NordREG
Nordic Energy Regulators
POWER THROUGH COOPERATION

Electricity distribution tariffs

Report by the NordREG Network Regulation WG

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Table of contents

Summary

A lot has happened on the electricity markets during the last years. New regulation in the clean energy package along with a rapid electrification of the industries and transport sector have changed the prerequisites for tariff design. This report provides an overview of the changes that might affect tariff design, as well as an update on the development of tariff structures in the Nordic countries and how well they incentivize an efficient network utilization.

Based on economic theory, in order to achieve an efficient network utilization, the tariffs should be cost-reflective. Thus, the tariffs should provide price-signals based on the short run marginal cost, for example costs of network losses and congestion. For the DSOs to receive full cost coverage, the remaining part of the revenue cap should be collected in a way that does not affect the short run consumption of electricity, since long run costs are not affected by short run consumption.

The tariffs must also be designed in a way such that customers can understand and react to the price-signals that tariffs give. In the report, we emphasize important principles for both customers and DSOs that need to be considered when designing tariffs.

In the Nordic countries, the objective stated in the national laws is to have objective and non-discriminatory tariffs, which means that they should be cost-reflective and not discriminate between customer groups. In practice, the analysis indicates that household customers have a larger variable fee based on energy consumption than what is motivated by the DSOs cost structure. Some of the countries are currently looking at developing the DSO tariff regulation to incentivize a more efficient grid utilization. One trend seems to be towards more available power-based tariff components for customers on lower voltage levels.

There is not a single tariff structure that fits perfectly for all grids, (no “one-size-fits all”). The optimal tariff structure can vary over time and location due to different prerequisites in the grid. It is important to set clear and transparent goals for DSOs’ tariff structure and that both the network operators and electricity consumers can understand and react in order to achieve an efficient use of the network. A power-based component in the tariff for even small electricity users and thereby more cost-reflective tariffs might be necessary in the future as one of the tools to achieve a more efficient grid utilization.

1 Introduction

Electricity network tariffs are used by DSOs (distribution system operators) and TSOs (transmission system operators) to recover their costs of providing electricity transmission and distribution services. The total amount of allowed revenues is set in the economic regulation by the NRA (national regulatory authority). Hence, the development of the tariffs is closely related to the development in the regulation. The design of electricity network tariffs has become an important component in contributing to efficient network utilization. Network tariff design needs to evolve in the light of changes in society, such as the decarbonization of the energy sector and the integration of intermittent and non-dispatchable electricity production from renewable energy sources into the power system.

The purpose of this report is to provide an updated view on tariff design in the Nordic countries, to present some of the main arguments for cost-reflective tariffs and to present the customer-focused challenges with a change in the tariff regimes. The report is primarily descriptive and does not present a common Nordic view on tariff structures.

The purpose of network tariffs is twofold. First, the tariff structure should ensure that each customer group face reasonable prices based on the cost they inflict on the grid and through the price signal are incentivized to use the grid in an efficient manner. Second, tariffs should recover the efficient cost for operating and investing in the grid (defined by the revenue cap).

In this report, we focus on how tariffs should be designed in order to stimulate efficient network utilization, rather than on the magnitude of the tariff. In order to do so we address the two latest tariff reports from CEER, (CEER, 2017) and (CEER, 2020), one regarding the main principles for tariff design, and one assessing how tariffs can be designed in order to incentivize efficient use of the network, from a Nordic perspective. We further explore the consumers' possibilities to respond to price signals and the cost-reflectivity in tariffs for the Nordic household customers.

In 2015, NordREG published a report (NordReg, 2015) describing the current trends in tariff methodology in the Nordic countries. The report assessed the importance of cost-reflective tariffs and demand response. Since then, the electricity markets have developed in a way that calls for further analysis of how costs are recovered through network tariffs. It is therefore an important task for NordREG to highlight the development in tariff design and how the different principles for tariffs will be affected by the new energy landscape.

The report is structured as follows: chapter 2 provides background and reasons for the need to address the tariff structure in the Nordic countries. This is further developed in chapter 3, where an overview of the main changes in the energy landscape are presented. Chapter 4 contains a theoretical overview of how to design optimal network tariffs, where the conclusions from CEER's papers are presented along with economic theory regarding tariffs. In chapter 5, we describe the development in tariff methodology for each of the Nordic countries. Chapter 6 highlights important principles for customer response, as well as provide further analysis of the effect of new tariff design. Finally, conclusions are presented in chapter 7.

2 Background

Fundamental principles of tariff design can be contradictory, especially when it comes to the requirements of simplicity and cost-reflectivity. Historically the DSOs have focused on making the tariff design simple and understandable rather than fully cost-reflective for customers on lower voltage levels (e.g. household customers). For these customers, the tariffs are mostly volumetric[1] which means that the tariff will vary depending on how much energy a customer consumes. A typical household customer pays a combination of a fixed and a volumetric tariff. For larger customers, a power-based component in the tariff has been more common.

A traditional combination of fixed and volumetric tariffs might have distortionary effects in the new energy landscape, as the customer groups do not necessarily face prices based on the actual cost they inflict on the grid. The simple tariff structure has worked well for cost recovery in a system with few large-scale production sources and no or few capacity constraints in the grid. However, recent trends in the energy landscape might call for the need for DSOs to change their tariff structure.

The main trends impacting tariff structures are identified as:

- More data is available from smart meters.
- Distributed generation and prosumers.
- Changed consumer potential and behavior.
- New EU legislation, strengthening the effects of the trends mentioned above.

The current trends present both challenges and opportunities. Smart meters and better information give the DSOs a greater possibility to respond to the changing cost structure due to changes in production and consumption patterns. We also see that consumers are more capable of affecting and adjusting their consumption in a way that reduces the costs for the DSOs. For the consumers to actively engage in activities, which reduce the costs for the DSOs, they need to be compensated for their actions.

2.1 Customer focus

To achieve efficient use of the grid through tariffs, consumers on all voltage levels need to receive correct price signals and be able to react to them. It must be especially clear for the consumer how they are to change their behavior to contribute to efficient use of the grid. The consumers should receive price signals based on the costs they inflict on the grid so it can be up to the consumers to choose how to react to the signals given by their preferences. The development of cost-reflective tariffs serves no purpose on its own if no customers adjust their behavior to use the grid in a more efficient manner.

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[1] A volumetric tariff contains a volumetric component, also named *energy component*. The volumetric component is a price per kWh consumed, e.g. €/kWh.

An important but challenging question is what type of tariff design would deliver the best incentives? And how well can the customer respond to a price signal, if they do not have real-time information about their current consumption?

New technologies with the abilities to reduce capacity constraints, avoid storage and incentivize the electrification of the transport sector create opportunities for the users of the grid to reduce the costs of transmitting and distributing electricity. It is important that the tariffs should reflect the benefit arising from measurements taken to reduce the costs for the DSO.

A lot of work has been done recently on tariffs in relation to the new challenges presented above. Many recent reports (The Brattle Group, 2018), (Borenstein, 2016), (Meeus, Govaertes, & Schittekatte , 2020) focus on cost-reflective tariffs, while fewer have studied the impact that new tariff designs may have on the consumers.

2.2 Purpose of this report

- Provide an updated view on tariff design in the Nordic countries.
- Present some of the main arguments and an academic background for cost-reflective tariffs.
- Present the customer-focused challenges with a change in the tariff regimes, where we describe how household customers can be affected by changes in the tariff structure.

3 Developed energy landscape

3.1 Introduction

In the NordREG report from 2015, the aim was to do a survey of the practice of power-based tariffs among DSOs in the Nordic countries and assess the policy options for NRAs to incentivize DSOs to design tariffs, which were compatible with the Energy Efficiency Directive (2012/27).

In 2015, the introduction of new technologies provided new possibilities for tariff design and network operation. In particular, smart meters made it possible to implement power-based tariffs as well as time-differentiated tariffs.

The Energy Efficiency Directive (2012/27) was a driver for the member states and energy regulators to consider a new tariff design. In terms of the design of the tariffs, this directive further emphasized the requirements of the Electricity Market Regulation (2009) regarding cost-reflective tariffs. In addition to tariffs being cost-reflective, they should also encourage efficient use of the grid.

In 2020, smart meters have been implemented in all the Nordic countries. However, the implementation of the above-mentioned directive or new technology has not contributed to a major shift in tariff design in the Nordics.

3.2 Technological challenges

Since 2015, there have been technological developments in many sectors that will have an impact on how the grid is being used. Among other things, the sales of electrical vehicles and solar panels have grown rapidly since 2015 and are expected to continue to increase in the coming years.

Intermittent generation does rarely have the highest production at times when the demand is greatest, e.g. solar powerplants do not generate as much electricity during the evenings, when the consumption tends to peak, as during the day when the sun is up and consumption tends to be low. An example of this challenge is electric vehicles, which are predominantly expected to be charged during the evening. In the Nordic countries, the seasonal pattern of consumption also leads to major challenges for intermittent power. With the right technology and incentive, however, this consumption can to some extent be controlled in contrast to intermittent production.

The fast-paced energy transition and the changed consumption patterns can also lead to capacity constraints locally and regionally if there are not sufficient investments in the grid. Historically, such changes have led to corresponding investments in the electricity grids, expanding the grid. However, there is a risk that DSOs will overinvest in the grid when faced with these challenges. Expanding the electricity grid is not necessarily the most efficient way of using society's resources, at least not in the short term. Demand side flexibility and cost-reflective tariffs may provide a more efficient solution to resolve emerging constraints.

The rising shares of intermittent generation, distributed generation and new technologies need to be integrated into the energy system without risking security of supply.

3.3 Clean Energy Package

One of the main issues regarding technical developments was whether the DSOs themselves would be allowed to incorporate these new technological opportunities into their operations. Economic efficiency and market level playing field have been one of the driving forces for the development of the European electricity market and this meant early on that electricity generation could not be classified as a DSO activity. The new technical possibilities raised new questions about what responsibility the network companies should have.

The new Electricity Directive provides answers to these questions and clarifies what responsibilities DSOs will have in the future. This is especially true for procurement of flexibility and the ownership of energy storage. Member States (MS) shall provide incentives for DSOs to procure flexibility services, including congestion management. The regulatory framework shall ensure that DSOs are able to procure such services from providers of distributed generation, demand response or energy storage. DSOs shall not be allowed to own, develop, manage, or operate energy storage facilities. By way of derogation from these requirements MS may allow DSOs to own, develop, manage, or operate energy storage facilities under certain conditions. However, the overall message is clear. In the new energy landscape, the EU wants to provide space for new players to enter and compete for these services.

The Directive also sets requirements for DSOs to develop network development plans. The purpose of these plans is to enable better coordination for the expansion of the electricity grid, especially between DSO and TSO. The plans must also contain information on whether the DSOs see alternatives to traditional expansion of the electricity grid. This may, for example, be the issue of procurement of flexibility services or the use of energy storage facilities. They can thus serve as a platform for new players to see how their services are in demand.

Article 18 of the Electricity Regulation states that network tariffs shall be cost-reflective, transparent and take into account the need for security of supply. Tariff methodologies shall also provide DSOs with incentives over both short and long term. The network charges shall not discriminate either positively or negatively against energy storage or aggregation and shall not create disincentives for self-generation, self-consumption or for participation in demand response.

Article 18 (7) adds that distribution tariffs shall be cost-reflective taking into account the use of the distribution network by connected users, including active customers. MS shall also consider using time-differentiated tariffs when smart metering systems have been deployed.

3.4 Reforming tariff design is part of the solution

Distribution tariffs can guide network customers to make effective decisions regarding their use of the electricity network. Efficient use of the electricity network means that society's electricity needs can be met at the lowest possible cost. A price signal that reduces electricity demand during peak demand may lead to postponed or avoided investments in the grid. This can benefit all network users in the form of lower network fees in the long run. Efficient grid utilization can also contribute to making the electricity grid remain competitive and relevant in relation to other alternatives, such as micro-production and energy storage, which are becoming increasingly cost-efficient over time. This development is in the interest of grid owners, as well as society, as it avoids costly duplication of infrastructure linked to energy use.

4 General economic principles of tariff design

4.1 Economic principles

Typical elements in the cost structure of a natural monopoly, that electricity distribution networks are, is that the proportion of fixed costs is high and the proportion of variable costs is low. This implies that short term marginal costs are not equal to long term marginal costs. Subsequently marginal cost is still the economically optimal price signal, but residual costs need to be covered through other means. Article 18 of the Electricity Regulation states that tariffs shall be cost-reflective, transparent, take into account the need for network security and flexibility and reflect actual costs incurred insofar as they correspond to those of an efficient and structurally comparable network operator and are applied in a non-discriminatory manner. The tariffs shall not include unrelated costs supporting unrelated policy objectives.

Tariff design is typically based on cost allocation, where the DSO's costs are allocated to either fixed, variable or customer-specific costs and subsequently allocated to different customer groups. Typically, the structural elements of an electricity tariff are a fixed charge (€ /period), a volumetric charge (€/kWh/period) and a capacity charge (€/kW/period). The costs allocated to a given customer group influence the tariff for this customer group. Appropriate cost allocation is key in achieving the requirement for cost-reflective tariffs according to Article 18 (1). In this report, we focus on the principles stated in CEER 2017 Guidelines of Good Practice (CEER, 2017).

According to (CEER, 2020) the short-run marginal costs are typically costs of network losses, congestion and expected loss of load. The short-term marginal costs must provide correct short-term price signals to promote efficient network use. The marginal cost of using electricity increases the closer the electricity consumption comes to the maximum capacity in the network due to exponentially increasing network losses. An efficient energy-based component should thus send the price signal that it is more expensive to use electricity at a high load in the networks, since this is most cost-reflective due to the higher network losses and the higher risk of subscriptions to overlying networks being exceeded when close to maximum capacity.

Long-run marginal costs according to (CEER, 2020) are the costs related to the future capacity of a network and may be the cost of increasing network capacity. A forward-looking tariff component contains price signals to network customers on how their current behavior affects future needs for investments in capacity. The purpose of the price signal is to show network customers what costs their network use entails and thereby give them incentives to reduce their consumption and thus the need for expensive investments in the network. The network utilization will affect the need for new network investment and congestion management services. As a result, the part of the distribution tariff related to infrastructure costs are said to have a long-term perspective and is consequently forward-looking. A forward-looking component should only be used at times when the load is at its highest in the network and should advantageously be geographically differentiated in order to be able to handle local congestion. In networks with abundant distribution capacity, such a forward-looking tariff component is not necessary. Typical designs for forward-looking tariff component are semi-marginal pricing through time-of-use (ToU) tariffs or critical peak pricing (CPP).

The costs related to historic investments in the network are a large part of the total distribution network costs. How residual costs/sunk costs are covered by the tariffs is a matter of economic efficiency (minimizing economic distortions) and a collective and objective contribution from all users. This basically implies an optimal lump-sum charge, i.e. a fixed rate paid collectively by all users of the network, in cases where costs cannot be linked with a specific network user. As the costs do not vary with the use of the network, the revenue to cover the residual costs must be collected in a way that does not affect the use of the network. Following the principles of Ramsey-Boiteux pricing, this charge should achieve cost recovery with minimal distortions. Typical ways to design this part of tariff in practice are lump sum, lump sum differentiated by capacity demand and lump sum + capacity.

In conclusion, according to economic theory cost-reflective distribution tariffs should combine a short-term marginal energy-based component, a fixed component to recover the residual costs and a forward-looking component based on a forward-looking cost model if capacity is scarce. The economic principles of good practice in tariff design for DSO tariffs can be divided into network operator- and customer-oriented principles.

4.2 Network operator-oriented principles

DSOs should be able to recover their efficiently incurred costs through tariffs. As well as tariffs for use of the distribution system, DSOs may also recover costs through connection charges and regulated services. This is called ***the cost recovery principle***.

For efficient use and development of the grid, as far as practicable, tariffs paid by network users should reflect the cost they impose on the system and give appropriate incentives to avoid future costs. Tariff design should reflect that electricity networks have high fixed costs and low variable costs in the short-term. This is called ***the cost reflectivity principle***.

In (CEER, 2017) it has pointed out that tariff structures should be sensitive to the different costs of network provision and include the costs of providing capacity at peak, the costs of maintaining the grid, operational expenditure and losses etc. Each of these costs should be reflected appropriately through tariff structures. In the shorter term, a proportion of the DSOs' costs will not be related to load, and can be seen as residual costs that should be recovered in ways that are objective and cause the least possible distortion of network use. In the longer term a greater proportion of the costs can be related to load.

However, cost-reflective tariffs according to economic theory would probably lead to unmanageable changes in price for a large number of customers if other principles were not taken into account, as they would mean higher bills for lower energy users. CEER's approach is to balance the demand for increased cost-reflectivity in tariff design with customer-oriented principles.

4.3 Customer-oriented principles

DSOs' costs should be recovered in ways that avoid distorting decisions around access to and use of the network and market offers. This is called ***the non-distortionary principle.*** In (CEER, 2017) it is stated that costs should be recovered in ways that avoid distorting decisions around access and use of the network. Distribution network tariffs should not be a barrier to innovative market offers that will add value or reduce costs for consumers e.g. related to flexibility and energy efficiency.

DSO tariffs should not include any undue discrimination among network users. This principle is ***the non-discriminatory principle***. It has been pointed out in (CEER, 2017) that self-generators, who use the network, should face network tariffs, which are objective and cost-reflective in the same manner as consumers, who exclusively rely on the network for their energy supply.

The methodology for calculating tariffs should be transparent and accessible to all stakeholders. ***Transparency principle*** is essential in communication of DSO-oriented principles of cost-reflectivity to customers.

It is also important that network users can effectively estimate the costs of their use of the distribution system, facilitating efficient long-term investment by network users. ***Predictability principle*** is therefore an essential link in connecting the cost-reflectivity principle and customer behavior in a way that supports efficient use of the network.

As far as possible, tariffs should be easy to understand and implement. The simpler they are, the easier they are for network users to respond to the signals that tariffs give. ***The simplicity principle*** has a guiding effect on how well the network users respond to the signals that tariffs give. Tariffs can be simplified by having time-differentiated tariffs and not geographical or nodal tariffs. This implies that charges can be based on the grid users' contribution to the system peaks. Second, tariffs can be simplified by pricing critical periods rather than peaks and by sacrificing their location and temporal granularity.

CEER (CEER, 2017) has pointed out that fixed or ex-ante capacity tariffs have advantages of simplicity, stability, and predictability for both the consumers and DSOs. This is because a material proportion of distribution costs are fixed in the short run, but to a certain extent dependent on capacity in the long run, and therefore it may be appropriate to recover them through fixed or ex-ante capacity tariffs. However, according to (CEER, 2017) fixed tariffs do not give signals in relation to long term costs, and the benefits should also be weighed against higher bills for lower energy users. Fixed tariffs do little to encourage energy efficiency and system flexibility. Contracted capacity charges according to (CEER, 2017) can be based on subscribed or installed capacity and have similar advantages and disadvantages to fixed costs. However, when differentiated based on capacity, they will give a signal that capacity has a price.

4.4 Future development

The changing nature of the energy system means network tariffs will need to evolve over time. The energy transition will influence network tariff design. Electricity distribution tariffs should support the energy transition. According to (CEER, 2017), tariffs should not be a barrier to new technologies and innovative market offers from market actors, who will add value or reduce costs for consumers, for example related to flexibility services and energy efficiency.

This means that customers should be exposed to forward-looking price signals to reflect changes in their grid utilization to affect future network costs. The tariff design should also aim at reducing system peaks and individual peaks. Advanced differentiation in time and location, for example through dynamic tariffs[2] or interruptible tariffs, would most likely increase the extent of how cost-reflective tariffs are for specific network users and may also incentivize beneficial network behavior.

Article 18 (7) of the electricity market directive 2019[3] states that distribution tariffs shall be cost-reflective taking into account the use of the distribution network by system users including active customers. Subsequently they may contain network connection capacity

[2] Dynamic tariffs means that the price signal is defined at shorter notice, possibly close to real-time.

[3] Directive (EU) 2019/944 of the European Parliament and of the Council of 5 June 2019 on common rules for the internal market for electricity and amending Directive 2012/27/EU, OJ L 158, 14.6.2019

elements and may be differentiated based on system users' consumption or generation profiles and where appropriate, time-differentiated network tariffs may be introduced to reflect the use of the network, in a transparent, cost efficient and foreseeable way for the final customer.

According to (CEER, 2017) network tariffs are only one of many tools to give price signals to consumers. Other tools, which can signal congestion, include market-based signals for flexibility procurement and connection charges. Incentivizing network-beneficial customer behavior is not only possible through dynamic tariffs, but also through procurement of flexibility. Explicit procurement of flexibility through contracts creates more certainty for DSOs and allows customers willing to provide flexibility to be adequately remunerated.

According to (CEER, 2020) once a tariff structure is defined, with the components that best reflect different cost drivers, it is still necessary to set cost allocation rules. Common approaches so far have included the application of a cost cascading principle to cost allocation across voltage levels and the allocation of all distribution costs to loads and not to generation. Cost cascading principle is based on the simplifying assumption that energy flows from the highest to the lowest voltage level. As a result, distribution tariffs have traditionally been allocated on the grounds that each network user should pay for the voltage level of connection, as well as for all voltage levels above.

However, as (CEER, 2020) has pointed out, a network with substantial distributed generation, together with storage facilities and prosumers, might observe inverted power flows (from lower voltage levels to higher voltage levels) on a frequent basis. This will open the debate about whether network users connected at higher voltage levels should be charged for lower voltage grids. Since large industrial network users are usually connected to upper network levels, they pay on average less in network costs, due to the cost cascading principle. Adjusting the cost cascading principle in order to take into account reverse power flows may lead to significant impacts on network users. Increased distributed generation might require introduction or increase of tariffs for production, while taking into account that network charges should not discriminate positively or negatively between production connected at the distribution level and the transmission level. Subsequently distribution tariffs applied to customers with energy storage facilities should reflect the use of the network in terms of both energy withdrawal and injection. CEER (CEER, 2020) considers that any double charging for storage facilities should be avoided.

Changing distribution tariffs may also imply welfare transfers between different customer groups, which can be politically sensitive. According to (CEER, 2017), all tariff structures reflect multiple objectives, which need to be balanced and these may evolve over time. They may also differ from country to country. Tariff design therefore requires careful planning and there is a need for effective management of transitions.

5 Developments in tariff design in the – legal and economical

This section provides an overview of the developments in tariff regulation since the previous NordREG report on tariffs from 2015, (NordReg, 2015). For each country, the development in energy markets, legislation and tariff principles are described.

5.1 Development of DSO tariff design in Finland

5.1.1 Latest developments

A price cap regime was introduced in the national Electricity Market Act in 2017 allowing a maximum price increase of network tariffs within a rolling twelve-month period of 15 percent. The overall principles for DSO tariffs have remained the same.

5.1.2 Overall principles

According to Electricity Market Act distribution tariffs must be fair, equal and reasonable. Tariffs for consumers must be clear and understandable. No terms or conditions are allowed that are detrimental to energy efficiency or overall efficiency of production, transmission, distribution and sales. Subsequently no terms or conditions are allowed that are detrimental to providing demand response to markets or keep retailers from providing system operation services for demand flexibility or control. Tariffs must also take into account the costs and benefits of demand flexibility and demand management measures. Finnish NRA does not approve the methodology of the tariffs or the tariffs themselves.

5.1.3 Tariff structure

Despite the fact that there are several provisions in the Electricity Market Act for tariffs, current tariff structure in Finland has been based on the principles of cost-recovery, non-distortionary and predictability. Cost-reflective allocation of costs has been the main driver for the gradual increase of fixed fees and the introduction from few DSOs of power-based tariffs for consumers in Finland.

For smaller customers the tariff is traditionally based on two components: an energy-based component and a fixed component. The fixed component is often adjusted according to the dimension of the main fuse. A time-differentiated component may also apply. During the past three years, five distribution network companies have introduced a power-based component for consumers. For all customers, including larger customers, there are currently 19 different versions of defining a power-based price component at use in Finland. A harmonization project of DSO tariff components will start with a working group of Energy Authority in November 2020.

5.1.4 Energy production and consumption

The move towards the green transition has started in Finland. Individual solar panels connected to the DSO grid in Finland have increased 630% from 2016 to 199 968 solar panels connected to the DSO grid in 2019. Electric vehicles registered in Finland have also increased almost 800% from 2016 to 40 315 EVs registered in 2019. There are also several battery storages connected to the distribution grid in Finland. However, the consumption of electricity in Finland has not been increasing significantly in recent years.

5.1.5 A push towards power-based tariffs

Although there have not been dramatic changes in the general distribution tariff design in Finland there is a clear trend towards power-based tariffs. Tampere University of Technology has in a report from 2019 for Energy Authority studied the effects of different tariff designs for different customer groups. Tampere University of Technology found that increasing the share of fixed fees in the current tariff design can be to note that high proportion of fixed fees are more affordable for customers, who use more electricity, but for low-power customers, the situation is different, as, for example in the case of a customer group consisting of summer cottages and apartment building homes. Moving towards power-based tariffs would thus mean an increase in the overall tariff level of these low-power customer groups. Assumption of the study was that both OPEX and CAPEX costs are divided to tariff components based on fixed fees and power-based charges. The study also indicated that effects in rural networks and urban networks can be quite different across customer groups and tariff variations. This indicates the importance of considering equality among different customer groups when making changes to tariff design.

5.1.6 Future developments

Even though the green transition has accelerated the need for change in tariff design, there is a contradiction between the goals of energy efficiency and increasing proportion of fixed fees in the Finnish DSO tariff design.

The Smart Grid Working Group of Ministry of Economic Affairs and Employment has a positive view on replacing the fixed charge with a power-based component, which provides customers with better opportunities to influence their distribution network bills. The Finnish Energy Authority has also set up a Smart Grid Forum’s sub working group for harmonization of DSO tariff components that will start its work in November 2020.

5.2 Development of DSO tariff design in Iceland

5.2.1 Latest developments

The overall principles for DSO tariffs have remained the same since 2015.

5.2.2 Overall principles

According to regulation no 1040/2005 on the implementation of the Electricity Act no. 65/2003, DSO tariffs must be non-discriminatory, objective, and transparent. The tariff shall be structured in such a way that it encourages improved utilization of the distribution system outside peak hours, e.g., with time-differentiated components.

5.2.3 Tariff structure

The same tariff shall apply in the distribution zone of each DSO for the consumption of low voltage electricity, i.e., 230-240 V. If the energy from the distribution system is delivered at a different voltage, the tariff may be adjusted accordingly. Other differences in services, such as reduced quality of supply may be considered.

DSOs are permitted to apply to the NRA for permission to maintain a separate tariff for rural areas where the cost of distribution is demonstrably higher than in urban areas. The condition for permission to maintain a separate rural tariff is that the use in the rural area in question must amount to a minimum of 5% of the total use in the distribution zone of the DSO

The regulation states that both energy (volumetric) and power-based tariffs should be available. It is not explicitly stated whether those tariffs should be available for all customer groups, respectively.

The energy-based tariff has a fixed component and a volumetric component. Power-based tariffs have a fixed component, a volumetric component, and a power component plus a phase deviation charge. Energy-based tariffs traditionally apply to smaller customers where the fixed fee is adjusted according to the dimension of the main fuse (A) and the components may have different time-differentiated components (e.g., night-day-evening division and/or winter-summer).

Power-based tariffs may be set for unmeasured use, e.g., outdoor lighting or other small uses where it is impractical or inefficient to measure electricity. The power charge generally has a higher price for the fixed component and a lower fee for the energy-based component and is thus more appropriate for larger customers.

There are various versions between the DSOs in terms of defining both energy-based and power-based price component. The association of the Icelandic electricity industry (Samorka) has been working on a harmonization project for the DSO tariffs for the past year.

5.2.4 Energy production and consumption

Almost all electricity produced in Iceland comes from a renewable energy source. Electricity produced from small renewable utilities (smaller than 10 MW) has increased in recent years. Energy consumption from the distribution system has not increased in recent years in terms of energy (kWh). However, electrical vehicles (EV’s) registered in Iceland are rapidly increasing, resulting in more demand for capacity in the system. Some of the future challenges for DSO tariffs are charging points installation for EVs in the distribution system (both urban and rural) and whether it is necessary to modify the DSO tariff further in terms of more capacity driven demand.

5.2.5 Future developments

The NRA plans to publish rules and/or guidelines on tariff structure for further harmonization of customer groups between DSOs.

5.3 Development of DSO tariff design in Norway

5.3.1 Latest developments

In recent years, RME (Norwegian regulatory authority for energy) has worked on developing a new, more power-based tariff design in order to achieve more cost-reflective tariffs.

5.3.2 Overall principles

According to the tariff structure regulation, all DSOs are responsible for determining tariffs within their allowed revenue. The DSO should set the tariff level in a way that stimulates efficient utilization and development of the network, and in a way that is non-discriminatory. The regulation also states that the tariffs can be differentiated based on network related criteria that are objective and verifiable.

5.3.3 Current tariff structure

In Norway, customers with an electricity consumption higher than 100 000 kWh per year have cost reflective tariffs, with an energy component covering marginal cost of transportation, and a lump sum plus a capacity component covering residual fixed costs. The capacity component ensures that customers with a high power demand pay a higher tariff than the customers with a low power demand.

Tariffs for customers with less than 100 000 kWh yearly electricity consumption are predominantly based on the consumers' electricity consumption, with a smaller fixed component and a larger energy component. For a typical customer, the energy component constitutes 2/3 of the network tariff, while the remaining 1/3 is covered through a fixed component.

Cost reflectiveness and lack of incentives to reduce power consumption are areas to improve regarding the Norwegian tariff structure. In theory, a cost-reflective energy charge should only cover the marginal cost of transporting electricity from producer to consumer. This is much lower than today's energy charge, and closer to 1/6 of the total tariff. Furthermore, the fixed charge is a yearly lump sum, equal for all household customers within a DSOs geographical supply area. There is no differentiation between household customers with high power demand and household customers with low power demand, and thus no incentive to restrict power consumption. In total, this affects the distribution of cost, and customers' measures to save energy or reduce power demand does not reflect the associated potential tariff reduction.

5.3.4 Energy production and consumption

Like other countries, Norway is experiencing more local production as well as more power-intensive consumption. For example, the number of EVs is increasing, and is estimated to reach 1.5 million by 2030.

Looking forward to 2040, we expect an increase in the overall consumption, despite an expected decrease in consumption for households and commercial buildings due to energy efficiency. The main reasons for the expected increase relate to electrification of industry and transportation. In addition, we expect to see more power-intensive industry, such as hydrogen production and data centers, being established for the years to come. We expect the energy production to increase in line with the increase in consumption. The production will increase mainly due to new hydro power and upgrades to existing hydropower plants, but also due to new wind and solar power.

The recent and future development regarding energy production and consumption requires that the consumers be faced with a cost-reflective tariff structure which provides as accurate price-signals as possible. This will help ensure an efficient use of the electricity grid.

5.3.5 A push towards more cost-reflective and power-based tariffs

In 2017, RME proposed a shift to a model of subscribed capacity. The model was based on a subscription level of power consumption and an overspending component (per kWh) during hours where the customer exceeded the subscription level. However, stakeholders were critical and thought that such a model could be too complex for customers to understand, and that it would be difficult to implement in practice. DSOs also commented that they would like to have the opportunity to implement other models, such as measured capacity and variants of time-of-use.

RME presented a revised proposition in February 2020. The proposition takes a more principle-based approach, with an emphasis on the division of costs between various tariff elements, rather than enforcing only one tariff model. Importantly, the new regulation will make a distinction between fixed and variable costs.

As such, future tariff models shall consist of an energy charge, equal to the cost of marginal losses, when there is sufficient capacity in the network. When capacity is expected to be constrained, the DSO may use time-of-use principles, setting the energy charge higher to incentivize reduction of consumption. However, this price should, in principle, be capped at the long-term marginal cost of expanding the network.

Finally, the remaining residual costs will be covered through a fixed charge differentiated by the individual customer’s demand for power. This charge will, in practice, be fixed in the short-to-medium term but can be affected by investments or lasting behavioral changes. Thus, the consumer also has an incentive to optimize the long-term utilization in accordance with the actual willingness to pay for the network service. Power consumption could also be time differentiated, to ensure that consumers utilizing the network in constrained hours pay a higher share of the residual costs.

5.3.6 Ongoing and future developments

After the public consultation, RME has recommended that the tariffs for low-voltage outlets in the distribution network shall consist of a fixed charge (NOK/year) and an energy charge (øre/kW). The tariffs for industry customers with an annual consumption of more than 100 000 kWh may also include a power component (NOK/kW).

The fixed component shall be designed so that the customer covers a reasonable share of the fixed costs in the network and be differentiated based on the customer's demand for power. The fixed charge does not need to be differentiated for industry customers if the DSO chooses to include a power component.

The energy charge shall as a minimum cover marginal loss. The energy charge can have a surcharge when the grid is heavily loaded, to allow for critical peak pricing or time-of-use pricing. It can also cover a share of the DSOs fixed costs, but the revenues from the energy charge cannot exceed 50% of the DSOs tariff revenues from a customer group.

5.4 Development of DSO tariff design in Denmark

5.4.1 Latest developments

The tariff regime for DSOs in Denmark has not changed much in recent years. The overall principles for DSO tariffs have remained the same.

However, in June 2020 the Danish government has published recommendations for a future tariff design for DSOs in the electricity sector. The purpose of the work was to identify potential for a more cost-reflective tariff structure and give recommendations for changes in the law to support this. The recommendations are mostly overarching principles and guidelines for a future tariff design and not concrete law or regulation on a new tariff regime.

Also, the Danish Energy Association and the Danish TSO, Energinet, are in the process of developing a suggestion for a future tariff design in Denmark for the Danish electricity DSOs and TSO. The Danish Utility Regulator (DUR) must approve the new tariff methods.

5.4.2 Overall principles

As described in the previous NordREG tariff report (2015) it is still the case that:

- Prices for the DSOs' services must be set in accordance with the revenue cap, which are set to cover cost for an efficiently operated grid.
- Grid tariffs must be set in a fair, objective (cost-reflective) and non-discriminatory way, according to the costs that the respective consumer groups apply. Price differentiation for the sake of effective use of the grid and security of supply are legal.
- The DSOs are obliged to report their tariffs and to announce changes in the tariff method to DUR. DUR must determine whether to approve or decline the method. After DUR has approved the method, the DSO can use the approved method to set the tariffs.

The industry organization, Danish Energy Association, has made standardized guidelines for the tariff method to set the tariffs (called *Tarifmodel 2.0*). DUR has already approved this tariff method. Most DSO follows the Danish Energy Association's standardized guidelines, wherefore DUR can make "fast track" decisions regarding these DSOs' methods. If the DSO's method derogates from the guidelines, DUR must make a specific decision to approve the DSO's method according to whether the method with that derogation to the standard fulfills the principles in the law.

5.4.3 Tariff structure

The tariffs in Denmark are mostly volumetric (energy-based). The tariff for households and smaller customers (and larger customers connected to the DSO grid) consists of a fixed component and an energy-based component, where the energy-based component can be time differentiated.

The tariff structure for DSOs follows the cost cascading principle, where each customer pays for the voltage level of connection and the voltage levels above. The DSO tariffs are set based on the revenue cap and cost allocation to different customer groups based on their connection point. Afterwards, the costs allocated to the group are decided to be fixed or variable in regards to whether the costs should be recovered by a fixed or variable tariff. Cost types based on consumption are mainly tariffed as a part of the variable tariff, whereas non-consumption-varying cost types like administration and metering are tariffed as a part of the fixed tariff.

There is only a small variation in the tariff structure amongst the Danish DSOs, but there can be substantial variation in the fixed tariffs amongst the DSOs.

The network tariffs accounts for about 15% of the total price on electricity due to the high electricity taxes.

5.4.4 Energy production and consumption

Recommendations from the Danish government published in June 2020 state that there has been a huge increase in renewable energy sources in Denmark, especially land windmills and solar panels, which has led to (and is expected to continue to lead to) an increase in distributed generation. This challenges the cascading principle. The increase in electric vehicles and EV charging points might also increase the demand for capacity in the grid unless the existing capacity is used more effectively.

The current tariff regime is not cost-reflective due to the changed electricity landscape with increased decentralized production and higher risk of bottlenecks in the grid due to electrification.

Two main barriers are emphasized in the recommendations from the government from June 2020: 1) Geographical differentiated tariffs are not allowed despite local bottlenecks, and 2) Zero generation tariffs despite increasing renewable energy sources and distributed generation. Therefore, one of the recommendations is that it must be considered to implement cost-reflective generation tariffs and connection fees for producers, to ensure a greater match between who requires the cost and who pays for the cost. The generation tariffs and the connection fees should both be geographically differentiated to incentivize a more appropriate location of the renewable energy sources in the grid.

5.4.5 A push towards power-based tariffs

In Denmark, all DSOs must have implemented smart meters ultimo 2020 making it possible to have power-based charging hourly for households and thereby power-based tariffs.

The government's recommendations do not concern concrete recommendations regarding the design of consumption tariffs, but it is assessed that there are no barriers in the law regarding more time-differentiated tariffs. One of the recommendations is that the sector composes a new tariff design for DSO and TSO, which to a greater extend reflects the marginal cost of grid use and encourage flexibility in the electricity consumption, like high degree of time-differentiated tariffs and a power-based component in the tariffs.

The project between the Danish Energy Association and Energinet is aimed at creating a new tariff design with more time-differentiated tariffs on both DSO and TSO level and a fixed power-based component on higher voltage levels.

5.4.6 Future developments

We expect to see a change in the tariff design soon, since the sector has been working on a new tariff design (*Tarifmodel 3.0*), which they have now announced to DUR, and DUR must then approve or decline the new tariff method.

One of the recommendations the Danish government has published in June 2020 states that it must be considered whether to give DUR the mandate to set requirements to the tariff design/method in the future, e.g. mandate to set these in a notice.

5.5 Development of DSO tariff design in Sweden

5.5.1 Latest developments

In 2019, Ei was given the mandate to publish a notice on how the DSOs shall design tariffs in order to promote an efficient use of the grid. With the implementation of the energy efficiency directive from 2012 and a new rule in the Swedish Electricity Act that tariffs must promote an efficient use of the grid, few DSOs have changed their tariff design. There can be many reasons for this, for example, it is not clear what is meant by an efficient use of the electricity grid. Due to the lack of changes in the tariff structure Ei suggested to the government that Ei should have a mandate to publish a notice on how to design tariffs that promote an efficient use of the grid. In 2019 Ei started a project in order to find out how tariffs can be designed to promote an efficient use of the grid. The project is still ongoing and is projected to finish in 2021.

5.5.2 Overall principles

The rules for the design of electricity network tariffs are set out in the Electricity Act. The DSOs defines the tariff methodology by themselves and is not subject to NRA approval. Ei does not approve the tariffs but only reviews them in cases where complaints are received.

The Electricity Act states that the tariffs must be objective and non-discriminatory. The fact that the tariffs must be objective means that they must reflect the costs in the network that each customer group causes. Non-discrimination means that no special treatment in tariffs between network users may take place.

The tariffs shall be designed in a way that is compatible with an efficient use of the electricity grid and an efficient electricity generation and use. DSO tariffs may not be designed with regard to where a connection is located. Since 2019, an opportunity has been introduced to test a certain tariff for a limited number of electricity users (so-called pilot tariffs). These provisions state that such a tariff may be applied if necessary, to develop network tariffs that promote the efficient use of the electricity grid.

5.5.3 Tariff structure

For smaller customers, the tariff has historically been composed by two components. One fixed component, based on the size of the fuse, and one energy component. For the main part of the customers the tariff is not time-differentiated. Since the NordREG report from 2015, it has become increasingly popular with a power-based component in the tariff structure. In the tariff data for 2020, 17 DSOs stated that they offered tariffs with a power-based component to customers with a fuse of 63A or lower. For larger customers it is more common with a power-based component instead of the fixed fee based on the fuse. It is not unusual that the power-based tariffs have some sort of time-differentiation, either by season or by time of the day.

5.5.4 Energy production and consumption

On the production side, Sweden has historically had a lot of centralized production from large scale hydro- and nuclear plants. In the last two decades, it has, however, become increasingly popular with more local production. In the reports to Ei from 2013 the DSOs reported around 4 000 local production subscriptions. The same number for 2019 was around 40 000 subscriptions to producers. The amount of local energy produced has increased by 224 percent for the same time period to 16.14 TWh in 2019. A lot of this increase comes from wind power generation (the largest impact on the locally produced energy) and small scale photovoltaic solar power (many facilities but relatively small change in energy produced).

On the consumption side there has been a steady increase in the number of electrical vehicles (EV) during the last years. Only in 2020 from January to September there have been more than 16 000 new EVs registered, more than was taken into traffic during the whole 2019. Also, hybrid cars are becoming increasingly popular with around 68 000 new cars registered from January to September 2020.

With more variable, weather dependent, production in combination with the electrification of the transport and industry sector, it becomes more important to send correct price signals to the end-users to adjust their load and use the grid efficiently. We already see companies and aggregators coming up with new ideas and technologies to steer load away from the peaks. By sending correct price signals through the tariffs it is likely to become increasingly popular in the future.

5.5.5 Can power-based tariffs solve congestion?

The need for electricity and electrification is increasing both globally and within Sweden. Driving factors are urbanization, population growth with increased housing construction, automation and electrification of industries. Recently the increased demand for electricity locally has led to a shortage of grid capacity in Sweden's growth regions. Ei has identified that one way to reduce capacity shortages and use the network more efficiently is to apply cost reflective tariffs, with high temporal and geographical resolution.

5.5.6 Future development

We are currently experiencing a rapid development in the field of tariffs. Many DSOs state that they see potential in flexibility and more active consumers. At the same time there is a debate regarding the capacity in the grid. The work with new regulation will hopefully in the long run lead to more cost-reflective tariffs, were the customers face and react to correct price signals from the DSOs.

An entirely cost reflective tariffs would lead to large changes in tariffs for many customers, in particular for small consumers. It might also be too complex for consumers to understand, risking no or an incorrect response on the price signals.

Different grids might have a need for different tariff structures depending on the conditions in each grid. An expanding grid might for example have need for a larger power-based component when capacity is becoming scares, while another grid in a depopulating area with excess capacity probably does not have the need to for power-based prices.

It might therefore be most beneficial for society in the future that the DSOs, who have the best knowledge of their grid, still have some degree of freedom when designing their tariffs and that they take more than the principle of cost-reflectivity into account when doing so.

5.6 Common trends in the Nordic countries

In this chapter, we have presented the ongoing trends in the energy markets and the tariffs for each of the Nordic countries. All the Nordic countries face similar challenges as the ones described in chapter 3, with more decentralized, intermittent production, ongoing electrification of the transport and industry sector, and more information and technical solutions available.

In most of the Nordic countries, it is stated in the legislation that tariffs should be objective and non-discriminatory. Relating this to the principles described in chapter 4, objective tariffs means that they are cost-reflective and non-discriminatory relates to the principle of non-distortionary tariffs.

In practice, smaller consumers face volumetric tariffs in all the Nordic countries with a relatively large energy component. In chapter 6, we will look deeper into the tariff structure for household consumers.

The trend in the Nordic countries seems to lean towards more cost-reflective tariffs, where a larger part of the tariff might be power-based. All the Nordic countries have also specified that the tariffs need to steer toward efficient network utilization.

6 Customer-focused considerations in tariff design

In this chapter we will present pilot projects regarding electricity consumers and consumer behavior. Then we will look at the cost structure in each Nordic country compared to the tariff structure for household consumers. Finally, we will discuss the results from the previous chapters of the report.

6.1 Studies and pilot projects

As mentioned in the introduction, although many pilot studies have been conducted regarding optimal tariff structures in the electricity sector, relatively few studies have been found with the primary focus on electricity consumers. This section will highlight some of the more extensive papers from the existing literature, as well as addressing some specific pilot studies of relevance for the Nordic context.

6.1.1 Meta studies on consumer behavior and tariff structures

In *A Meta-analysis of Time-Varying Rates for Electricity* (Faruqui, Sergici, & C., 2017), the authors look at how electricity consumers change their behavior as a response to price signals during respectively high and low loads in the grid. To take it further, the paper also addresses whether the effect in responses changes with technological aid, such as steering equipment. In this study, data from over 300 tariff experiments conducted between 1997 and 2017 was used. The results obtained indicate that electricity consumers responded to price-signals by reducing their consumption during peak hour with relatively high prices. The consumer response increased as the difference in price increased between peak and off-peak times. The same results were obtained for all tariff-structures that was tested. Furthermore, the effect on consumer behavior was magnified when the consumer had access to technological equipment that helped them to monitor and change their consumption in line with the price signals.

Similar results were presented by (Faruqui A. , 2014) using an earlier version of the same dataset. The results indicate a larger customer response on power-based tariffs. This is explained by a larger difference in price between peak and off-peak times. In general, they find that the greater the price-signal, the larger is the response to shift load.

Looking at a softer approach for customers to adapt to a more efficient network utilization, (Pöyry och Menon Economics, 2019) made a consultant report describing behavior economics and what effect it might have on consumption. They investigate how non-economic incentives can be used to change consumers behavior. What they find is that consumers must understand the price signal, how they can adjust to it, and why they should contribute to the system beyond the economic incentives. Information about non-economic aspects, such as environmental impact and integration of renewables, was some of the actions deemed to have high potential for making consumers willing to adjust their consumption.

6.1.2 Specific pilot studies of relevance to the Nordic context

In recent years Norway has been working on a transition towards a more power-based tariff structure. During the work process multiple reports and pilots have been conducted. In a report based on a survey done by Trøndelag R & D Institute (NVE Report 2016: 86) consumers‘ attitude regarding various designs of capacity tariffs were evaluated based on a survey. They found that consumers in the study will accept changes in their network tariff if it is possible for them to understand why the change is made, how they are supposed to change their behavior, and what the consequences could be if they do not change their behavior. The feedback makes it clear that changes made to the tariffs must be clearly communicated and explained to the consumer beforehand.

The results from the survey were confirmed in a pilot study conducted by Lyse Elnett4. The study points out that consumers had difficulties changing their behavior regarding energy consumption. For consumers to be able to focus more on their own consumption, they want to be able to follow their own consumption in real time, ideally in combination with a control system. Furthermore, the consumers had difficulties understanding the difference in the concepts of energy and power. This highlights the importance of useful information for consumers beforehand. The study also shows that for the consumers to change their behavior, they require a relatively large price reduction in their tariff.

Currently, there are two ongoing pilots in Norway addressing, how to implement a new tariff structure in a way that is easy for the consumers to understand and react to. The pilot “Aktive Hjem” (active homes), conducted by Elvia, will test different communication strategies, and observe how the different strategies lead to behavioral changes among consumers. In “Smart Nettleie” (smart tariffs) by Glitre Energi Nett, it is highlighted that a new tariff structure must be easy for the customer to comprehend. Preliminary results from this study indicate that a significant tariff reduction is needed for customers to change their behavior.

In Denmark, two pilot studies with time-differentiated tariffs have been conducted by SEAS-NVE, “Win with new electricity habits” and “Flyt dig”. In the pilots, households with smart meters, no electrical heating, and no solar panels were included in the test group. The tariff varied over three different timespans, daytime, night, and peak. No technical aid was given to the consumers to help them adjust their consumption. In ”Win with new electricity habits”, electricity was free during the night and the price were high during peak. This led to a change in peak consumption to early night, were the new peak was higher than the peak prior to the new tariff structure. The significant difference in price made the participants shift much of their consumption to times when the price was low. In “Flyt dig”, there were only minor differences between peak and other timespans. Focus in the pilot was on information and education of the consumers. The results were a change in consumer behavior, which led to less total energy consumed and lower peaks. In both studies the participants stated that they had lost interest after a while. In “Flyt dig” the changes seemed to be lasting despite the loss of interest. The results from the pilots show the importance of correct, and not too strong, price signals. Also, the results indicate that information and education can give lasting changes to consumer behavior.

Other studies of relevance to the introduction of new tariffs can be found all over the world, some examples are pilots in Great Britain, which support the plausibility of shifting load due to time-differentiated tariffs. In France, there was an early version of dynamic tariffs, the Tempo Tariff, with red, yellow, and green days in combination with time-differentiation, where quite effective results were obtained. In California, there was a pilot before the entire state shifted to time-differentiated tariffs. The findings were that consumers adapt to new price signals and that the effect is larger with technological aid. In Ontario, time-differentiated tariffs have been an option for all consumers since 2013. They have since conducted pilots to further develop the tariffs. The results are similar to

[4] “Analysis of testing of tariffs among customers” – pilot conducted by Lyse Elnett AS

those in the other studies; significant differences in the tariff between low and high load increased consumer response. Non-economic actions such as information and education reduced the peak consumption.

To sum up, consumers respond to price signals. The greater the signal, the greater the response. The response to price signals is enhanced by technological aid, such as automatic steering equipment. Customers in the pilots tend to welcome stronger price signals if it is clear how and why they should respond. Non-economic factors such as nudging, more information, and education have a significant impact on the response from the consumers.

Related to the customer-oriented principles mentioned in chapter 4, it is clear that these principles are of importance for an efficient tariff design. For consumers to respond to the price signals, it is important that the principles of simplicity, predictability and transparency are considered when the DSOs are designing the tariffs. Without understanding the tariffs, consumers will not be able to respond to the price signals and could develop a negative attitude towards the DSO. With information, education, and predictability, it is plausible for the DSO to improve their relations with the consumers while at the same time achieving the desired behavior from the consumer. Customer-oriented principles are important complements to cost-reflectivity when designing tariffs for efficient use of the grid.

6.2 Cost structure vs. tariff structure

To identify how cost-reflective tariffs actually are, we look at the accumulated cost in each of the Nordic countries, identify a variable component and from there evaluate how it is reflected in the household tariff.

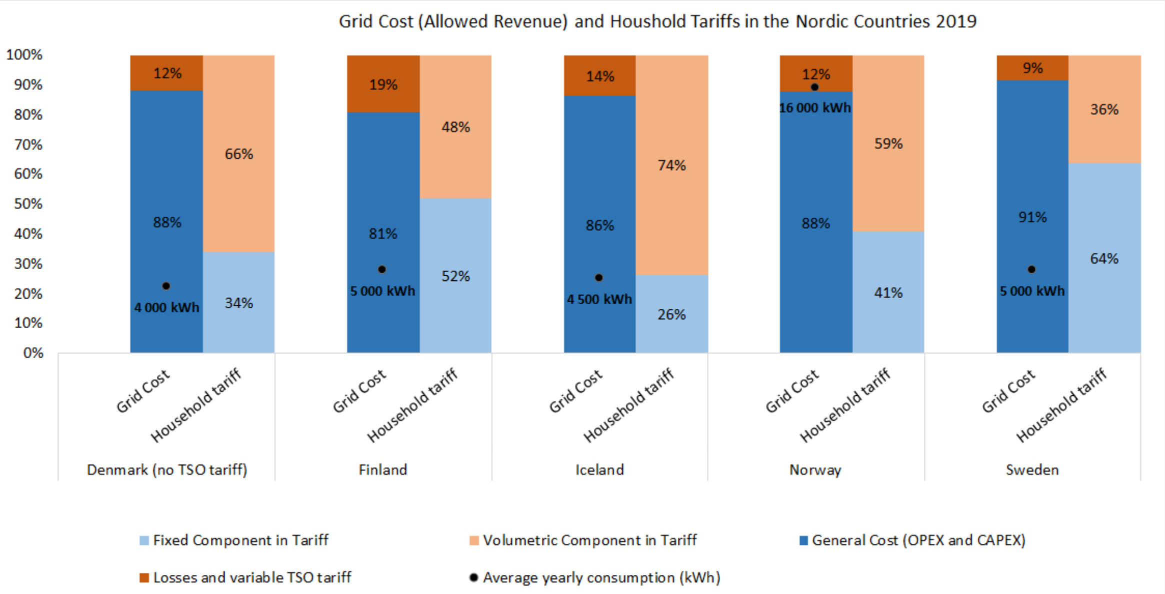

Figure 1 – Tariffs and Costs

Figure 1 shows accumulated network costs in each of the Nordic Countries, split between general cost and costs form network losses and variable TSO charges, retrieved from the total revenue cap (allowed revenue) for DSOs. The costs of network losses and variable

TSO tariffs are part of the DSOs' costs that are affected by consumer behavior and therefore should be treated as variable in the short run. The forward-looking costs have not been plausible to determine based on the data available; it is also important to have in mind that forward-looking costs should only be included for those hours with capacity constraints in the grid for those grids that suffers from congestion. The network costs are compared with the most common household tariff[5] which has a volumetric and fixed charge. The household tariffs are based on a yearly average consumption for one specific customer group[6]. The average tariff for each country is weighted in terms of energy consumption. Note that the average yearly consumption differs between the Nordic countries. While Denmark, Finland, Iceland and Sweden on average have a consumption of 4 000 to 5 000 kWh/year, Norway has a consumption of 16 000 kwh/year.

Figure 1 does not reflect a perfect picture of the cost components in the tariffs, since it only represents a part of the revenue (tariff from one customer group) and a part of the energy consumed in the system. The cost structure for the DSOs also varies over time, with higher losses and higher TSO tariffs (given that there is a variable part in the tariff) when the load in the grid is high. The cost structure also depends on the local prerequisites for each grid. With excess capacity, the network losses will be lower than in a constrained grid and there will not be a need for any forward-looking component. This is further explained later in this chapter.

Figure 1 gives an indication of how the tariff is related to the costs in the Nordic countries. At first sight, it suggests that the household tariff, contrary to the grid cost, covers more cost through volumetric charge. The overall structure is similar in all countries for both the cost structure and the tariff structure. Sweden has a higher proportion of fixed component in the tariff than the other Nordic countries.

Different approaches to TSO charges might explain some of the differences between the grid costs in the Nordic Countries. TSO charges are not a part of the DSO cost structure in Denmark. In Finland 100% of the TSO cost is treated as variable cost, in Sweden around 40% of the TSO cost is volumetric, and in Iceland 38% of the TSO cost is volumetric. This explains why variable costs in Finland are higher than in the other countries.

Figure 1 implies that households, which use a lot of electricity, pay more than the cost they inflict on the grid, due to the high proportion of volumetric charge, while households with lower electricity consumption pay less. Too strong price signals can entail too low consumption relative to what is socioeconomically efficient. With a high volumetric charge there is a risk that too small an amount of energy will be consumed, which might hinder the electrification process in the countries. On the other hand, a customer with only a fixed charge has no economic incentive to change his behavior to benefit the system. However, a fixed charge up to a certain volume and/or an added capacity charge with a lower volumetric charge instead, might add to the cost-reflectiveness for this

[5] The tariff *excludes tax* and is based on a weighted average in terms of energy consumption. The most common tariff to households is typically without a capacity charge.

[6] The Swedish household tariff here is based on a fuse size of 0-16A, where the next customer group would have fuse size of 16- 20A. The Icelandic household tariff here is based on a fuse size of 0-80A, where the next customer group would have fuse size of 81-160A.

customer group (small households). Such a change would need to be considered in terms of the situation in the system as well as an awareness of avoiding an unfair shift of compensation from richer to poorer consumers (Schittekatt & Meeus, 2018) or from industry to household.

It is important to note that Figure 1 only represents one customer group[7]. To get a deep understanding of the tariff structure of the entire system in each country, further analysis of different customer groups, time-differentiating, and locational signals are needed.

6.3 Discussion

In this chapter we will discuss what we found out in the sections above.

There seems to be a push towards more cost-reflective tariffs in the next couple of years. It is not yet clear in all the Nordic countries how the more cost-reflective tariffs will be designed. Options include further emphasis on time-differentiated tariffs, power-based tariffs at a lower capacity level, nodal tariffs, or otherwise geographically differentiated tariffs.

6.3.1 What is the goal?

From the Energy efficiency directive, one goal is to achieve a more efficient network utilization. From an economic point of view, it is also a goal to have as cost-reflective tariffs as possible.

In theory, cost-reflective tariffs lead to more efficient use of the network, because customers will act according to their preferences given the price on usage of the grid. However, for consumers to adapt and respond to price signals, it is important to consider consumer-related principles. This is due to the notion that prices in the electricity sector are not so easy to relate to for customers compared to other sectors. Therefore, it requires a greater effort to make the price signals simple, transparent, and predictable for electricity customers to react.

In the short term, efficient network utilization means using existing network resources as efficiently as possible. The price signals must inform customers about the costs of using the network at different times. Customers react by moving their load based on their preferences to the price signals. However, it is not a goal in itself to get consumers to react. They should only react according to their preferences, if the willingness to pay is higher than the marginal cost, the welfare will increase by a transaction. As long as the tariffs are cost-reflective and consumer-related principles are followed, the goal of a more efficient network utilization is manageable to obtain.

More efficient network utilization can lead to lower costs in the long run for customers, since the grid is used in a more flexible way, wherefore investments in the grid can be avoided or postponed.

[7] In Iceland, the household customer group (0-80A) pays for 57% of the DSO revenue and utilizes 38% volume in the system.

6.3.2 Obstacles to more efficient use of the grid

The goal of achieving efficient network utilization through tariffs presents a challenge. The tariffs need to be theoretically correct, i.e., being as cost-reflective as possible, and still taking DSO-oriented and customer-oriented principles into account to be functional.

The difference between energy efficiency and capacity efficiency needs to be considered. The primary goal with cost-reflective tariffs is to incentivize more efficient use of the grid. This does not necessarily require less energy consumption, but more flexible energy consumption, taking the peak capacity of the grid into account. It is important to remember that electricity network tariffs are only one part of the overall electricity price. Retail prices also give incentives to reduce energy consumption based on the cost structure in the retail market. Taxes and levies set by the government further strengthen the incentive for energy efficiency. Hence, a smaller energy component in the network tariff might only have a small impact on the total incentive for energy efficiency.

6.3.3 The effect of changing the tariff structure for the consumer

Based on the cost structure and the average tariff presented in Figure 1, a more cost-reflective tariff might lead to a reduction in the energy-based component of the tariff and a rise in the fixed component. This might imply an increase in the network tariffs for smaller households and a reduction for smaller industries given that their consumption does not change and they pay the same fixed component.

Changing the tariff design affects cost allocation, i.e., how cost should be covered and by which customer groups. Implementing more cost-reflective tariffs will not necessarily change the total bill for an average electricity customer in the short term. However, over time the changes in the tariff design will contribute to avoiding or postponing investments in the grid. This will lower the cost of the grid in the long term, implying that network costs will be lower than they would have otherwise been. Therefore, one could say that more cost-reflective tariffs in the long term are beneficial for the regular electricity grid customer since the tariff design might save costs for the DSOs and thereby the customers.

The effect of more cost-reflective tariffs might overall be beneficial for very price elastic customers and unfavorable for very price inelastic customers, ceteris paribus. For example, one can assume that a family with children living in an apartment will be more time restricted regarding cooking and washing and other electronic devices, than a single person living in a house, who can more easily change his/her consumption pattern. One could also imagine that some small industries might have an easier task of moving their consumption than other small industries. Whether this is fair is a political question to raise, but it does not change the fact that economically speaking the price of using 1 kWh in the grid should still be as cost-reflective as possible. What is cost-reflective can vary over time and location. One could imagine that owners of EVs and heat pumps might be more price elastic to the network tariff, especially with the development in technological aids and the role of aggregators helping to control consumption for smaller households.

For DSO systems like the ones in the Nordic countries most of the costs are residual costs (based on ex-post economic regulation). Residual costs are not consumption-dependent and are, for example, future costs of historical investments. Residual costs must be covered by the tariffs since they are a part of the revenue cap. How residual costs should be allocated through tariff design is the underlying question, since they often cannot be linked directly to certain customer groups. Theoretically, residual costs should be allocated to the end users' price in such a way that the price will not affect the marginal use of electricity. This can be done in different ways; by lump-sum fixed charges for the consumers; based on price elasticities, where inelastic users pay relative more than users with higher price elasticity (Ramsy-Boiteux pricing); or in proportion to the use of the network that is based on the connection. It can also be done through a combination of the three alternatives mentioned above; for example, a fixed lump sum for different customer groups, based on either their price elasticity or their maximum power-use of the grid. All the alternatives mentioned would increase the fixed costs for most of the customers in the short run.

A completely fixed tariff would not serve the goal of efficient utilization of the system since customers would not have economic incentives to use the grid in an efficient manner. Although, it was observed in some pilots according in the previous section that information and education also can help to change behavior without economic incentives; however, the change in behavior was found to be larger as the economic incentives got bigger.

Also, it is important to understand what costs are reflected by the revenue cap and what costs are reflected by the user. Different customer groups might inflict different costs on the grid in the long run. Therefore, it is important to allocate network costs accordingly between customer groups, and also be open to new kinds of customers and customer groups in terms of recent technologies, needs and the role of the DSOs.

6.3.4 Grid constraints over time or in certain areas

There are observed geographical differences within network areas. Some parts of a DSO's grid can be very restricted in capacity and experience regular congestion, whereas other parts of the DSO's grid have lots of free capacity available. The geographical differences usually apply to larger DSOs. Therefore, it will not be cost-reflective to have the same tariff for a given customer group in the whole DSO's grid. It should be less expensive to use the network in a less restricted area than in a restricted area. The price signals need to take this into account, and one possible development in the future will be geographical differentiated tariffs within a DSO grid.

One example of geographically differentiated tariffs is to use nodal pricing within the DSO to send correct price signals to all areas in the grid. The tariff can then be designed based on the different prerequisites that might exist within a grid and hence give correct price signals to all consumers.

This could also help the challenges with the increase in renewable energy sources and distributed generation in some areas. The importance of the timing of electricity consumption will increase as more intermittent, distributed generation enter into the system. One of the biggest challenges with distributed generation is that the supply seldom meets the demand for electricity during the day or during the season.

Whether it is fair that the customers resident in the area with lots of renewable energy sources pay higher (nodal prices) than the ones living in e.g., the city with less or no renewable energy sources might raise political questions that are out of the scope of this report.

7 Conclusion

Many papers and reports have been written on utility regulation and tariff structure. It is quite clear that setting a cost-reflective tariff structure that incentivizes efficient use both in terms of energy and capacity is not an easy task.

The regulator needs to carefully consider the balance between cost-reflectiveness and the other consumer- and network operator-oriented principles to achieve an efficient utilization of the systems. The wide variety of grid topologies in the systems and different combinations of users means that there are no one-size-fits all tariff structure.

Most of all, it is important that the regulator sets clear and transparent goals, where both the DSOs and the customers understand the price signals with both short term and long term usage of the system in mind.

In establishing these goals, it is also important for regulator to research further: what are the different customer groups and how they are changing? Are new customer groups being formed? What is the best way to set and calculate the actual capacity charge? And how do the tariffs and the price signals relate to the regional or TSO level?

With the changing energy landscape, it is certain that we need to look further into tariff designs in the Nordic countries to ensure more cost-reflective tariffs. We already today experience lots of capacity constraints in the network and we also foresee an increased demand for power in the coming years. Therefore, a power-based component in the tariff, even for smaller electricity users, might be necessary in the future to achieve more cost-reflective tariffs and thereby a more efficient usage of the electricity network through tariffs.

As mentioned, changing the tariff design to a design with a more cost-reflective tariff structure is not the only way to achieve the goal of a more efficient grid utilization. Flexibility services are another way to achieve a more efficient grid utilization, where smarter usage of the existing network can avoid further investments in the grid.

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