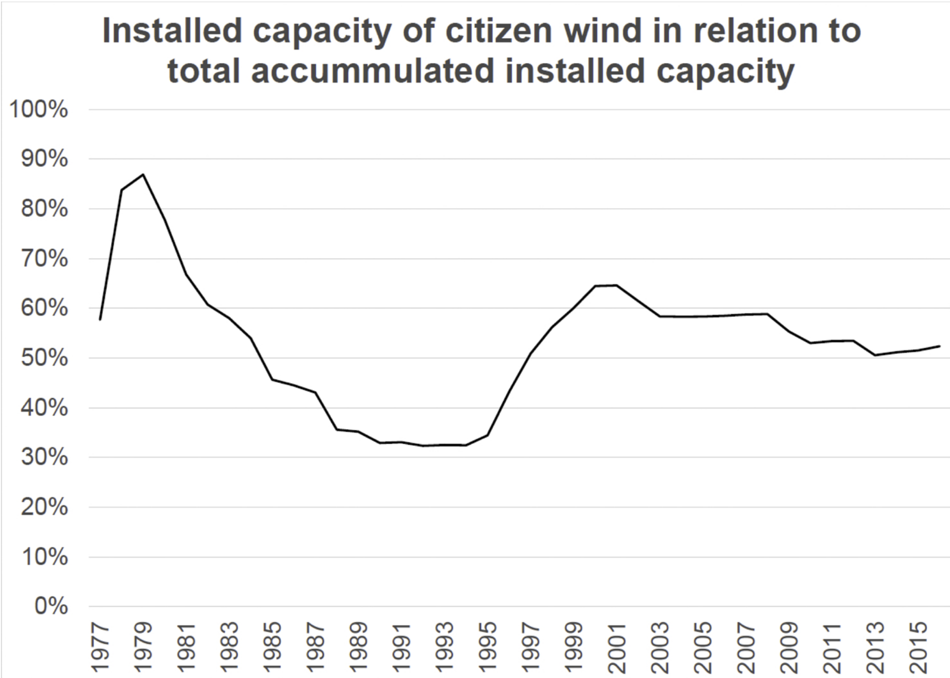
offshore wind farms were connected to the grid in 2002, 2003, 2009, 2010 and 2012/2013, accounting for a significant percentage of the total installed capacity of large investor ownership in those years (see Graph 1).

The analysis concludes that citizen ownership has contributed greatly to Danish wind turbine implementation in 1977–2016 —especially in the late 1970s and early 1980s, the second half of 1990s and after 2008 (see Graphs 1 and 2). Individual ownership accounts for 23–41% of the existing installed capacity in 2016 and collective ownership accounts for 11–30% (see Table 2). Contrary to what could be expected based on the amount of literature focusing on Danish collective citizen ownership of wind turbines, individual citizen ownership has contributed far greater to Danish wind power implementation. These results show a good reason to investigate alternative forms of ownership of energy beyond the understanding of community energy related to *communities of locality* or *communities of interest*. Besides, results for the period after 2008 refute the perception of a recent dominant ownership of "utilities and professional project developers" introduced by e.g. Bauwens et al. [15].

The large percentage of unidentified citizen ownership shows the considerable uncertainty surrounding the analysis. Additionally, literature about the early involvement of power utilities in wind development gives evidence about the limitations in the study. The first time power utilities invested in wind turbines in Denmark was in 1987 [17,41]. This was the result of the Government decision of 1985 to charge power utilities with building 100 MW of wind power in 1986–1990 [8,34,36]. According to Maegaard [8], it was a political decision made in order to involve these companies in wind development —which until then had been organised in a local bottom-up manner. Later on more wind quotas were assigned to large power utilities; 100 MW in 1991, 200 MW in 1996 and several hundreds of MW of offshore capacity after 1998 [34,36,39]. The fact that no large power companies invested in wind turbines in Denmark until 1987 seems not to concur with the results presented in Graph 1 . The first reason for the variance may be the simple criterion used in this paper to define the main two categories for analysis: citizen ownership and large investor ownership. Large investor ownership does not only include energy companies and utilities, but also project developers and other types of investors who owned more than 10 wind turbines in Denmark by December 2016. Consequently, the variance is not necessarily an error ascribed to the applied methodology, but could be derived from a difference in definition of categories for analysis. However, a more detailed examination of the cases shows that 75% of the turbines that were assigned the large investor ownership before 1986 were decommissioned before reaching the technical lifetime of 20 years. A possible interpretation of this is that large investors (as defined in this paper) bought the wind turbines from citizens in order to get repowering subsidy schemes [8,15,33] or available space for their new wind farms. If this was true (even if just for some cases), it would mean that only the name of the last owner was registered in (Doc_DEA). As mentioned in



Graph 1. Annual installation of wind capacity in Denmark by type of owner. The values are calculated by applying the methodology presented in Appendix A, Fig. A1.



Graph 2. Citizen ownership of wind turbines in Denmark in relation to total installed accumulated capacity. The values are calculated by applying the methodology presented in Appendix A Fig. A1 and include individual, collective and unidentified citizen ownership. The drop of citizen ownership in the 1980s is due to the implementation of large investor ownership, which after 1987 resulted from the 100 MW programmes promoted by the government [8,34]. 1711 MW of existing and citizen-owned wind turbines are at least 15 years old in 2018; these ageing turbines account for 69% of the citizen ownership in 2016. If all this capacity was replaced by large investor ownership, citizen ownership of wind turbines would decrease to 20% by 2023–2028.

Section 2.3, the large amount of data to be processed and its significant limitations do not enable accurate values but only approximate estimations for citizen ownership of wind turbines in Denmark, which together with the illustrative examples may help to better understand this concept in the Danish context.

It is worth noting that the current ownership distribution of wind turbines in Denmark (as presented in Graphs 1 and 2) could experience notable changes in the coming years and move towards a sector dominated by large investor ownership [16]. First, 1711 MW of existing and citizen-owned wind turbines are at least 15 years old in 2018; these ageing turbines account for 69% of the citizen ownership in 2016. Second, the Danish Energy Agreement of 2018 reflects a preference for large wind farms offshore rather than for wind farms onshore and tenders for onshore and open-door offshore wind farms have recently been introduced, which could hinder citizen participation [13,42]. Developing ownership specific policies could be crucial for the future Danish citizen ownership of wind power. To this end, additional information about the implemented citizen ownership models is required.

3.2.1. Early years: local citizen ownership

During the first years of wind development after the oil crisis in 1973, citizen ownership of wind turbines was limited by the *residence criterion* and the *consumption criterion* [17,34,35]. The residence criterion set a maximum distance between wind turbines and the residence of eligible owners. The consumption criterion —introduced in 1985— limited the amount of shares that could be purchased in a collectively owned wind turbine/farm; the limitation was in line with the buyers' household consumption. Similarly, a maximum capacity for individually owned wind turbines was introduced and the turbines had to be built on the owner's property.

In the 1980s, the promoters of wind cooperatives (a small group of local residents) would invite all local residents to participate in the development and ownership of a wind turbine or farm in their vicinity —the restriction in number of shares per adult made it necessary to open the project to other local residents [8]. The invitation was made through a call for a public meeting, where the idea of building a collectively owned wind project in the local area was shared and discussed, often even before having decided the location or having calculated the project economy [8]. Residents were informed and involved from the very beginning of the planning phase and could participate in the decision-making. Wind turbines were seen as a solution to increase security of supply and as an alternative to nuclear energy after the oil crises in the 1970s [17,36]. All these factors, together with good project economies, created an attractive environment for local wind co-operatives and broad acceptance of wind turbines [8].

3.2.2. The development towards exclusive and distant citizen ownership

From 1985–2000, the residence and consumption criteria were loosened by increasing the distance and the amount of shares [17,35]. Finally, the limitation in number of shares per adult was abolished [8] and there has been no local ownership restriction since 2000 [15,35], only the obligation to offer 20% of the shares at cost price to local residents since 2009 [14,33].[1] The development of the ownership criteria is often attributed to increasing turbine sizes and capital investments.

The loosening of ownership regulation, the more restrictive onshore wind planning and the repowering schemes brought important changes in wind ownership [8,15,17,35] (as reflected in Graphs 1 and 2). This is particularly obvious in the pronounced increase of individual citizen ownership in the second half of the 1990s. Examples of individual ownership are often found among farmers and households [8,17]. An example is that of Skinnerup in Thisted Municipality (personal communication), where a farmer installed a 0.66 MW wind turbine in 2000. Approx. 0.05 MW is used for self-consumption and the rest is sold to the grid. The same farmer also owns his own biogas plant. Examples of household prosumers have flourished with 1278 small wind turbines with capacities equal to or below 25 kW installed since 2008

[1] The shares must be offered first to residents within 4.5 km from the wind turbines and second to residents of the municipality. Since 2018, the requirement also includes owners of holiday houses without commercial use. Note that the 20% rule has been criticised for its ineffectiveness [17] – opponents to the projects are not willing to buy shares in it and profits seem not to pay for the perceived value of local losses [14]. Due considerations about the 20% rule are: (a) the percentage might be too low to encourage a real bottom-up citizen participation process and (b) it is designed in a top-down fashion and enters too late in the planning process, and therefore can be perceived as a "monetary compensation" instead of a real "benefit" (ownership).

(Doc_DEA).

Nowadays, influenced by the current institutional incentives, cases of open ownership beyond the 20% rule or involvement of communities in initial phases of the planning process are very rare, also when it comes to local collective ownership. Wierling et al. [16] estimate that more than 60% of the existing wind companies with a collective citizen ownership have five shareholders or less. Less than 20% have more than 50 shareholders. This shows a strong tendency for wind guilds.

The differences of cooperatives and guilds are often overlooked when analysing the collective citizen ownership of wind turbines in Denmark (e.g. in [16]). Cooperatives are characterised by open membership and democratic decision-making (i.e. each member holds one vote) [43]. In contrast, guilds are commercial partnerships with closed membership and voting rights based on ownership of shares. The reason why these very relevant differences are often overlooked when analysing the Danish wind ownership is that wind cooperatives have been registered as commercial partnerships in Denmark because of tax advantages [41].

Examples of wind guilds may be found all over Denmark; some have only local members, others also non-local. In 2012, Thisted Municipality assessed seven wind project applications consisting of 40 wind turbines in total and submitted by small groups of local investors (20 people in total) (personal communication). The wind farm built in 2013 in Nørhede-Hjortmose consists of 22 wind turbines and has a total capacity of 72.6 MW. The project was started by 22 citizen investors [44] and has 19 registered local and non-local owners (including the 20% owned by local residents) (Doc_DEA). All of these projects need to comply with the 20% rule even if they have been started by local investors.

3.2.3. The evolution of inclusive citizen ownership

The loosening of the residence and consumption criteria has also resulted in innovative forms of inclusive collective ownership beyond the traditional local cooperatives –which still remain [15,16]. The new inclusive models are not necessarily local. A well-known example is the nearshore wind cooperative Middelgrunden Vindmøllelaug I/S in Copenhagen, with more than 8000 members spread across Denmark [45]. The cooperative owns ten wind turbines with a total capacity of 20 MW connected to the grid in 2000. An example of a local wind cooperative is Thyborøn-Harboøre Vindmøllelaug I/S af 2002 (personal communication), which owns four 2 MW nearshore wind turbines connected to the grid in 2002 and 2003 and has 600–700 local members. The success of this project motivated a new one, consisting of four 7 MW nearshore wind turbines built in the same area and connected to the grid in 2017. In this case, approx. 1400 local residents became members and own 55% of the new wind farm. The remaining 45% was sold to Jysk Energi, the local utility company, a consumer cooperative with about 30,000 customers in Lemvig Municipality.

There are also a few examples of municipal companies, e.g. on Samsø and in Copenhagen, which have significant differences in strategies to meet their local green political agendas. The Municipality of Samsø started an energy company called Samsø Vedvarende Energi ApS to own five of the ten nearshore wind turbines which were built close to the island in 2003. The wind farm is part of the Renewable Energy Island project, in which local stakeholders played a central role, with high levels of active citizen participation [46]. HOFOR A/S, the local municipal utility company in the Copenhagen Greater Area, has invested in wind turbines outside the municipal area to meet Copenhagen's climate target of becoming CO_2 neutral by 2025 [47]. When doing so, it is common practice of HOFOR to offer local residents 20% of the shares [48,49], i.e. only what is required by law. HOFOR's seems to be an inclusive ownership model for the citizens in the Copenhagen Greater Area, but at the same time rather exclusive for the local communities where the projects are built. The examples of Samsø and Copenhagen illustrate how different municipal ownership may be, both in terms of economic resources and in levels of local community involvement.

Finally, there are also at least three wind foundations (similar to a trust fund) in Denmark [50]. The first one is found on Ærø. The wind project was developed in collaboration with Ærø's Energy and Environment Office and Ærø's Renewable Energy Organisation. The foundation Ærø Vedvarende Energipulje owns shares of the three 2 MW wind turbines, which were connected to the grid in 2000, and has the aim to "promote renewable energy and energy saving measures" on Ærø, Denmark and abroad [50]. The second foundation is in Hvide Sande [29]. It owns 80% of the three 3 MW wind turbines, which were connected to the grid in 2011. The wind project was started to partly finance the harbour expansion project, which was perceived as a strategic move for the economy of the town. Approx. 400 local residents own the remaining 20% of the shares. The third foundation owns some shares of a wind turbine in Trolhede (personal communication) and provides funds to promote clean energy, the local environment and culture. The project was initiated by two farmers who are brothers, was connected to the grid in 2012 and consists of six wind turbines with a total capacity of 18 MW. The ownership of the wind turbines is shared among the two farmers, a local cooperative and the foundation.

The shared characteristic of these models is a stronger social focus than individual ownership models or wind guilds. Furthermore, inclusive models involve a larger amount of citizens, which implies a broader distribution of decision-power and benefits. Therefore, when the local community is engaged in inclusive ownerships, a more fair distribution of losses and benefits is promoted, which may enhance local acceptance.

3.2.4. Summary of wind turbine ownership

Wind turbines were initially installed based on local citizen ownership (either single or collective) and limited by the consumption criterion. At this time, inclusive local citizen ownership in the form of open and collective membership was common practice. Later on, changes in legislative and economic incentives fostered exclusive and distant citizen ownership as well as large investor ownership [8,34,35].

After the abolition of the local residence criterion, large investor ownership and citizen ownership had the same opportunities to invest in onshore wind. The contribution of citizen ownership to installed onshore capacity is larger also in recent years, however, indicating either higher investment attractiveness, higher success rates or a combination of both. In contrast, all offshore wind tenders have been won by large energy companies [39]. Policy makers should pay attention to this fact.

In spite of the trend in distant and exclusive ownership starting in the 1990s, the examples presented in Section 3.2.3 show that new inclusive ownership models have been implemented, both locally and nationally. The analysis of the evolution of citizen ownership of wind turbines in Denmark demonstrates the capability of adaptation and reinvention of citizen ownership [15,17].

3.3. Citizen ownership of district heating systems

In DH systems, citizen ownership has been represented either in the form of municipal companies (mostly in the large cities) or consumer-owned cooperatives (mostly in rural areas). According to the Danish Utility Regulator [20], there were 407 DH companies in Denmark in December 2016, out of which 47 were municipal companies and 341 consumer cooperatives (see Table 3 for more details). The dominance of

Table 3
Summary of ownership of DH systems in Denmark in December 2016. [20,31].

General data	Quantified ownership categories	Number of DH systems	DH demand supply (%)
DH systems supplied heat and hot water to approx. 64% of all households in Denmark in 2016	Citizen ownership	388	96
	Municipal company	47	60
	Consumer cooperative	341	36
Approx. 52% of the DH demand was met with RE in 2016	Commercial company	13	4
	Others	6	0
	TOTAL	407	100

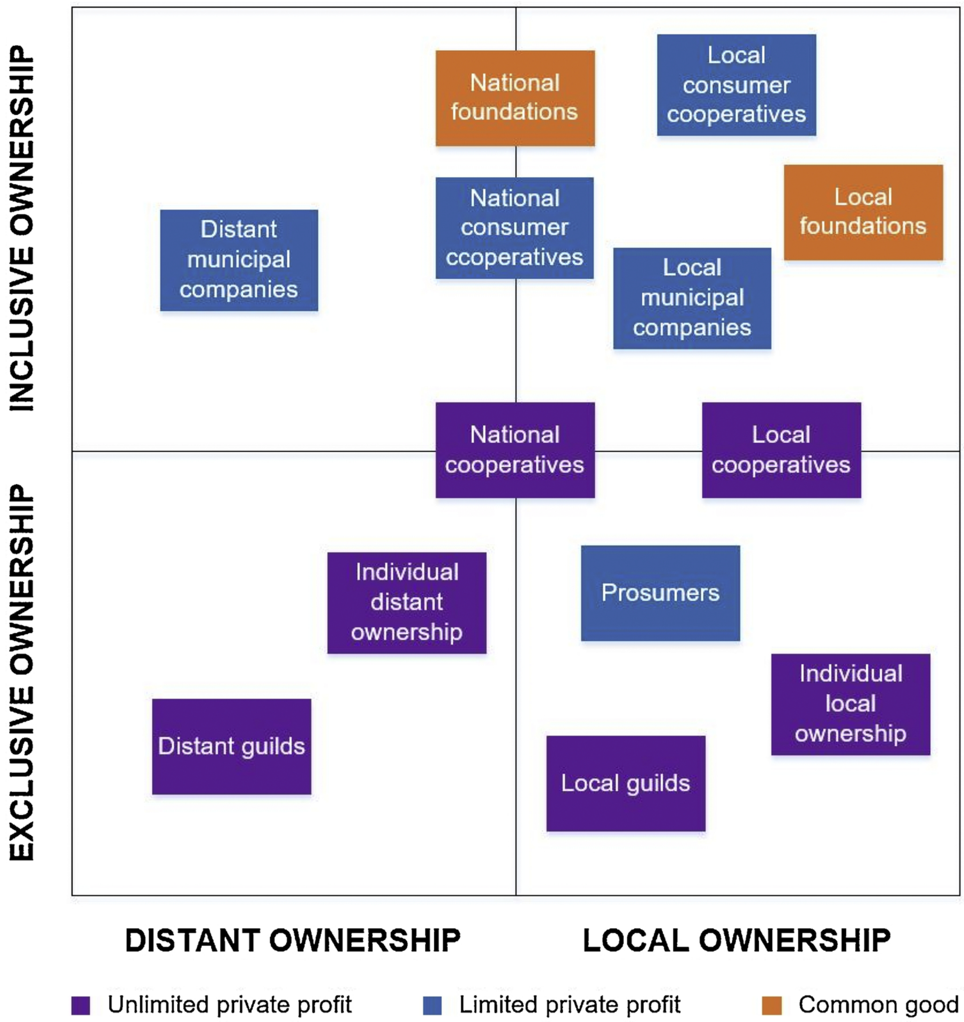


Fig. 2. Danish citizen ownership categories and their connection with Danish citizen ownership models. The ownership of energy infrastructure and utility companies may consist of several citizen ownership models. Consequently, the ownership may be formed by a combination of different citizen ownership categories. Note that prosumers traditionally have been individual owners, but opportunities for collective prosumers are emerging and will create changes to this ownership model [54]. When reading the diagram, note that the categories are represented in boxes and that there are no axes with units showing a higher or lower degree within the category.

citizen ownership in the Danish DH is the direct result of profit generation being prohibited (i.e. the non-profit rule), which makes investments in DH systems unattractive for commercial investors and attractive for consumers —who benefit from lower energy bills [7,36]. The non-profit rule is one of the top-down measures to protect consumers from possible abuse by the monopolistic DH companies. As a bottom-up measure, in municipal and consumer cooperatives, consumers exercise their power over the DH companies through directly or indirectly elected representatives for the company board. Consumer ownership of Danish DH has put pressure on the management and decision-making of DH companies, leading to lower heat prices for consumers and a continuous development of the systems by adopting the best available solutions in the market [7].

Some of the DH systems are partially supplied by commercial companies, e.g. owners of large CHP plants or industry. This is the case in the DH system in Aalborg [51], which is owned by the municipal utility Aalborg Forsyning and provides heat to customers in the cities of Aalborg and Norresundby and some nearby towns. In this DH system, the three main energy suppliers are the large coal-fired CHP plant (Nordjyllandsværket), the cement factory (Aalborg Portland) and the waste incineration plant (RenoNord). Nordjyllandsværket was initially owned by ELSAM (the consumer-owned company from Jutland and Funen), later by Vattenfall and since 2015 by the municipal company Nordjyllandsværket A/S. Aalborg Portland is owned by an international holding of the same name and RenoNord is a company owned by five municipalities in the North Jutland Region. A number of municipally owned heat generation units meet the remaining heat demand.

In smaller DH systems, usually owned by consumer cooperatives, it is common that all heat production units are owned by the DH company. This is the case in e.g. Lemvig and Hvide Sande. Lemvig DH has approx. 3650 consumers and owns a biogas-fired CHP plant, a biogas boiler, two woodchip boilers and two oil boilers. The biogas is supplied by the local non-profit farmer cooperative, Lemvig Biogas A.m.b.a., and the woodchips by suppliers in Northwest Jutland [52]. Hvide Sande DH owns a natural gas-fired CHP plant, two natural gas boilers, a large electric boiler and solar collectors [53]. Since July 2018, the DH company also owns two of the three local wind turbines (personal communication).

3.4. Comparison of citizen ownership of wind turbines and DH systems

The analysis and examples presented in Sections 3.2 and 3.3 conclude that citizen ownership of collective wind turbines and DH systems was rather similar in the 1980s because both were meant to meet the energy demand of their owners, who were local and democratically organised and who gained limited financial benefits. Ownership of DH systems has remained unchanged due to stable regulation affecting ownership choice, i.e. the non-profit rule. In contrast, citizen ownership of wind turbines has experienced ongoing rearrangements as a result of changes in regulation. Besides regulations, the long lifetime of DH systems and the linear relation between the size of DH systems and the number of consumers (payers) might also have influenced the steadiness of citizen ownership within DH systems. In comparison, wind turbines have a shorter lifetime, which implies shorter —and potentially more diverse— ownership cycles. Moreover, the areas with the best wind resources in Denmark tend to have low population densities, which might limit the potential of local citizen ownership in a context of increasingly large wind turbines and farms due to capital availability/needs.

With the loosening and elimination of the residence and consumption criteria, relevant differences arose between citizen ownership of wind turbines and DH systems. Now wind turbines are seen as profit-driven investments for citizens from across Denmark (and large investors), who are entitled to build wind turbines in any part of the country without involving others, except the 20% to be offered to locals. In spite of this, the examples introduced in Section 3.2.3 show that there are still local and inclusive initiatives in Denmark, some without the purpose of private profit (e.g. the foundations). However, these examples do not represent the norm anymore.

4. Categories of citizen ownership in Denmark

The description of the multiple citizen ownership models implemented in the Danish wind and DH sectors discerns distinctive key characteristics: (1) local — distant, (2) inclusive — exclusive and (3) common good – limited private profit – unlimited private profit. These three dimensions are used to develop the citizen ownership categories presented in Fig. 2.

Distant ownership and *local ownership* allude to whether the owner resides or develops his main economic activity outside or inside the local area where the energy infrastructure has been built. In the Danish context, local refers to the municipality. This is a merely geographical distinction, which falls in line with discussions about the meaning of community energy and is often used as a boundary parameter for the study of citizen ownership (e.g. in [4,11,22]). Despite that, *distant ownership* and *local ownership* are not incompatible as shown by some of the illustrative examples introduced in Sections 3.2.2 and 3.2.3. This has also been pointed out e.g. by Becker & Kunze [25]. van Veelen [11], Gubbins [22], Hicks & Ison [12] and Klein & Coffey [23], among others, have also acknowledged partnerships with large distant investors.

Inclusive ownership is that in which all citizens within a pre-determined geographical area have an equal opportunity to benefit from the energy project; this may be the result of open ownership (either in the form of shareholder or consumer with direct or delegated decision power) or spread distribution of profits through financing of development projects. *Exclusive ownership* is that in which the project promoter(s) decide(s) to keep the possibility to benefit within a selected group of people, excluding the rest of the community or society from the ownership. The benefits mentioned here omit environmental protection and all derived benefits as these are inherent to the technology and independent of ownership.

Unlimited private profits are possible in investments where non-profit regulation does not apply (e.g. in electricity generation technology) and there is no regulative restriction in the size of technology (unlike e.g. in household wind turbines). *Limited private profits* are possible in investments where non-profit regulation applies (e.g. DH companies or distribution system operators) or where consumers are the owners (e.g. consumer-owned utilities). In these cases, with appropriate top-down regulation and bottom-up governance, consumers will earn profit in the form of lower energy bills [7,28]. The private profit of consumers is considered limited because it may only be reduced from what is initially paid to zero. Limited private profits are also possible in companies that voluntarily set a cap on profits to be gained by shareholders (e.g. the farmer-owned biogas plant in Lemvig (mentioned in Section 3.3), where the benefit is a treated fertiliser of higher quality) and where there is regulatory restriction on the size of technology. An investment is considered *common good* when benefits are reinvested in development projects. All three cases contain an incentive to improve the economy of projects and therefore to promote innovation. Yet the differentiation is relevant in the discussion about factors that influence e.g. local acceptance and local development. Ownership models that are exclusive and of unlimited private profits (e.g. a small group of local farmers investing in wind energy) will potentially encounter more opposition. Profit is a variable previously used to differentiate among (local) citizen ownership models e.g. in [11,12,22].

To the best of the authors' knowledge, the most novel contribution of the citizen ownership categories presented in this article is the distinction between inclusive and exclusive ownership. Inclusiveness is a characteristic that has commonly been associated with community energy and a core value of cooperatives [43]. However, the idea is often implicit and not explicit in the discussion about ownership, which the authors see as problematic. Collective is not a synonym of inclusive —more than 60% of the wind companies with a collective citizen ownership in Denmark have five members or less [16]. The differentiation has relevant policy implications, i.e. when pursuing local acceptance or local development [4,8]. In this regard, it might be more relevant to ask what percentage of the local residents are involved in the ownership of a given project, rather than what percentage is owned by local residents; in other words, to focus on inclusiveness rather than on (collective) localism, as in [10].

Special attention should be payed to some considerations about inclusiveness. First, distant inclusive ownership may exclude local communities if they are not engaged beyond what is required by law. An example is the case of distant municipal companies presented in Section 3.2.3. Excluding the local community may have negative implications for e.g. local acceptance. Second, not all citizens have the resources to invest in shares, which automatically excludes a part of society. Therefore, the open ownership of wind cooperatives is not completely inclusive. All in all, consumer cooperatives, local municipal companies and foundations are seen as the most inclusive citizen ownership models. To ensure the inclusivity of these models, boards ought to be formed carefully to guarantee proper attention to the interests of consumers and the local community.

To sum up, the citizen ownership categories presented in this article advance the understanding of citizen ownership and are compatible with typologies and categories that have previously been developed in the field. They provide a new vocabulary to refer to citizen ownership and highlight distinctive key characteristics to be considered when analysing benefits of ownership or developing ownership specific policies. Finally, the categories help reduce the current confusion about citizen ownership.

5. Discussion and conclusions

Climate change urges an energy transition to drastically reduce CO_2 emissions. Citizen empowerment and participation are considered strategic for EU's energy transition. Citizen ownership of energy would be the highest form of citizen participation. However, insufficient understanding hinders appropriate policy design because it overlooks the diverse characteristics and qualities of the several citizen ownership models grouped under the label of community energy [11,12]. This is problematic because differing and ambiguous definitions of the concept may lead to unintended political consequences, such as large distant investors fitting the definition of "citizen project" [13] or ineffective ownership measures to address e.g. local opposition [14].

This article advances the understanding of citizen ownership and its relevance for the energy transition by describing the empirical features of citizen ownership of wind turbines and DH systems in Denmark in the period of 1975–2016. Statistical analysis, literature review and contact to experts have been used to scope, quantify, describe and categorise Danish citizen ownership models.

Various forms of citizen ownership have been identified and the significant contribution of citizen ownership to wind energy and DH implementation evidenced. Furthermore, ownership has been proven to be strongly dependent on institutional incentives, even if also influenced by other factors such as resource availability and discourse [17,24]. Therefore, ownership specific policies ought to be considered to avoid tender support schemes to stop citizens from investing in RE.

The estimation of citizen ownership of wind turbines is not fully accurate due to data quality and the need of a systematic approach. Nevertheless, it provides an approximate estimation that advances previous work done by Mey & Diesendorf [17] and Wierling et al. [16]. Furthermore, it adds to the existing quantitative knowledge from other countries like Germany [9] or the UK [18]. The statistic results highlight the relevance and ability of individual ownership and exclusive collective ownership (which do not meet the normative understanding of community energy) to realise investments that are of utmost importance to the energy transition. In line with Becker and Kunze's observations [25], this finding encourages an expansion of the research of ownership beyond community energy. The citizen ownership categories presented in this article pave the way for this.

The great variety of models explains the current confusion about citizen ownership and the high difficulty of assessing the benefits of e.g. local ownership beyond case studies [4]. The categories advance the understanding of citizen ownership and are compatible with typologies and categories previously developed in the field. However, they are not free of authors' subjectivity. Nevertheless, they provide a new vocabulary to refer to citizen ownership and highlight distinctive key characteristics to be considered when analysing benefits of ownership or developing ownership specific policies. Special attention should be payed to the differences between inclusive and exclusive ownership models. Consideration of all three dimensions of ownership presented in this paper is highly recommended for future research in the topic.

The categories are limited to characteristics related to the outcome (i.e. geographical spread, profits and distribution of profits) and do not consider characteristics related to the process (e.g. motivation, communication, decision-making, etc.). However, it is acknowledged that the outcome is dependent on the process. Therefore, further analysis is needed so that the citizen ownership categories include aspects related to the process. This analysis could help develop an improved and more practical definition of inclusive and exclusive ownership, which would be beneficial to policymaking. Future research efforts could also focus on which kinds of categories (or percentages of citizen ownership) really do encourage both good processes and high shares of citizen ownership.

Meaningful ownership registration is concluded to be crucial for policy ownership design. Quantification of ownership has proven to be a very important tool for developing a comprehensive understanding of the energy transition. Therefore, ownership registration of energy infrastructure should be (re)started or continued. The registration categories should be explicitly defined and obey either to ownership models or citizen ownership categories such as those presented in this article. All models or categories ought to be registered (not only that of the main owner) and the type of ownership should be publicly available information. These measures would increase the precision of ownership analysis.

The quantification of ownership performed in this study should be extended to other energy infrastructures and utility companies in order to provide a holistic understanding of the role of citizen ownership in energy transitions. This will also help to better assess the possible influence of different institutional incentives in the implementation of different types of ownership for new technologies and decentralised energy systems.

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Appendix A

See Fig. A1.

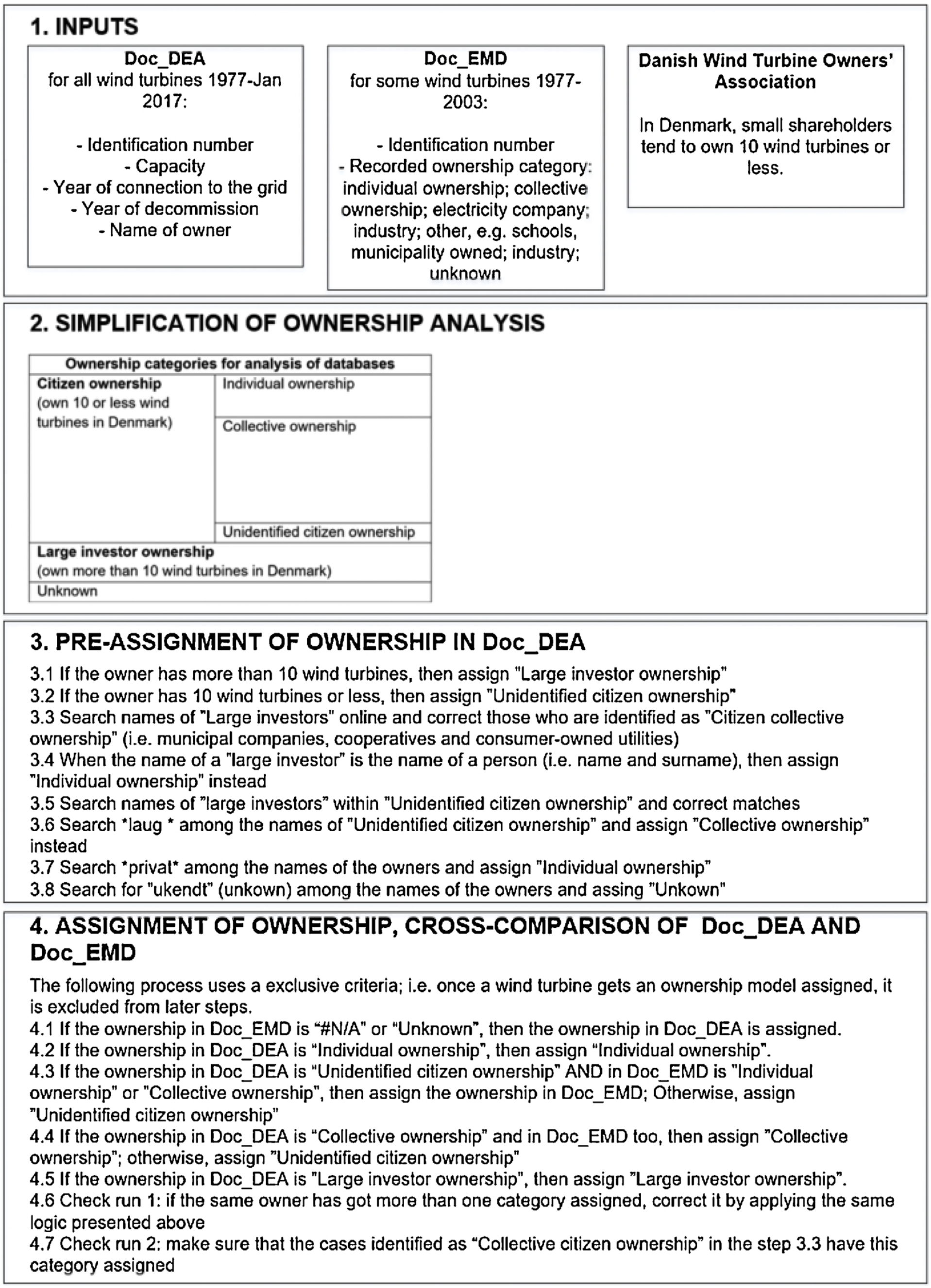

Fig. A1. Procedure for analysis of wind turbine databases and assignment of ownership. The data of Doc_DEA and Doc_EMD is matched using the wind turbine identification number. The translation of "laug" is guild; in practice, "laug" is also used for cooperative. The differences of cooperatives and guilds are often overlooked when analysing the collective citizen ownership of wind turbines in Denmark (e.g. in [16]). Cooperatives are characterised by open membership and democratic decision-making (i.e. each member holds one vote) [43]. In contrast, guilds are commercial partnerships with closed membership and voting rights based on ownership of shares. Apart from the vocabulary issue, the reason why these very relevant differences are often overlooked when analysing the Danish wind ownership is that wind cooperatives have been registered as commercial partnerships in Denmark because of tax advantages [41].

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