CEER

Council of European Energy Regulators

Fostering energy markets, empowering **consumers**.

Electricity Distribution Network Tariffs

CEER Guidelines of Good Practice

Ref: C16-DS-27-03

23 January 2017

Council of European Energy Regulators asbl
Cours Saint-Michel 30a, Box F – 1040 Brussels, Belgium
Arrondissement judiciaire de Bruxelles – RPM 0861.035.445

INFORMATION PAGE

Abstract

This document (C16-DSO-27-03) presents guidelines on how different electricity network tariff structures may be used to manage future distribution network challenges such as integration of embedded generation and increased self-consumption. The document also sets out where we are today, the need for change and principles of tariff design. The benefits of different approaches to tariff design are considered in the context of the challenges and opportunities facing the distribution networks in the future.

Target Audience

Internal CEER report for the Distribution Systems Working Group.

Keywords

Electricity, networks, prices, contracts, tariffs, affordability, quality of service, reliability, simplicity, vulnerable customers, tarrification, transparency, smart meters & smart grids, energy efficiency & energy savings, renewables, micro-generation, green offers.

If you have any queries relating to this paper please contact:
Mr Andrew Ebrill
Tel. +32 (0)2 788 73 30
Email: brussels@ceer.eu

Related Documents

CEER documents

- Principles for valuation of flexibility, A CEER Position Paper, Ref. C16-FTF-09-03, July 2016
- Renewable energy self-generation, A CEER Position Paper, Ref: C16-SDE-55-03, Sept 2016
- Scoping of flexible response, A CEER Discussion Paper, Ref. C16-FTF-08-04, May 2016
- The Future Role of DSOs, A CEER Conclusions Paper, Ref. C15-DSO-16-03, July 2015
- CEER Advice on Ensuring Market and Regulatory Arrangements help deliver Demand Side Flexibility, 26 June 2014, Ref: C14-SDE-40-03
- A 2020 Vision for Europe's energy customer, CEER and BEUC Joint Statement, 13 November 2012 updated in June 2014

ACER documents

- ACER Market Monitoring Report 2016, September 2016.
- Joint ACER-CEER response to the European Commission's Consultation on a new Energy Market Design, 7 October 2015
- Energy Regulation: a Bridge to 2025, Conclusions Paper, 19 September 2014

External documents

- Eurelectric position paper on network tariffs, March 2016
- Study on tariff design for distribution systems, Final Report Prepared for: DIRECTORATE-GENERAL FOR ENERGY and DIRECTORATE B – Internal Energy Market, January 2015

Table of Contents

EXECUTIVE SUMMARY

Network tariffs are used to recover the costs of operating and investing in electricity distribution networks. The recovery of these revenues should be fair and designed to incentivise efficiency in both network use and investment.

The fundamental changes in how distribution networks are used have been discussed elsewhere.[1] Developments include the integration of large amounts of variable renewable generation, the increase in self-generation and in the potential of smart meters, demand side flexibility and storage. The associated challenges and opportunities for distribution tariff design present a critical policy and regulatory challenge.

In that context, National Regulatory Authorities (NRAs) oversee tariff design to ensure there is the right balance between competing charging objectives, manage difficult, complex trade-offs between different options, considering impacts on all network users. NRAs ensure that they are fit for purpose within the context of the wider regulatory regime and industry structure specific to each Member State.

Work on the changing role and regulation of distribution networks is a priority for CEER, as set out in the Conclusions Paper on the Future Role of DSOs, which was published in July 2015. The importance of network tariffs was also mentioned in ACER's "Bridge to 2025" document. The purpose of this paper is to create CEER guidelines of good practice with the aim of both aiding NRAs in their future design of distribution tariffs, as well as agreeing common positions to effectively contribute to an already active debate in an area of core NRA competency.

Objectives and Contents of the Document

This guideline of good practice explores how distribution tariffs should be designed in the context of the transformation in the wider energy system by looking at:

1. Where we are today and the drivers for change.
2. Examples from across Europe about how different NRAs have met the challenges of distribution tariff design in different contexts.
3. Key principles behind distribution tariffs.
4. Key considerations in the application of those principles.
5. The characteristics and merit of different network tariff methodologies.

DSO costs are recovered mainly by tariffs for use of the networks, but also through other mechanisms, such as connection charges, regulated services or contractual arrangements with industrial customers and generators flexibility services. These guidelines only cover tariffs for use of the networks.

[1] http://www.ceer.eu/portal/page/portal/EER_HOME/EER_PUBLICATIONS/CEER_PAPERS/Cross-Sectoral/Tab1/C15-DSO-16-03_DSO Conclusions_13 July 2015.pdf

Brief Summary of the conclusions

Tariff structures may need to be reassessed regularly to ensure that they are still efficiently, and fairly recovering the costs of network provision whilst also sending appropriate signals to network users. All distribution network tariff structures must prioritise and balance multiple objectives. However tariffs are not the only tool DSOs have, to address the challenges and realise the opportunities created by the profound changes to the energy system. It is therefore important to be clear, practical and limited in the objectives of tariffs design. There are other tools and mechanisms to achieve wider goals.

As well as being fit for purpose in the present, tariffs also need to be resilient to anticipated future changes. There are no deterministic rules to determine the right methodology and CEER does not take a 'one size fits all approach' as there is a wide variation in the context in which DSOs operate and different approaches may be appropriate in different regions.

Further principles governing the relationship between the energy sector and its customers are outlined in the a joint statement from CEER and BUEC on the 2020 vision for Europe's energy customers.[2] We have identified seven key principles for distribution network tariffs listed below:

Seven key principles for distribution network tariff structures

- **Cost reflectivity**: 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;
- **Non-distortionary**: costs should be recovered in ways that avoid distorting decisions around access to and use of the network, and market offers;
- **Cost recovery**: DSOs should be able to recover efficiently incurred costs. As well as tariffs for use of the distribution system, DSOs may also recover costs through connection charges and regulated services;
- **Non-discriminatory**: there should be no undue discrimination among network users;
- **Transparency:** the methodology for calculating tariffs should be transparent and accessible to all stakeholders;
- **Predictability:** it is important that network users can effectively estimate the costs of their use of the distribution system, facilitating efficient long term investment by network users. However, the changing nature of the energy system means network tariffs will need to evolve over time;
- **Simplicity:** 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.

Seven key considerations in the application of the principles in the design of tariffs for use of distribution networks

---

2 http://www.ceer.eu/portal/page/portal/EER_HOME/EER_PUBLICATIONS/CEER_PAPERS/Customers/Tab3/CEER-BEUC%202020%20VISION-joint%20statement_Long_v161014.pdf

- **Network tariff design should, as far as possible, be future-proof**,
  Tariffs should not be a barrier to new technologies and innovative market offers from market actors that will add value or reduce costs for consumers, for example related to flexibility and energy efficiency.
- **Tariff structures should be sensitive to the different costs of network provision**
  These include the costs of providing capacity at peak, the costs of maintaining the grid, operational expenditure and losses etc. Each should be reflected appropriately through tariff structures. In the shorter term, a proportion of the DSO costs will not be related to load, and can be seen as residual costs that should be recovered in ways that are fair and cause the least possible distortion of network use. In the longer term a greater proportion of the costs can be related to load.
- **Net metering on self-generation that prevents the fair contribution of self-generation towards network costs should be avoided**
  Self-generators that use the network should face network tariffs which are fair and cost-reflective in the same manner as consumers that exclusively rely on the network for their energy supply.
- **Network tariffs are only one of many tools to give price signals to consumers**
  Other tools that can signal congestion include market-based signals for flexibility procurement and connection charges. When 'firm response' is needed, tools other than tariffs may be required.
- **There is a need for a coherent approach across all voltages.**
  Distribution network users' decisions on where to build new assets, how to dispatch plants and when to consume energy are not made in isolation. The arrangements at transmission level are relevant. Coherence is important and network tariff driven regulatory arbitrage should be avoided.
- **All tariff structures reflect multiple objectives which need to be balanced**,
  - These may evolve over time;
  - They may differ from country to country;
  - Tariff design requires careful planning and there is a need for effective management of transitions.
- **Regulators should have sufficient expertise**
  Regulators should have sufficient expertise, and resources, to assess, choose and implement appropriate tariff structures.

Rapid technological change, which transforms how distribution networks are used, means network tariffs may need to change to be appropriate. This is a highly complex area, and this is the start of our work to ensure that distribution tariff design delivers for European energy consumers.

1 Background

This document contains CEER's best practice guidelines on tariff structures for electricity distribution networks. The Distribution Systems Working Group (DS WG) has been investigating the future role of distribution networks and how innovation in the energy system will influence regulatory processes in different areas[3]. The development of guidelines of good practice for Distribution Network Tariffs complements other on-going work of the DS WG, particularly on:

- The interactions between Transmission System Operators (TSOs) and DSOs
- CEER Guidelines of Good Practice on Incentive Schemes for DSOs, including innovation, and
- Best Practice Guidelines for Flexibility Use at Distribution Level.

These DS WG deliverables cover different regulatory aspects in relation to the foreseen increased need for change at different levels in the electricity sytem. The overall objective of network tariffs is to recover costs of building, operating and maintaining networks while incentivising efficient use and development.

There may be a role for tariffs in signalling flexibility, which would need to be aligned with broader flexibility considerations. A wider system approach is important when designing distribution network tariffs, with consideration of how to value flexibility in different parts of the electricity system. There are important linkages between this paper and other CEER work, including the principles for valuation of flexibility recently presented by CEER.[4] That paper examines different regulatory arrangements for flexibility, with a focus on the participation of demand response and decentralised flexibility. Although primarily concerned with electricity markets and balancing, many of the principles are more widely applicable. Other relevant work on Renewable Energy Self-Generation has also been developed by CEER.[5] This sets out the key principles that NRAs and policy-makers should take into account in energy market design, to allow markets to find the appropriate generation solution.

This paper outlines current practices and the need for change, and proposes guidelines to inform NRA's assessment of the right distribution tariff arrangements in light of dramatic changes to the use of their distribution networks.This document does not include consideration of transmission or harmonising distribution tariffs as it is beyond the scope of our work. Connection charging arrangements are also not considered although they are clearly very closely linked. As well as recovering costs through use of system charges, DSOs may also recover them through connection charges and regulated services. We think aspects of these linkages would benefit from further examination by CEER.

There are no deterministic rules to determine the right methodology and CEER does not take a 'one size fits all approach'. There is a wide variation in the context in which DSOs operate and different approaches may be appropriate in different regions.

[3] The future role of DSOs, A CEER Conclusions Paper, Ref. C15-DSO-16-03, July 2015

[4] Principles for valuation of flexibility, A CEER Position Paper, Ref. C16-FTF-09-03, July 2016

[5] Renewable energy self-generation, A CEER Position Paper, Ref: C16-SDE-55-03, Sept 2016

2 Where we are today

This section briefly sets out observations on current network structures, distribution tariff structures and case studies.

2.1 Current Network and Tariff Structures

Historically, distribution networks have been dominated by demand only customers. Distributed generation was not a feature, power was transferred from large scale transmission networks, and customers did not play an active role in providing flexibility. The current tariff arrangements were largely designed to ensure cost recovery, cost reflectivity and fair allocation of costs based on this network usage. There are several studies and papers on tariff regimes across Europe. Of particular note is the 2015 'Study of tariff design' commissioned by the European Commission from the consortium of AF-Mercados, REF-E and Indra.[6]

There is considerable variation in European countries particularly in the following areas:

- Where generation is connected varies widely across Europe, due to incentives in different regions as well as climate conditions. Generation can be TSO-connected, DSO-connected, off-grid (for example, islands) or self-generation.
- There are differences in where the boundaries between transmission and distribution networks lie in terms of operated voltage levels. There are also differences in the engineering planning requirements and the associated redundancy and reliability levels of the distribution networks.
- Other variations can be due to the geography of the region (density of population, level of industrialisation, nature of the housing stock) or even the topologies of the established grid.
- There are varying national policies on regional differences in distribution tariffs, more uniformity means more equity amoung final customers but less ability to send locational cost signals.
- Market arrangements and the scope of the activities of DSOs varies across Europe.

Tariff structures vary widely across Europe in how costs are allocated to different users of the distribution networks. Distribution costs are generally allocated to distribution network users[7] using a combination of a fixed fee depending on type of customer, level of energy consumption, maximum capacity utilised or contractually committed capacity.[8] Time of use distribution tariffs are implemented for electricity in several countries, typically for non-domestic consumers and with daily (night/day) or seasonal (winter/summer structure). Flexibility services sold as an explicit product for network purposes, are currently almost exclusively provided by industrial and commercial consumers.[9] Domestic customers' provision of flexibility is with few exceptions presently limited to providing implicit flexibility via time of use or interruptible tariffs.

6 Study on tariff design for distribution systems, Final Report Prepared for: DIRECTORATE-GENERAL FOR ENERGY and DIRECTORATE B – Internal Energy Market, January 2015

7 Distribution network users include consumers as well as distributed generation, storage and electric vehicle recharge points

8 Other attributes can also be included, such as reactive power.

9 By explicit demand response, we mean demand response sold as an explicit product (volume) in the different market segments, or as network related services to system operators. Explicit control and verification of the

2.2 Case studies

In Annex 2, we present case studies highlighting interesting aspects of current arrangements. These case studies are summarised in the table below:

Sweden - Principles based regulation of tariff structures designed by DSOs - There is considerable variation in tariff structures between DSOs (>170), which creates an opportunity for empirical research on customer response to tariff price signals - Results shows that customers do act on tariff price signals, although the average effect is small.
Germany - Significant impacts on the distribution system due to move toward supply from renewable energy sources by 2022 - Resulting conflicts between network and wholesale market signals, and the need for work on tariff formation in the light of both network-based and wholesale market-based objectives.
Norway - A recent review of distribution tariffs has concluded that tariff design is important for how the network is utilised and developed, and for cost allocation amongst network users. NVE intends to improve the utilisation of the network by shifting to a more cost-reflective tariff design. - NVE intends to propose changes to the regulation so the tariff reflects that demand for capacity during peak hours is a cost driver, when investing in the network.
The Netherlands - Capacity based tariffs were introduced in 2009 for small electricity and gas users - Transitional arrangements were put in place, allowing consumers an option of reducing their connection capacity and providing compensation to those who could not. In addition the energy tax was adjusted to avoid reduced energy efficiency incentives.
Portugal

load is typically required to sell explicit demand response, Implicit demand response can either be realised by provision of price signals to the customer, such as time-of-use retail pricing and dynamic network tariffs, but also by an explicit control and change of the load.

- Static ToU tariffs represent 80% of the total demand in Portugal and recently ERSE has created the regulatory framework for the introduction of dynamic ToU network tariffs to promote demand side flexibility. - Therefore, in 2017, the Portuguese DSO will implement a Pilot Project on dynamic tariffs, which will allow to confirm a preliminary positive Cost Benefit Analysis (CBA) before putting into place the dynamic tariff. The Pilot will have the duration of one year and will be on industrial consumers, which are likely to engage most.
Great Britain - In 2010, Great Britain implemented a distribution tariff structure based on long run incremental cost principles - A model is used to calculate the cost of a unit of demand at system peak and to allocate these costs among different users. Tariffs are then adjusted to ensure that the predicted derived revenue matches the revenue DSOs are allowed to recover under their price control.
Italy - AEEGSI has been working on gradual reform to network tariff structures for households and in 2015 issued a final proposal on redesigning the tariff system for households, eliminating historical progressivity with electricity consumption that was introduced in the 1970s as a first energy efficiency measure. - From 2017, network tariffs for households will become linear, cost reflective (largely capacity-based) and homogenous for all low voltage users (households and business customers), providing the right incentives for energy efficiency and self-consumption.

3 The need for change in distribution network tariff structures

Changing use of distribution networks and technological advances create opportunities and challenges for DSOs in the operation and development of their networks. Current tariff structures are based on a traditional use of the network. New challenges for DSOs in this changing environment include:

- Predictability problems due to changing consumption patterns and the integration of intermittent generation at the distribution level.
- Variable localised congestion;
- Reverse flow and quality control;
- An increased risk of cross subsidies between network users (e.g. demand customers paying for costs driven by distributed generation); and
- DSO revenue uncertainty if tariff structures have a largely volumetric basis. Even if the revenue can be recovered with a time lag, this can cause DSO cash flow concerns.[10]

3.1 Changed consumption patterns and demand for network services

Technological change creates opportunities and challenges for consumers, generators and DSOs. New technologies are key drivers for change in network use, in particular, the increase in self-generation and storage. They also create opportunities for new strategies from a network management perspective, with the availability of real time data. This allows distribution networks to be managed more efficiently, with more scope for taking advantage of new services that may be delivered by consumers. New technology is changing how distribution networks are used. This includes:

- **Consumers access to meter data**
  The rollout of smart meters and advances in electricity settlement regimes mean that customers will have access to far more information on their consumption, which could be harnessed to incentivise more flexible use of the network.
- **Smart appliances**
  Smart appliances with automated functions will give new possibilities for flexible use and also for new business models in paying for electricity use.
- **Storage**
  Improved technology and lower costs may result in increased use of storage solutions, in particular battery storage. This could be used for a number of purposes such as decreasing consumption from the grid at peak times, avoiding network reinforcement, providing ancillary services to network or system operators, or for energy arbitrage. For customers with their own means of generation, it will reduce their use of the grid for energy supply, and provide additional security of supply. As a result, storage creates opportunities to avoid tariff and system levies. The degree to which this can lead to grid defection and much reduced or occasional network access are important considerations for NRAs when setting tariffs.

[10] Volume risk is an important aspect of both the regulatory frameworks and tariff structures, it is not covered in further detail in this document.

- **Electric vehicles**
  An increase in Electric vehicles (EV) will increase demand on the distribution network at certain points, with a significant impact on the operation and maintenance of the distribution network. It can, however, offer opportunities for more flexibility. EV provides demand that could potentially be managed by DSOs and may also represent significant connected storage capacity. Recent studies suggest that electric vehicles could add significantly to peak loading.[11] Almost all of the demand due to electric vehicles is expected to be connected to the distribution network, and is likely to be highly clustered. This presents challenges for network management, as grid tariff design and connection conditions need to evolve to accommodate EV at least cost alongside the wider storage flexibility potential.
- **Distribution connected generation**
  The growth in embedded and self-generation means that large numbers of distribution network customers are no longer just passive demand customers but may also be able to provide flexible export services to the distribution network. More embedded generation can put pressure on the distribution networks which were designed for demand. This may justify investment in the distribution network to accommodate distributed generation as well as increased network protection systems.

3.2 Future developments in operation and management of distribution networks

As the system changes, DSOs are facing new challenges and opportunities. Some of the new challenges being faced by DSOs can be addressed, in full or partly, through the use of flexible demand and supply side solutions, provided they can be used without harming competition. For instance, DSOs could potentially make use of flexibility to avoid or defer reinforcement, manage losses, or address network issues. This flexibility can either be procured explicitly or to a certain extent be valued implicitly through network tariff price signals. An advantage of implicit price signals is that they can be combined with other flexibility signals in the market, so long as appropriate settlement structures are in place. Price signals through network tariff design do not guarantee an immediate change in customer behaviour. The design of network tariffs is critical to efficient network use, and should not be a barrier to the wider deployment of new sources of flexibility in the electricity system.

As DSOs are looking at more innovative and active approaches to managing their networks, this and other system changes are leading to a growing need for interactions between TSOs and DSOs. There is, therefore, a growing and urgent need for regulators, DSOs and TSOs to take a whole system approach to management of the electricity system.[12] Network tariff arrangements are central to this. CEER describes the importance of regulatory arrangements which expose market participants to appropriate signals/incentives reflecting the costs and benefits their actions may have on the wider system.[13]

[11] See, for example, Wardle, Capova, Matthews, Bell, Powells, & Bulkeley, 2014

[12] More detail on this will be included in the upcoming CEER DSO/TSO paper

[13] The Future Role of DSOs, A CEER Conclusions Paper, Ref. C15-DSO-16-03, July 2015

4 Guidelines of good practice

4.1 Introduction to the guidelines of good practice

The aim of these guidelines is to ensure that distribution network tariffs work in the short and long term interests of energy consumers. NRAs should ensure tariff structures contribute to an efficient use and development of the network; including the ability to adapt to technological change. Further principles governing the relationship between the energy sector and its customers are outlined in a joint statement from CEER and BUEC on the 2020 vision for Europe's energy customers.[14]

CEER has identified seven principles for the design of distribution network tariffs:

1. Cost reflectivity: 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. To ensure that costs are allocated to those users who impose costs on the network, the right price variables should be chosen, that is, those variables that capture the need for investment or operation. The primary cost drivers of network provision are location, time of use and power quality. See chapter 4.3 for a discussion on price variables.

2. Non-distortionary: 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.

3. Cost recovery: DSOs should be able to recover efficiently incurred costs. This key principle should also provide efficient long term management conditions to ensure a sustainable development of the electricity network, not only to benefit today's customers of the network but also to safeguard the needs of future customers at reasonable prices. As well as tariffs for use of the distribution system, DSOs also recover costs through connection charges and regulated services.

4. Non-discriminatory: there should be no undue discrimination among network users The same use of the network should result in the same network tariff under the same circumstances.

14 http://www.ceer.eu/portal/page/portal/EER_HOME/EER_PUBLICATIONS/CEER_PAPERS/Customers/Tab3/CEER-BEUC%202020%20VISION-joint%20statement_Long_v161014.pdf

5. Transparency: the methodology for calculating tariffs should be transparent and accessible to all stakeholders. Transparency in the cost components included in the distribution tariffs and in the methodology of calculating the tariffs should be ensured to facilitate comprehension and acceptance. The methodologies underlying the calculation of tariffs, should be explained, discussed and published. Consulting stakeholders on the methodology is good practice and facilitates comprehension. Tariffs should be published prior to their entry into force. Transparency ensures that market participants understand and can respond to the signals network tariffs provide.

6. Predictability: it is important that network users can effectively estimate the costs of their use of the distribution system, facilitating efficient long term investment by network users. However, the changing nature of the energy system mean network tariffs will need to evolve over time.

7. Simplicity: as far as possible tariffs should be easy to implement and to understand, particularly at point of use. The simpler they are, the easier they are for consumers to respond to.

Some of these principles have already been foreseen in the Directive 2009/72/EC, concerning common rules for the internal market in electricity, namely cost-reflectivity, transparency and non-discriminatory tariffs.

4.2 Key considerations in the application of the principles in the design of tariffs for use of distribution networks

Tariffs for use of the distribution networks cover the costs of building, maintaining and operating the distribution networks. The costs are generally allocated among demand users based on various cost reflectivity criteria. Traditionally, costs have been recovered from demand users to reflect network usage, however cost drivers are increasingly driven by new factors such as the growth of distributed generation and the management of intermittency – making it now more complex.

As well as recovering costs, distribution tariffs also need to firstly send, or at least not unduly distort, short term operational price signals. For example signals for consumers to provide demand response. Secondly, they also need to provide network users with long term investment signals. This means not only a balancing and prioritising of tariff principles but also that there is no definitive optimal network tariff methodology. A theoretical approach that models a network's long run marginal costs is one option, but the practical limitations of trying to model accurate incremental costs are substantial. Alternative approaches, for example based on actual costs, are sometimes preferred.

CEER has identified the following central considerations for application of the above principles to tariff design:

1. **Network tariff design should as far as possible be future-proof.**
   Tariffs should not impede management of future challenges in operation and investment in electricity distribution networks as well as the overall system, including due to increasing use of electricity storage, electric vehicles, distribution-connected generation and demand

side flexibility. A key aspect of making tariffs future-proof is having robust change processes that will allow network charging structures to evolve over time.

2. **Tariff structures should be sensitive to the different costs of network provision.** These include the costs of providing capacity at peak, the costs of maintaining the grid, operational expenditure and losses etc. Each should be reflected appropriately through tariff structures. In the shorter term, a proportion of the DSO costs will not be related to load, and can be seen as residual costs that should be recovered in ways that are fair and cause the least possible distortion of network use. In the longer term a greater proportion of the costs can be related to load.

3. **Net metering of self-generation that prevents the fair contribution of self-generation towards network costs should be avoided.**
   Self-generators that use the energy network should face network tariffs which are fair and cost-reflective in the same manner as consumers that exclusively rely on the network for their energy supply. Net metering implies that system storage capacity is available for free. It reduces consumers' time-value sensitivity to volatile energy prices and hence undermines efforts to enhance flexibility and to develop a wider demand-side response.

4. **Network tariffs are only one of many tools to give price signals to consumers.** Tariffs should recover costs in a way that does not prevent the efficient procurement of flexibility services through competition from alternative service providers (e.g. through market mechanisms). Whilst distribution tariffs can send an incremental price signal which generally reduces peak demand, this may not be sufficient when a 'firm response' is needed and procurement of flexibility may be necessary through agreements on access to the network and market-based signals.

5. **There is a need for a coherent approach across all voltages**.
   Distribution network users' decisions on where to build new assets, how to dispatch plant and when to consume energy are not made in isolation. The arrangements at transmission level are relevant. Coherence is important and network tariff driven regulatory arbitrage should be avoided.

6. **Any network tariff structure reflects multiple objectives which need to be balanced**
   It may be better to reach specific objectives via other means than to try to send all price signals through a network tariff structure. Each country will make different trade-offs regarding tariff principles due to the specificities of their market structure, the pace of change and the development of their retail market. The costs and benefits of changes to current approaches depend on the starting point and will evolve over time.Tariff design requires careful planning, with effective management of transitions

7. **Regulators should have sufficient expertise and resources**
   Expertise and sufficient resources are necessary to assess, choose and implement appropriate tariff structures, with consultation of stakeholders. The regulatory framework for tariff structures is a core regulatory responsibility.

4.2.1 Distribution tariffs and energy user behaviour

In the context of wider system aspects, cost-reflective price signals, sent through distribution network tariffs, may not be material enough to trigger manual behavioural responses from consumers. Further, from a consumer perspective, and especially for domestic consumers, the value and potential for flexibility use is complex and can be hard to comprehend.

According to the research project S3C, end-user energy usage decisions are influenced by a broad range of both behavioural and situational factors. Behavioural factors include 'rational' factors (like financial gains), non-monetary motivators (like beliefs, values, habits, and routines), social influences (like norms and leadership), and personal capabilities (like knowledge, skills, and financial means). Situational factors, amongst others include institutional ones (laws, and regulations), culture, infrastructure and social networks, that may all influence energy behaviour. This implies that a nuanced view on end-user behaviour is required, taking both behavioural and situational factors into account.[15] Furthermore, the combined effect of these factors might not be sufficient for them to realise the value of their flexibility by changing consumption patterns in response to needs of the distribution network. This barrier might be partially overcome by designing flexibility products, which limit the end-user's participation to a minimum with automation. Practical experiences and wider studies show that enabling technology can substantially increase the peak load reduction by customers. Rates coupled with "active" technologies (which automate customer response) reduce peak load by an additional 10–20 percentage points compared to the same rate without technology. Automatic control also becomes a better fit with tariff structures based on a more frequent update of the price signal as it allows the end-user to take full advantage of the tariff structure[16].

Further insights into consumer behaviour, and wider engagement in their energy and network usage, include that:

- Often a small percentage of the participants are responsible for the total response, while it remains unclear why and how they responded and why the rest did not. On average 30% of households were responsible for 80% of the load shifting[17].
- Consumers may find rebates more difficult to understand than higher prices, since rebates are calculated relative to a consumer's reference demand which makes it difficult for consumers to estimate the savings they make from shifting demand away from the peak. Moreover consumers may be loss averse[18].
- Enabling technology may be the most important determinant of whether customers actually respond to a demand charge price signal. It is possible that sufficiently educated customers will respond by reducing peak demand, but technology that

[15] S3C, D1.1 FINAL, WP 1: "Framing – Development of the theoretical framework" Deliverable 1.1: "Report on state-of-the-art and theoretical framework for end-user behaviour and market roles", November 2013

[16] Rocky Mountin Institute, A review of alternative rate desigs – industry experiences with time-based and demand charge rates for mass-market customers, May 2016

[17] Breukers, S., and R.M. Mourik (2013). The end-users as starting point for designing dynamic pricing approaches to change household energy consumption behaviours. Report for Netbeheer Nederland, Projectgroep Smart Grids (Pg SG). DuneWorks, March 2013

[18] DECC "Demand Side Response in the domestic sector- a literature review of major trials", Department of Energy & Climate Change, UK, August 2012.

automates their response will reduce the possibility of customers not changing their behavior due to confusion about the rate[19].

- Enablers and barriers are found to fall under the following key categories: comfort, control, environment, finance, knowledge & information, security, and social process[20].

The interaction between tariff and end user behaviour is also dependent on market structure.

1) In countries where network tariffs are bundled with other energy costs, in combined customer bills, suppliers should play an active role providing consumers with the information to help overcome any lack of knowledge about how to take advantage of their flexibility in relation to the price signals sent by the distribution network component of their bill. If suppliers are billed directly by DSOs for their customers' network usage, suppliers will be able to design their own incentives, and retail products to cost efficiently encourage customers to benefit from behaving in ways that minimises the suppliers overall distribution network costs.

2) Where consumers are billed directly by DSOs for use of the distribution network[21] there is an opportunity to transparently expose customers directly to network tariffs reflecting network costs. Compared to time-of-use supply prices (e.g. timeband based contracts) distribution network tariffs with an element of time differentiation or based on power consumption may also be designed to be more predictable for the consumer and thus easier to accept and react upon. However customers may receive conflicting signals when the network tariff sends a signal that is different to energy price signals if they have a ToU supply contract. As for bundled tariffs it remains crucial that the applied price signals are as transparent and easy to understand as possible.

In tariff structure design, relevant research into consumer behaviour should be considered, including how the high level principles presented in this report may be applied for different types of customers – for example the application of the principles of predictability and transparency will differ between different groups of customers.

4.2.2 Distribution charges in the context of a wider system approach

The extent to which network price signals trigger action will be partly dependent on the size and structure of other levies included in consumer electricity bills, e. g. to handle wider social and environmental policy costs. Further, how different transmission system costs and costs for balancing services are allocated in each country are also other key factors that will influence the extent to which the price signals efficiently reflecting distribution network costs will actually influence end user behaviour.

[19] Rocky mountin Institute, A review of alternative rate desigs – industry experiences with time-based and demand charge rates for mass-market customers, May 2016

[20] S3C, D1.1 FINAL, WP 1: "Framing – Development of the theoretical framework" Deliverable 1.1: "Report on state-of-the-art and theoretical framework for end-user behaviour and market roles", November 2013

[21] Customers receive two separate bills, one for energy by the supplier and the other for network tariffs and system charges by the DSO.

In enabling flexibility, the distribution network tariffs signal may or may not be aligned with wholesale energy price signals. For instance, during certain circumstances local congestion may occur during periods with low wholesale prices e.g. due to EV charging. The combined effect may decrease, or even eradicate, price signals from network tariffs. This needs to be considered in overall market design questions.
.

4.2.3 Distribution tariffs and incentives for DSOs

As well as distribution tariffs, signals about the cost of network access can be provided through connection charges and contracts for delivery of flexibility such as interruptible tariffs. They all send signals which affect and manage long and short term congestion, voltage control and management of network stability, minimising grid losses and deferral of grid investments. DSOs may also use local flexibility resources to deliver ancillary services to other parts of the network within the boundaries of the regulatory framework. In order for DSOs to view flexibility as an effective alternative to grid investments, they, and other stakeholders, must have a good overview of current and future capacity challenges in their grid, have access to necessary flexibility resources at locations with capacity constraints and be able to count on the availability of the resources when needed.

Lack of knowledge about actual power flows and load on network components over time makes it difficult for DSOs to predict where and how often capacity challenges may occur. Without this overview, investments in new grid capacity will be a more attractive alternative rather than using tariffs and other flexibility means to handle constraints. This barrier will partially be overcome with the roll out of smart meters and new technology, as it will improve DSOs knowledge, and increase their ability to exploit different flexibility options and tariff structures, to improve the overall efficiency of the network.

4.3 Ways of charging for use of distribution networks

Distribution network tariffs applied to customers are designed to promote efficient use of the network, as well as recover costs. They may be fixed or may be variable, depending on power (utilised capacity, kW) or energy (kWh). These may be charged at a flat rate or can vary by time of day, location, quality and voltage level. Particular metering arrangements are necessary for some tariff structures. For example, dynamic time of use tariffs require appropriate metering and messaging to provide consumers with signals as the tariff changes. Given the different characteristics of the tariffs, a combination would allow costs to be recovered as cost refelectively as possible.The following paragraphs set out the primary options for tariff structures.

4.3.1 Fixed charge or contracted capacity charges

Fixed or ex ante capacity tariffs have advantages of simplicity, stability, and predictability for both the consumers and DSOs. 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, it may be appropriate to recover them through fixed or ex-ante capacity tariffs. However a fixed tariff does 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 can be based on subscribed or installed capacity, and have similar advantages and disadvantages to fixed costs. If they are differentiated based on capacity, they will give a signal that capacity has a price.

4.3.2 Capacity usage based tariffs

Capacity usage based tariffs are charged retrospectively, based on the actual power used. When we consider the costs induced by consumer behaviour, in the long term, user contribution to higher peak power usage will lead to capacity related reinforcement investment costs. Network reinforcement is driven by the expected peak load, which depends on both consumers' subscribed capacities and the probability that they are simultaneously used at peak time. Contracted capacity tariffs are therefore only partly cost-reflective, as they reflect the former, but not the latter. Capacity usage based tariffs can capture actual usage patterns, allowing more cost reflectivity, though at the cost of greater complexity in tariffs.

Capacity usage based tariffs can have different effects depending on how they are designed:

- A tariff based on the highest used capacity in a year will be close to a subscribed capacity tariff, and are only partially cost-reflective because they do not differentiate between capacity used at peak time and capacity used off-peak.[22]
- A tariff based on the highest capacity used in a shorter timeframe, for instance the highest each month, is more cost reflective, especially if the use of capacity is during months when peak consumption generally occurs is charged more, however it requires smart metering.
- At the other extreme, a tariff based on the highest capacity used in a very short timeframe (for instance day, or even hour) would be more cost-reflective. But it would also be extremely complex and less predictable for many consumer groups. It may therefore be less acceptable to consumers. All these *ex post* usage based capacity charges also require network users to anticipate peaks themselves, with the necessary equipment to do so.

Both the European literature review and the answers to the EC public consultation on Energy Market Design (question 15) indicate a general support for a move towards capacity based charging, with the option of a hybrid of capacity and consumption based charging to incentivise a change in consumer behaviour.

---

[22] As well as being only partially cost refletive from a network perspective, a maximum capacity approach could also create even bigger inefficiencies in the wider system. For instance, if a customer is separately being incentivised to increase their demand during off peak periods in order to balance out excess local generation, a maximum capacity approach may provide an incentive in the opposite direction, despite the customer providing network/system benefits.

4.3.3 Energy usage based tariffs

Energy usage based network tariffs charge consumers for the energy they take from the grid. Consumption may be charged at a flat rate or on a static or dynamic ToU basis. Energy usage based tariffs have advantages in terms of acceptability to consumers, but they may also give rise to revenue uncertainty.[23] As some distribution network costs are driven by the need for reinforcement to meet peak capacity, flat-rate volumetric tariffs are less cost reflective than tariffs that have a time element which correspond to that peak network usage. An energy price charged on a short period of time (for instance, the 100 hours of higher demand in the network) has similarities to a capacity usage based tariff. It charges the consumption at times of peak demand, which is the main driver of investment costs.

Energy usage based tariffs are reflective of the costs related to the procurement of electricity to cover the losses in the distribution grid. Losses are taken into consideration during planning, thus network investments are also justified by present and future losses.

Flat-rate volumetric network tariffs can over-incentivise network users' reduction of metered units of consumption (relative to the marginal cost saving to the system). They can also over-incentivise self-generation, which will not necessarily reduce distribution costs, because it is not always synchronised with system peaks (the network must be still designed to cover peak demand for situations when there is little production from intermittent generation).

4.3.4 ToU (dynamic and static) elements in network tariffs

Both capacity usage and energy usage based tariffs can be charged on a ToU basis. ToU tariffs have the following objectives:

- Provide grid operators with an alternative mechanism to minimise grid use costs, since it encourages the reduction of demand in periods of high consumption. This can lead to postponement or avoidance of new investment.
- Enable energy consumers to benefit financially through active participation in mechanisms that lead to lower grid costs.
- Minimise the impact of intermittent distributed generation on the electricity network by creating incentives to change consumer behaviour in a way that helps to manage congestion of the network.

ToU tariffs can be static or dynamic:

- Static ToU tariffs define certain time periods where the charges for use of the distribution system vary. These time splits usually reflect predicted peak and off peak times and do not change to take account of actual system conditions. Although static ToU tariffs provide incentives to permanently shift load from peak periods to off-peak periods, they do not have the flexibility to allow for variability in when peak conditions

[23] Volume based tariffs give rise to revenue uncertainty for DSOs, recovery of revenues is specific to the price control mechanism. This is not considered further in this paper.

actually occur. This may be more significant an issue where there are high levels of intermittent renewables or use of storage and demand-side-response. Where peak periods are set in advance there is a chance they will not coincide with actual peak periods, although the time periods may be adjusted over time to reflect changes in load profiles. On the other hand knowing what periods of the day to avoid in advance makes it easier for many network users to take decisions on how to value their flexibility.

- Dynamic tariffs have set price bands but the timing of these bands can change on a day by day basis (or even more frequently). The peak period price can be triggered to target specific system events, such as unexpectedly hot or cold days or availability or not of intermittent renewables. Consumers are typically notified of the higher peak period price on a day-ahead or day-of basis. Examples of dynamic pricing include critical peak pricing[24] and price rebates. The flexibility introduced by dynamic ToU tariffs increases the probability that demand, motivated by strong price signals applied in critical times for networks or generation, responds to price variations.

If ToU tariffs are used to recover a high proportion of DSO required revenues, network users that have access to flexibility resources, e.g. those with storage and solar PV, could largely avoid network costs. A network user who avoids the peak should not be able to avoid all charges as DSOs still need to recover costs that are not associated with network reinforcement. Regardless of consumers' ability to respond to network price signals they should still make an appropriate contribution to DSO cost recovery, otherwise those consumers who cannot change their consumption patterns will face ever higher charges.

Regarding ToU for management of network congestion, this will be highly geographically specific and variable over time. Signals will need to be able to reflect these. There are also risks of all consumers responding simultaneously to a single price signal (e.g. all electric cars delaying charging to the same moment in time).

[24] Critical peak pricing is where usage is charged based on a short period of time (e.g the 100 hours of highest demand in the network). It recovers the costs of building and maintaining the networks based on consumption at times of peak demand, which is the main driver of investment costs.

4.3.5 Interruptible tariffs

Interruptible load controlling can also be a means to support flexibility (e.g. utilisation of storage capacity and/or enabling smart grid technologies). The term "interruptible" indicates that the DSO is technically equipped and eligible to interrupt system usage of its customers for security of system reasons. According to the 2015 'Study of tariff design' commissioned by the European Commission, DSOs in about half of the European countries can control such interruptible loads.[25]

To reward this type of network usage, DSO can use an interruptible tariff. The incentive to choose such a tariff to compensate the disadvantage of not having a permanent connection to the grid of the customers is a lower tariff compared to a non-interruptible equivalent. For example, no capacity component or taxes are being charged and the tariff often is combined with separate charges for day time and night time. A lower interruptible tariff must not violate the principle of full cost recovery of the network costs and lead to an unintended socialisation of costs between customer groups. Therefore the granted reduction in the tariff should reflect the value of the provided flexibility (e.g. the avoided costs or generated benefits) for the system.

The interruption should also meet certain criteria: the actual interruption should happen automatically and support the network only during emergencies and risky situations. Such situations happen mostly on a very local scale and only for very limited periods a year. Therefore, it is necessary that the interruption is done with consumers' consent and triggered automatically.This should not be done at contractually predetermined times and should only be used when benefit can be proven by the DSO. This also should guarantee that the interruption does not discriminate between and within network users and market participants or interfere with flexibility options or other usages provided by the market.

Current usages of the interruptible tariff are especially load intensive appliances such as electric heaters or refrigerators/freezers. These appliances are mostly connected on a separate circuit and do not need permanent power supply. Therefore an interruptible tariff design does not give a strong incentive to the consumers to intentionally reduce consumption or peak usage. However, a desired peak usage reduction is achieved nonetheless which gives the DSO the possibility to postpone network reinforcements. Another benefit of the interruptible tariff would be that it is easier to invoice and more predictable compared to other flexibility options (e.g. dynamic tariffs).

4.3.1 Managing transitions

The challenge facing national regulatory authorities is not just how to design new tariff structures given the wider changes to the energy system but how to estimate, and where necessary ameliorate, the impact of those changes on some groups of customers,

[25] Interuptible tariffs are strongly linked with other flexibility provided by DSOs and is discussed in the work on GGP for flexibility use in distribution networks

particularly vulnerable groups as well as those who have made investments based on the signals from existing tariff structures. A gradual, or phased, approach may be appropriate although this delays adaption to change and the benefit to the overall electricity system.

5 Conclusions

We have provided an overview of how distribution network tariffs are currently structured and why there is a need for change. Our economic and policy analysis has not provided a clear solution that can be applied to tariff structures in any situation but it effectively frames the issues and sets out key principles and considerations.

Tariff structures may need to be reassessed to ensure that they are still efficiently and fairly recovering the costs of network provision whilst also sending appropriate signals to network users. All distribution network tariff structures must prioritise and balance multiple objectives. However tariffs are not the only tool DSOs have to address the challenges and realise the opportunities created by the profound changes to the energy system. It is therefore important to be clear, practical and limited in the objectives of tariffs design. There are other tools and mechanisms to achieve wider goals. As well as being fit for purpose in the present, tariffs also need to be resilient to anticipated future changes. There are no deterministic rules to determine the right methodology and CEER does not take a ‘one size fits all approach’. There is a wide variation in the context in which DSOs operate and different approaches may be appropriate in different regions. The principles and key considerations we have outlined in this document should provide guidance to the NRAs. The princples are cost reflectivity, non-distortionary, cost recovery, non-discriminatory, transparency, predictability and simplicy.

Our guidelines of good practice seek to help ensure that changes to tariff structures are as economically efficient as possible, while recovering costs from users fairly. Further work could examine how these principles and key considerations could be extended to connection charges. Rapid technological change, which transforms how distribution networks are used, means network tariffs may need to change to be appropriate. This is a highly complex area, and this is the start of our work to ensure that distribution tariff design delivers for European energy consumers.

Annex 1 – List of abbreviations

Term	Definition
ACER	Agency for the Cooperation of Energy Regulators
BEUC	Bureau Européen des Unions de Consommateurs, The European Consumer Agency
CEER	Council of European Energy Regulators
DSO	Distribution System Operator
DSO WG	Distribution System Operator Working Group
EV	Electric Vehicles
GGP	Guidelines of Good Practice
kV	Kilovolt
kW	Kilowatt
kWh	Kilowatt-hour
NRA	National Regulatory Authority
PV	Photovoltaic
ToU	Time of Use

Annex 2 – Case studies

Sweden

In Sweden the tariffs are not set by the national regulator (Ei) but by the DSOs themselves. However there are certain legal requirements that tariffs have to meet, e. g. the tariff should be objective and non-discriminatory. The Energy Efficiency Directive has been implemented into Swedish law through a supplement stating that the tariff must incentivise efficient use of the grids, but also incentivise efficient production and use of energy. Ei supervises to ensure that these requirements are fulfilled.

In a defined concession area the DSOs have to treat all their customers equally, independent of the customer's location in the concession area. The concessions are granted by Ei and when mergers of DSOs occurs concession areas will be redefined according to geographical circumstances. It is worth noting that large companies like Vattenfall Elistribution might consist of several separate subsidiary companies in different parts of the country meaning that within the parent company different tariff levels exist. As Sweden has around 170 DSOs of very different sizes and characteristics, their asset base varies substantially depending on geography, population etc., which means that tariff levels vary greatly between different concession areas and DSOs. Small DSOs with mainly rural distribution normally have the highest tariff levels.

Within the framework of the income cap defined by the regulation each DSO decides themselves which tariffs to apply – proportion of fixed and variable costs, time of use tariffs, capacity based tariffs etc. Some DSOs also provide customers with possibilities to choose between different tariff offers. This possibility is facilitated by the fact that customers are billed directly by the DSOs, i.e. customers receivr two separate bills, one from their DSO and one from their retailer. In the future, Sweden is planning to introduce a supplier centric model with combined billing. However the distribution costs will still be distinguishable from the retail cost on the bill. DSOs are responsible for keeping the total revenues within the limits of the income cap during the whole regulatory period of four years (with some limited possibilities for borrowing and banking in relation to the next regulatory period). This provision helps keep tariffs stable over a longer period without transfering management (of e. g. volume and volatility risks related to tariff structure) from the DSO to the regulator.

Most of the tariffs for domestic customers are based on a fixed fee depending on size of the fuse, and a volume fee per kWh. Larger customers are normally exposed to tariffs including both a fixed fee, a capacity fee based on subscribed capacity and a volume fee (kWh). With the role out of smart meters the possibility of using dynamic or hybrid time of use tariffs and capacity based tariffs also for households and other small consumers has increased and recommendations on tariff design are under development both within the industry and as part of a governmental assignment given to Ei *(different recommended models could be specified).*

There are also interesting experiences from DSOs who have already introduced these kind of tariffs for domestic consumers both as regular tariffs and as part of pilot projects. In some cases the impact on customer behaviour of the new tariff design has been analysed empirically. In general, the results show that customers do act on the tariff price signals by decreasing peak demand in peak periods and shifting electricity use from peak to off-peak hours. However the average effect is fairly marginal and limited to households living in single-family homes with electrical heating or heat pumps, which are rather common heating solutions in Sweden[26]. The results further indicate that demand–based tariffs have an effect on household's attitudes and intentions to shift electricity use from peak to off-peak hours*).*

[2626] Bartusch, C. and Alvehag, K., 2014, Further exploring the potential of residential demand response programs in electricity distribution, Applied Energy, Volume 125, 15 July 2014, Pages 39–59.

Norway

Current Norwegian tariff design

The current regulation gives DSOs a large degree of freedom regarding how to design tariffs based on their allowed revenue, as set by NVE. Tariffs for households, vacation homes and small commercial customers mainly consist of a fixed charge (NOK/year) and an energy charge (NOK/kWh). On average, the fixed charge constitutes about 30% of the network tariff.

Customers with an installed capacity exceeding a set limit, for example over 80 or 125 amperes, or customers with an expected annual consumption exceeding 100 000 kWh, usually have a capacity charge (NOK/kW) in addition to the fixed and energy charge. The capacity charge is based on used capacity within defined periods of time.

When designing tariff regulations, it is important to be clear on the objectives. The Norwegian Energy Act Regulation gives guiding principles, which state that tariffs shall be designed so that they contribute to effective utilisation and development of the network. Furthermore, tariffs shall ensure customers' non-discriminating access to the energy market, cover grid owners' costs within allowed revenue, as well as provide a fair allocation of costs between network users.

Future tariff design

By 1 January 2019, all Norwegian electricity consumers should have new advanced metering systems (AMS). AMS-meters will measure the customers' electricity consumption on an hourly basis, and provide far better information about actual customer usage. AMS enables customers that adapt their consumption to price signals from the electricity market and from network tariffs to reduce their costs relating to energy consumption. By measuring the energy consumption not only in volume, but also over time, consumers may contribute to more efficient utilisation of the grid, and also with flexibility (demand-response) that may delay or reduce the need for grid investments. This will benefit all customers through lower tariffs than in the case with grid investments.

Marginal costs arising in the grid by consumer use are mainly related to losses, provided sufficient grid capacity. The energy component of the tariff for households, vacation homes and small commercial customers is far higher than the value of marginal losses. This affects not only the cost allocation among customers, but also the relative ratio between electricity from the grid and other options, such as energy saving and self-generation. In case of new connections or reinforcement of the network caused by customers' request for added capacity, network companies may require a connection charge to cover investment costs in the local distribution network (22 kV or lower). NVE considers the possibility of deeper connection charges.

The ongoing discussion regarding tariff design suggests less energy-based and more capacity based tariffs. NVE has undertaken a public consultation[27] on possible changes to the regulation for setting network tariffs for customers connected to the grid with a voltage of 22 kV or lower. Stakeholders generally support the need to make changes to the current regulations. It is NVE's intention to provide clearer guidelines for how DSOs design tariffs. The main cost is related to being connected to the network and having the opportunity to use electricity from it. When investing in the network, demand for capacity during peak hours is a cost driver. In NVE's opinion, this should be reflected in the tariff.

A Norwegian consultancy firm[28] commissioned by NVE has surveyed consumers´ attitudes, perceptions and evaluations regarding various designs of capacity tariffs. Consumers in this study were very clear that they would accept changes to network tariffs as long as it is possible for them to understand why they are made and what consequences they would have. There were consensus amongst participants towards flexibility and the possibility to influence their costs being connected to and using the electricity network, by adjusting consumption. Most of the participants also want predictability in network costs. Furthermore, it is apparent that consumers are concerned with convenience and comfort, and any consumer behavior entails that neither comfort nor economy are affected negatively.

[27] http://publikasjoner.nve.no/rapport/2016/rapport2016_62.pdf

[28] http://publikasjoner.nve.no/rapport/2016/rapport2016_86.pdf

The Netherlands: The introduction of capacity based tariffs

In the Netherlands capacity based tariffs were (to full extent) introduced in 2009 for small electricity and gas users. The capacity of those users is up to 3*80A for electricity and up to 40m3/h for gas ('consumers' hereafter). In the Netherlands around 7.5 million electricity connections are present.

There are two main reasons that capacity based tariffs were introduced in the Netherlands. Firstly, ACM has the view that the grid costs of DSOs mostly depend on the capacity of the grid rather than the volumes of usage (in kWh or m3). This makes it more fair to use capacity based tariffs. Secondly, administrative costs would be significantly lower for DSOs, as there would be no volume-data required and billing would be simplified. With several other measures (like billing by the retail companies and the introduction of smart metering) it was estimated costs could be reduced in the whole energy sector by 100 million euros per year. It was estimated that the introduction of capacity based tariffs by itself would lead to a cost reduction of around 30 million euros.

Consequences for consumers were, however, present. Consumers with a relatively high consumption in kWh or m3 compared to their capacity would benefit from the capacity tariffs. On the other hand consumers with a relatively low consumption would face higher costs. Consequently there would be the effect that it would reduce incentives for energy efficiency, when grid tariffs do not depend on kWh or m3.

For consumers the following measures were taken:
- Consumers were given favourable conditions to reduce their connection capacity in order to avoid higher costs, as previously the costs resulting from the capacity of the connection may not have been taken into account. Consumers could reduce the capacity of their connection against a reduced fee (50 euros), instead of the normal higher fee.
- Consumers who could not reduce the capacity of their connection and who would pay significantly more with capacity based tariffs would receive compensation. This compensation of those customers added up to 30 million euros in 2009 and 15 million euros in 2010. In Dutch this compensation arrangement is called 'Tegemoetkomings-regeling'.

For the DSOs it had the following consequences:
- Overall, the starting point was that the income of DSOs would not change with the introduction of capacity based tariffs. There are a couple of exceptions:
- The DSOs were obliged to reduce connection capacities (the costs could be included in regulation) and pay the compensation to consumers (also the compensation could be included in the regulatory costs).
- Income was reduced with (estimated) cost reduction. In this way the efficiency gained by the introduction of capacity tariffs would be passed through to the consumers.

The legislator, the Ministry of Economic Affairs, introduced the necessary legal framework. Also the negative impact on the incentives was solved. In order to maintain incentives for energy efficiency the Ministry of Finance changed the energy consumption taxes (increasing the tax-free threshold but also increasing the variable tax on kWh and m3).

In the experience of ACM, one of the most difficult parts was to determine the cost reduction, as there is no objective way to determine the magnitude of the cost reduction. Many assumptions and inputs from DSOs were needed (of course the DSOs had an incentive to reduce the 'realized cost reduction'). An external consultancy bureau helped to determine a magnitude.

On the practical application of the tariffs, ACM found the following results. Only the second tariff was changed with the introduction of the capacity based tariffs. The following tariffs for small customers are in place:
- Transport tariff: a fixed component (administrative costs)
- Transport tariff: a capacity based component (transport costs)
- Connection tariff: a capacity based tariff for the initial connection
- Connection tariff: a capacity based tariff for maintaining the connection

For the capacity based component of the transport tariff, the following table applies for electricity (in Dutch):

Tabel: rekencapaciteit

Afnemerscategorie	Doorlaatwaarde van de aansluiting	Rekencapaciteit [kW]
1	t/m 1*6A op het geschakeld net	0,05
2	t/m 3*25A + alle 1-fase aansluitingen[1]	4
3	> 3*25A t/m 3*35A[2]	20
4	> 3*35A[2] t/m 3*50A	30
5	> 3*50A t/m 3*63A	40
6	> 3*63A t/m 3*80A	50

For small users (up to 3*80A) there are six distinct capacity categories.

All categories receive a certain ‘accountable capacity’ factor that determines the size of the tariff. ACM sets a general tariff per kW. Each customer gets billed for [tariff per kW] x [Rekencapaciteit]

For the capacity based component of the transport tariff, the following table applies for gas (in Dutch):

Tabel 2 Rekencapaciteit per afnemerscategorie

Afnemerscategorie	Capaciteit [m³(n)/uur]	Standaardjaarverbruik* [m³(n;35,17)]	Rekencapaciteit [m³(n;35,17)/uur]
1	≤ 10	< 500	1½
2	≤ 10	≥ 500 en < 4.000	3
3	≤ 10	≥ 4.000	6
4	> 10 en ≤ 16	n.v.t.	10
5	> 16 en ≤ 25	n.v.t.	16
6	> 25 en ≤ 40	n.v.t.	25

For small users (up to 40m3/h for gas) there are four distinct capacity ranges. The first range is further distinguished into three categories (1, 2 and 3), where the distinction is made on m3. The calculation of the of the tariff is similar to the approach for electricity.

Portugal: A pilot study of dynamic time of use access tariffs

In Portugal, static time of use tariffs (ToU) have been in place for a long time and a significant percentage of consumers use them, representing 80% of the total demand. For all industrial consumers[29], who accounts for 50% of total demand, four time periods tariffs are in place as a minimum requisite, which does not prevent theese consumers from choosing tariffs with more time periods. Household consumers[30] may choose between tariffs with one, two or three time periods.

While static ToU tariffs provide incentives to permanently shift load from peak periods to off-peak periods, they do not have the flexibility to allow for an increase in response on short notice. In this context, ERSE, the Portuguese energy regulator, has created the regulatory framework for the introduction of dynamic ToU grid access tariffs, which may lead to the active participation of users and thus the promotion of demand side flexibility. In the medium to long term consumers may choose, for instance, Critical Peak Pricing (CPP) tariffs besides the static ToU access tariffs already in place. The introduction of dynamic tariffs has the following objectives: (i) allow consumers to participate in mechanisms that lead to a more efficient use of the grids and consequently allows minimising grid costs, benefiting all consumers; (ii) provide the grid operator with an alternative mechanism to minimize costs, which allows the reduction of demand in the situations of higher consumption, and the postponement of new investments; (iii) allow the minimisation of the production variation impacts namely from intermittent generation to the benefit of the electric system operational security.

Before engaging in the use of dynamic tariffs, a Cost Benefit Analysis (CBA) was carried out. The Portuguese distribution system operator (DSO) performed a preliminary CBA on the introduction of access dynamic tariffs in Portugal, which concluded that the benefits clearly outweigh the costs. Therefore, in 2017 the Portuguese DSO will implement a Pilot Project on dynamic access tariffs, which will allow confirmation of the preliminary CBA before putting the dynamic tariff into place. The Pilot will have the duration of one year and will be on industrial consumers, which are likely to engage most.
The DSO has presented ERSE with a plan for the implementation of the Pilot, which will be put to public consultation in 2016, before the approval of the plan by ERSE. The public consultation will consult consumers on all the relevant aspects of the proposed dynamic tariff: (i) type of dynamic tariff; (ii) number of critical periods; (iii) duration of critical periods; (iv) prices; (v) minimum notification period; (vi) form of notification; (vii) trigger of the critical periods; (viii) coordination with suppliers; (iv) eligible consumers. Dynamic tariffs will be voluntary, avoiding the risk of penalising consumers who are unable to react to price signals.

[29] Consumers in medium voltage, high voltage and very high voltage.

[30] Low voltage consumers.

GB: Setting tariffs using long run incremental cost principles

The quasi incremental cost approach is based on the annualised cost of a scaled hypothetical network model (500 MW) with characteristics that match those of the actual network. The methodology is used to set distribution network tariffs for all customers in Great Britain connected at voltages below 22 kV, i.e. to the High Voltage (HV) and Low Voltage (LV) networks[31]. This is done using the Common Distribution Charging Methodology (CDCM), which was developed through joint collaboration between DSOs, Ofgem and interested stakeholders.[32] The CDCM was implemented in April 2010 and is incorporated into the contractual relationship between DSOs and network users. There are no locational signals within the different DSO areas, but the inputs to the methodologies reflect the particular characteristics of the network and consumers in each DSO area. Since the implementation of the CDCM, interested parties have proposed a range of changes to improve the CDCM and allow it to adapt to the changing use of the network. Many of these have been approved by Ofgem. Changes without significant customer impact are made under self-governance arrangements.

Calculating the cost of a unit of demand at system peak

The CDCM assumes that only units consumed at times of system peak impose costs on the DSO. The cost of a unit of demand at system peak is estimated using a distribution reinforcement model. This calculates the cost that would be incurred by the DSO to install, maintain and operate the assets required to serve a hypothetical network to supply a notional demand of 500MW. The design must not rely on any spare capacity that might exist on current network assets.

Allocating the costs among user groups

The CDCM seeks to identify the costs imposed, at times of system peak demand, by customers at different voltages of connection. This is done through an estimate of the coincidence of the customer's consumption with system peak. Within the CDCM, tariffs are determined for 27 different types of user group, mainly defined in terms of:

- Whether they are a generation or demand customer, although similar tariff structures apply to generation and demand, for generation all CDCM tariffs are applied as credits;
- The voltage level to which they are connected and their metering arrangements; and
- Their 'profile class', tariffs for different users are calculated based on their predicted load volume and use of assets, where this is not available for an individual customer, profile classes identified in the Balancing and Settlement Code are used. For each user type, a number of charges are calculated, including p/kWh unit charges, fixed charges (p/meter/day), capacity charges (p/kVA/day) as well as reactive power charges (p/kVArh) and excess capacity charges (p/kVA/day), not all customers incur all the different charges.

Adjustment to allow recovery of total costs

[31] An exception is for customers connected to the HV busbars in primary substations.

[32] The tariff setting methodologies are incorporated into the Distribution Connection and Use of System Agreement, this agreement also sets out the methodologies and the procedure for interested parties to propose changes.

The process for allocating the remaining costs is called scaling. The tariffs estimated using the 500 MW model are adjusted to ensure that the predicted derived revenue matches the DSO's allowed revenue under its price control.[33]

[33] Price controls determine how much income DSOs can collect from network users. This 'Allowed Revenue' is set at a level that allows recovery of the efficient costs of network operation and some reinforcement. It does not include connection costs. Distribution Use of System (DUoS) tariffs are used to collect the allowed revenue, mainly from the electricity suppliers who use the electricity networks to distribute energy to their customers. Suppliers then include network charges as part of end users' total energy bills.

Germany: Tariff Formation in the Light of Market-Based and Network-Based Objectives

In the year 2011, the German parliament adopted a law on the modification of the Atomic Energy act, aiming at the abolishment of electricity supply from fossil fuels and nuclear energy. According to this law, the actual aim is that the demand of electricity shall be covered up to 45 % by renewable energy resources by 2025. In the course of the implementation of this decision, the number of power stations generating capacities from renewable energy sources is constantly growing all over the country. Naturally, energy supply from renewable sources takes place feature-dependent and hence regardless of the current network load. As a consequence, electricity can no longer be generated according to demand.

Based on the idea that now the demand has to be adapted to the volatile electricity supply, some believe that network tariffs should be used as an instrument to promote the synchronization of supply and demand. However, tariffs should be formatted network-oriented rather than market-based, because the network is primary geared towards a reliable and predictable prevention of high loads, in order to keep the need for further network expansion to a minimum.

In Germany, network tariffs are composed of two components, namely a power based price and a power band price. Because network users have an influence on the need for network expansion through their individual contribution to the simultaneous peak load, network costs are allocated to the users under the causation principle, taking into account each user's (statistically probable) contribution to the annual simultaneous peak load in the formation of the power based price.

In principle, this system of tariff formation is beneficial for the network as well as for the market. The power based price effectively limits the individual load peaks. Meanwhile, loads below the peak can be optimized flexibly with regard to the market, as the power based prices remain steady within this load range that does not affect the network.

However, in the view of BNetzA, network and market objectives have to be clearly distinguished, as they may in some cases even be conflicting. If for example, many users simultaneously react to a market signal, i.e. market-oriented behavior, they may cause significant shifts of load. In addition to the network's none-simultaneous base load, this "new" simultaneous load may lead to a new peak load which again results in the need for network expansion.

Considering the aforementioned conflicts between market and network goals, the tariff formation system should be further developed seeking a way to fulfill the following requirements as far as possible:

- Promotion of market and network-oriented behavior,
- cause and division-appropriate tariff formation,
- prevention of misplaced incentives and windfall effects,
- transparence and predictability and
- promotion of efficient behavior.

Italy: The role of energy efficiency in reforming the Italian electricity tariffs for households

A case study from Italy on tariff design for households

"*The more electricity you use the higher will be the price for each new kWh*": this was the basic principle introduced in the early 1970s by the Government for pricing the supply of electricity to Italian households, in order to discourage excessive consumption by domestic Italian customers.

At that time Italy, like many other European countries, was facing the consequences of an oil crisis and there was a desperate need to encourage energy savings in all sectors. Moreover, a rapid development of the natural gas network was under way in Italy to promote the use of this efficient energy vector not only in the industrial sector but also for heating and cooking in the residential sector; natural gas rapid deployment was at that time another good reason to sustain the use of electricity in the houses only for "obliged uses" (lighting and appliances) and not for thermal ones.

At that time, no competition was in place, the State-owned utility (Enel) was still bundled along the whole value-chain from generation to supply, a unique supplier was active and tariffs for electricity supply to end-users were defined by ministerial decrees, including all underlying costs (generation, transmission, distribution, dispatching, measurement, etc.), as the independent regulator was not yet established.

Two different tariff structures were defined for households, one for supplying houses of primary residence with a limited power usage (no more than 3,3 kW peak, limit assured by a breaker installed onboard the meter) and a higher one for holiday houses or for "energy intensive" households (i.e. with a contractual capacity higher than 3,3 kW).

Tariff structure for the first group (residents, the large majority of households) was designed as a "progressive tariff" or "increasing consumption-block tariff", as it is now called in international literature. Lower and upper boundaries of each block were defined (in terms of kWh/year or in kWh/month for monthly billing), following the results of statistical surveys over a sample of Italian households: in 1971-1973 half of them used less than 2 kW and 1.000 kWh/year and the average energy consumption was around 1.350 kWh/year. These were then the boundaries of the three blocks: up to 900 kWh/year for application of the lowest price (subsidised), 901-1.800 kWh/year for the average price (proxy of a cost-reflective one), over 1800 kWh/year for the highest price (the same applied to holiday houses or intensive users).

Over the following forty years the number of blocks increased from three to four/five and the shape of prices for each block changed a few times (probably also partially losing a direct connection to the original rationale; see Table 1), but the definition of such boundaries didn't change much, despite the net increase in the average use of electricity by Italian households: in 2013 only 2% of them used less than 2 kW and the average consumption was around 2.200 kWh/year.

Table 1 – Evolution of the Italian increasing block tariffs (expressed in terms of % of the highest price applied)

	from 1st to 900th kWh/y	from 901th to 1800th kWh/y	from 1801th to 2640th kWh/y	from 2641th to 3540th kWh/y	from 3541th to 4440th kWh/y	from 4441th kWh/y
1991	29%	62%	**100%**	**100%**	**100%**	**100%**
2000	21%	29%	50%	**100%**	92%	50%
2007	32%	40%	61%	**100%**	92%	61%
2015	43%	43%	62%	85%	85%	**100%**

NOTE: Since July 2007, with the complete opening of the retail market to competition, the application of increasing blocks structure has been limited to the regulated components of the households' energy bill (network tariff and system charges)

In 2012 the new Energy Efficiency Directive (2012/27/UE) was issued, promoting the efficiency of heating and cooling, the transparency of billing, the user involvement and the "*removal of those incentives in transmission and distribution tariffs that are detrimental to the overall efficiency (including energy efficiency) of the generation, transmission, distribution and supply of electricity or those that might hamper participation of demand response [...]*".

Working on the national implementation of this Directive, the Italian Parliament and Government identified the existing structure of households' electricity tariffs as non-compliant with the objectives mentioned above, as it does not take into account the radical change in the socio-demographic structure of households, energy markets, electro-efficient technologies for heating/cooking and the framework of European legislation regarding the promotion of energy efficiency:

- it is ineffective for the promotion of efficient heating and cooking technologies as it applies an unjustified burden over the operating costs of efficient heat pumps, electric vehicles and induction plates;
- It is not cost reflective and hampers the user in performing a neutral economic comparison between concurrent technologies based on different energy vectors (e.g. heat pumps vs gas boilers or EVs vs fuel fired vehicles);
- It hinders transparency and user awareness, as the price blocks make the energy bills extremely complex to read and difficult to understand, preventing people to have a clear idea of the price they pay for each kWh and then of the benefits they could gain from an investment in energy efficiency or demand response.

International literature has shown that people are hardly aware of the variations in the marginal price and are more responsive to the average price of electricity supply which, in an increasing blocks tariff, sends contradictory signals. Moreover, unlike the few other countries where progressive tariffs have been implemented, the blocks in Italian tariffs are applicable to all households, regardless of their size, climate and heating technology. This is very different to the Californian experience, where block boundaries have been defined as a percentage of a user-specific reference yearly consumption.

This tariff structure has been considered outdated and no longer capable of fulfilling its original goals of promoting sustainable use of electricity by households. The NRA has been given the task of gradually reforming it, revising the old design to make it more cost reflective and transparent and taking into account the social impact that such reform will have on low incomes.

After long consultation with all relevant stakeholders, following the Regulatory Impact Analysis guidelines, in December 2015 AEEGSI issued the final decision redesigning the tariff system for electricity supply to households, aimed at removing increasing blocks in 2018, with a two-year transition:

- from 2017 network tariffs will be completely linear, cost reflective and homogeneous for all LV users (not only households); the cost for each kW of contracted power increases, but more flexibility is granted to all LV users to define their ideal contractual capacity; a first step has been already implemented at beginning of 2016;
- from 2018 tariff components related to system charges (levies for RES support and other public interest policies related to electricity) will be completely linear, with holidays houses paying a higher fixed yearly amount than primary residence homes (mirroring a differentiation widely used in the Italian fiscal system).

As far as the promotion of energy efficiency is concerned, network tariffs are not the only tool. In particular, labelling of electric appliances, performance requirements defined in the European ‘ecodesign’ framework[34] and other public policies to promote customer awareness of electricity consumption, can be used to convey signals that may encourage the choice of electro-efficient appliances. In this context, the decrease of the economic value of electricity that could be saved investing in efficient lighting or appliances by those households who have been so far affected by the highest price blocks (> 2700 kWh/year) impacts on a small fraction of users (no more than 15% of approx 29 million households), while for around 43% of them (using less than 1800 kWh/year) the tariff redesign implies an increase in the economic value of savings.

[34] https://ec.europa.eu/energy/en/topics/energy-efficiency/energy-efficient-products

About CEER

The Council of European Energy Regulators (CEER) is the voice of Europe's national regulators of electricity and gas at EU and international level. CEER's members and observers (from 33 European countries) are the statutory bodies responsible for energy regulation at national level.

One of CEER's key objectives is to facilitate the creation of a single, competitive, efficient and sustainable EU internal energy market that works in the public interest. CEER actively promotes an investment-friendly and harmonised regulatory environment, and consistent application of existing EU legislation. Moreover, CEER champions consumer issues in our belief that a competitive and secure EU single energy market is not a goal in itself, but should deliver benefits for energy consumers.

CEER, based in Brussels, deals with a broad range of energy issues including retail markets and consumers; distribution networks; smart grids; flexibility; sustainability; and international cooperation. European energy regulators are committed to a holistic approach to energy regulation in Europe. Through CEER, NRAs cooperate and develop common position papers, advice and forward-thinking recommendations to improve the electricity and gas markets for the benefit of consumers and businesses.

The work of CEER is structured according to a number of working groups and task forces, composed of staff members of the national energy regulatory authorities, and supported by the CEER Secretariat. This report was prepared by a Task Force of CEER's Distributed Systems Working Group.

CEER wishes to thank in particular the following regulatory experts for their work in preparing this report: Lynda Carroll, Nathan Macwhinnie, Anne Glomnes, Karin Widegren and Isabel Apolinário.

More information at www.ceer.eu.