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Hvelplund, Frede; Arler, Finn; Lund, Henrik

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Price Efficiency, Green Transition and Channels for Regulating Natural Monopolies: The Case of the Distribution System Operators (DSOs)

Frede Hvelplund, Finn Arler, Henrik Lund

ABSTRACT

The subject of this chapter is the governance system of the distribution system operators (DSOs), i.e. the companies that own, operate and develop regional and local electricity networks. These companies are natural monopolies, and subsequently need strong regulation by public authorities and/or by consumers. The role of the DSOs has been changing fundamentally in recent years, together with the rest of the electricity system, due to the transition from stored fossil fuel-based electricity to electricity based on fluctuating renewable energy sources. The paper analyses the changing circumstances for the DSOs in the development of integrated smart energy systems, based on an innovative theoretical framework with a strong focus on ownership in the understanding of governance of natural monopolies. After a comparative analysis of shareholder versus consumer ownership, based on two cases, the paper sets up several conclusive recommendations about ownership, governance and the new role of the DSOs in the developing smart energy system.

KEYWORDS: Price Efficiency, Natural Monopolies, Distribution System Operators, Ownership, Governance

1. INTRODUCTION

This chapter deals with the governance system of the distribution system operators (DSOs), i.e., the companies that own, operate and develop regional and local electricity networks. The DSOs are, in general, natural monopolies, because they work in a setting where competition from the establishment of alternative grid systems would be extremely costly and inefficient. Due to the lack of competition, the DSOs' activities need strong regulation, both by public authorities and by consumers in the consumer owned DSOs.

The role of the DSOs has been changing fundamentally in recent years, from a system where stored fossil fuel-based electricity can be produced when needed, to a system based on fluctuating renewable energy sources that are harvested when available and converted into power when needed by the customers. This transition challenges the role of DSOs and the governance of their natural monopoly. The DSOs are no longer just distributing electricity produced at large fossil fuel power plants but are becoming active players, facilitators and coordinators in a complex smart energy system.

It is the aim of this paper to analyse and give policy recommendations regarding how DSO companies should be owned and governed in order to pursue the old goals of price efficiency and security of supply, at the same time as they support the innovative transition to a zero-climate gas emission energy system. Even though consumer ownership power is ignored in almost all economic literature as an important part of natural monopoly governance, it is argued in this paper that consumer ownership is a very efficient way of securing stable and price efficient electricity supply in the DSO monopolies.

Denmark has had some of the lowest electricity costs and prices in the EU for decades. In the first half of 2020, Denmark had the lowest excl. tax electricity prices for non-household consumers, with prices 25% below EU28 average and 40% below UK prices (Eurostat 2020). Although unusual in most other countries, consumer ownership governance power has been, and still is, the main and most efficient way of organizing natural monopoly companies in Denmark and a very important part of the Danish DSO governance model.

The paper begins with a description of the changes in the context of DSOs when a transition is taking place towards integrated smart energy systems. It then develops a theoretical framework and approach to include ownership in the understanding of governance of natural monopolies. Next, the paper makes a comparative analysis of external shareholder versus consumer ownership, based on two cases. Finally, it sets up a series of conclusive recommendations about ownership and governance in the green transition.

2. THE FUNDAMENTAL CHANGE OF THE CONTEXT OF THE DSOs

When discussing regulatory models, it is important to analyse how the DSO localization in the electricity system value-added chain is shifting in the transition process from a fossil fuel-based to a renewable energy-based electricity system. During the next 20-40 years, the fossil fuel system will be replaced by energy conservation, energy storage, and renewable energy systems. The official goals of the Danish parliament

encompass a 100% climate neutrality in 2050, an increase in the wind power share of electricity consumption to around 60% in 2030, and a general reduction in greenhouse gas emission by 70% from 1990 to 2030 (Danish Ministry of Climate Energy and Utilities 2020).

This will result in a fundamental change in the electricity system value-added chain and thus also in the role of the DSOs, which in the coming years not only have to deliver secure electricity at low prices, but also embrace the facilitation, coordination and collaboration roles linked to the innovative transition to greenhouse gas neutral power production.

2.1 DSOs AND THE VALUE-ADDED CHAIN IN A FOSSIL FUEL-BASED SYSTEM

Figure 1 illustrates the cost and value-added flow in the traditional coal-based consumer owned electricity system. This consumer ownership has often been referred to as a non-profit system. However, as argued later, "consumer-profit" system is a better term, since rationalization profits are distributed to the consumers by means of lower prices. The value-added in the direct electricity supply system part represents "clean" cost numbers, as the system was a consumer-profit system, where all costs were paid by consumers, and profits were returned to the consumers through lower prices.

Despite the extensive reduction of the fossil fuel share in the Danish electricity supply system, the culture, organization and governance of the present distribution system are still to a large extent shaped for the old fossil fuel world with large central power producers. This situation has not been fundamentally changed by the introduction of the intermediary electricity trading companies. All consumers within a specific consumer category still pay the same distribution fee per kWh, independent of the electricity trading company used.

The electricity supply system in figure 1 is divided into a *direct* and an *indirect* part. The direct part consists of the value added by the employees at the power plants and in the transmission and distribution systems. The distribution part of the value added includes the electricity billing costs. The indirect electricity supply system consists of the value added by capital equipment, such as production equipment at power plants and grid system hardware.

Figure 1 shows that in the traditional system, only 27.3% of total electricity sales is paid to the Danish value-added employment share in the direct system (production, transmission and distribution). The rest is paid for imported coal and capital equipment in the indirect system.

Until the turn of the century, the direct part in Denmark was typically controlled by a singular company that bought fuels, produced, transmitted, distributed and sold power. However, after the EU induced reforms before and after the year 2000 (Miljø- og Energiministeriet 1999, Folketinget 2003) and later supplements, particularly with the

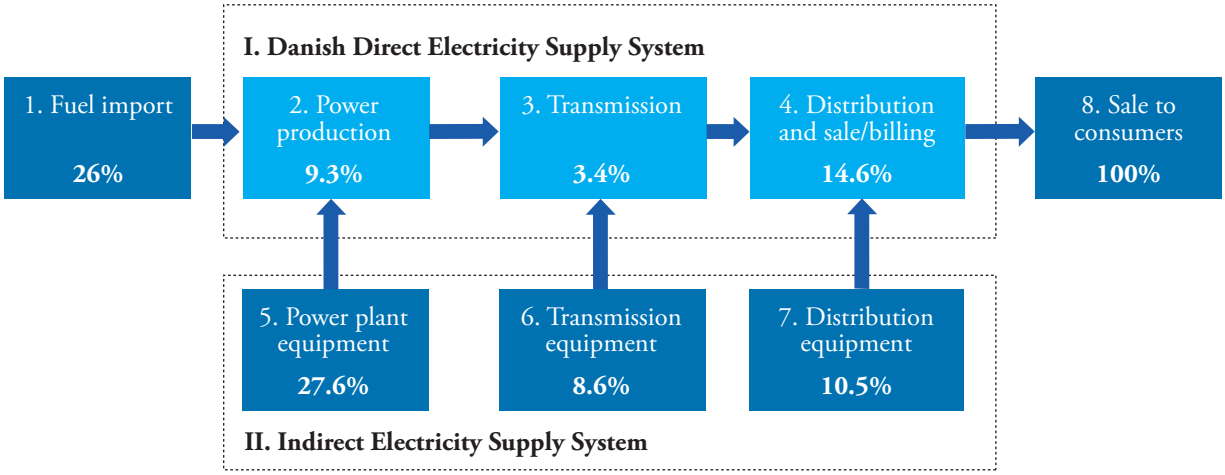

FIGURE 1. THE VALUE ADDED AT EACH STEP OF DISTRIBUTION IN A TRADITIONAL FOSSIL FUEL-BASED ELECTRICITY SUPPLY SYSTEM, AS A PERCENTAGE OF TOTAL SALES.

Note. The numbers are based on concrete numbers from the transparent accounts of the ELSAM power association in Jutland and Funen and relate to a 1998 electricity system with large coal fired power plants with a load factor of 5,000 hours. As a consumer owned system, there was at that time 100% transparency for cost details until it was partly privatized around 2000 and the transparency policy was abolished.

Source: Based on Hvelplund, 2001.

so-called 'engros-model' that was implemented through several changes to the *Law of Energy Supply* between 2012 and 2016, the traditional all-encompassing companies have been split up into separate companies (or sub-companies) focusing on either production, transmission, distribution or sale. The licensed sale companies – many of which are owned by the corporations that also own the DSOs, but kept separate from these – now compete on an open consumer market and buy electricity from competing production companies and services from the natural monopoly DSOs and the TSO. Consumers can compare the electricity prices of the various companies on the elpris.dk website, managed by the Danish Utility Regulator (DUR).

The direct part of the energy system continued to be organised in well-defined direct supply companies though, and until recently, these have not been mingled with activities in the indirect electricity supply system. However, with the transition to renewable energy systems, this sharp separation is changing character, and the DSOs are likely to achieve an increased role as participating in, facilitating, co-ordinating and collaborating with the indirect system.

2.2 DSOs AND THE VALUE ADDED IN A SMART ENERGY SYSTEM

How will the electricity system based on "new" non-fossil fuel technologies look? Figure 2 attempts to illustrate a possible answer to this question by means of a hypothetical example, where the renewable energy system has production at the offshore, onshore and cooperative prosumer organization level. The exact distribution will be different in other cases, but the main characteristics remain the same.

The main principle in the distribution of value-added numbers in this hypothetical case is that the fossil fuel plus power plant value added of around 63% in figure 1, is replaced in figure 2 by around the same value-added percentage in the renewable energy production, together with the systems for integrating the fluctuating energy source. The patterned arrows in figure 2 show new activities compared to figure 1.

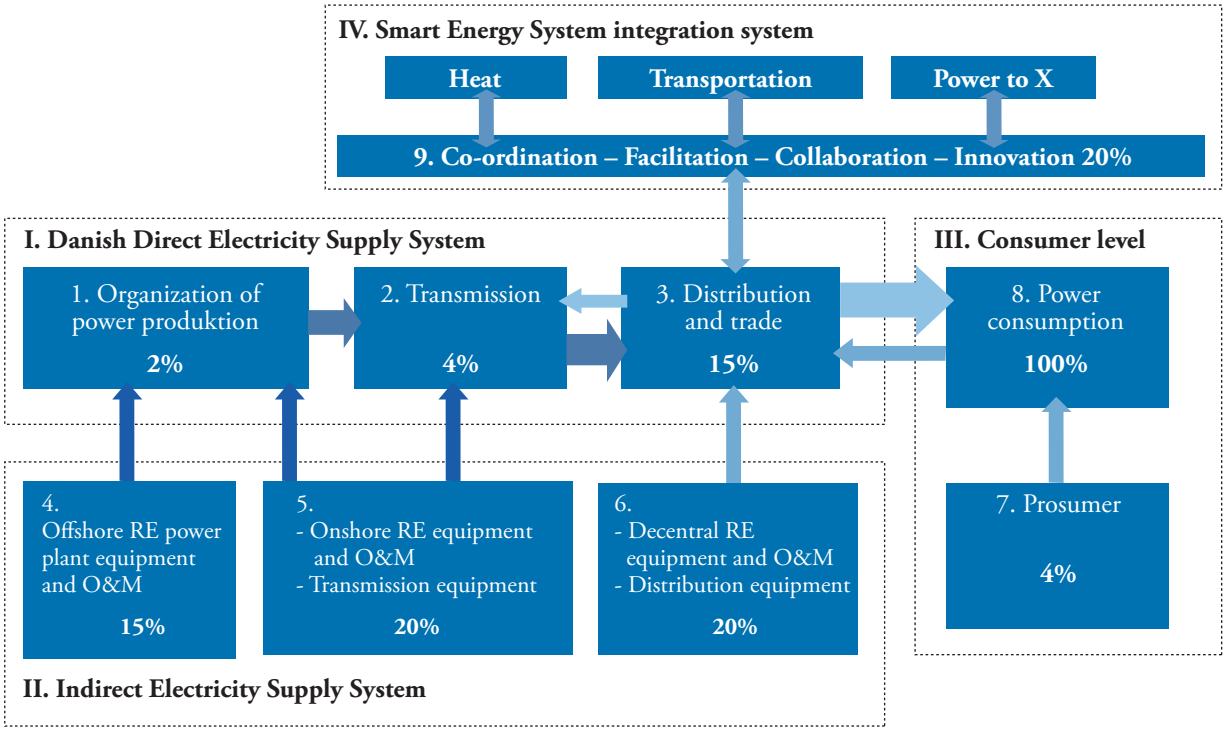

FIGURE 2. HYPOTHETICAL VALUE ADDED AT EACH LINK OF THE CHAIN FOR FUTURE RENEWABLE ENERGY AND CONSERVATION SYSTEMS, AS A PERCENTAGE OF ELECTRICITY SALES TO CONSUMERS.

Note. We assume that the renewable energy equipment and its maintenance is mainly a part of the indirect electricity supply system, except for the offshore wind power production. In the real world the numbers may be different, but the categories within the energy system would approximately be as indicated by boxes 1-9.

The characteristics of the changes are:

1. The fuel import box in figure 1 is replaced by the "Smart energy integration system" box in figure 2, i.e. the infrastructure aimed at *compensating for the loss of fossil fuel storage facilities*.

2. In general, a large share of the direct electricity supply system has been replaced by the indirect electricity supply system activities. The value added in fuel imports and coal fired plant is replaced by value added by employees at the wind turbine, solar panel and electricity conservation equipment factories in the indirect system.

3. Renewable energy is to a large extend based on energy conservation, solar panels and wind turbines, that once established are energy automatons, producing electricity to the direct electricity system.

As illustrated with the patterned arrows in figure 2, DSOs potentially may become increasingly central actors in the new system. They are no longer just receiving and distributing fossil fuel-based electricity, but also participate as active facilitators and collaborators in the innovative development and O&M of new smart technologies. These activities encompass coordinating and preparing infrastructure for electric cars, collaboration with district heating companies on integrating electricity and heat through heat pumps and heat storage facilities etc., establishment of Power-to-X facilities, facilitating horizontal consumer trade with photovoltaic and wind power, energy conservation and electricity storage facilities.

The old task of buying and distributing electricity to consumers remains, but the DSO activities must be redesigned along with the development of a smart energy system, where heat, electricity, transportation, and electro-fuels are integrated across sectors in order to handle large amounts of fluctuating renewables (Connelly, Lund and Mathiesen 2016; Hvelplund et al. 2014; Ridjan et al. 2016), and in which a cross-sectoral approach facilitates the implementation of affordable infrastructure (Lund et al. 2016) and storage solutions (Lund 2018). The question of how the DSOs should be owned and governed in order to cope both with old and new tasks will be discussed in the following sections.

3. DEVELOPMENT OF THE THEORETICAL APPROACH

We find it important both to be aware of the changing aims of the electricity system and to develop a theoretical approach that encompasses the governance abilities and reactions of companies with different ownershipS. This is an extension of traditional governance theory, where companies are not seen as different entities but supposed to react in the same way upon a given public regulation activity (Hvelplund 2001, Hill, R, 2000).

3.1 THE CHANGING AIMS AND THE GOVERNANCE SYSTEM

The classical goals in energy systems are the need for *security of supply* and *cost and price efficiency*. By price efficiency is meant that low costs are reflected in low consumer prices rather than in high external shareholder profits. The new goals in a transition to a fossil free electricity system are to become *environmentally, innovation,* and *system efficient*.

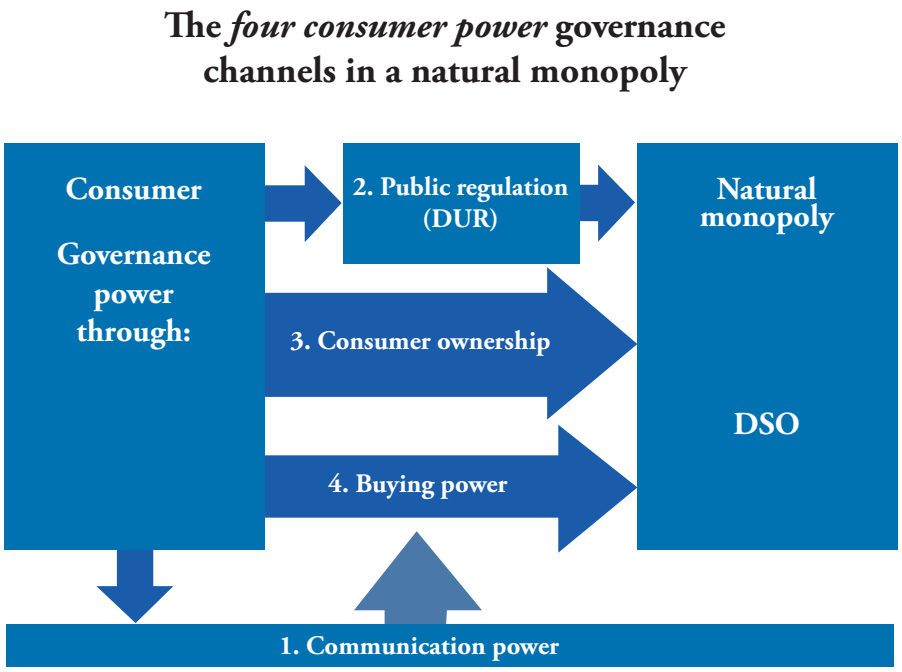

FIGURE 3. THE FOUR CONSUMER GOVERNANCE CHANNELS.

- *By environmental efficiency* is meant that DSOs must pursue societal environmental goals including a major reduction in greenhouse gas emissions.

- *By innovation efficiency* is meant that governance system should incite the development and establishment of new organisational and technological systems in all phases of the *innovation* process that support a green transition

- *By system efficiency* is meant that DSOs should support the ability to give space for, develop and establish smart energy systems that can integrate increasing shares of fluctuating renewable energy sources and energy conservation.

The question is, which DSO governance systems are efficiently pursuing both classical goals related to supply security and price efficiency, and the new demands for environmental, innovation and system efficiency (including electricity conservation). In order to answer these questions, it is necessary to understand how the governance system works – particularly the links between ownership and governance.

Furthermore, as openness and transparency are crucial values in any governance system, it is necessary to have a special focus on how communicative power works alongside the classical channels of governance: public regulation power, ownership power, and consumer buying power. It is a specific feature of the theoretical approach used in this paper that it underlines how a consumer power governance system is executed through four channels (see also Hvelplund 2007; Hvelplund and Djørup 2019). This is illustrated in figure 3.

A theoretical approach encompassing all four consumer power channels is fundamental for a useful description of Danish DSO governance systems, where the majority of DSOs are either consumer or municipality owned.

(1) *Consumer communication power* is the "water" in which the other three power categories – public regulation, consumer ownership, and buying power – are "sailing". Low levels of information openness and a weak democratic dialogue makes it difficult for the other three power categories to function. Consumers cannot compare prices, the public regulator cannot see the price calculations, and consumers as owners cannot control their own representatives. It is interesting that there was a much higher level of cost transparency in the consumer owned monopolies of the 1990s than there has been since the electricity system became partly liberalized starting in around 2000.

(2) *Consumer power through public regulation* can, if it stands alone without consumer ownership power, also be considered as relatively weak, due to asymmetry of resource and information power between the regulator and the regulated large companies. DUR has just over 100 employees. To put the number in perspective, one of the companies they regulate was the Copenhagen DSO, RADIUS, owned by the electricity company ØRSTED with around 6500 employees, and a turnover of around 9 billion Euro. These kinds of asymmetries make it obvious that consumers' regulative power is much stronger when discussions take the form of open political debates where consumers can influence the political process as *citizens*. This influence is crucial for public influence on new and upcoming green transition activities.

(3) Together with consumer communication power, *consumer ownership* power is the most important element of governance in a natural monopoly system. Surprisingly, consumer ownership's effect on price efficiency of natural monopolies is neither described in international economic textbooks nor in the scientific literature (Hvelplund and Djørup 2019). This makes it an analytical innovation to include consumer ownership power as an important part of the governance system (Hill, FR, 2000). This inclusion makes it easier to understand, as we shall see later, why consumer owned DSOs react very differently to public regulation than shareholder owned DSOs.

(4) In the short term, *consumer buying power* over a DSO is insignificant, because all consumers, despite the possibility of shifting between electricity trading companies, have no alternative distribution network. They must pay the same tariff to their own "natural monopoly" DSO company. However, in the longer term, considerable consumer buying power is executed through new consumption needs such as electric cars, electricity for heat pumps, etc., which will influence both the DSO network design and electricity prices.

4. THE GOVERNANCE STRUCTURE OF THE DSOs

The number of DSOs in the Danish electricity sector were reduced from 189 in 1999 to around 62 in 2017. Out of these, 11 are municipality owned, mainly in large cities, and 50 are consumer owned. One very large company, Radius Net, is organized as a shareholder company. So, until now, there is consumer or municipality ownership in almost all Danish DSOs.

Table 1 illustrates two different natural monopoly DSO ownership models. One with *external* owners, for instance shareholder owned or owned by foreign consumers, and another, *internally* owned by the consumers that use the distribution system. The division between external or internal ownership determines whether governance power is only executed by the state (top-down) or is complemented with consumer pressure (bottom-up).

TABLE 1. DSO GOVERNANCE AND EXTERNAL VERSUS INTERNAL OWNERSHIP

	1. External DSO owners of grid system (or distant consumer owners)	2. Internal DSO owners: Consumer ownership of own grid system
a. Top-down regulation	Yes	Yes
b. Bottom-up regulation	No	Yes

Table 1 shows that with external ownership there is no bottom-up price efficiency regulation, whereas a consumer owned DSO has a double governance system of both top-down and bottom-up regulation. In brackets we mention "distant consumer owners" as similar to external DSO ownership, as consumer owned companies can merge to such a degree that the bottom-up regulation is weakened – the administration becomes very distant – and the balance of power between the administration of a DSO and its consumers is tilted away from consumer governance power. In both externally owned, and consumer owned DSOs there is a top-down price regulation, but the efficiency of this regulation is dependent upon efficient bottom-up pressure.

As mentioned, the Danish DSOs are mainly consumer and municipality owned, and thus located in table 1´s consumer owned category. The bottom-up consumer ownership power may become increasingly inefficient, however, due to the ongoing merging of DSOs into very large consumer owned companies.

4.1 THE PRESENT DANISH DSO GOVERNANCE SYSTEM WITH CONSUMER OWNED DSOs

The system with consumer owned DSOs constitutes a *pincer/double regulation* regarding price-cost and environmental performance, illustrated by figure 4 below. The double regulation consists of:

A. The *top-down* cost, price, security of supply and environmental performance, etc. governance by the Danish Utility Regulator (DUR) (illustrated by the broad patterned arrow).

B. The *bottom-up* cost and price etc. regulation by consumer or municipality ownership (broad bottom-up black arrow).

The efficiency of the top-down regulation is a function of the bottom-up regulation and vice versa.

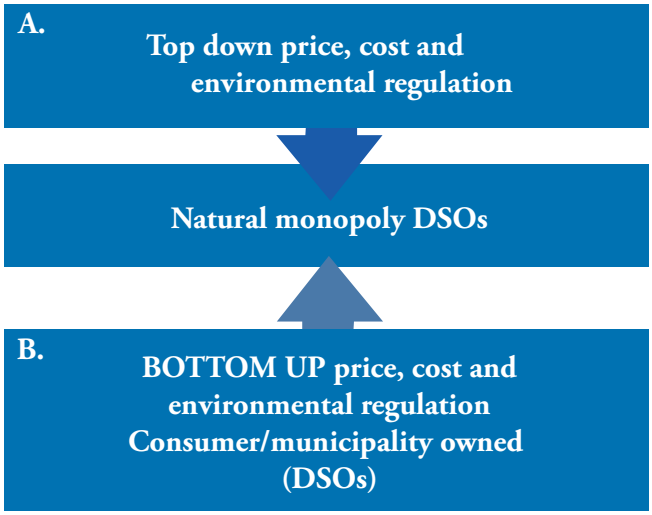

FIGURE 4. THE COMBINATION OF TOP-DOWN NATIONAL AND BOTTOM-UP CONSUMER/MUNICIPALITY OWNERSHIP REGULATION.

The top-down regulation is performed through DUR. DUR is the regulatory energy authority in Denmark and carries out tasks and assignments including controlling prices, costs, security of supply, innovation, etc. according to the energy laws within natural gas, heat and electricity. As an organization it is independent from the Ministry of Energy. It governs an array of legislative duties, according to the *Law on Electricity Supply* § 22 (Klima-, Energi- og Forsyningsministeriet 2020), levied upon the DSO in collaboration with the TSO (Transmission System Operator), which since 2005 has been the state-owned company Energinet. The DSOs' main duties are to make sure that there is sufficient well maintained and cost efficient power transportation available for existing power consumption, and prepare the distribution system for power consumption.

The top-down price and cost regulation is constituted as a *revenue cap regulation* (Energi-, Forsynings- og Klimaministeriet 2018; Klima-, Energi- og Forsyningsministeriet 2020) until 2017 with a price cap based on 2004 costs per kWh, which is afterwards both regulated up in accordance with the annual inflation index and regulated down in order to further increase productivity using an economic benchmarking procedure. In this way a *price ceiling* is established on what the DSO can charge. After 2017, with a revenue cap based on DPU´s estimation of costs in each DSO. The *bottom-up regulation* refers to the regulative effect of consumer ownership power regarding price efficiency, environmental efficiency etc. (blue bottom-up arrow, figure 4).

Figure 5 gives a more precise description of this double governance system of consumer owned DSOs.

Most importantly, there is concordance between the motivation of the consumers and the public regulator, DUR. Both want low costs and low prices. Through their elected representatives, the consumer owned DSOs are motivated to influence the price of the grid payment share of the electricity prices. Both the costs and prices of the distribution system are influenced by the DSO representatives.

In addition, consumer owned DSOs have a possibility of generating a profit, if they distribute electricity at lower costs than the revenue cap calculated by DUR. The consumers within the DSO grid area thus have a dual incentive. Firstly, they want low prices for their own electricity consumption. Secondly, they want low DSO costs in order to generate a profit that can be used for different green transition purposes.

As the consumer representatives decide how a profit is used, this regulation model also increases the meaningfulness of becoming an elected representative. This motivation for participation as a DSO representative is what we, in the "incentive box" in figure 5, name profit driven democracy linked to green projects. In the case of the DSO KONSTANT, for instance, regulation has given profit and funds for a wide range of green projects, which is further to be discussed below. Even though these green projects are not always systematically focused upon facilitating and coordinating smart energy system technologies, they still strive to engage and empower local actors in the Green Transition.

4.2 GOVERNANCE OF AN EXTERNALLY OWNED DSO

In May 2006, the Copenhagen Municipality owned DSO, Københavns Belysningsvæsen, with around 1 million customers, was sold to the

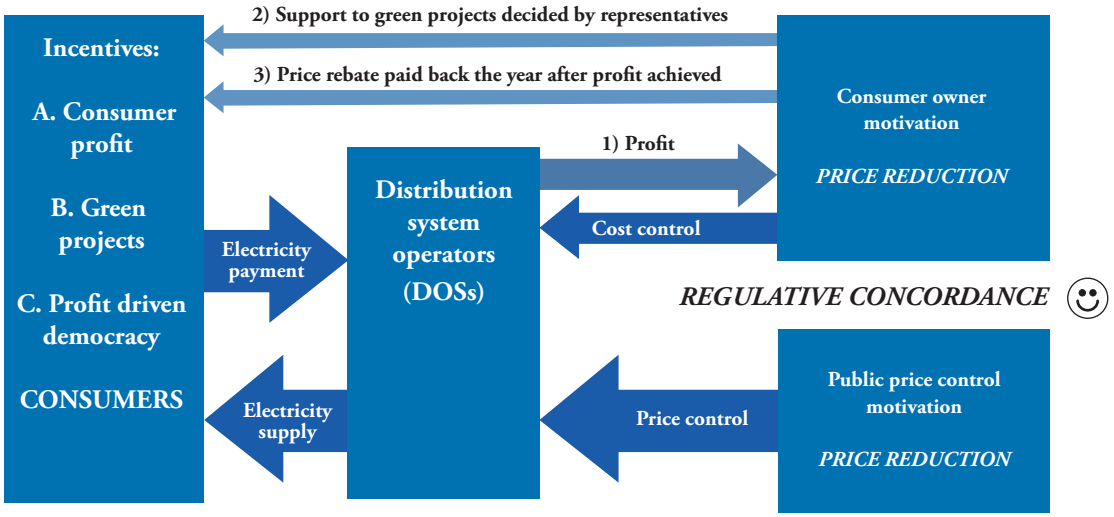

FIGURE 5. PRICE, COST AND GREEN PROJECTS INCENTIVES IN A CONSUMER OWNED DSO UNDER A "REVENUE CAP" PUBLIC REGULATION. SOURCE: HVELPLUND (2019).

large shareholding power company DONG (now renamed to Ørsted) for 0.63 billion Euro. In 2016 it changed name from DONG-elkabler to RADIUS, and in 2019 DONG (now renamed to ØRSTED) sold RADIUS to the Seeland DSO, ANDEL for 2.8 billion Euro. (The name ANDEL, is referring to the long-standing Danish cooperative movement, where a share is called an *andel*)

So in Denmark, since 2006 DONG–elkabler/RADIUS is the first and only clear example of an externally shareholder owned DSO. Still, both with ØRSTED as owner from 2006-2019 and with ANDEL as owner after 2019, we are dealing with external owners, and the bottom-up consumer ownership governance is hardly existing.

In the RADIUS case, we still have the top-down regulation by DUR, but have lost the bottom-up cost and price efficiency due to consumer owner regulation. Figure 6 illustrates the cost and price efficiency motivation in an external shareholder owned DSO.

The main conclusion is that an external shareholder owned DSO primarily will be motivated to maximize shareholder profit. This is achieved by a combination of cost minimization and price maximization by constantly trying find methods to elevate the costs that are the base for DUR determination of the revenue cap.

DUR will try to estimate the objective right distribution costs as a base for the revenue cap. This is not easy, both due to asymmetry of calculative and lawyer power and the fact that the controlled DSO has detailed knowledge of the costs in their DSO, which the controller, DUR has not. Furthermore the DSO may make organizational changes with a sub-contractor system, as we shall see later, to construct high

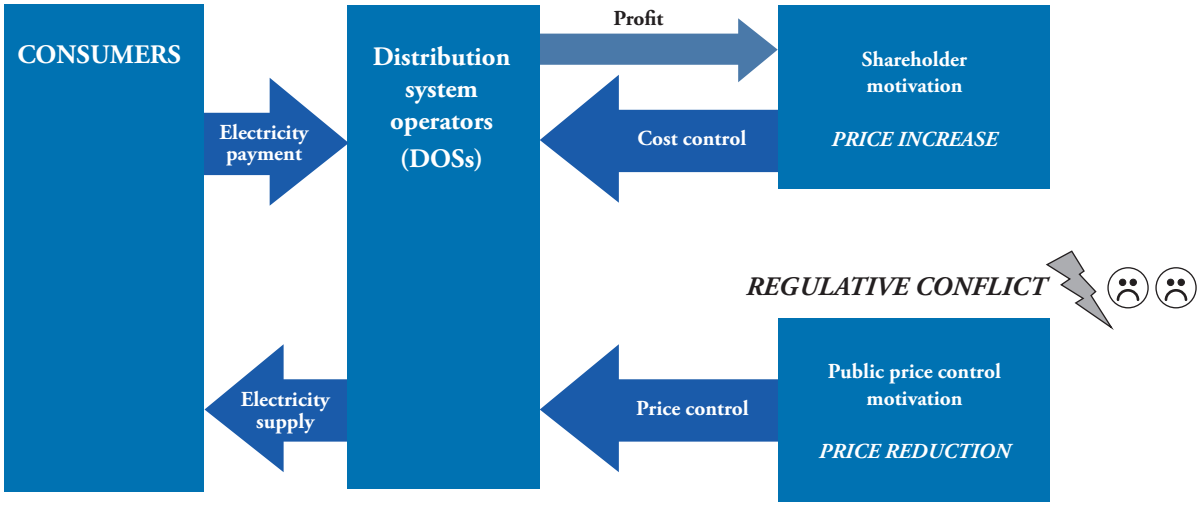

FIGURE 6. MOTIVATION FOR HIGH PRICES IN AN EXTERNAL SHAREHOLDER OWNED DSO. SOURCE: HVELPLUND (2019).

"objective" distribution costs that constitute the cost base for a high DUR revenue cap. Even though the procedure of creating the revenue cap at a macro level is based on objective criteria, it is in its details implemented by means of disputable cost definitions (Forsyningstilsynet 2020, Forsyningstilsynet 2019), where the final revenue cap in cases with strong DSOs is the result of tough competition between the regulator and the regulated DSO (RADIUS Elnet 2018, Forsyningstilsynet 2019). This fight concerning calculation of the cost base for the revenue cap risks being lost by the Danish Utility Regulator (DUR), due to an overwhelming asymmetry of power and resources between DUR and the regulated company, for instance RADIUS.

Often the Danish DSO regulation system is called a non-profit regulation, due to its historical cost-based pricing and the present revenue cap regulation. But seen from an incentive point of view, the consumer owned DSOs should rather be described as regulated by a *consumer profit* mechanism, as cost reductions due to efficiency improvements are paid back to the consumer as lower prices within a period of not more than 5 years. A consumer profit model has a much stronger incentive to keep prices low than a privatized model.

This makes it easy to price regulate for the authorities and results in both cost and price efficiency. It also gives the consumer owned DSOs economic means and incentives for supporting new green technologies. This increases the motivation to participate as an elected representative and further green innovation efficiency. The representatives are often just as interested in supporting the green transition as in keeping electricity prices low.

5. CASE: SHAREHOLDER VERSUS CONSUMER OWNERSHIP

5.1 COMPARISON OF PRICE PERFORMANCE

Figure 7 shows that the prices in the external shareholder DSO, RADIUS, Copenhagen, are between 54% and 142 % higher than the prices in the consumer owned DSO, KONSTANT, Aarhus. The RADIUS prices are between 18% and 104% higher than the average prices of all the consumer and municipality owned DSOs in Western Denmark.

How is this big price difference possible in a system with revenue cap price control of DSOs executed by DUR? When trying to understand this, it might be worthwhile to look closer at the organizational relationship between the mother company ØRSTED, and its subsidiary company RADIUS. On one hand, ØRSTED is not subdued to *price control* and has the r*ight to earn a profit*. On the other hand, RADIUS is by law subdued to *price control* or *revenue cap regulation* administered by DUR, and the company must report costs etc. However, RADIUS – with an annual turnover around 250 mill Euro – has only one employee, its director, and borrows/leases on subcontracts the people doing the DSO work tasks, around 700 persons, electricians, consultants etc. from ØRSTED subsidiary company Sales and Distribution (S&D), which has no profit restrictions and is 100% owned by the mother company (RADIUS Elnet 2017).

When trying to explain the high RADIUS distribution tariffs, there may be three possible reasons why they are almost twice as high as KONSTANT's prices. A first possibility is that it simply costs twice as much to distribute electricity in the Copenhagen area, but we have

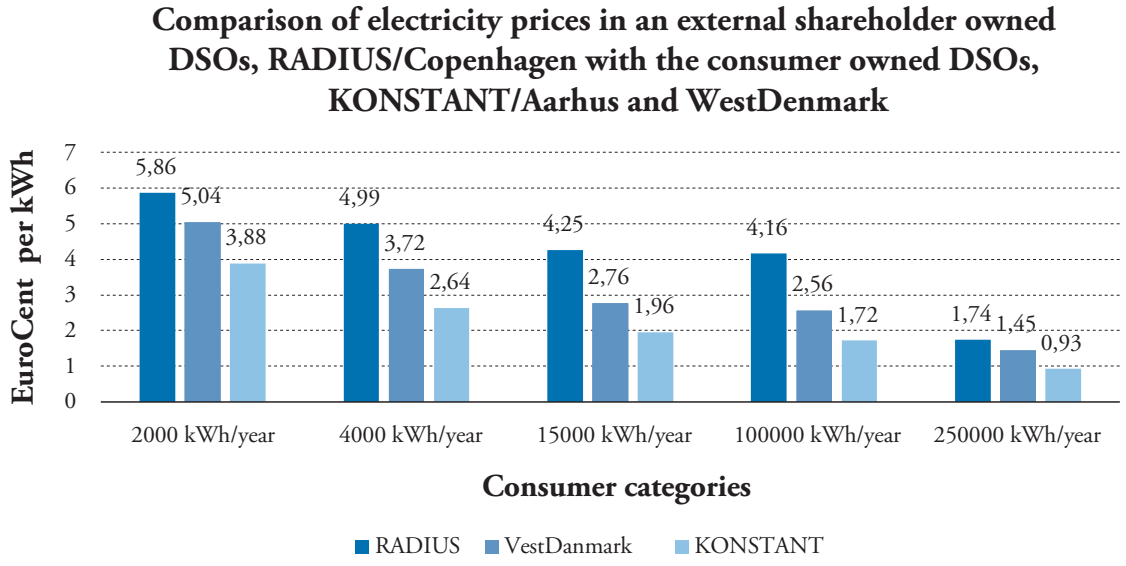

FIGURE 7. COMPARISON OF ELECTRICITY DISTRIBUTION PRICES IN EUROCENT PER KWH IN EXTERNAL SHAREHOLDER OWNED DSO RADIUS, COPENHAGEN, WITH THE CONSUMER OWNED DSO KONSTANT (AARHUS) AND THE AVERAGE PRICE OF ALL DSOS IN VESTDENMARK.

not seen any explanations why this should be the case. A second possibility is that the ØRSTED subsidiary (Sales and Distribution/ S&D) is extremely cost inefficient, which might be legally unacceptable, but time consuming to investigate. A third possibility is that ØRSTED's subsidiary S&D is overbilling the services, which would be illegal, but difficult to investigate. We cannot say which of the explanations are most valid. Still, from a cost and price efficiency point of view, neither of them are satisfactory, and the second and the third are also legally problematic. It also remains to be explained why ØRSTED has chosen a rather strange corporate structure with only 1 employee in profit restricted RADIUS, combined with a system of subcontracted services from the not profit restricted ØRSTED subsidiary S&D.

It is obvious that there is a temptation to transfer profit from RADIUS to ØRSTED. However, it should be underlined that both the PriceWaterhouse Coopers auditing and DUR have accepted the RADIUS price and cost structure for several years. Nevertheless, in 2018 there was a debate regarding the RADIUS prices, and in a draft report from DUR, a large saving potential was estimated. In this draft report, an efficiency improvement potential of 34.4% of the annual 250 million Euro turnover, or around 85 million Euro annually was estimated (Forsyningstilsynet (DUR) 2018). In the email linked to this report DUR mentions, quote; "We call attention to the fact that this material has not been used in the DUR decisions, and that DUR therefore considers it obsolete". (Letter from DUR, 11. December 2020.)

We have not analysed in depth why DUR in 2018 estimates an efficiency improvement of 34.4% and later does not use this knowledge, and says that the conclusions in the report are obsolete. But we know that the DUR 2018 report on saving potential underwent a hearing process, where its conclusions were strongly opposed by RADIUS and Dansk Energi, among others. We cannot determine whether the 34.4% saving potential, or the much lower potential contended by several hearing participants, is correct. But we can conclude that there was a discussion during the hearing procedure as to whether the saving potential was 34.4% or very much lower. This in itself is an interesting conclusion, and underlines that the "objective" cost can end up with a very broad spectrum of values. In addition, due to the asymmetry of calculative and lawyer resources, it is very difficult for DUR to cope successfully with resource consuming disputes regarding cost level definitions with large DSOs. However consumer ownership of DSOs could be one way of doing this, as consumer owned companies, like DUR, have an incentive to keep prices low.

In August 2019, ØRSTED sold RADIUS, which they had bought for less than 800 million Euro in 2006, to SEAS-NVE/Andel for 2.8 billion Euro. SEAS – NVE/Andel is a consumer owned company with 400,000 co-operative owners. RADIUS has around 1 million grid customers, and the customers in RADIUS so far have not received voting rights equivalent to the number of customers. The grid distribution system in RADIUS/Copenhagen is still not controlled by the consumers using this grid system, and RADIUS consumers do not have a bottom-up governance capacity, as they so far only have minority influence in ANDEL.

5.2 IT IS THE CONCRETE VERSION OF CONSUMER OWNERSHIP THAT MATTERS

Because of the energy reforms in the early years of the century, old monopolies were split up. Power transmission was taken over by the state-owned company Energinet. The power plants were sold by the local consumer or municipality owned energy companies to the Swedish state-owned company, Vattenfall, and the then newly established state-owned company DONG Energy A/S (now ØRSTED) – a fusion of 5 major actors in the energy sector, including the previous state-owned company DONG (Danish Oil and Natural Gas). What was left to the local companies, organized as consumer owned cooperative societies, was Distribution System Operator (DSO) companies and electricity sales, organized in new electricity sale companies.

Due to the divestiture of the power plants, the local cooperative companies became quite wealthy and could invest in other activities. This way, several local companies became corporations with a palette of sub-companies along with the DSOs and sales companies. Electricity sales were liberalized, and new sale companies entered the market. After a new reform in 2016, where the so-called engros-model was implemented, the local companies were forced to separate DSOs and sales further, e.g., by using different names, logos and accounts for the two parts.

In the following we will describe an example of how a consumer ownership structure works. We have chosen one of the larger cooperative corporations, NRGi – which owns the DSO analysed in table 1, KONSTANT – with 215,000 consumers/members of the cooperative society and some 1,200 employees (when employees in subsidiaries are included). There are a few bigger companies, including the buyers of RADIUS, SEAS-NVE/Andel (seas-nve.dk; andel.dk) with 400,000 members, and the recent fusion of two large companies in Jutland, Sydenergi (SE) and Eniig, into Norlys (norlys.dk) with more than 700,000 members. Other companies in Eastern Jutland are smaller than NRGi: Ewii (ewii.dk), previously TREFOR, has 150,000 members, whereas AURA (aura.dk) has 110,000 members. All these companies originally stem from many much smaller local companies that have merged stepwise.

5.3 THE BOARD OF REPRESENTATIVES

Like most other Danish electricity companies, NRGi is organized as a cooperative society, and the superior power rests with the board of 100 consumer representatives, who are elected every 4th year in each their districts. These 100 representatives elect an executive board of 11 people, including two representatives of the employees. Half of the board is up for election every year, so each board member is elected for 2 years. The board develops strategies, appoints directors etc. Board members are also board members of sub-companies within the corporation.

The number of voters is on average between 15% and 20%, depending on the intensity of the political activity in a specific district. The percentage of voters has increased considerably since electronic voting was established, but in some districts the percentage is still below 10%. This is not truly surprising, though. Electricity consumption only comprises some 2-4% of the after-tax budget of normal households – and a change of representatives will not have major impact on the energy bill – so many consumers show little interest in the elections. Still, they may jump forward as watchdog voters that "bark", if something goes wrong in the company.

The price of electricity, including the costs of distribution, is not the only issue that is important for the representatives. Like other similar companies, the NRGi corporation covers several activities or sub-companies, with a palette of green activities beside the monopoly distribution managed by KONSTANT. One of the activities is electricity sales, not only through NRGi Elsalg, but also through other electricity sales companies that recently have been bought, and through shares in the company EnergiDanmark, which focuses on larger electricity consuming companies.

A significant part of the assets earned through the sale of the power plants were invested in laying out a fibre network. This investment was expected to be beneficial for the consumers/cooperative members in the long run, even though it was bound to be costly in the short term. NRGi later merged this sub-company with a similar sub-company in the electricity company SEAS-NVE/Andel into Fibia (with the content supplier Waoo), now a major national player in the area. Another area, where NRGi and SEAS-NVE/Andel co-operate is the establishment of infrastructure for electric cars through the company Clever, which sets up stands for electricity charging.

Several of the companies that contain DSOs with distribution monopolies are engaged in developing renewable energy facilities, which will influence the structure of the power distribution network. NRGi has recently established a new division, NRGi Renewables, that has invested in several wind power and photovoltaics projects. A few years ago, NRGi planned the establishment of a near-cost wind farm at Mejlflak in Aarhus Bay. The board of representatives backed up the project, which was only cancelled due to a major drop in electricity prices.

These initiatives make it even more appropriate to combine the management of the DSOs with the handling of other challenges in the green transition. A natural extension of this is NRGi's involvement in the local municipality's strategic energy planning (Aarhus Kommune 2020) – together with AURA and ØRSTED, which owns the largest local power plant in Studstrup. Finally, NRGi is engaged in energy savings and efficiency in buildings and construction through ownership of the consulting firms EBAS and KUBEN Management, and in electrical installations through the company EL:CON.

For all energy companies, the major issue these years is how to organize the needed green transition, and like other consumer owned companies, a focus point of NRGi is sustainability and how to contribute to the developing smart energy systems. This development is also in full compliance with – and probably the only way to fulfil – the DSOs' set of duties according to previously mentioned § 22 in the *Law on Electricity Supply*.

This is also reflected in the discussions in the board of representatives, which not only relate to consumer prices, but comprise a broad range of questions like: How much should the company invest in wind power and photovoltaics? How can the duty to further energy conservation be better fulfilled? Should the company make further long-term investments in facilities for electric cars? Etc. These and similar questions have become increasingly important during the latest decade and now even overshadow another major – controversial – subject, the involvement in fibre network layout and communication. The representatives' broad approach is fully in line with a strong long-standing trend in Danish energy policy, where policy engagement cannot be reduced to short-sighted gain (Arler et al. 2020).

5.4 LESSONS LEARNED

Like most other cooperative electricity companies, NRGi has an extensive website (nrgi.dk). This includes a page where the consumers/shareholders/voters can see the candidates – with photos and 5-10 lines CV and policy – from each of the election districts as well as the results of the latest elections. The districts are placed in the Eastern part of Jutland (figure 8). Several of the districts go back to the old smaller DSOs, from which NRGi has emerged through mergers. The election in districts makes it possible to deal with specific local problems and possibilities.

FIGURE 8. NRGI´S CURRENT DISTRICTS (HTTPS://ANDELSHAVER.NRGI.DK/SELSKABET/). THE AREA IN THE MIDDLE BETWEEN THE TWO CLUSTERS OF DISTRICTS IS OCCUPIED BY THE COMPANY AURA AND, FURTHER TO THE WEST, NORLYS.

The general policies of NRGi can be seen on the website, including information on business areas, green projects and policies, annual reports, etc. Altogether, the combination of a website, electronic elections and policy advertisements for candidates is fundamental for the maintenance and development of democracy. At the same time, NRGi is embedded in a top-down regulation with *revenue cap regulation* and regulation regarding *openness of information*. Some lessons can be learned from the organization of the consumer ownership in companies like NRGi:

1. *Big and small*. NRGi is a both big and small organization. 220,000 shareholders is a very large number, but the division into 24 districts lowers the size of each election district to less than 10,000. The number of districts will be reduced to 9, and the number of representatives to 90, in order to boost public interest in the elections, but

the connection to the members may still be intact. The organization is big enough to take major green transition initiatives and to reap size advantages, but small enough to protect the close relationship to the consumers/members.

2. *Openness of information*. The website with policies and intentions, and email and postal addresses for all consumer representatives makes it possible for the shareholders to communicate with their representatives.

3. *Owning the grid*. The shareholders are cooperative consumer shareholders of their own distribution grid. They profit from streamlining and can influence the specific development of the grid to make it suitable for green transition initiatives.

4. *Revenue cap and profit for green initiatives*. KONSTANT is regulated by a revenue cap regulation. If the company is cost efficient, it may perform below the cap and earn a profit, which the elected representatives can use either for price reductions or, for instance, for selected green projects.

As shown in table 1, KONSTANT has been able to keep prices low compared to the external shareholder DSO RADIUS. The profit is used for an array of green projects. These projects are not all systematically linked to the establishment of smart energy system solutions, though. Some are, for instance, intended to empower local organizations by satisfying their electricity needs in greener ways.

6. CONCLUSION

6.1 THE CHANGING ROLE OF THE DSOs

The changing role of the DSOs is elucidated in the transition from figure 1 to figure 2. Instead of just governing added value of around 25% of the electricity price as distributors of electricity from fossil fuel power plants, the DSOs are becoming actors, facilitators and co-coordinators of 80-90% of the added value of the smart electricity system. This way they also achieve co-responsibility for activities outside the electricity sector.

The electricity sector is losing the storage facility of using fossil fuels, where electricity can be produced when it is wanted. Instead, renewable energy resources are being used that must be harvested, when the sun shines, the wind blows, etc. Without fossil fuels, the security of supply must be guaranteed by a series of interrelated activities in a smart energy system, including combining heat and electricity, electric cars, Power-to-X (fuels), flexible electricity consumption, some biomass-based electricity production and electricity conservation.

This smart transition must be coordinated, facilitated and "produced" by a number of actors in a complicated collaboration process. This points to a new and central role of the DSO cooperative, at the same time as the old role of distributing electricity with high supply security and at reasonable prices remains.

6.2 WHAT HAVE WE LEARNED?

It was proven useful to apply a novel theoretical framework of the governance system with *four consumer power areas*: ownership power, power through public regulation, buying power and communicative power. A special feature in this framework is that *consumer ownership power* is included as a part of the DSO governance structure in a combined bottom-up and top-down regulation system.

This is an innovative approach not dealt with in existing regulation literature, but it makes it possible to understand how the efficiency of public regulation of natural monopolies depends on the ownership structure of the regulated company (DSO). Furthermore, this paper has introduced the concept of "*price efficiency*", which makes it possible not just to focus on cost efficiency, but also to analyse the difference between prices and costs, and thus analyse the level of ownership transaction costs of specific ownership models.

Based on the analyses, various conclusions can be drawn. The main lessons are:

- A four-consumer power governance system, or *a combined top-down and bottom-up regulation* of a natural monopoly like a DSO is more price efficient than an externally owned shareholder owned DSO. This is the case because consumer owned DSOs are relatively easy to price regulate, as consumers want the same as DUR: low consumer prices. The DSOs *should therefore be consumer owned*.

- *Consumer ownership areas should be identical with supply areas* to preserve an inherent ownership-linked interest in low prices. If a foreign consumer owned company (A) owns a DSO in another area (B), the foreign consumer owned company (A) has no inherent ownership interest in keeping the consumer prices low in area (B).

- *Ownership of DSO grid systems by foreign/external consumers should be converted to consumer ownership*, where consumers own the grid system from which they get their electricity. A DSO owned by external shareholders is very difficult to price regulate. External shareholders want profit via high consumer prices, and since they have superior calculative and lawyer power to DUR, they can find ways and arguments for increasing the cost base for the revenue cap determination.

- *Consumer ownership is not "enough" in itself*; it is the *type* of consumer ownership that matters. Values like transparency and genuine consumer/citizen involvement are crucial for the green transition. The organisations containing DSOs should also *become still more aware of and take responsibility* for the replacement of the storage facility of the fossil fuel system. Many decisions need to be made on the local level, and the consumer owned energy companies with DSO responsibility are key players in this transition.

- *There are not sufficient incentives* that make the DSOs invest in and/or facilitate and co-coordinate smart energy system solutions, such as facilities for electric cars, co-coordination of fluctuating renewable energy with district heating and heat storage, Power-to-X systems, developing and supporting electricity savings, etc. This should be changed.

- *The DSO should not cover too large an area*. When DSOs merge, it becomes more and more difficult for ordinary consumers/citizens to participate and become engaged in the development of smart energy systems. The process will be become still more dominated by technicians and professional politicians. Rules should maintain the *motivational link* between the consumers and the grid system they own. Some DSOs should be split up; they can still cooperate on major projects.

- *It should be considered* whether the grid system should be *opened for horizontal communication/trade of electricity between consumers and producers in an area*. Rules could be established that make the cost calculations behind the grid leasing price transparent. This might free up an innovation potential of the kind that is essential for a successful transition to renewable energy and for achieving the 70% greenhouse reduction goal in 2030.

  In several of the DSO-owning organisations a lot of green projects have been started, either by means of the profit earned due to lower costs than the revenue cap or as investment opportunities. But these projects are not always systematically dealing with the establishment of smart energy system technologies that replace the lost storage facility of the fossil fuel systems. This should be encouraged more wholeheartedly by the regulation of the energy sector.

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