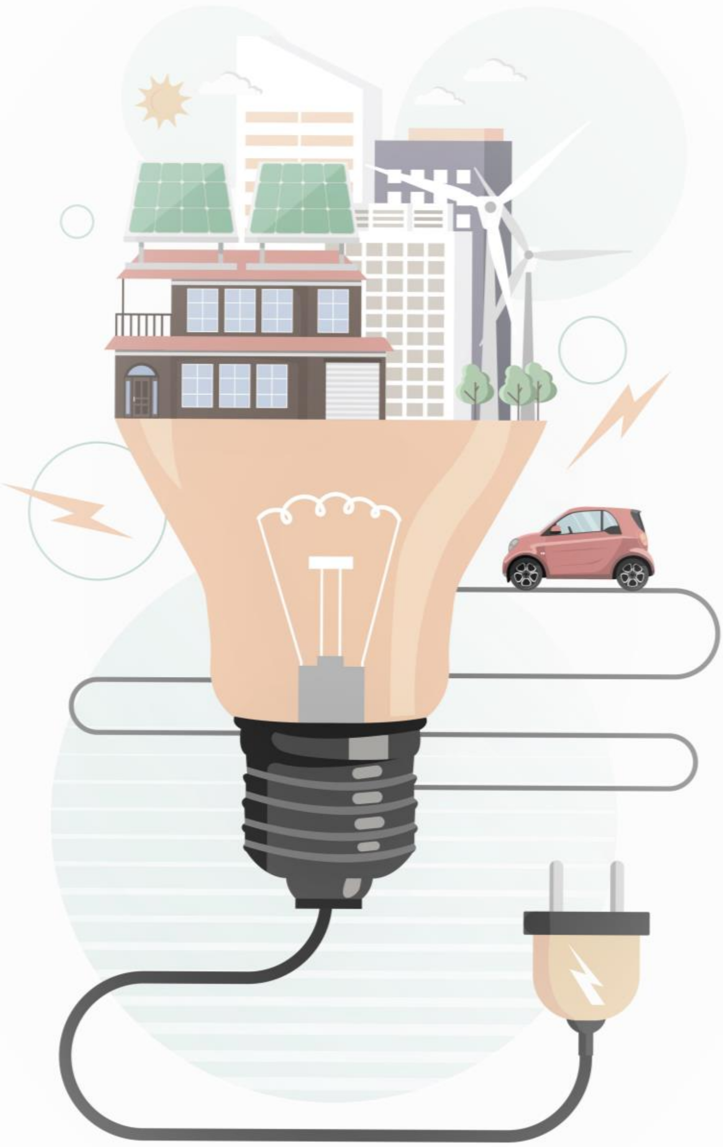
ASSET Study on

Dynamic retail electricity prices



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About the ASSET project

The ASSET Project (Advanced System Studies for Energy Transition) aims at providing studies in support to EU policy making, research and innovation in the field of energy. Studies are in general focussed on the large-scale integration of renewable energy sources in the EU electricity system and consider, in particular, aspects related to consumer choices, demand-response, energy efficiency, smart meters and grids, storage, RES technologies, etc. Furthermore, connections between the electricity grid and other networks (gas, heating and cooling) as well as synergies between these networks are assessed.

The ASSET studies not only summarize the state-of-the-art in these domains, but also comprise detailed qualitative and quantitative analyses on the basis of recognized techniques in view of offering insights from a technology, policy (regulation, market design) and business point of view.

Disclaimer

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Authors

This study has been developed as part of the ASSET project by a consortium of Tractebel Impact, E3M and Guidehouse.

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ABBREVIATIONS

CBA	Cost-benefit analysis
CHP	Combined heat and power
CPP	Critical Peak Pricing
CPR	Critical Peak Rebates
dTOU	Dynamic Time-Of-Use
EC	European Commission
EU	European Union
GWh	Gigawatt hour
kV	Kilovolt
kWh	Kilowatt hour
MWh	Megawatt hour
MS	Member State
PMU	Phasor measurement unit
PSO	Public Service Obligation
PTR	Peak Time Rebates
RES	Renewable energy source
RTP	Real Time Pricing
TOU	Time-Of-Use
VAT	Value added tax
VPP	Variable Peak Pricing

EXECUTIVE SUMMARY

The Clean Energy Package aims at empowering consumers and increasing electricity market integration. More and more households are being equipped with smart meters that enable monitoring, adapting domestic consumption to real-life power price changes and availability of variable RES-E. Dynamic tariffs can lead to system cost reductions, energy savings, as well as increased market transparency and consumer awareness. In this study, we provide an overview of the existing price structures, create insight in the dynamic power pricing options, discuss impacts and potential of the dynamic prices and conclude with a strategic proposal for further implementation of the dynamic pricing process in the EU.

Electricity price structure

Electricity supply is typically financed by allocating generation-, transmission- and distribution costs to consumers. Retail power prices in the EU– paid by the final consumers – are typically built up in three parts: 1) the cost of energy, 2) network costs (both transmission and distribution) and 3) a policy component such as a renewable energy support tax and other charges, taxies and levies.

Retail consumer prices vary for different consumer classes. In the report, the following classes were identified: households, non-households (small and medium sized enterprises as well as smaller sized industries) and energy intensive industries.

In most Members States, the dominant policy costs concern RES support, environmental taxes and excise taxes. For households, SME & small industries, network costs typically account for about 40% of the consumer price, whilst taxes & levies typically form a minor part of total retail price. For energy-intensive industries, the energy component is the most dominant price component. Network costs are the second most significant price component but still represent lower relative shares in the total price compared to the other consumer classes. The share of taxes & levies is comparatively low, and even negligible in some Member States, mainly due to exemptions promoting industrial competitiveness.

Dynamic pricing options

There are several power pricing models that could add dynamicity to varying degrees to the final consumer price:

- Real time pricing (RTP), which serves to reflect the real-time cost of electricity: The price changes can occur on an hourly basis, every quarter-hour or even more often. Usually, the price variations are achieved through coupling with the wholesale market. RTP is typically the pricing model that adds the largest dynamicity to the final power price.
- Time-Of-Use (TOU), where the electricity prices are set for specific periods of time such as peak and off-peak hours.
- Dynamic Time-Of-Use (dTOU) - electricity prices and the peak and off-peak periods change regularly, which allows for a more accurate reflection of the situation in the energy market.
- Variable Peak Pricing (VPP) - a hybrid between TOU rates and RTP where specific periods of electricity price fluctuations are defined in advance. The price fluctuations that occur in the defined periods, vary depending on the energy supplier and the market conditions.

- Critical Peak Pricing (CPP) involves the raising the price of electricity substantially during periods of excessive demand or of a particularly low feed-in from renewables. The peak rate can be either defined beforehand or determined dynamically based on the market conditions.

Finally, consumers can be remunerated for decreasing their electricity consumption during critical periods instead being punished by higher electricity prices.

The goal of the European Commission is to allow all consumers to participate in demand response. The advancing smart meter roll-out is the key enabling technology for RTP tariffs and is therefore crucial for the future of dynamic pricing in Europe. Most of the European countries plan to finish the wide-scale (>80% of consumers) roll-out by 2020.[1]

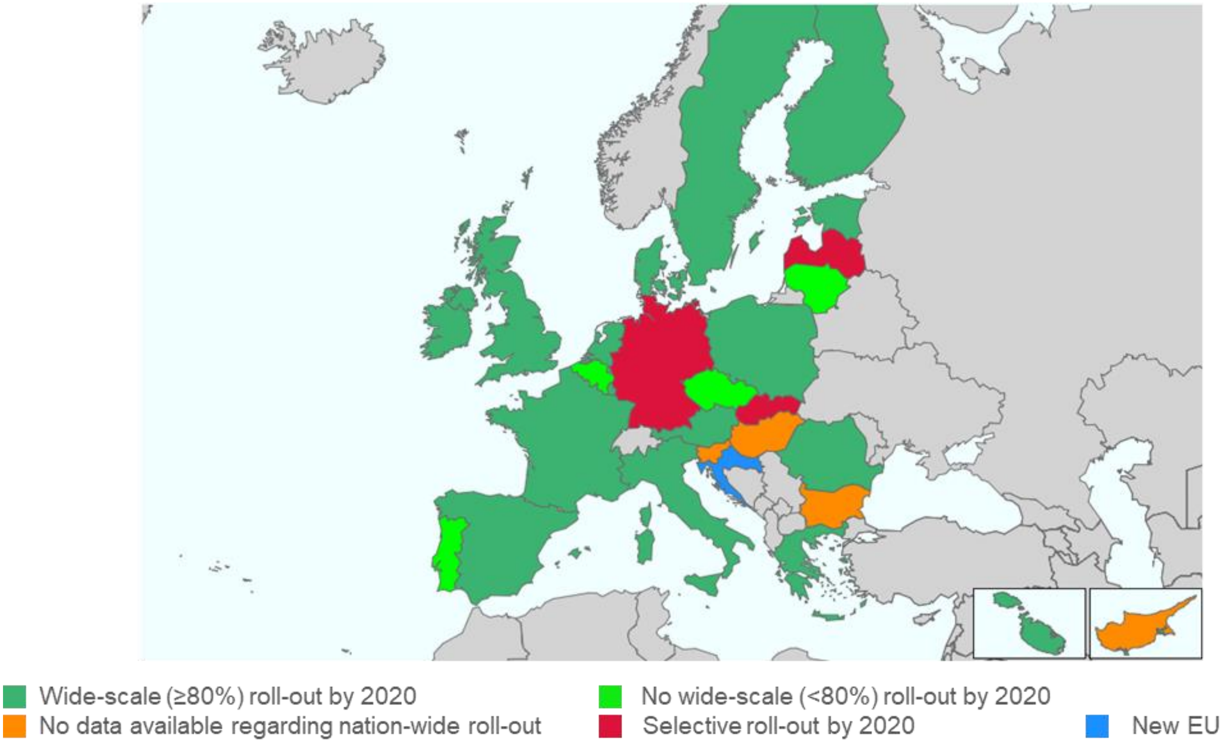

Figure 1: Smart meter roll-out in selected countries of the EU. (source: JRS, 2018)

The different outcomes of the CBAs across Member States result partly from diverging attitudes towards a higher transparency of power demand and data protection. Consequently, the reception of dynamic electricity prices is also subject to regional differences and the national implementation plans and information campaigns must address the national circumstances.

Dynamic price impacts

The figure below provides an indication of the risk premiums that were estimated in several studies for the different tariffs. The concave shape of the graph demonstrates the relation between the need for hedging the price risk by the supplier and the customer's exposure to the wholesale market price. As a result, the supply of electricity becomes cheaper because costly risk premiums are avoided.

[1] JRS, 2018

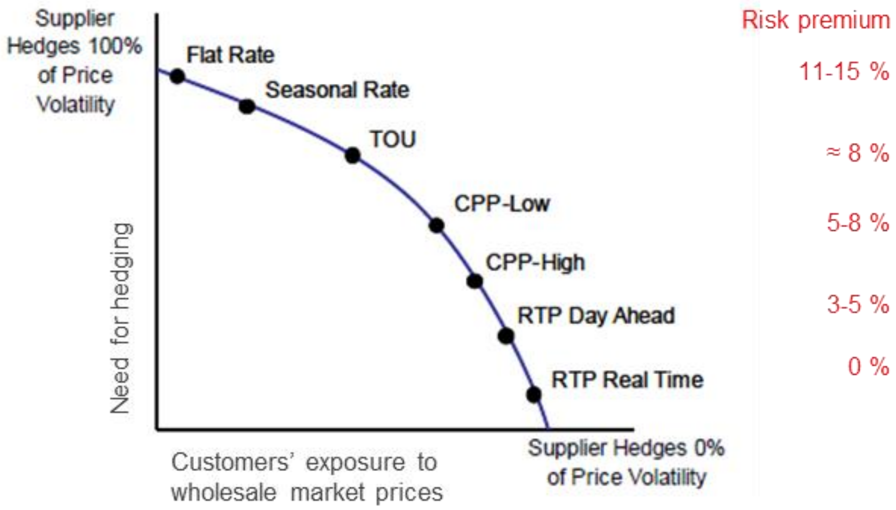

Figure 2: Indication of risk premiums of different tariffs. (source: The Brattle Group, 2008)

Consumers with peaky load profiles and a high electricity demand during peak hours impose higher power system costs than consumers with flat load profiles. A flat rate represents a de facto cross-subsidy from households with flat profiles to households with peaky profiles. Moreover, particularly low-income households are characterised by flat power demands.[2] Consequently, the most low-income consumers are burdened disproportionally. Dynamic pricing would therefore not only lead to electricity bills savings for most consumers, but also support low-income households and allocate costs to where and when they are incurred.

Demand response can additionally increase the benefits of dynamic pricing, thus making the energy system more efficient and lead to even higher electricity bill savings. Consumers can respond to price signals by decreasing their load during peak hours and shifting their consumption to low price periods. Lower peak demand reduces the losses in the electricity grid as variable grid losses grow quadratically with increased peak network loading.[3] Dynamic prices incentivise demand shifting to times of lower prices which usually indicate times of high intermittent renewable energy resources (RES) feed-in. Curtailment costs of RES and fuel costs of dispatchable generation can be decreased. A higher flexibility in the power system results also in a stabilisation of the wholesale market prices. Very low or negative prices as well as price peaks are mitigated and the overall wholesale market price level stabilised. This allows RES operators to increase their revenue on the power market and decreases the need for governmental support.[4] Finally, as renewable generation replaces conventional generation fuel, costs and CO_2 emissions can be saved.

Consumers can actively reduce their electricity costs by shifting their power demand to low-cost periods. These savings depend on the ability or willingness to shift the demand and the electricity price curve.

The following figure illustrates the electricity bill impacts of demand response for a CPP tariff. The figure shows the bill increase and decrease for households with a CPP tariff based on their

[2] The Brattle Group, 2010
[3] Ecofys, 2013
[4] BMWi, 2015

electricity demand profile. Secondly, the figure shows the effect of a hedging cost (or risk premium) credit of 3%. Finally, the figure shows the impact of consumers' demand response measures. If consumers can adapt their load to the price signals, the proportion of households benefiting from a CPP tariff can be increased further to around 90%.

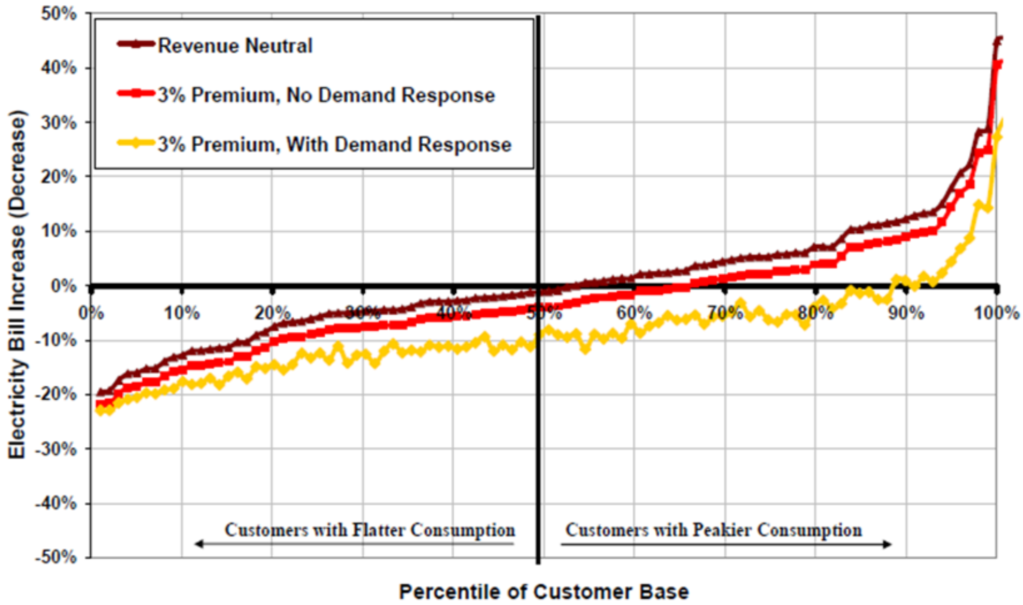

Figure 3: Distribution of Bill Impacts under a CPP Rate for households including a 3% Hedging Cost Credit, (source: Guidehouse based on The Battle Group, 2010A)

The scope to adapt the load to the price signals varies between and within the different consumer groups. Low-income households have a lower potential to respond to dynamic prices than average households and thus benefit less from potential electricity bill reductions gained from demand response.[5] On the other hand, low-income households embrace demand response generally more than average households if savings can be achieved and therefore are still likely to benefit from lower electricity bills overall due to an increase in their disposable income.[6]

Similarly, industrial competitiveness might increase due to dynamic prices. It depends, however, on the flexibility potential of industries, which is additionally constrained by working hours, the interdependency of industrial processes and electric appliances as well as other business internal factors.

The closer connection to the wholesale market also translates into a higher price variance and perceived price uncertainty or risk by the consumer. If consumers oppose more dynamic price schemes or fail to adjust their power consumption, then the feasible rewards turn out to be smaller. In this case the discounts from a flat rate could converge.

[5] The Brattle Group, 2010; RAP, The Brattle Group, 2012

[6] The Brattle Group, 2010; RAP, The Brattle Group, 2012, AECOM, 2011

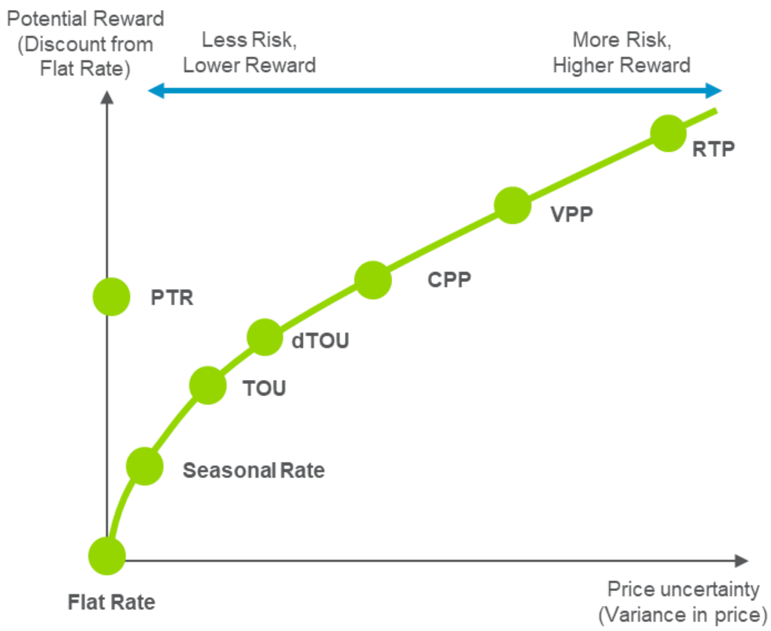

Figure 4: Potential reward and price uncertainties of tariffs. (source: Guidehouse based on RAP; The Battle Group 2012; Schneider, Sunstein, 2016)

To facilitate the uptake of dynamic tariffs and maximise the rewards, it is therefore important to understand and address the behavioural biases of consumers. Whilst commercial companies seek to maximise their competitiveness through minimising their cost, households can act more irrationally and are typically particularly biased. Most households initially oppose a change of the status quo. Therefore, it is important to explain why a regulatory change and the implementation of dynamic tariffs is important and beneficial. This requires a comprehensible information campaign from regulators, energy suppliers and national agencies.[7] Additionally, the electricity tariff should be made easy to understand. Complex combinations of different tariff types can seem opaque and frighten consumers off from choosing this tariff. As people accept and get used to a higher degree of digitalization and automatization in their daily life, the attitude towards dynamic electricity tariffs also changes.

Another important factor is the normative social influence. Once a critical mass of households accepts RTP and the social benefits become evident, the acceptance of such tariffs accelerates. Therefore, the biggest hurdle is to reach a critical mass and the communication of the reasons for choosing for dynamic electricity tariffs.

Dynamic price potential

The demand-side flexibility potential is the ability or willingness to shift load and is dependent on multiple factors, such as balancing of load, duration, frequency and temperature. On a European level, the load reduction potential is well distributed over households, the commercial sector and industries whereas the load increase potential is low for industries and very high for households.

The figure below shows the average load reduction potential of single industries, processes and appliances and the range from minimum available potential to maximum available potential throughout the year considering varying demands and temperature effects. The biggest load reduction potential lies within the cross-sector technologies (ventilation, air-conditioning, heat

[7] Schneider, Sunstein, 2016; Fraunhofer ISI, 2012, EcoAlign, 2013; Hobman et. al. 2014

circulation pumps) and household appliances (freezers/refrigerators, washing machines, tumble dryers). The influence of frequency of use and ambient temperature are reflected in the results. Heating and cooling technologies and household appliances that are not constantly in use and used at typical times (e.g. washing machines) show the biggest variation in available potential. For the industry, only the electric steel industry shows a stable average potential close to 10 GW. Further energy intensive industries with an average potential between 1 to 4 GW are pulp and paper, cement, chlorine and aluminium. Cement is produced mainly at nights which offers the opportunity to shift the process time. The chloralkaline process is a flexible process, but difficult to control.[8] In total, the load reduction potential in industry is of a similar magnitude as the load reduction potential of households and the commercial sector. The energy industry has a significant share of the load reduction potential of the industry sector.

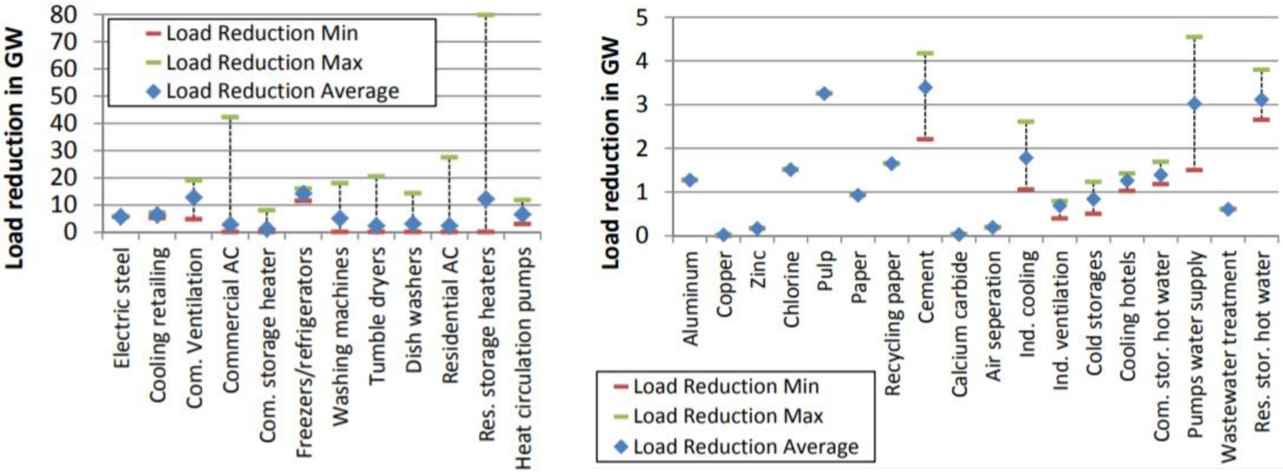

Figure 5: Load reduction potential of single appliances, processes, and industries. (source: DLR, 2015)

The figure below shows the load increase potential. Again, household appliances have a high potential, followed by cross-sector technologies. However, the high load increase figures for household appliances are based on the fact that the load from multiple consecutive hours can be shifted to earlier times. The so-called free load of appliances with a low capacity factor (e.g. washing machines) results in a high theoretical potential. The drop in potential following a use of potential is not reflected, i.e. the duration of the potential can be low compared to other processes. The same holds for residential storage heaters which show a high potential which is limited by the heating demand and heat storage facilities. The load increase potential in industry is rather low. Energy-intensive processes are most often operated at a high capacity factor with only limited load increase potential. This affects the total load reduction potential as well. If processes are influenced by load shaving (e.g. load reduction without an increase at another point in time), the total load must be balanced, i.e. the limited load increase potential limits the load reduction potential throughout the year.

[8] FfE 2014

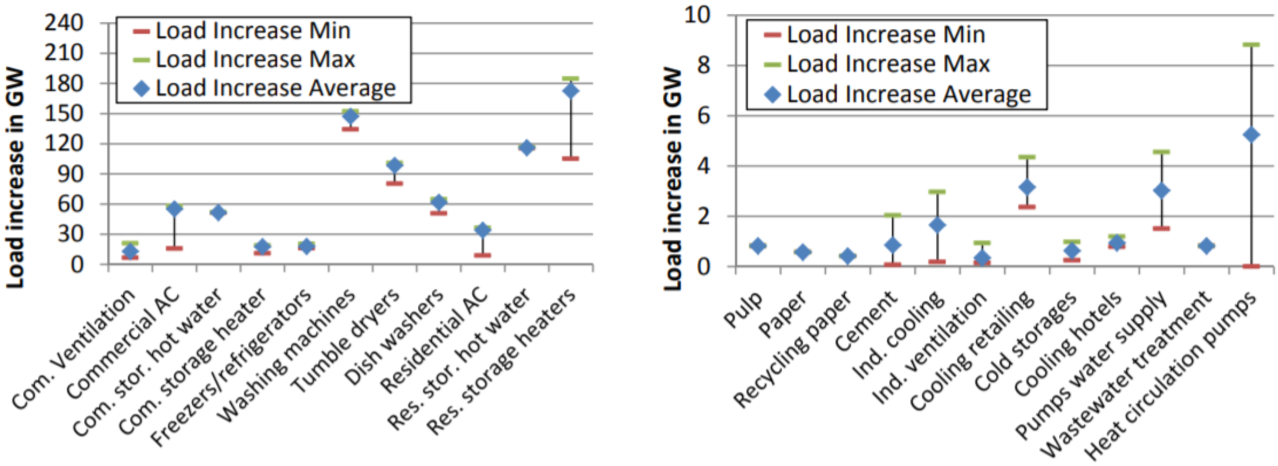

Figure 6: Load increase potential of single appliances, processes, and industries. (source: DLR, 2015)

An analysis for the energy intensive industry in Germany has shown that there exists demand-side flexibility potential for load shifting coming from cross-sector technologies but also from energy-intensive processes itself. Moreover, the energy-intensive industry offers a substantial load shedding potential. The load shifting potential as share of the total demand-side flexibility potential is high in the chlorine and steel industry.[9]

The figure below shows the load reduction potential per country as a share of the country's peak load. Load reduction potential is available in all countries and throughout the whole year. The figure illustrates, that there is substantial potential of about 10 to 30% of the countries' peak load on average and can reach up to 80% and can go down to not less than 5% in single countries throughout the year.

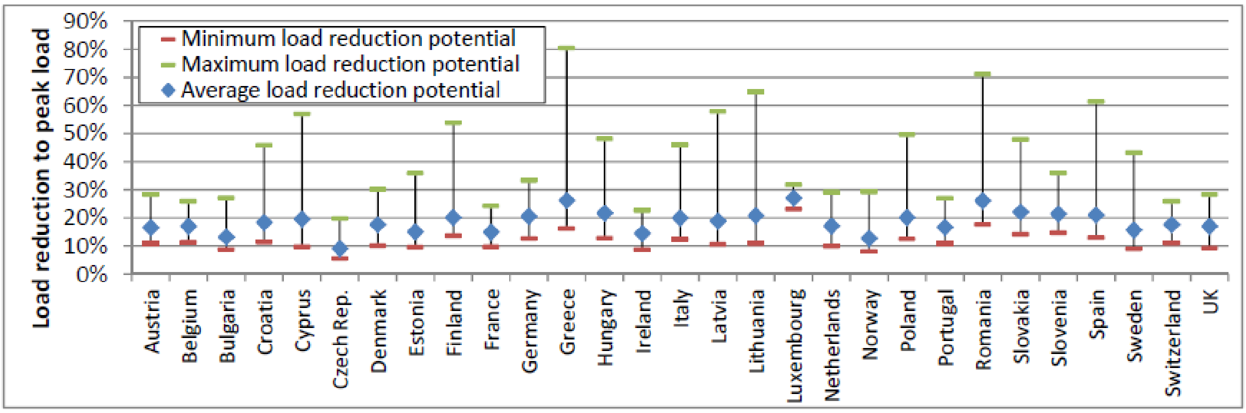

Figure 7: Share of load reduction potential of countries' peak load. (source: DLR, 2015)

There is load reduction potential across all sectors and in all countries. The load increase potential is not evenly distributed between sectors. Households have a very high theoretical load increase potential due to high free loads. The load increase potential for SMEs and industries is in a similar

[9] FfE, 2014

magnitude as the load reduction potential and dominated by cross-sector technologies. The load increase potential in the energy-intensive industry is low.

The technical controllability of the theoretical potential differs amongst sectors and is expected to increase over time along with the increasing digitalisation and electrification of heating and transport that will add new flexible loads to the system.

The potential benefits that can be generated by consumers are confronted with activation costs. The costs for demand response can be divided into initial costs for the investment into ICT infrastructure and storages for load flexibilization, and activation costs for an actual demand response call. Activation costs have two components:

- fixed operating costs occur regularly independent on the number of demand response calls. They comprise information, transaction, and control costs.
- variable activation costs influence the operation of the flexibility potential. The financial benefits of load shifting must exceed the variable costs.

In general, for cross-sector technologies initial costs are high whereas the activation costs are low. In contrast, initial costs for energy-intensive processes are low whereas activation costs are high. For smaller companies, initial costs can be higher if internal load management and automation appliances need to be installed.

The largest influencing factor is the flexible load available for load shifting. Load shifting can be offered with low marginal costs of less than €20/MWh, on the one side for cross-sector technologies but also with available load shifting potential of energy-intensive processes. The potential of households and SMEs and industries is high when aggregated. Single households and sites show a low potential compared to energy-intensive industries. Therefore, activation costs for households, SMEs and industries are typically higher than for load shifting in energy-intensive processes and cross-sector technologies.

Conclusions and recommendations

Dynamic electricity tariffs are no longer a rarity across Europe. In many Member States consumers can already choose dynamic electricity tariffs, although this usually only encapsulates the energy-related price component. Currently, TOU for the energy component is the most prevalent dynamic tariff type across Europe, but the share of RTP is increasing. Dynamic policy and network costs, particularly on household level, are still relatively rare. And therefore, the increasing implementation of RTP tariffs across Europe should be further encouraged.

Price variations should be noticeable to leverage the demand response potential. Particularly the dynamization of network charges can additionally support price variations as these constitute a significant cost component for most Member States and all consumer groups. Therefore, the variation of network costs would have a perceptible impact on the total retail price for electricity. Moreover, network costs are more homogeneous than policy related costs. Consequently, the modification of their price structure would be easier than of several different taxes and levies.

Dynamic network tariffs can support a smarter congestion management in addition to the alignment between wholesale price signals and the grid situation. Dynamic electricity tariffs that incorporate the local grid situation can help to prevent the risk of simultaneous and strong consumer reactions to price signals that can lead to critical situations in the electricity system.[10]

[10] FfE, 2015

They may also foster a fairer distribution of costs, charging for where, when and which stress consumers cause on the electricity grid.

A shift towards dynamic network tariffs across all consumer groups requires a rethinking from network operators, encouraged by exchanging international experience and through insights from pilot projects and further supplementing studies.

The network cost should be made volumetric by coupling the energy charge to the wholesale market prices, eradicating the capacity charge and minimising the fixed charge. The coupling to the wholesale market price should be realised through a multiplicator so that the network operators can cover their cost and the incentive for demand response is large enough. Dynamic network costs would additionally increase the price variations on the wholesale market.

Every Member State should decide on its own whether it wishes to implement dynamic policy costs to reflect the specificities of the local markets. The design of the RTP tariffs should be specified at MS level, reflect the national framework conditions and first experiences with RTP. Potential price floors, fixed costs or margins should be minimal (or even absent) and only serve to cover the fixed cost such as administration as well as decrease the overall risk in the market.

Dynamic power pricing should move towards RTP at intervals equal to the market settlement frequency, as this tariff option can offer the greatest benefit, assuming a smart metering infrastructure is in place. We recommend a three-step implementation approach, shown in the figure below.

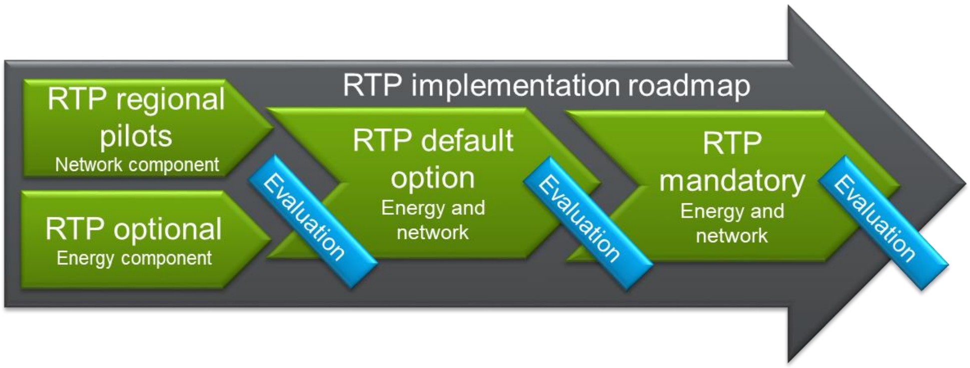

Figure 8: RTP implementation roadmap towards dynamic pricing

For a dynamization of the network component, we recommend precursory regional pilot projects in specific regions in order to gain more insight in local threshold values, consumer behaviour that might be cultural dependent, system operator requirements and market dynamics.

We suggest going beyond the recommendation in the Internal Market Directive and pursue the implementation of RTP more firmly. After experience with dynamic tariffs has been gained and the awareness of dynamic pricing has been raised, RTP should be made the default option for all consumers, for both the energy and the network component.

All consumers equipped with smart metering devices should be exposed to price variations at the wholesale market, as this is the most efficient and optimal pricing method. The final step would be a mandatory RTP for all consumers, for both the energy and the network component.
Finally, we recommend conducting an evaluation after each step to fully understand the impacts of the roll-out of RTP and adjust the specific requirements and price setting methodology to increase effectiveness and efficiency of RTP.

TABLE OF CONTENTS

1 INTRODUCTION

Due to the European Commission's Clean Energy Package, passed in November 2016, new legislative proposals on clean energy transition for all Europeans are put forward.[11] Their main aim is to empower consumers and increase electricity market integration with smart metering and offering dynamic tariffs. More and more households will be equipped with smart meters which will enable them to monitor and adapt their consumption of electricity more accurately and timely. Moreover, the integration of intermittent renewables in the electricity mix requires increasing demand side management. Dynamic prices can thereby lead to energy system cost reductions, energy savings, and increased market awareness and transparency.

However, before any adoption of dynamic pricing the structure of electricity pricing needs to be studied in detail and the options of dynamic price models need to be better understood. In this study, we propose strategies for the further implementation of dynamic retail electricity prices in the EU. For this purpose, we describe firstly the current electricity price structure in chapter 2. The options impacts and potential of dynamic electricity prices are discussed in the chapters 3, 4 and 5 respectively. In chapter 6 we provide an overview of the current dynamization development across the EU before we draw our conclusions and make our recommendations for dynamic retail electricity price strategies.

[11] EC, 2018

2 ELECTRICITY PRICE STRUCTURE

In this chapter, the structure of electricity prices is described for all Member States for various consumer classes. Firstly, we describe the split of the retail electricity prices into components that relate to the described activities in the process of electricity supply as it has been applied in previous studies[12]. In addition, we define representative consumers to allow for a comparison of electricity prices between Member States. Finally, the structure and the components that constitute the final electricity retail price are presented, providing the basis for the potential assessment of increased price dynamization in the remainder of this report.

2.1 Methodology and assumptions

The electricity supply involves different activities; the generation of electricity in conventional or renewable power plants, its transmission and distribution towards final consumers using electricity networks, and trading at wholesale and retail markets. Those activities are typically financed by allocating the respective costs to final consumers as part of the electricity price.

Retail prices refer to the prices paid by the final consumer, for example households or industry. Retail electricity prices are typically divided into three components: energy, network and taxes & levies. The energy component reflects the generation stage, the network component relates to the transmission and distribution stages and taxes & levies finance policy support costs and other regulated activities. Figure 9 illustrates the theoretical impact of government policies on the different components of electricity prices.

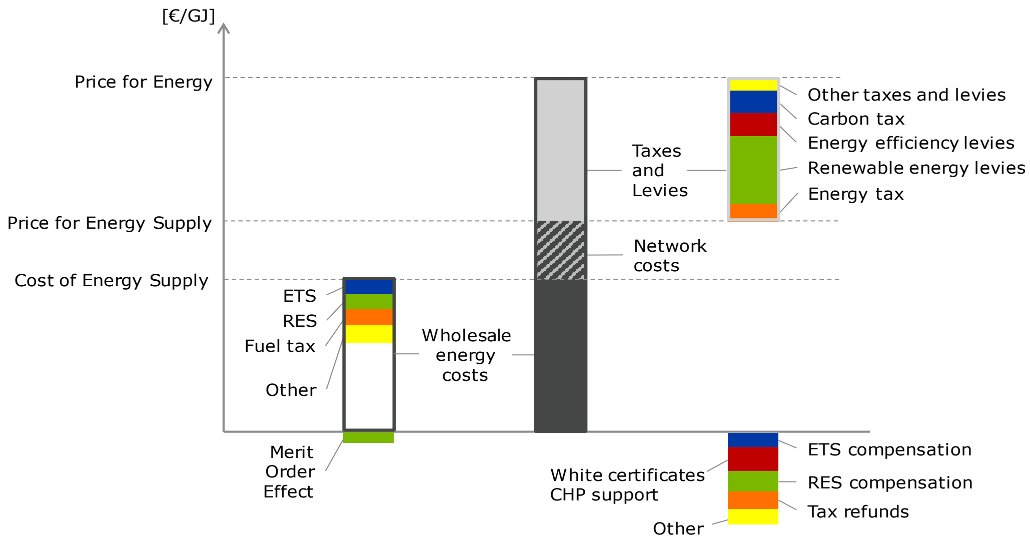

Figure 9: Government policies are influencing electricity prices in several ways (source: Guidehouse)

Although the division of retail prices into these three components is ubiquitous, an EU framework lacks to ensure that each component comprises the same elements. In consequence, Member

[12] See for example Ecofys, 2016

States can report most prices elements in any of the three components. This practice implies that a comparison of certain components can be misleading due to their divergent composition.[13]

Differences in reporting practices between Member States need to be corrected to allow for a comparison of price components. Within this report, price components are therefore decomposed into subcomponents, following the methodology Guidehouse developed in the EU Energy Costs and Prices Report.[14] Subcomponents aggregate price elements within the three components via their main purpose as illustrated in Figure 10.

	Components	Subcomponents	Elements
Retail electricity price	Taxes & Levies	• RES support • CHP support • Nuclear support • Energy efficiency support • Social tariffs • System operation • Market operation • Security of supply • Environmental taxes • Excise taxes • VAT • Other	• Individual taxes financing general state budget • Ear-marked levies financing policies
	Network	• Transmission • Distribution	• Transmission costs of investment and operation • Distribution costs of investment and operation • Metering • Network company's margin
	Energy	• Energy	• Wholesale energy cost • Supplier's margin

Figure 10: Components, subcomponents and elements of retail electricity prices (source: Guidehouse)

The energy component comprises wholesale energy costs and the supplier's margin. Subcomponents of the network component aggregate price elements classified as costs for investment and operation of transmission and distribution infrastructure, the network company's margin as well as metering and billing. In most cases, the elements of energy and network component are reported consistently by Member States.

The composition of the taxes & levies component is diverse due to country-specific support policies and regulated activities. Levies are typically ear-marked with a specific purpose in contrast to taxes that contribute to general state budget. Levies are typically raised to collect income, on the one hand, for policy-related activities such as renewable energy sources (RES) support, combined heat and power (CHP) support, nuclear support, energy efficiency support and social tariffs and, on the other hand, for regulated activities such as system operation, market operation, regulatory authority and security of supply mechanisms. Taxes are aggregated in subcomponents for local taxes, environmental taxes, excise taxes and value added taxes (VAT).

[13] EurElectric, 2014
[14] Ecofys, 2016

Since 2003, every Member State is required to charge final consumers with an excise tax by Council Directive 2003/96/EC. The minimum excise tax level is €1/MWh for households and €0.5/MWh for non-households. In addition, Member States are also mandated to apply a VAT on electricity sales. The VAT is an indirect tax that is recovered by companies according to their contribution to the value added of a good or a service and is effectively paid by final consumers. VAT payments are refundable for commercial consumers.

Retail electricity prices vary for different final consumer classes. Typically, domestic consumers pay higher prices per consumed unit of electricity than commercial consumers. Those differences can be explained by reduced wholesale market prices for commercial consumers due to higher purchase quantities. Also, households are connected to the lowest grid level making use of the entire electricity network. Energy-intensive consumers, in contrast, are typically connected to higher voltage levels. Lower network costs for those consumers are therefore reasonable since they avoid the usage of part of the network. In addition, large commercial consumers could be eligible for reductions and exemptions from certain taxes and levies. Other reasons for differences in final prices amongst consumers are exemptions and reductions that might be granted either to domestic consumers exposed to the risk of energy poverty or commercial consumers in international competition.

To allow for comparability of electricity prices between countries, we have defined representative consumers classes. The first consumer class are *Households*. The average consumption of households varies significantly between Member States as shown in Figure 11. Those variations can be explained amongst other things by differences in habits, weather conditions, heating and cooling technologies or equipment with electrical appliances. One reason for higher electricity consumption in Sweden, Finland and France, for example, is that electric heating is more common than in most other Member States. Assuming an average consumption per Member State assures that the compared electricity prices are those that are really paid by the majority of the households and are thus representative for each country.

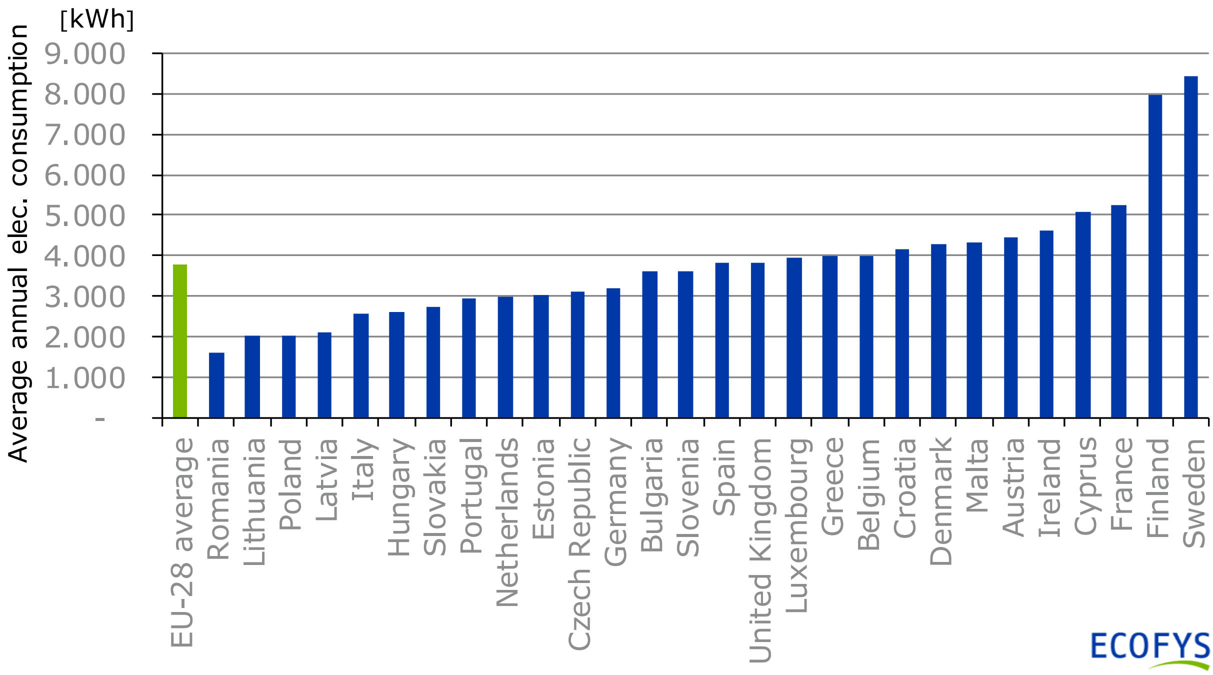

Figure 11: Average annual consumption of households in EU Member States (source: Guidehouse based on Eurostat, 2018)

Consumer classes representing non-households, are defined based on EU average values. The second representative consumer class are *Small and Medium Enterprises (SMEs)*[15] *& Small Industries.* The consumer class is characterised by a grid connection of 20 kV medium voltage level and an annual consumption ranging from 20 to 500 MWh, in accordance to Eurostat consumption band IB.[16] SMEs & Small Industries are typically not eligible for reductions or exemptions in the elements of their electricity prices.

Energy-Intensive Industries depict the third representative consumer class. The annual consumption of electricity is defined to be above 150 GWh. The grid connection is assumed to be at 110 kV high voltage level. The key characteristics of the three representative consumer classes are summarised in Table 1.

Table 1: Characteristics of representative consumer classes

Representative consumer	Annual Consumption	Level of grid connection
Households	**1,600 – 8500 kWh/a** *Average household consumption per MS*	**400 V** *Low voltage*
SME and small industries *not eligible for any reductions/exemptions*	**20 - 500 MWh/a** *Eurostat Consumption Band IB*	**20 kV** *Medium voltage*
Energy-intensive industries *eligible for potential reductions/exemptions*	**above 150 GWh/a** *Eurostat Consumption Band IG*	**110 kV** *High voltage*

Price structure refers to the composition of electricity prices for a specific class of consumers, such as the share of energy, network and taxes & levies component or of specific subcomponents or elements in the total retail electricity price. In this section, price structures are described. The analysis is performed for each representative consumer class and Member State separately.

The dataset for the energy and network components is based on Eurostat, 2018. The component Taxes & Levies is based on the Guidehouse electricity price database that includes potential reductions and exemptions in each Member State for the entire consumer population. The method is following the approach Guidehouse developed for the EU Energy Costs and Prices study published as part of the EU Winter Package.[17]

2.2 Households

The structure of households' retail electricity prices with taxes & levies divided into their subcomponents is depicted in Figure 12.

[15] The European Commission defines SME as enterprises with less than 250 employees and either a turnover lower or equal to €50m or a total balance sheet lower or equal to €43m. SMEs represent 99% of all businesses in the EU.

[16] Consumption bands are statistical groups of consumers according to their yearly consumption.

[17] Ecofys, 2016

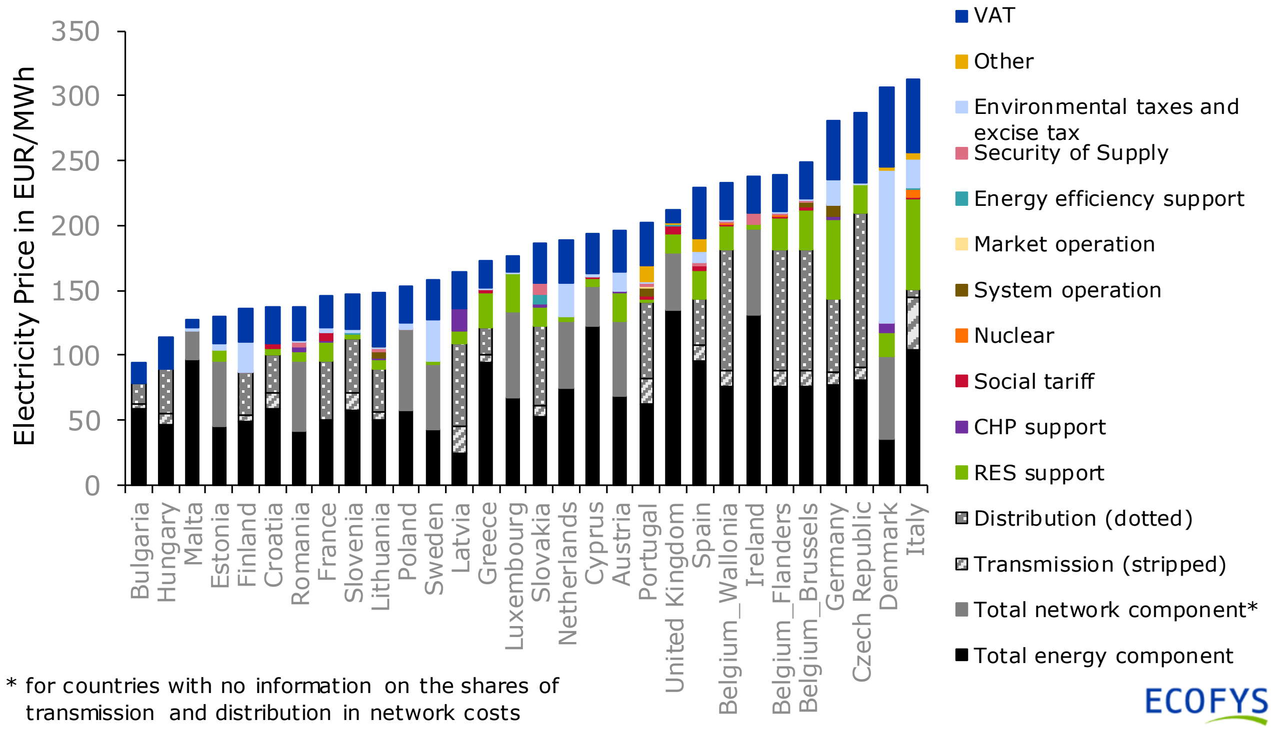

Figure 12: Retail electricity prices for households in EU-28, 2015-2017. (source: Guidehouse based on Eurostat, 2018)

Households' retail electricity prices are lowest in Bulgaria with €94/MWh and highest in Italy with €312/MWh. Taxes & levies in households' retail electricity prices range from 6% to 68%, however, in most countries this share makes up less than 20% of the total price, excluding VAT. Bulgaria and Slovakia do not charge an excise tax to households regardless of the minimum tax level of €1/MWh as stated in Council Directive 2003/96/EC. Household electricity prices are highest in Denmark mainly because of a particularly high electricity tax. Denmark lowered the level of income taxes and increased the electricity tax in an environmental tax reform in 2009 to reduce the energy consumption by 4% in 2020 and limit CO_2 emissions. Despite the high retail price for households, the Danish energy component is the second lowest after Latvia in the EU. In Italy and Germany, retail prices are comparably higher than in other EU Member States mainly because of the high level of RES support in both countries. In general, main drivers of the households' taxes & levies component are VAT, RES support and environmental taxes & excise taxes.

Network costs make up 15% to 51% of total retail electricity prices for households, but typically constitute 40% of the total retail price. For the 16 countries for which data was available, we have illustrated the share of transmission and distribution costs of total network costs. Distribution costs account for above 70% of the network component for all countries with available data except Italy, where transmission network costs have been reported to be at 87%. France, in contrast, stated that 100% of households' network component is related to the distribution network. However, cross country comparisons should be treated with caution as a harmonised distinction between transmission and distribution grids is absent.[18]

[18] Ecofys, 2016

2.3 SMEs and small industry

Retail electricity prices for SME & Small Industries range from €90/MWh in Bulgaria to €190/MWh in Germany. In general, prices for this consumer class tend to be somewhat lower than those for households, however the price structure is similar, see the figure below.

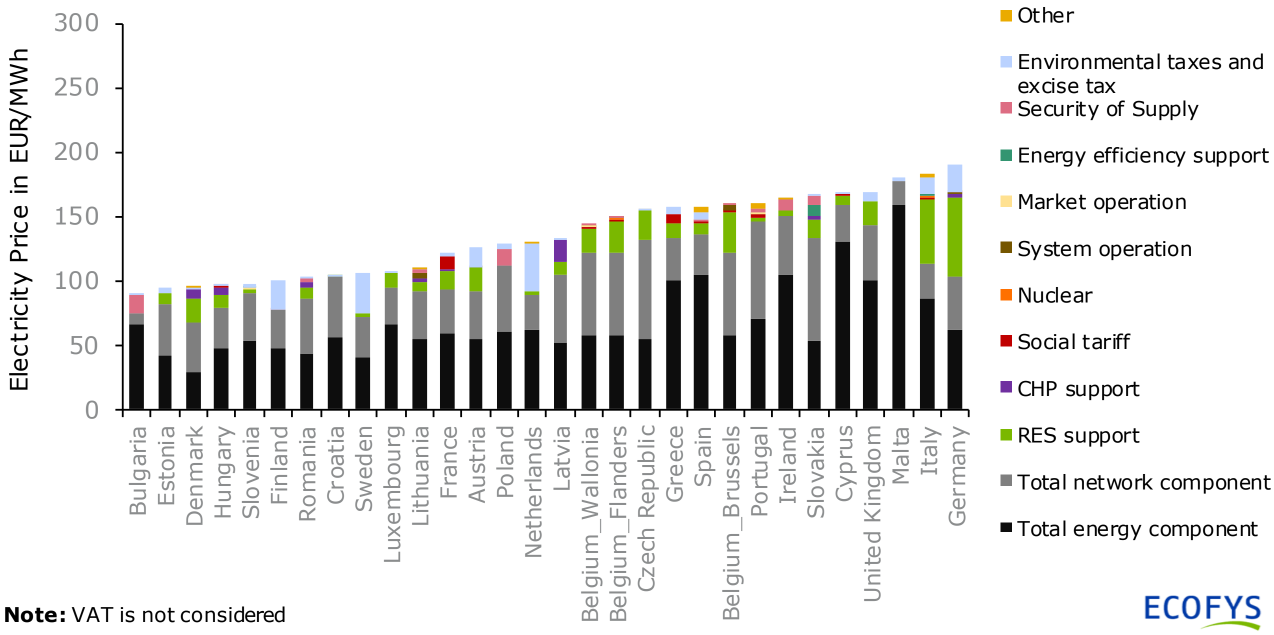

Figure 13: Retail electricity prices for SMEs and small industry in EU-28, 2015-2017. (source: Guidehouse based on Eurostat, 2018)

The share of taxes & levies in the total retail price ranges from 1% to 46% and is on average 18%. In the taxes & levies component, RES support, and environmental and excise taxes are the most relevant price elements. The VAT is recoverable for this consumer class, and consequently not considered. The share of the network component ranges between 8% and 50% and accounts on average for 40% of the total retail price. SMEs & Small Industries have been defined in this study equivalent to Eurostat consumption band IB (20-500 MWh/a). The split between distribution and transmission costs has only been published for band ID (2000-20000 MWh/a), and to avoid confusion and misinterpretation we have not illustrated the division of the network costs.

2.4 Energy intensive industry

For energy-intensive industries, retail prices are significantly lower than for the other consumer classes and differ in their price structure. The energy component is dominant with a 65% to 75% share in the total retail electricity price. Taxes & levies are relatively lower for energy-intensive industries and differ in their composition compared to consumer classes with a lower electricity consumption. Whilst RES support is represented with higher shares, environmental and excise taxes have a lower impact on prices of energy-intensive industries. In several Member States, taxes and levies imposed on energy-intensive consumers are recoverable and significant reductions and exemptions exists. The structure of retail electricity prices for energy-intensive industries is depicted in the figure below.

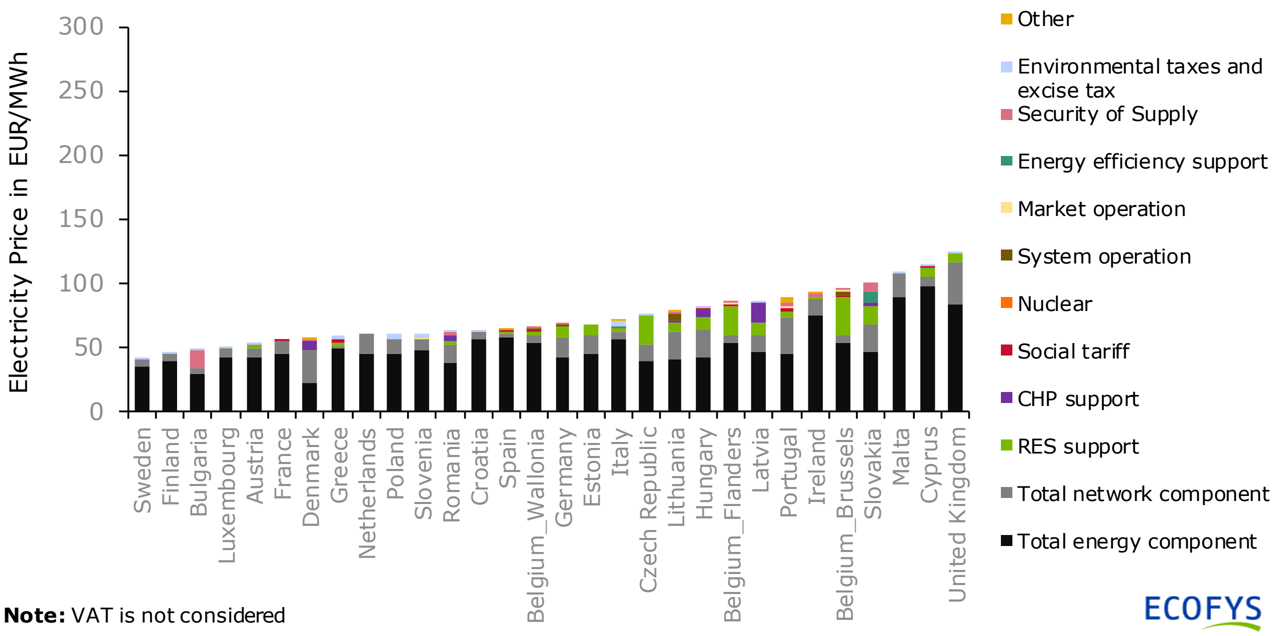

Figure 14: Retail electricity prices for Energy-Intensive Industries in EU-28, 2015-2017. (source: Guidehouse based on Eurostat, 2018)

Network costs depict a share of between 1% and 44%, on average 17%, of retail prices of energy-intensive industries. Energy-intensive industries are typically connected to medium-voltage or high-voltage level and thus contribute less to costs of the distribution grid[19] In almost all Member States, taxes & levies have a maximum share of 20% of the retail price, and often less (13% on average). Because VAT is recoverable for this consumer class, it is left out of further consideration.

In conclusion, in most Members States, the dominant policy costs concern RES support, environmental taxes and excise taxes. For households, network costs typically account for about 40% of the consumer price, whilst taxes & levies typically form a minor part of total retail price. In a few countries, however, the share of policy costs is more significant. The structure and level of SME & small industries' retail electricity prices are similar to those of households. For energy-intensive industries, the energy component is the most dominant price component. Network costs are the second most significant price component but still represent lower relative shares in the total price compared to the other consumer classes. The share of taxes & levies is comparatively low, and even negligible in some Member States.

[19] Ecofys, 2016

3 DYNAMIC PRICING OPTIONS

In this chapter we discuss the various dynamic electricity pricing options. We will also provide a summary of the European regulation related to dynamic pricing and describe the outlook of the European smart meter roll-out.

3.1 Dynamic pricing models

Real time pricing (RTP) is one of several possible options for dynamic power prices. RTP involves the most frequent price fluctuations and serves to reflect the real-time cost of electricity. The price changes can occur on an hourly basis, every quarter-hour or even more often. Usually, the price variations are achieved through coupling with the wholesale market.

The most simplistic dynamic tariff type is Time-Of-Use (TOU). In case of this pricing scheme the electricity prices are set for specific periods of time such as peak and off-peak hours. Peak hours are characterised by a high electricity demand and higher prices, while off-peak hours are characterised by a lower electricity demand and cheaper electricity prices. The most common examples of TOU are day and night tariffs as for instance applied in Italy. Additionally, the TOU can also consider whole days and distinguish these into several categories. A prominent example are the Tempo tariffs in France.[20]

TOU pricing can be further differentiated into dynamic Time-Of-Use (dTOU). In this case the level of the electricity prices and the peak and off-peak periods change regularly. This allows a more accurate reflection of the situation on the energy market.

Variable Peak Pricing (VPP) is a hybrid between TOU rates and RTP where specific periods of electricity price fluctuations are defined in advance. The price fluctuations that occur in the defined periods, vary depending on the energy supplier and the market conditions. This tariff is not very common but can be found in several cases in the United States such as the Connecticut Light and Power's VPP Ride program.[21]

Critical Peak Pricing (CPP) involves the raising the price of electricity substantially during specific periods of time. This can occur during periods of excessive demand or of a particularly low feed-in from renewables. The peak rate can be either defined beforehand or determined dynamically based on the market conditions.

Finally, consumers can be remunerated for decreasing their electricity consumption during critical periods instead being punished by higher electricity prices. In this case, the electricity price remains the same, but consumers are refunded for any reduction in power consumption relatively to what the energy company expected. The figure below provides an overview of the most common dynamic pricing options.

[20] The Tempo tariff divides all days of the year into three categories which are visualised by different colours - blue, white and red. Most of the days are "blue" days, during these days the electricity prices are comparatively low. "Red" days indicate that the balance between power demand and supply is comparatively tight. Consequently, these days are the most expensive. During the "blue" days the power supply-demand balance and power prices lie in between the other two categories. Furthermore, all days are further distinguished in (more expensive) day and (less expensive) night tariffs. (Giraud, 2004)

[21] Navigant Research, 2016

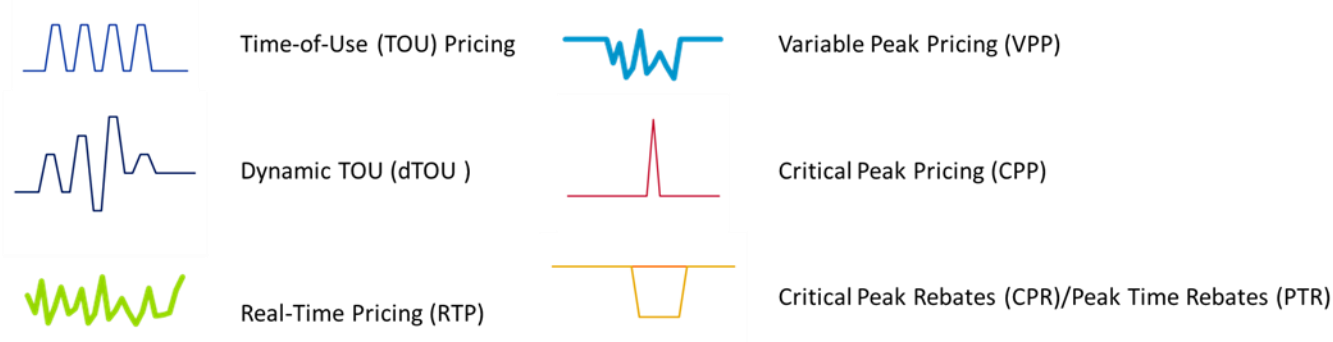

Figure 15: Dynamic pricing models

3.2 European regulation

On 30 November 2016 the European Commission presented the "Clean Energy for all Europeans" package that represents a step towards an Energy Union – making energy system in the EU more secure, integrated, efficient, affordable and sustainable. Amongst other legislative proposals, the package seeks to amend the existing Internal Market Electricity Directive (2009/72/EC that replaced 2003/54/EC) and therefore to redesign the European electricity market. The Transport, Telecommunications and Energy (TTE) Council agreed on its negotiating position on the directive on common rules for the internal market in electricity on 18th December 2017 which is here referenced as the Internal Market in Electricity Directive Draft.[22] Overall, the Commission and the Council seek to account for the profound technological, social and economic changes in the energy sector by enabling consumers to participate more actively in the energy market. Central cornerstones of this goal are the provision of higher transparency of the consumers' electricity consumption and to facilitate market access. To achieve this, the linkage between the wholesale and retail market should be strengthened and consumers should be reasonably exposed to wholesale price risk.[23]

From all the options for dynamic pricing, the European Commission and the Council favour RTP. For instance, the Internal Market in Electricity Directive Draft defines dynamic pricing solely as real-time pricing. Accordingly, a dynamic electricity price contract should reflect "the price at the spot market, including at the day-ahead market at intervals at least equal to the market settlement frequency." The goal of the European Commission is to allow all consumers to participate in demand response. Thus, all consumers should get the option of installing smart meters and benefiting from the higher granularity measurements through dynamic electricity pricing contracts. More specifically, the Internal Market in Electricity Directive Draft requires every member state to ensure that at least one energy supplier offers a RTP tariff.

The advancing smart meter roll-out is the key enabling technology for RTP tariffs and is therefore crucial for the future projects of dynamic pricing in Europe. As every consumer should have the right to install a smart meter to get deeper insight in its electricity consumption and the roll-out

[22] European Council, 2017

[23] Proposal for a Directive of the European Parliament and of the Council on common rules for the internal market in electricity 15886/17. Online at: http://data.consilium.europa.eu/doc/document/ST-15886-2017-INIT/en/pdf)

is mandatory in various Member States, the logical consequence is to allow these consumers to combine this granular metering technology with an appropriate electricity tariff.

3.3 Smart meters

Smart meters are the key technology for fostering and measuring price responsiveness to dynamic power prices. Most of the European countries plan to finish the wide-scale (>80% of consumers) roll-out by 2020,[24] see the figure below. In general, a smart meter only includes a metering device, but does not contain any controlling device that would enable an automatic adjustment of power demand to price signals (e.g. smart charging, smart appliances). Some countries such as Germany decided based on the national Cost-Benefit-Analysis (CBA) only to make the roll-out mandatory for larger consumers (electricity consumption of >6000kWh/year).[25] However, smaller consumers can install a smart meter on a voluntary basis and therefore could also benefit from dynamic electricity pricing. The different outcomes of the CBAs across Member States result partly from diverging attitudes towards a higher transparency of power demand and data protection. Consequently, the design and technical capabilities of a smart meter in Italy differs greatly from a smart meter in Germany. As the differences regarding the smart meter roll-out illustrate, the reception of dynamic electricity prices is also subject to regional differences. Therefore, the national implementation plans, and information campaigns must address the national circumstances and concerns if the uptake of dynamic pricing should be encouraged and facilitated.

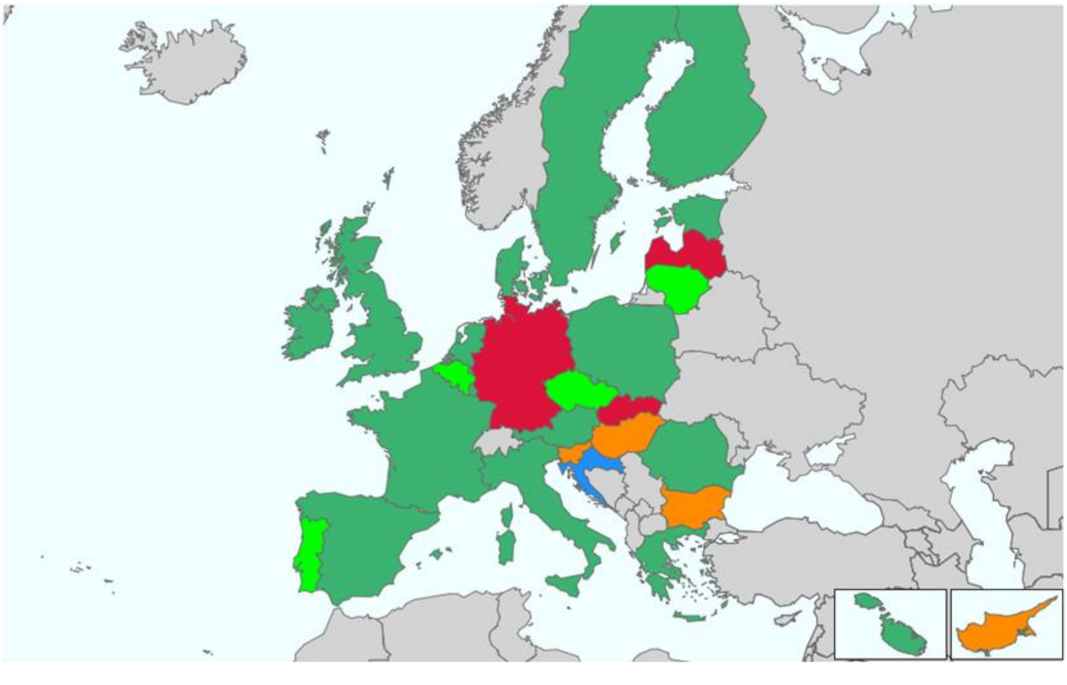

Figure 16: Smart meter roll-out in selected countries of the EU. (source: JRS, 2018)

[24] JRS, 2018

[25] MsbG, 2016

4 DYNAMIC PRICE IMPACTS

In this chapter, we discuss the impacts of dynamic electricity prices. The various expected benefits and other impacts for households and industry are described on a system- and consumer levels. We also provide insight in consumer choice and behaviour towards dynamic prices.

4.1 Expected benefits and impacts on households and industry

A part of the expected benefits can be achieved independently from any customer reaction. In this chapter we will first describe why and where these benefits occur. Then, we will show how demand response can leverage the price variations and therefore increase the potential benefits even further.

4.1.1 Savings independent from demand response

4.1.1.1 System level

In case of a flat rate tariff, the energy supplier is exposed to wholesale price variations and bears the price risk. If the actual power demand is higher than the forecasted power demand, the energy supplier must purchase the difference at the spot market even at a premium price to ensure the security of supply. Consequently, the energy supplier is exposed to the risk of price variations at the wholesale market which they seek to limit through hedging. This comes at a cost that is passed on to the customer in the form of a risk premium. The risk premium is inversely linked to the customer exposure to the wholesale market prices, as illustrated below.

This figure provides an indication of the risk premiums that were estimated in several studies for the different tariffs. In case of a flat rate the customer is completely shielded from price variations which results in the highest risk premium. The concave shape of the graph demonstrates the relation between the need for hedging the price risk by the supplier and the customer’s exposure to the wholesale market price. While the step from a flat rate to a TOU decreases the need for hedging only marginally, CPP and RTP lead to substantially lower hedging requirements. If costs are passed on directly to the customers on the intraday market, the risk premium should be in theory zero. Nonetheless, most RTP tariffs are linked to day-ahead market prices. Thus, the energy supplier is still subject to some small price variations, although the price risk decreases closer to delivery.

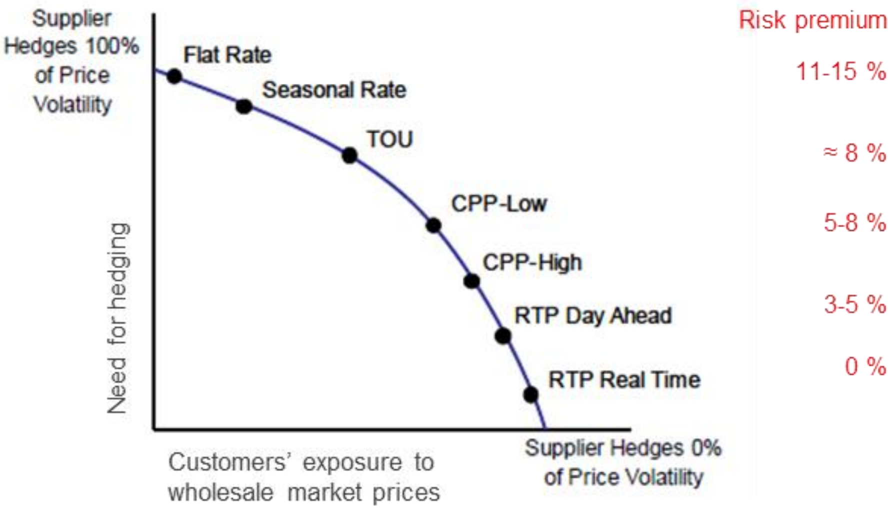

Figure 17: Iindication of risk premiums of different tariffs. (source: The Brattle Group, 2008)

Overall, the supply of electricity becomes cheaper because costly risk premiums are avoided. Moreover, in contrast to the energy supplier, the consumer can address the price risk by shifting its part of its electricity demand to low price periods. By transferring a part of the price risk to the consumers the power system aligns cost incentives with the scope for action and leads to a more efficient power system. The impacts of such an alignment are later in this chapter.

4.1.1.2 Customer level

Even if no adjustment in power demand occurs dynamic power prices lead to electricity bill savings for around 55% of all consumers (see Figure 18). The impact on the electricity bill differs, depending on the load profile; the flatter the consumer profile, the higher the potential savings. On the other hand, consumers with peaky load profiles, particularly during peak hours, will experience an electricity bill increase and might therefore oppose dynamic tariffs.

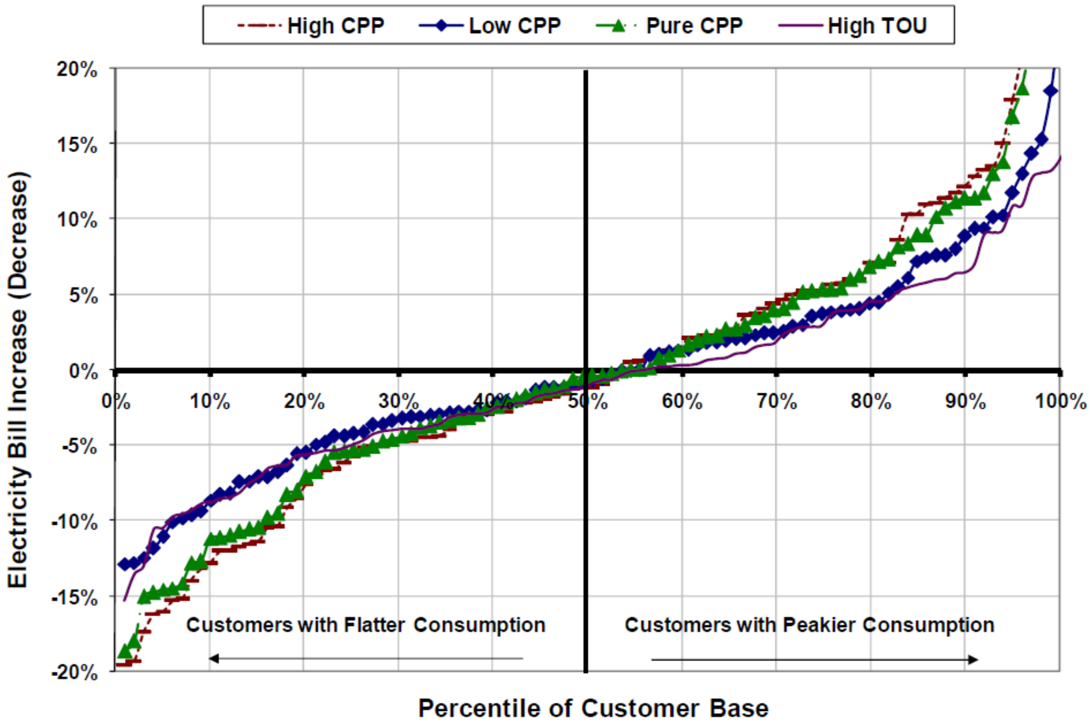

Figure 18: Allocation of electricity costs between customers with flat and peaky profiles. (source: The Brattle Group, 2010A)

This allocation of electricity costs between consumers with flat and peaky profiles can be a desired outcome. Consumers with peaky load profiles and a high electricity demand during peak hours impose higher power system cost than consumers with flat load profiles. A flat rate represents a de facto cross-subsidy from households with flat profiles to households with peaky profiles. Moreover, particularly low-income households are characterised by flat power demands.[26] Consequently, the most low-income consumers are burdened disproportionally. Dynamic pricing would therefore not only lead to electricity bills savings for most consumers, but also support low-income households and allocate costs to where and when they are incurred.

4.1.2 Savings resulting from demand response

Demand response can additionally increase the benefits of dynamic pricing, thus making the energy system more efficient and lead to even higher electricity bill savings. Consumers can respond to price signals by decreasing their load during peak hours and shifting their consumption to low price periods. Below, we discuss impacts on a system and consumer levels.

4.1.2.1 System level

The flexibility that demand response provides to the power system, can lead to different benefits depending on which type of demand response occurs – peak reduction or load shifting. Overall, the benefits can be categorised as follows:

- Peak reduction: Reduces the required installed grid and generation capacity.

[26] The Brattle Group, 2010

- Load shifting: Local integration of renewable energies and system balancing.

The consumer's reaction to dynamic prices is often measured by the achieved peak reductions. The electricity infrastructure, the amount of dispatchable generation capacity and energy storage must accommodate the peak electricity demand. Therefore, peak loads have a great impact on the required investments in the power system. Flatter load profiles can help to integrate a higher share of electric vehicles and heat pumps without the need of further investment in grid reinforcement and additional generation capacity. As these benefits concern future avoided investments, they can be categorised as a long-term measure.[27] However, savings could also be immediately noticeable if they result in lower reserves. In addition to that, lower peak demand reduces the losses in the electricity grid as variable grid losses grow quadratically with increased peak network loading.[28]

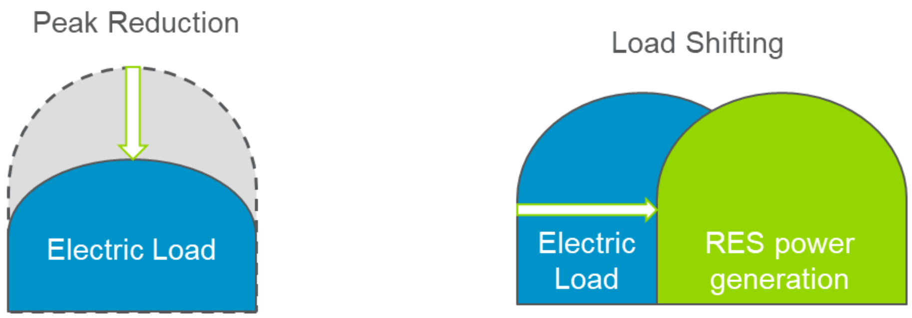

Figure 19: Peak load reduction and load shifting through demand response. (source: Guidehouse)

Usually, the observed peak reductions are mapped against the peak to off-peak ratio of the offered electricity tariff. Although the observations in different trials and pilot projects show a wide range of reactions to potential peak reductions, they allow several conclusions to be drawn:[29]

- Higher peak to off-peak ratios lead generally to higher peak reductions, but at a decreasing rate;[30]
- The achievable peak reductions vary by tariff type.
- Enabling technologies that increase the technical potential (e.g. heat pumps, programmable thermostats) or that communicate the price signal (e.g. smart meter) increase the peak reductions.
- Communication and motivation play a large role in informing and convincing consumers to adapt their behaviour.

Additionally, dynamic prices incentivise demand shifting to times of lower prices which usually indicate times of high intermittent renewable energy resources (RES) feed-in. The use of excess electricity can reduce local congestion and therefore facilitate the integration of RES in the energy system. Furthermore, the additional flexibility can balance the power system and avoid the operation of expensive dispatchable generation.[31] Hence, curtailment costs of RES and fuel costs of dispatchable generation can be decreased. A higher flexibility in the power system

[27] Ecofys 2016A

[28] Ecofys, 2013

[29] Faruqui, Palmer, 2012

[30] This means that an increase of the peak to off-peak ratio from 2 to 3 will have a larger impact on the peak than increasing the peak to off-peak ratio from 20 to 21. This is due to the fact that most of the available potential for demand response is already exploited.

[31] Ecofys 2016A

results also in a stabilisation of the wholesale market prices. Very low or negative prices as well as price peaks are mitigated and the overall wholesale market price level stabilised. This allows RES to more easily refinance themselves on the power market and decreases the need for governmental support.[32] Moreover, as renewable generation replaces conventional generation fuel, costs and CO_2 emissions can be saved. Although these savings happen at system level, these benefits can be also passed on to the consumers.

4.1.2.2 Consumer level

Consumers can actively reduce their electricity costs by shifting their power demand to low-cost periods. However, the consumer reaction depends and a variety of factors such as their ability to shift demand or their willingness to shift. This willingness is influenced by a range of behavioural biases, which will be further discussed at the next section in this chapter, but also on the absolute or relative electricity cost variations. Ultimately, the savings depend on both, the ability to shift and the electricity price curve.

The following figure illustrates the electricity bill impacts of demand response for a CPP tariff. Firstly, the figure shows the bill increase and decrease for households with a CPP tariff based on their electricity demand profile. Secondly, the figure shows the effect of a hedging cost (or risk premium) credit of 3%. As discussed earlier in this chapter, dynamic pricing decreases the price risk for the energy supplier and can lead to a lower risk premium for the consumer. This effect increases the share of consumers that benefit from lower electricity bills from 55% to 65%. Finally, the figure shows the impact of consumers' demand response measures. If consumers can adapt their load to the price signals, the proportion of households benefiting from a CPP tariff can be increased further to around 90%.

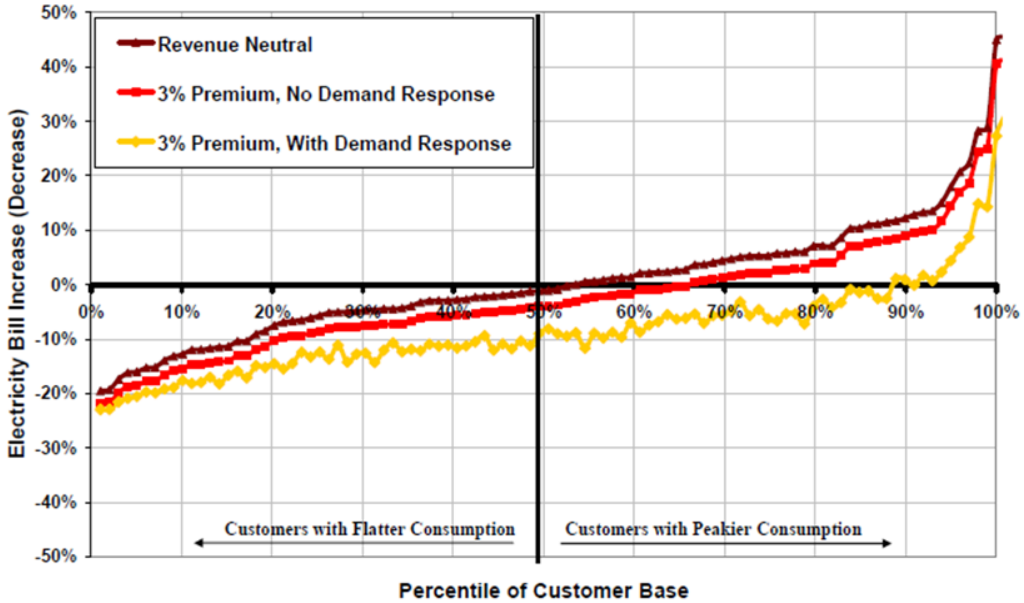

Figure 20: Distribution of Bill Impacts under a CPP Rate for households including a 3 % Hedging Cost Credit, (source: Guidehouse based on The Battle Group, 2010A)

[32] BMWi, 2015

The scope to adapt the load to the price signals varies between and within the different consumer groups. Earlier we have seen that low-income households have usually flatter consumption profiles and thus benefit from reduced hedging costs. However, several trials show that low-income households have a lower potential to respond to dynamic prices than average households and thus benefit less from potential electricity bill reductions gained from demand response.[33] This can be explained with the fact that low-income households have a lower demand response potential. An advancing electrification (e.g. electric vehicles, electric heat pumps) and automatization (e.g. smart home appliances) could intensify this effect even further. We will discuss the flexibility potential in more detail in the next chapter.

On the other hand, low-income households embrace demand response generally more than average households if savings can be achieved. But above all, low-income households are still very likely to benefit from lower electricity bills overall due to the bill impacts which were previously described.[34] The Impacts on the affordability of electricity differs also per Member State. Countries such as Luxembourg and the Netherlands have the highest affordability, but also highest electricity prices in absolute terms whereas Hungary and Bulgaria have the lowest electricity prices and the lowest affordability of electricity prices. Figure 21 demonstrates the variation in the share of household income devoted to electricity expenditures across the EU. Therefore, the cost impact in absolute terms will be most likely differ across the EU.

An approximation and comparison of cost reductions in absolute terms is therefore problematic. If the cost reduction in relative terms is the same across MSs, it would have the same relative impact on affordability. However, lowering the share of income devoted to electricity costs from 11 to 9% will have probably a stronger effect for Bulgarians than lowering it from 3 to 1% for Luxembourgers.

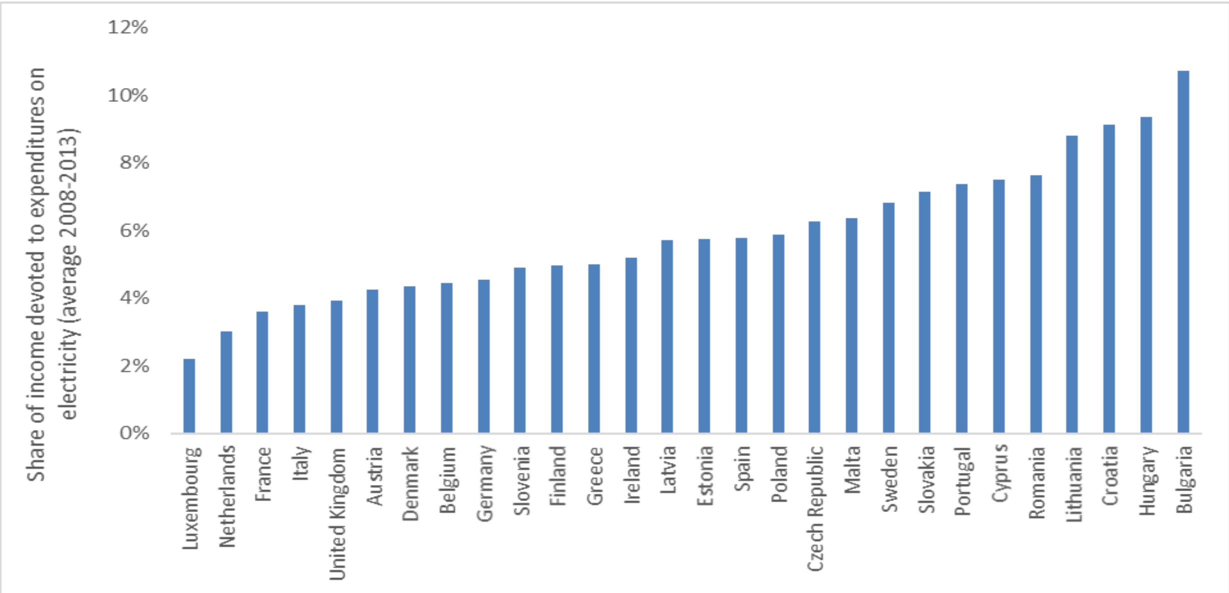

Figure 21: Affordability of electricity costs across the EU. (source: Guidehouse based on Eurostat, 2018)

Similar to the benefits on the affordability of electricity for households, industrial competitiveness might increase due to dynamic prices. It depends, however, on the flexibility potential of

[33] The Brattle Group, 2010; RAP, The Brattle Group, 2012

[34] The Brattle Group, 2010; RAP, The Brattle Group, 2012, AECOM, 2011

industries, which is additionally constrained by working hours, the interdependency of processes and electric appliances as well as other business internal factors. The next figure exemplifies how different load profiles and flexibilities can affect the electricity costs of two imaginary companies. While company A manages to adjust its power demand to a mostly constant load (24-7 industry), the load of company B remains nearly unchanged despite dynamic electricity prices. Company B represents industries whose power demand is high throughout the day such as commerce and retail. As result of dynamic pricing, in this particular example company A can decrease its electricity costs by 10% while company B faces higher electricity costs of around 7%.[35] The flexibility potential will be discussed in more detail in the next chapter.

Nonetheless, this is only an illustration of the different circumstances of consumers and the resulting bill impacts. In practice, the net bill effect depends on the impact of all previously discussed savings and cost factors.

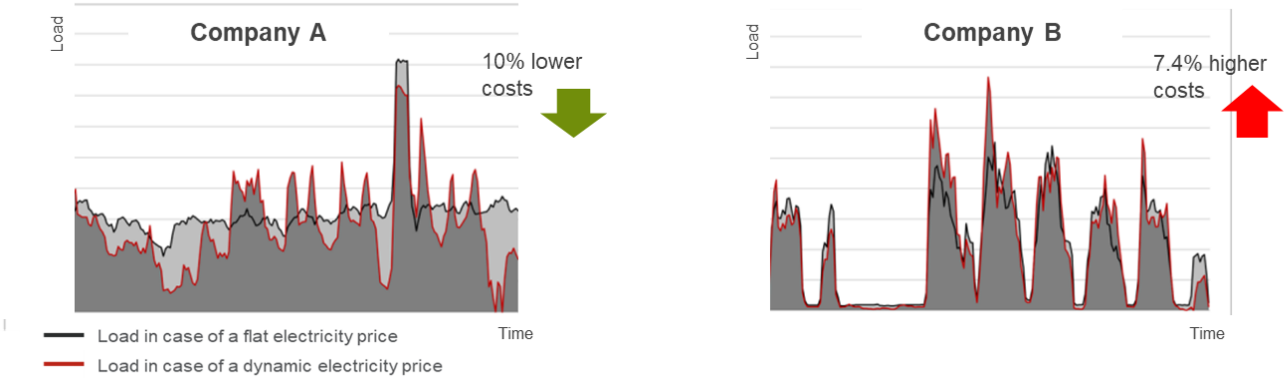

Figure 22: change in load profiles of two exemplary companies with different flexibility potential. (source: BET, Frontier, 2016)

4.2 Consumer choice and behaviour

As shown earlier in this chapter, dynamic pricing can offer significant savings and system benefits. In theory, a higher price dynamicity allows a closer linkage to the dynamics of the power system (e.g. to the production and transport cost of electricity). This linkage translates into higher potential savings for the consumer. As indicated in Figure 23, the maximum discount from a flat rate for RTP is higher than for TOU. However, the closer connection to the wholesale market also translates into a higher price variance and perceived price uncertainty or risk by the consumer. If consumers oppose more dynamic price schemes or fail to adjust their power consumption (e.g. due to limited demand response potential, high activation costs), then the feasible rewards turn out to be smaller. In this case the discounts from a flat rate could converge.

[35] BET, Frontier, 2016

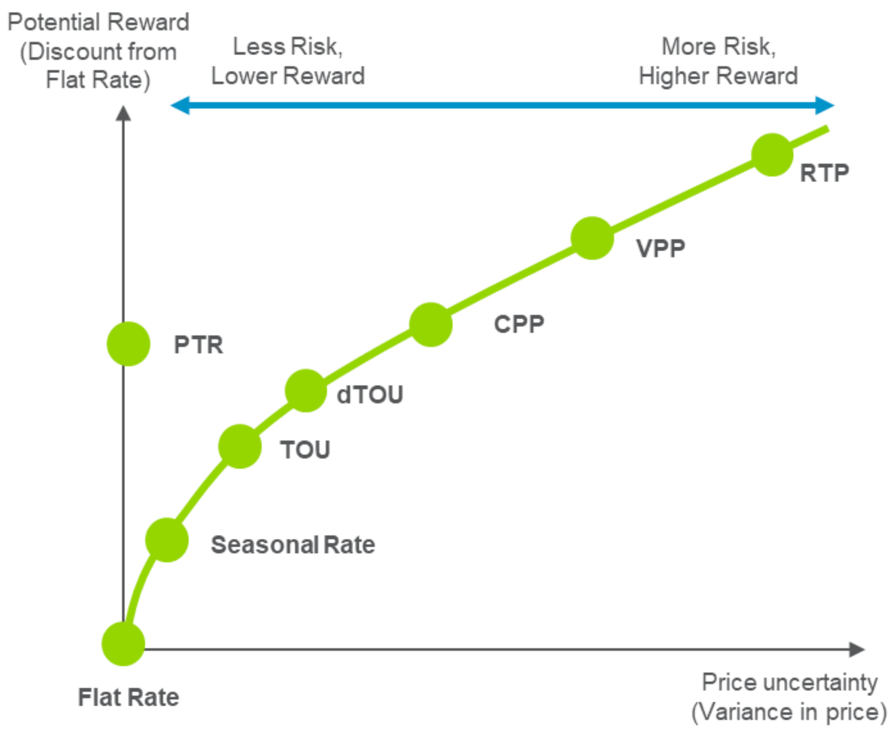

Figure 23: Potential reward and price uncertainties of tariffs. (source: Guidehouse based on RAP; The Battle Group 2012; Schneider, Sunstein, 2016)

To facilitate the uptake of dynamic tariffs and maximise the rewards, it is therefore important to understand and address the behavioural biases of consumers. Whilst commercial companies seek to maximise their competitiveness through minimising their cost, households can act more irrationally and are typically particularly biased. Most households initially oppose a change of the status quo. Therefore, it is important to explain why a regulatory change and the implementation of dynamic tariffs is important and beneficial. This requires a comprehensible information campaign from regulators, energy suppliers and national agencies.[36]

Usually, people are also risk averse. The wide majority, around 93%, focuses stronger on the potential losses than on comparative potential gains.[37] Therefore, several surveys found that than 60% of the respondents initially prefer tariffs with lower price variations such as TOU.[38] Additionally, short-term returns, even if smaller, are generally preferred over long-term rewards.[39] Consequently, energy bill savings should be made perceptible as soon as possible. Potential losses could be minimised through price caps for exceptional events, such as blizzards. To address the fear of not recovering the investments in smart appliances or smart meters, households could be supported through offers to stretch the investment costs over a period of time or to decrease the investment costs by sharing the savings. The payment structure for smart meters, where consumers pay for the use of smart meters a yearly fee instead of a high upfront investment, is a positive example in this regard.

Moreover, most people are averse towards decision making, particularly if the issue is complex.[40] Therefore, the electricity tariff should be made easy to understand. Complex combinations of different tariff types can seem opaque and frighten consumers off from choosing this tariff.

[36] Schneider, Sunstein, 2016; Fraunhofer ISI, 2012, EcoAlign, 2013; Hobman et. al. 2014
[37] Hobman et. al. 2014
[38] EcoAlign, 2013, Synopia, 2017; Fraunhofer ISI, 2012; Homburg & Partner, 2008
[39] Hobman et. al. 2014
[40] Hobman et. al. 2014

Several trials that test and evaluate the responsiveness to price variations could provide more insight in this issue. If a participant has difficulties understanding the equipment, is not properly informed about the benefits of these tariffs or does not have enabling technologies installed (such as smart meters, displays communicating the power prices, electric heating or cooling devices), then the price responsiveness is expected to be limited. Over time, a response fatigue for manual load adjustments can be observed.[41] However, with an increasing electrification of the heating and mobility sector as well as an advancing automatization, manual adjustments and daily decision making when to activate which appliances would not be needed anymore. Owners of enabling technologies to see the potential benefit of dynamic tariffs have generally a more positive reaction to switch to such a tariff and to adapt their behaviour.[42]

As people accept and get used to a higher degree of digitalization and automatization in their daily life, the attitude towards dynamic electricity tariffs also changes. In tech-savvy countries such as South Korea, more than 60% of the respondents in surveys prefer RTP over less dynamic tariffs such as TOU.[43] A similar trend can be observed in Estonia, a front-runner in terms of digitalization that experienced a doubling of the share of RTP tariffs since its introduction in 2013. Another important factor is the normative social influence. Once a critical mass of households accepts RTP and the social benefits become evident, the acceptance of such tariffs accelerates. Therefore, the biggest hurdle is to reach a critical mass and the communication of the reasons for choosing for dynamic electricity tariffs.

[41] Linear, 2014

[42] Faruqui, Palmer, 2012

[43] Kim et. al., 2016

5 DYNAMIC PRICE POTENTIAL

In this chapter, we discuss the potential dynamic prices can initiate. Firstly, we will describe the technical potential for demand response, i.e. to what extent are consumers able to decrease or increase their consumption. Secondly, we will provide insight in the activations costs necessary to unlock the technical potential.

5.1 Demand-side flexibility potential

Demand-side flexibility potential is the ability to shift load. Shifting load consists of two parts, load reduction at one point in time and a load increase in the same magnitude at another point in time. The demand-side flexibility potential of consumers is dependent on multiple factors. The most dominant factors that influence demand-side flexibility potential are:

1. **Balancing of load:** A shift of demand in time requires that a load increase is followed by a load reduction or vice versa, usually framed by process flexibility boundaries. The total demand must be balanced within a specific timeframe. For instance, cooling processes can be shifted in time but a reduction in cooling must be balanced by an increase in cooling within a specific timeframe to guarantee the temperature to stay within process limits.
2. **Duration:** The potential flexible capacity often varies by the duration of its use. A high load increase can be possible but limited in time whereas the same flexible load might be available over a longer period if only a part of the flexible capacity is used. This means the flexibility potential in MW is dependent on the duration from sec/min to hours/days.
3. **Frequency:** The availability of the flexibility potential might be restricted by the frequency the process or application is used. Processes that run only sometimes can require idle times. For example, the use of a washing machine can be planned flexible but once the washing is done the machine will not be used until there is again a demand for it.
4. **Temperature:** The ambient temperature influences the electricity demand of certain processes. Most prominent example are cooling and heating processes. The influence of the temperature differs across Member States based on the requirements. In summer, the ambient temperature strongly influences the cooling demand for air-conditioning in Southern Europe whereas in winter the ambient temperature strongly influences the heating demand in Northern Europe, especially in countries with a high share of electric heating.

On a European level, the German Aerospace Center (DLR) has conducted a comprehensive analysis of the theoretical demand-side flexibility potential. The theoretical potential is the potential that could be leveraged based on existing loads. In this section, we base our main findings on the analysis. The analysis covers the EU28 Member State as well as Switzerland, Norway and Liechtenstein.

In a second step, we assess the technical potential, i.e. the share of the theoretical potential which can be leveraged based on the existing and future ICT infrastructure. The technical potential includes the ICT infrastructure requirements of the public domain, e.g. the smart meter roll-out. The technical potential does not include the ICT requirements of the private domain, e.g. the technical appliances to intelligently, remotely and automatically control flexible loads.

Figure 24 illustrates the average load reduction and load increase potential for households, the commercial sector and industries. On a European level, the load reduction potential is well distributed over households, the commercial sector and industries whereas the load increase potential is low for industries and very high for households. The numbers shown represent the average potential over the year based on an analysis of the hourly load potential throughout the year.

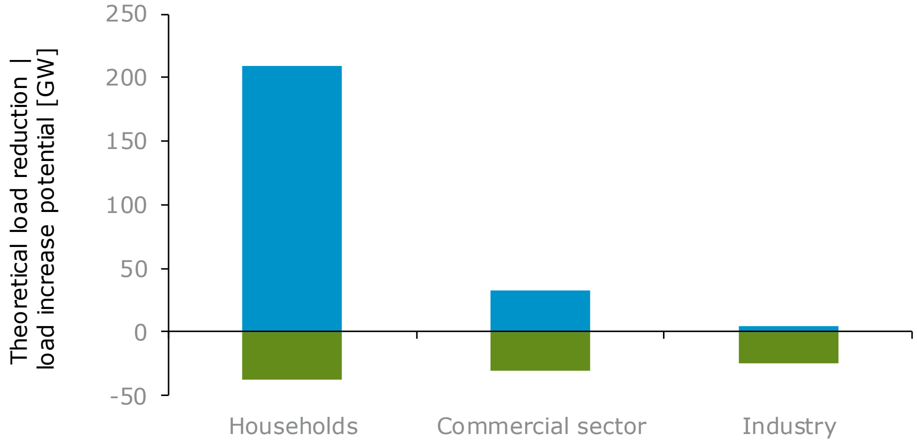

Figure 24: Average theoretical load reduction (negative) and load increase potential (positive). (source: Guidehouse based on DLR, 2015)

Figure 25 shows the average load reduction potential of single industries, processes, and appliances and the range from minimum available potential to maximum available potential throughout the year considering varying demands and temperature effects.

The biggest load reduction potential lies within the cross-sector technologies (ventilation, air-conditioning, heat circulation pumps) and household appliances (freezers/refrigerators, washing machines, tumble dryers). The influence of frequency of use and ambient temperature are reflected in the results. Heating and cooling technologies and household appliances that are not constantly in use and used at typical times (e.g. washing machines) show the biggest variation in available potential.

For the industry, only the electric steel industry shows a stable average potential close to 10 GW. Further energy intensive industries with an average potential between 1 to 4 GW are pulp and paper, cement, chlorine and aluminium. Cement is produced mainly at nights which offers the opportunity to shift the process time. The chloralkaline process is a flexible process, but difficult to control.[44] In total, the load reduction potential in industry is of a similar magnitude as the load reduction potential of households and the commercial sector. The energy industry has a significant share of the load reduction potential of the industry sector.

[44] FfE 2014

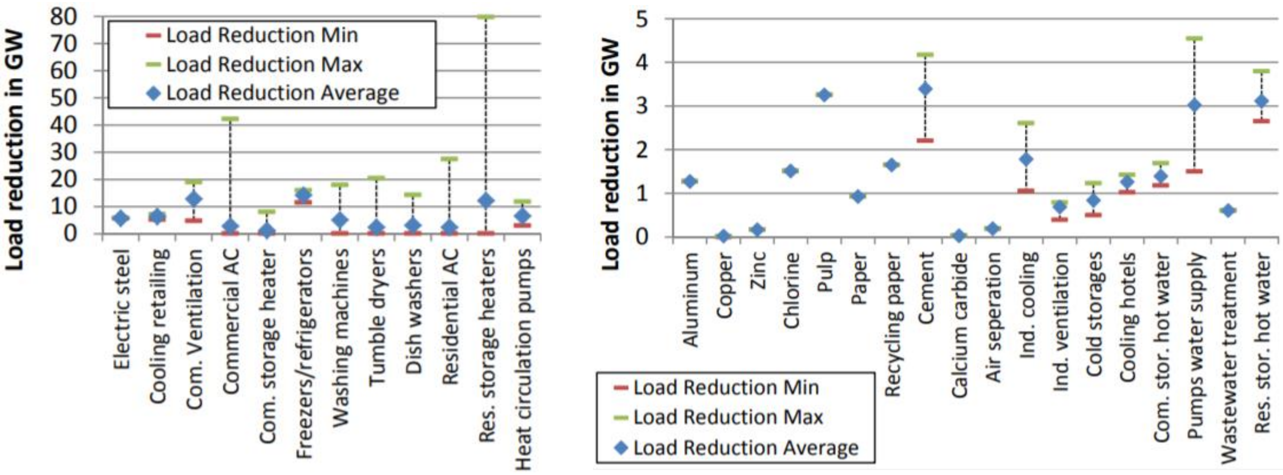

Figure 25: Load reduction potential of single appliances, processes and industries. (source: DLR, 2015)

Figure 26 shows the load increase potential. Again, household appliances have a high potential, followed by cross-sector technologies. However, the high load increase figures for household appliances are based on the fact that the load from multiple consecutive hours can be shifted to earlier times. The so-called free load of appliances with a low capacity factor (e.g. washing machines) results in a high theoretical potential. The drop in potential following a use of potential is not reflected, i.e. the duration of the potential can be low compared to other processes. The same holds for residential storage heaters which show a high potential which is limited by the heating demand and the heat storage facilities.

The load increase potential in industry is rather low. Energy-intensive processes are most often operated at a high capacity factor with only limited load increase potential. This affects the total load reduction potential as well. If processes are influenced by load shaving (e.g. load reduction without an increase at another point in time), the total load must be balanced, i.e. the limited load increase potential limits the load reduction potential throughout the year.

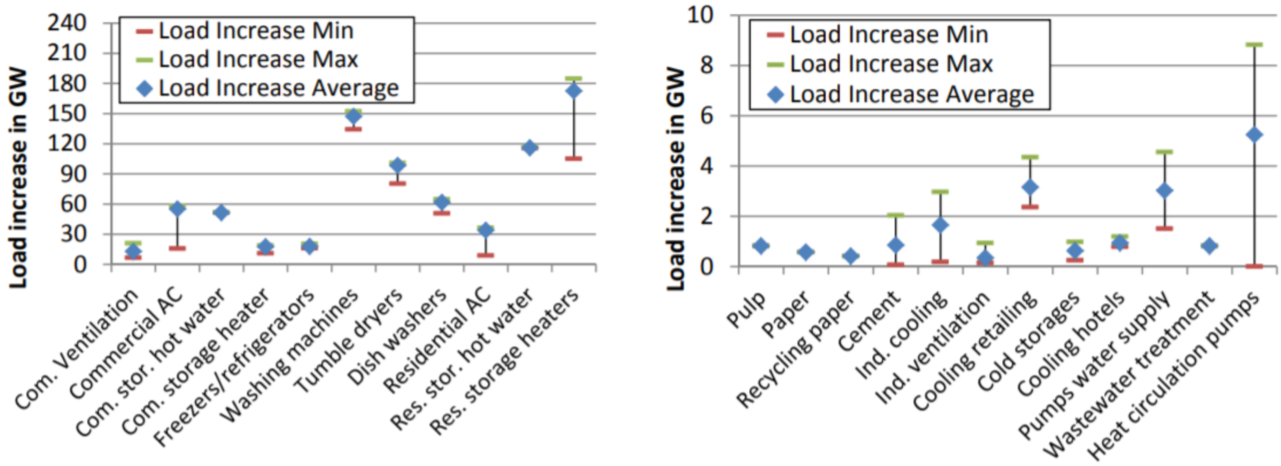

Figure 26: Load increase potential of single appliances, processes and industries. (source: DLR, 2015)

An analysis for the energy intensive industry in Germany has shown that there exists demand-side flexibility potential for load shifting coming from cross-sector technologies but also from energy-intensive processes itself. Moreover, the energy-intensive industry offers a substantial load shedding potential. The load shifting potential as share of the total demand-side flexibility potential is high in the chlorine and steel industry.[45]

Figure 27 shows the load reduction potential per country as a share of the country's peak load. Load reduction potential is available in all countries and throughout the whole year. The figure illustrates, that there is substantial potential of about 10 to 30% of the countries' peak load on average and can reach up to 80% and can go down to not less than 5% in single countries throughout the year.

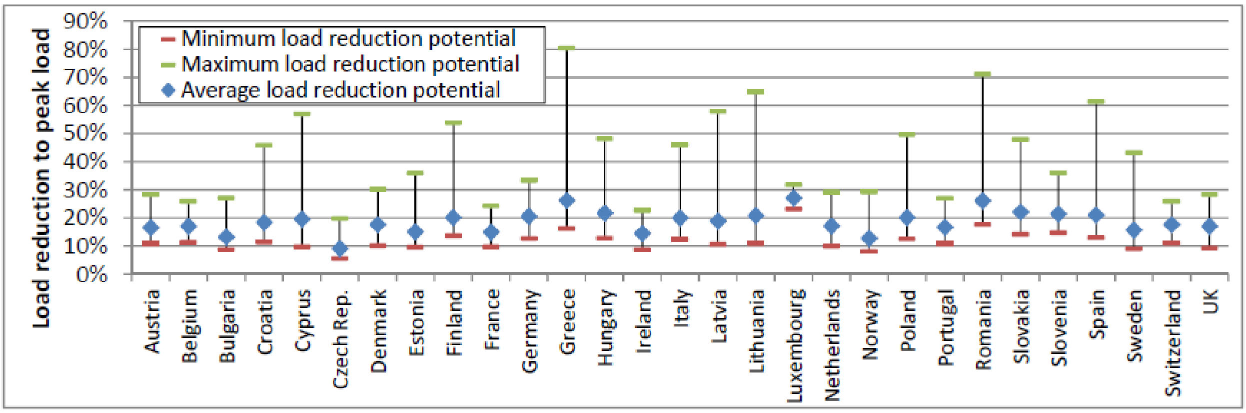

Figure 27: Share of load reduction potential of countries' peak load. (source: DLR, 2015)

Figure 28 shows the share of the average load reduction potential of the three sectors per country. The figure indicates that there is potential in every sector, in every country. Only smaller countries show a limited load reduction potential within the industry (Latvia, Lithuania, Malta, Cyprus). Therefore, targeting only one of the three sectors can leverage demand-side flexibility potential across all countries.

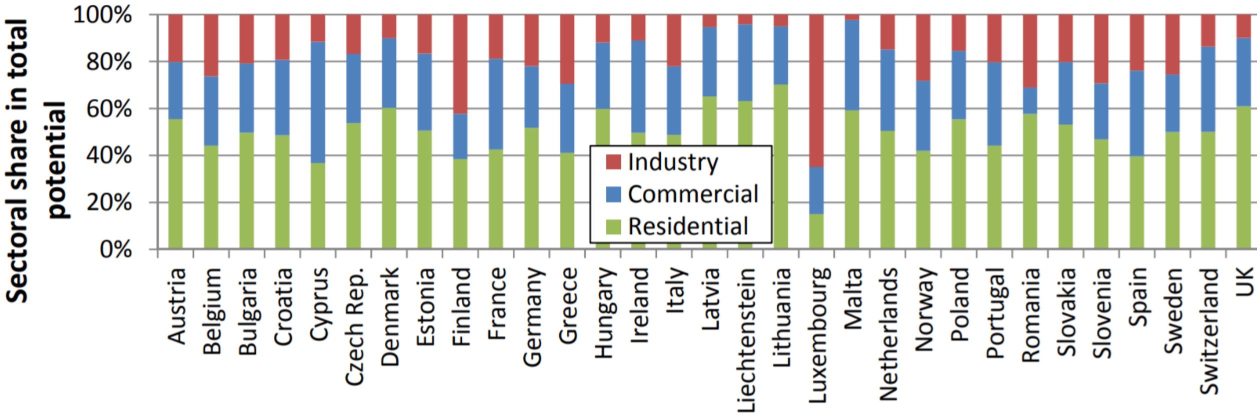

Figure 28: Average load reduction potential per sector and country. (Source: DLR, 2015)

The analysis of the theoretical potential has shown that there is load reduction potential across all sectors and in all countries. The load increase potential is not evenly distributed between sectors. Households have a very high theoretical load increase potential due to high free loads. The load increase potential for SMEs and industries is in a similar magnitude as the load reduction

[45] FfE, 2014

potential and dominated by cross-sector technologies. The load increase potential in the energy-intensive industry is low.

The technical controllability of the theoretical potential differs amongst sectors. Most industries have the relevant ICT infrastructure already in place, and the energy-intensive industry already makes use of the existing demand-side flexibility potential if financially beneficial. As demonstrated in the previous chapter, the required ICT infrastructure (smart meters) will be rolled out in most households in the near future unlocking the theoretical potential. For households, the increasing electrification of heating and transport will add new flexible loads to the system.

5.2 Activation costs

Chapter 4 has shown that dynamic tariffs can set financial incentives to activate the demand-side flexibility potential. The potential benefits that can be generated by consumers are confronted with activation costs. The theoretical potential includes the ICT infrastructure requirements of the public domain for being able to activate the theoretical potential, e.g. a smart meter roll-out. The analysis of activation costs focuses on the private domain, i.e. the costs for the consumer or aggregator to activate the flexibility potential, such as devices for intelligent control of loads and process costs.

The costs for demand response can be divided into initial costs for the investment into ICT infrastructure and storages for load flexibilization, and activation costs for an actual demand response call. Activation costs have two components; fixed operating costs occur regularly independent on the number of demand response calls. They comprise information, transaction and control costs. And variable activation costs influence the operation of the flexibility potential. The financial benefits of load shifting must exceed the variable costs.

Variable activation costs have multiple cost components dependent on the duration of the demand response reaction. The following example illustrates the activation cost components for the industry:

- Short activation periods: A short variation in load does usually not influence industrial processes. Therefore, only electricity purchase costs influence the reaction to price signals.
- Longer activation periods: For longer demand response durations, staff costs for maintenance and materials are added to the electricity purchase costs;
- Longer interruptions: Very long demand response durations can require an interruption of the production process, leading to production losses and therefore to significantly higher costs. These costs usually only occur for load shedding but not for load shifting.

Comparing initial costs and activations costs, a clear difference must be made between energy-intensive processes and cross-sector technologies. In general, for cross-sector technologies initial costs are high whereas the activation costs are low. In contrast, initial costs for energy-intensive processes are low whereas activation costs are high. For smaller companies, initial costs can be higher if internal load management and automation appliances need to be installed.

FfE (2014) has shown in an analysis of multiple applied approaches to assess the variable costs of demand response in the industry that the activation costs can vary significantly between industries. The largest influencing factor is the flexible load available for load shifting. Load shifting can be offered with low marginal costs of less than €20/MWh, on the one side for cross-sector technologies but also with available load shifting potential of energy-intensive processes.

Table 2 shows the share of load shifting potential and load shedding potential for energy-intensive industries based on an analysis of German industries. The chlorine and steel industry show significant shares of load shifting potential at low marginal costs. The activation costs for load shedding for the industries analyzed are ranging from €100/MWh to €500/MWh with chlorine and aluminium at the lower end, and cement, steel and paper at the upper end of the range. Previous studies have shown even higher costs for some industries with €2000/MWh or more.[46]

Table 2: Flexible load potential of energy-intensive processes. (source: Guidehouse based on FfE, 2014)

	Paper	Chlorine	Cement	Aluminium	Steel	Other branches
Mean operating hours (h/a)	7500	7700	5500	6100	6100	6721
Share of flexible load for load shifting	12%	60%	17%	24%	64%	5%
Share of flexible load for load shedding	88%	40%	83%	76%	36%	95%

The analysis has shown that activation costs depend on the load shifting potential. The initial and fixed costs are in general lower for high demand-side flexibility potentials. The potential of households and SMEs and industries is high when aggregated. Single households and sites show a low potential compared to energy-intensive industries. Therefore, activation costs for households, SMEs and industries are typically higher than for load shifting in energy-intensive processes and cross-sector technologies.

[46] EWI, 2010

6 DYNAMIZATION DEVELOPMENT

Dynamic electricity tariffs are no longer a rarity across Europe. In many Member States consumers can already choose dynamic electricity tariffs, although this usually only encapsulates the energy-related price component. Currently, TOU for the energy component is the most prevalent tariff type across Europe, but the share of RTP is increasing. Dynamic policy and network costs, particularly on household level, are still relatively rare. In this chapter, several case studies illustrate different national approaches to the dynamization of electricity prices. These cases and first experiences exemplify the dynamization development in Europe and allow us to derive conclusions and lessons learnt regarding a broader introduction of dynamic electricity tariffs.

6.1 EU overview

Within Europe, Spain is the sole country that bundles policy costs and charges these (at least partially) relatively to the RTP. In most countries, the policy costs are charged exclusively or predominantly through consumption charges (e.g. €/kWh). Some countries such as Austria and Portugal also impose a fixed (e.g. €/year) and capacity charge (e.g. €/kW).[47] Although several countries and reports classify the policy costs in some countries as dynamic, it is worth mentioning that "dynamicity" can be interpreted differently.[48] For example, Denmark aggregates its policy costs into a PSO-levy and is labelled dynamic. This levy varies only every quarter depending on the forward-prices and other cost elements.[49] Although the policy costs in Denmark are partially classified as dynamic, it is debatable whether a quarterly adoption of the PSO-levy justifies such a categorisation.

Similar to the policy costs, network costs can be collected through an energy, consumption or capacity charge. However, network costs are mostly constituted by capital costs. Operational costs mostly cover grid losses, maintenance as well as balancing and redispatch costs. Whereas most countries charge policy costs through a consumption charge, the picture of network charges is more nuanced.[50] In most countries, the network operators cover their cost through two different types of charges. In Europe, the consumption charge represents on average 70% of the network costs for households in comparison to 55% for industrial consumers. In France, the share of the consumption charge for households and industrial consumers is even 80% and 70% respectively. Some countries such as the Spain and Sweden, are at the other end of the spectrum; in these countries, the share of the consumption charge is below 25% for households.[51] In the last years, a general trend could be observed towards an increasing the share of the fixed charge at the expense of the consumption charge. For instance, Italy planned to triple the share of the fixed charge between 2016 and 2018. In Germany, the share of the fixed charged for households increased by around 50% between 2013 and 2016.[52] In Finland, the distribution network operators increased the share of the fixed charge from 49% for apartments and 26% for small industries in 2010 to 56% and 40% respectively in 2015. [53] In

[47] EC, 2015

[48] EC, 2015; Eurelectric, 2016; Eurelectric, 2017

[49] Kitzing et. al., 2016

[50] EC, 2015

[51] Université Paris-Dauphine, 2016

[52] RAP, 2018

[53] NordREG, 2015

the Netherlands, the consumption charge was abolished altogether. On the one hand, fixed charges are better in line with the capital-intensive cost structure of networks. On the other hand, fixed charges diminish the incentive for energy efficiency measures and burden smaller consumers disproportionally high.[54] In consequence, we believe such a cost structure is not in line with the intension of the Internal Market in Electricity Directive Draft for "cost reflective, transparent and non-discriminatory network charges".

However, even a non-dynamic consumption charge fails to capture how much cost a consumer caused the network. If two households have the same power consumption, but the peak load of one household is twice as high as the peak load of the other household, then a network charge solely based on the power demand would also not reflecting the cost adequately. A capacity charge could account for that, but it does not consider whether the time of peak load really puts additional stress on the grid or not. A demand peak could be incentivised through price signals in the wholesale market and not negatively impact the network system, but it would still be penalised through a capacity charge.

Dynamic network charges in form of consumption charges could resolve these problems. According to national regulators, Portugal plans to introduce dynamic network tariffs for industrial consumers (initially TOU tariffs, then potentially CPP) in 2018. The effects of dynamic network tariffs were first assessed in a Cost Benefit Analysis (CBA) which concluded that the benefits outweigh the costs.[55] To confirm these results, the TOU tariffs were tested during a one-year pilot project for industrial consumers in 2017.[56]

6.2 Case studies

6.2.1 Spain

In Spain, dynamic electricity prices also include elements of the taxes & levies component. One of the main differences to other countries is that the typical differentiation between network component and taxes & levies component is not reflected in Spanish electricity prices. Instead, network costs and costs induced by specific policies such as RES support and security of supply instruments are collected in one price element, so-called Access Tariffs. Spanish electricity prices consequently comprise an energy component and the Access Tariff component supplemented only by an excise tax and the VAT.

Access Tariffs are based on TOU pricing for commercial consumers. For households, RTP is being implemented after smart meters are rolled out since the end of 2017. Some network operators and other reports mention that RTP applies for 50% of the households, but data from the regulator suggests that the share is at 12%, representing 24% of households' final energy consumption.[56] Including commercial consumers, 75% of the Spanish final energy consumption is based on dynamic pricing. [57] Since Access Tariffs contain policy-induced price elements in addition to the network component, the dynamic share of Spanish retail prices is high compared to other countries.

The calculation of Access Tariffs is based on the consumers' contracted capacity and consumption. The capacity charge for households has been increased from 34% to 68% of the

[54] RAP, 2018
[55] Saraiva et. al., 2016
[56] CEER, 2017
[57] CNMC, 2018

Access Tariff from 2011 to 2014 to assure the recovery of fixed costs and to avoid incentives for self-consumption.[58]

The Spanish approach of structuring their electricity prices is particular but highly suitable for dynamization. The price structure is comprehensible because the network component and policy-induced elements are combined in one dynamic price element with a clear tariff structure without numerous reductions and exemptions. RTP for households and TOU pricing for the rest of the consumer population and the high dynamic share in final prices implies strong demand response incentives. Irrespective of small flaws after switching towards dynamic pricing, Spanish Access Tariffs are configured well in the meantime. The Spanish approach can serve as an example for including policy-induced price elements in addition to the network component in dynamic pricing.

6.2.2 Norway

Norway is a particularly interesting case for several reasons. The Norwegian power production is largely dominated by hydro (96%).[59] The availability of relatively cheap electricity led to a high electrification in the heating sector. Around 60% of residential homes heat with electricity.[60] Norway is also one of the frontrunners regarding electrification in the transport sector. Electric vehicles constitute already around 30% of new car sales, although their total market share is still limited with 3.7%.[61] The wide-scale smart meter roll-out is already advanced and is supposed to be completed by the end of 2018.[62] These factors favoured the introduction and broad acceptance of RTP. Currently, around 71% of households and 88% of SME und small industries chose RTP tariffs.[63] These tariffs are not only the cheapest, but also allow to switch the supplier at any time. In comparison, flat rate tariffs have a minimal contract duration of one year. Alternatively, consumers can choose a so-called “variable price contract” which includes dTOU tariffs. The supplier may choose the price and the duration of the peak and off-peak periods, though in general the prices follow the developments in the electricity market. The energy supplier must notify the consumer about any price changes at least two weeks in advance. If the consumer does not want to accept these price changes, he can switch the supplier at any time. However, some suppliers might profit from the inertia of their customers who mostly do not follow the price development regularly. Therefore, the dTOU tariffs are often more expensive than the other options.[64] Only 2–4% of SME and small industries have chosen this type of contract compared to 8–10% that have decided in favour of fixed price contracts. In comparison, around 27% of the households chose dTOU and only 2% fixed price tariffs.[65]

The example of Norway allows us to draw several conclusions. Firstly, when discussing whether dynamic tariffs, and particularly RTP, could become accepted by consumers, we can see that this is already happening. Nearly all households in Norway are already served with dynamic electricity tariffs and the majority favoured RTP. Secondly, the dTOU tariff turned out to be often the most expensive option for consumers, because energy suppliers can set the prices on their own. Additionally, as the prices change regularly, it becomes more difficult for consumers to compare the tariffs. Moreover, the price dynamicity makes it difficult to anticipate future electricity costs. Even if the dTOU tariff leads to energy system savings, these might not be

[58] IEA, 2016
[59] Statistics Norway, 2015
[60] Euroheat & Power, 2017
[61] Elbil, 2018, Statistics Norway, 2017
[62] Eurelectric, 2017
[63] Statistics Norway, 2018
[64] Strompris, 2018
[65] Statistics Norway, 2018

shared with the consumers. SME and industries that are more aware of the downside of the dTOU tariffs have therefore preferred fixed prices over dTOU.

6.2.3 Estonia

Estonia is often instanced as an advanced, digital society which stands out with its thriving start-up scene and governmental support for new technologies. Although the electricity market opening happened only in 2013, Estonia made dynamic electricity prices immediately available and is now one of the frontrunners regarding the implementation of dynamic electricity tariffs.[66] However, the different tariff options in Estonia are quite complex.

In general, consumers can choose between three main categories: fixed, combined and exchange packages. Within every package, there are several options available. The fixed package includes the option for a flat rate which is set for the duration between 6 and 36 months. Alternatively, consumers can choose a TOU tariff. In the exchange package, the prices follow the wholesale market prices, therefore this package is also called "spot tariff". Although this package includes the option to choose an RTP, it also includes other options where TOU rates are based on the wholesale market prices from previous months. As the name suggests, the combined package offers a combination of two tariffs types. Half of the power demand is billed with a RTP and the other half with a TOU tariff.[67]

The high number of tariff options makes it difficult to determine how many consumers have chosen a RTP in comparison to a TOU. Nonetheless, the general split between the three packages show that the share of residential consumers that chose a spot tariff more than doubled from 2013 to 27% in 2016. Thus, an increasing share of households wants prices to be related to the wholesale market price. In comparison, the share of households that chose the combined package stagnates since 2013 at around 7%.[68] Whilst the purpose of a combined tariff is to limit exposure to price risk for the consumers, it may appear unnecessary complicated to the consumers. Although the consumers have many different options and combination of these, this freedom of choice can go at the expense of transparency and clarity. Instead of empowering consumers, these tariff variations might unnerve consumers and lead to resistance.

6.2.4 Finland

As one of the Nordic countries, Finland has comparatively low electricity prices and therefore a high share of electric heating (85% of all consumers).[69] To better integrate the electric heaters, Finland introduced already in the 1970's TOU tariffs. The peak to off-peak ratio is around 1.2 and therefore significantly smaller than in most trials and pilot projects. Alternatively, households can also decide in favour of a monthly price. This is calculated as the average of the spot market prices of the previous month. Finally, consumers can either stick to a flat rate or choose a RTP tariff. According to the newest available data, only 7% have decided in favour of an RTP.[70] The TOU option with stable day and night tariffs was chosen by at least 17% as of 2012.[71]

[66] Riigi Teataja, 2017, Ots, 2017
[67] Eesti Energia, 2018, Eurelectric, 2017
[68] Eurelectric, 2017
[69] Annala, 2015
[70] Energy Authority, 2017
[71] Annala, 2015

Although Finland has a long history of dynamic power prices and already completed a wide-scale smart meter roll-out in 2016,[72] the RTP tariffs did not take off as fast as in the previous examples. Households with electric heating might feel that they have already chosen the appropriate dynamic tariff for their situation and show therefore less interest for RTP. It is also unclear whether the communication and marketing campaigns have managed to raise the public attention and interest sufficiently for RTP.

6.2.5 Italy

The Italian power consumption is characterised by a high share of air conditioning which constitutes around 75 % of the total residential energy demand.[73] Furthermore, Italy was one of the first countries embarking a wide-scale smart meter roll-out which it completed in 2011.[74]

Not surprisingly, Italy was one of the first countries that introduced on a wide scale dynamic electricity prices. Starting in mid-2010, TOU tariffs became mandatory for all residential customers that are supplied by a basic contract by their local energy supplier ("default service"). This price reform concerned around 25 million consumers, around 42% of the population. However, the peak to off-peak rate was with 1.1 comparatively small. A 10% price difference in the energy-related price component resulted only in a price difference of 3-7% of the final retail electricity price.[75] Although the price difference between the peak and off-peak rate was relatively small, around 60% of households shifted their power demand. Nonetheless, the total amount of energy that was shifted was low (1%).[76]

The mandatory roll-out of dynamic electricity tariffs is a way of rapidly promote dynamic pricing. Despite a low-price difference, the consumer reaction was not negligible. Nonetheless, arguably, a significantly higher price difference could have led to an even stronger consumer reaction.

[72] Energy Authority, 2017
[73] ENEA, 2015
[74] JRS, 2018
[75] Maggiore, 2014
[76] S3C, 2013

7 CONCLUSIONS AND RECOMMENDATIONS

7.1 General conclusions

We have seen that for European households, network costs typically account for about half of the consumer price, whilst taxes & levies typically form only a small part of total retail price. The structure and level of SME & small industries' retail electricity prices are similar to those of households. For energy-intensive industries, the energy component is the most dominant price component. Furthermore, we have demonstrated that dynamic power prices have the potential to lead to cost savings at the system and consumer level. Although there are several options to increases price dynamicity, RTP tariffs are the most obvious choice, and promise the largest benefits. Through the integration of renewable energy – and a decreased need for conventional, dispatchable power generation – the emissions in the power sector can be reduced. Moreover, there are many different developments that can support the implementation and effect of dynamic power prices; for example, smart meter roll-out across many Member States, electrification and digitalisation. Additionally, more and more households get increasingly accustomed to smart appliances and smart tariffs. The theoretical load reduction potential is quite equally distributed amongst sectors and Member States whereas the load increase potential is very high for households due to high free loads and low in the energy-intensive industry because of strict process requirements. The required ICT infrastructure for demand response will be available for most consumers in the near future due to the smart meter roll-out. Larger industries have the necessary infrastructure usually already in place and offer demand response if financially beneficial. A part of the demand-side flexibility potential can be leveraged at low costs. Activation costs for demand response are low for load shifting (mainly cross-sector technologies) but high for load shedding of energy-intensive processes. Therefore, we conclude that the increasing implementation of RTP tariffs across Europe should be encouraged. In the remainder of this chapter, we provide our recommendations on how the implementation should proceed. More specifically, we go beyond the recommendations of the Internal Market in Electricity Directive Draft and formulate concrete suggestions for the dynamization of non-energy related electricity price components. Finally, we formulate a dynamization roadmap to achieve a wide-scale uptake of RTP.

7.2 Higher price signals through dynamic network tariffs

Price variations should be noticeable to leverage the demand response potential. Particularly the dynamization of network charges can additionally support price variations as these constitute a significant cost component for most Member States and all consumer groups. Therefore, the variation of network costs would have a perceptible impact on the total retail price for electricity. Moreover, network costs are more homogeneous than policy related costs. Consequently, the modification of their price structure would be easier than of several different taxes and levies.

In addition, the energy transition to distributed, renewable electricity generation and an advancing electrification poses substantial challenges to the network operators. Therefore, distribution network operators will need to adapt and manage their grid more actively. Otherwise, substantial investments in grid extensions will become necessary which are significantly more expensive.[77] Dynamic network tariffs can support a smarter congestion

[77] Ecofys, 2017

management in addition to the alignment between wholesale price signals and the grid situation. Furthermore, dynamic electricity tariffs that incorporate the local grid situation can help to prevent the risk of simultaneous and strong consumer reactions to price signals that can lead to critical situations in the electricity system.[78] Additionally, dynamic electricity tariffs can foster a fairer distribution of costs, charging for where, when and which stress consumer cause on the electricity grid.

As already discussed in the previous chapter, we see an opposite trend as more and more network operators increase the share of fixed charges at the expense of energy charges. As capital cost constitutes the majority of network costs, this trend reflects the cost structure more accurately. Nonetheless, maintaining or even increasing fixed costs would prevent from exploiting the aforementioned benefits.

We realise that the shift towards dynamic network tariffs across all consumer groups requires a rethinking from network operators. This change should be encouraged by exchanging international experience and through insights from pilot projects and further supplementing studies. Dynamic network tariffs would only be eligible for households that are equipped with smart meters. To optimise the impact of dynamic pricing, we recommend that all customers falling under a RTP tariff for the energy component, should also have a dynamic network tariff. Non-dynamic network costs would limit the transparency and potential benefits for households and network operators alike.

7.3 Design options of dynamic network costs

To ensure that consumers contribute to the electricity system optimisation and cover their share of the grid costs in an adequate way, we suggest making the network cost volumetric by coupling the energy charge to the wholesale market prices, eradicating the capacity charge and minimising the fixed charge. The coupling to the wholesale market price should be realised through a multiplicator so that the network operators can cover their cost and the incentive for demand response is large enough. In order to mirror the situation in the electricity grid, the network tariffs should also include a dynamic local congestion charge. This is independent from the wholesale market price. Mathematically the calculation of dynamic network tariffs can be expressed as:

$$\text{Dynamic network tariff}\ (t) = \begin{array}{l} \text{Max}\ \{0, \text{Wholesale market price}\ (t)\ \text{x multiplicator} + \\ \text{local congestion charge}\ (t)\} \end{array}$$

The multiplicator should be based on the grid costs and projections of the electricity prices. The multiplicator could be adapted at certain time intervals, for instance quarterly, half-yearly or yearly. As energy-intensive industries might use the distribution grid to a lesser extent, the multiplicator might differ as the total network costs would be smaller. The multiplicator could also take into account the expected load shift of consumers. As households are less price sensitive than SME and small industries, they could be exposed to a larger multiplicator. In contrast, for SME and small industries a lower multiplicator might be more appropriate. All in all, the multiplicator has to be designed as such that the capital costs can be recovered whilst optimising system and consumer benefits.

[78] FfE, 2015

Dynamic network costs would additionally increase the price variations on the wholesale market. Figure 29 illustrates the German retail price for electricity if the energy-related cost component is replaced by the day-ahead prices in 2016 and if the network costs either remain static (red line) or are coupled to the wholesale market (blue line). If the day-ahead prices were known in advance, the multiplicator would be around 2.3. In addition to that, network operators could also share the cost benefits of lower needs for future investments. The figure assumes cost reductions of 10%.

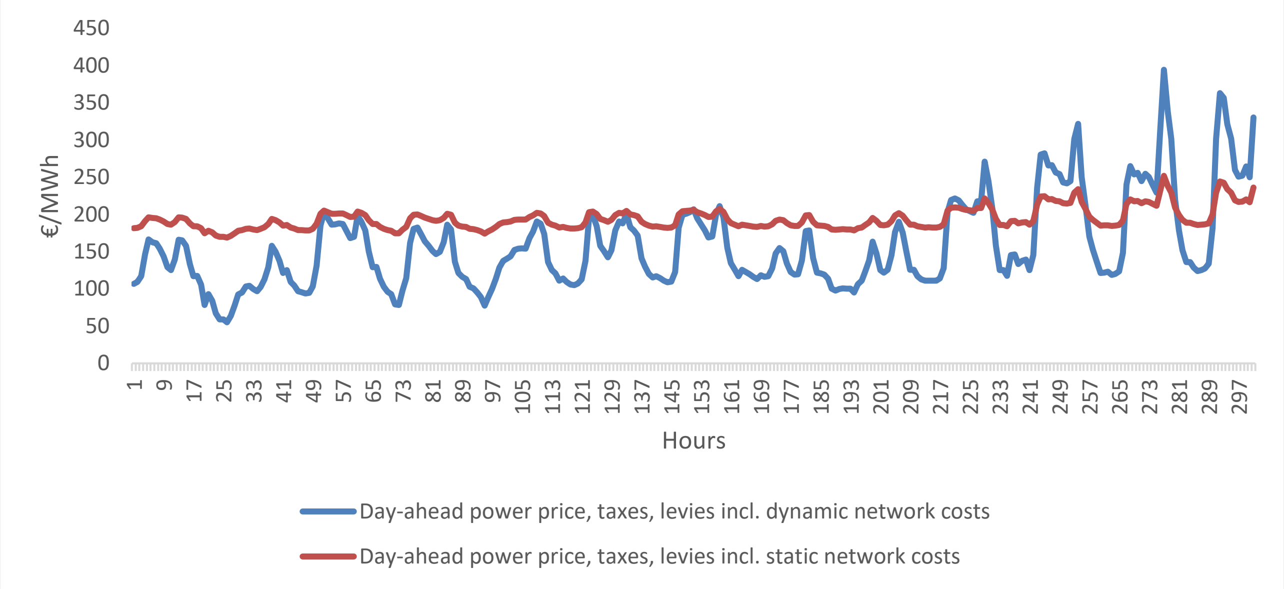

Figure 29: Impact of static and dynamic network costs. Source: Guidehouse calculations based on ENTSO-E and Eurostat data for Germany, 2018

In case the revenues are lower or higher than required, the network operators would have two options that are illustrated in Figure 30:

- Imposing a fixed charge or providing a premium until the budget is balanced; or,
- Adjusting the multiplicator to consider the actual budgetary requirements

It should be ensured that the amount of the fixed charge or premium is limited and does not allow the implementation of fixed network tariffs through the backdoor. The second option would prevent this risk and limit the steering mechanism only to an adaptation of the multiplicator. The adjustment of the multiplicator as suggested in the second option represents an inherent tariff optimisation strategy and seems therefore superior to the first option but could depend on the local system conditions. Additionally, the network costs should also include a local congestion charge reflecting the actual situation in the grid, as the wholesale market signals and situation in the grid not always align. The congestion charge should reflect the cost situation of the network operator and should be lower than grid extension costs. Over time, the local congestion charge should set incentives for the network operator to minimise its cost.

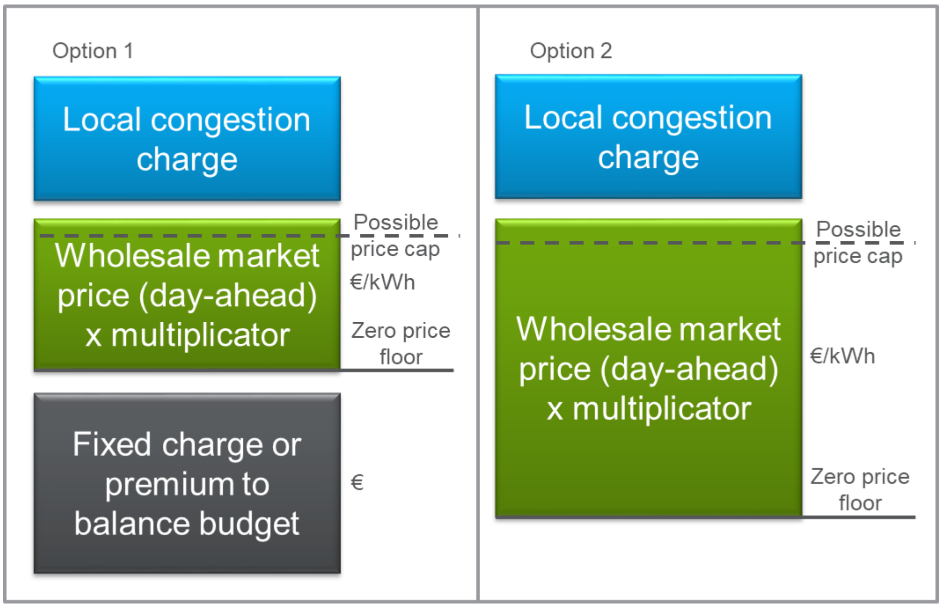

Figure 30: Tariff structure options for dynamic network costs

The benefits of such a RTP tariff are manifold. As already earlier, dynamic network costs increase the incentives for demand response by leveraging the benefits of dynamic electricity pricing overall. Moreover, dynamic network tariffs avoid the risk of competing incentives. Very low electricity prices would encourage the consumer to increase his load, even if the local network situation could temporarily not handle such a load increase. Additionally, high capacity charges might offset the benefits from demand response. Dynamic network costs remunerate consumers if their load profile is in line with the situation in the electricity grid and penalise if they cause additional cost to the grid (e.g. higher grid losses, grid congestion), thus preventing contradictory incentives from the wholesale market and electricity grid could and amplifying aligning incentives. Moreover, a consumption charge also rewards improvements in energy efficiency.

We recommend setting a price floor of zero, assuming the network costs are covered through an adjustment of the multiplicator, and a price cap that could be set by the Member States. If a price cap is applied, it should be set sufficiently high to prevent a distortion of the very impact dynamic prices try to effectuate, and only limit the price risk for consumers in extreme events.

Nonetheless, it should be noted that smart meters are not completely rolled-out yet. In case a smart meter cannot be installed at all consumers by the time RTP is introduced, the cost calculation should use standardised load profiles for specific consumer groups. Moreover, to provide information on local congestion, there is an even larger gap in sufficient information technology. In order to determine a local congestion charge, an anticipatory congestion planning is required. A wide-scale smart meter roll-out can improve the grid congestion forecasts but also provide real-time information on grid congestion. However, to use this information the distribution grid will need to upgrade its control systems. In addition to that, supplementary equipment would need to be installed to provide other useful network information (e.g. voltage). To minimise the costs, this equipment could be limited to particularly congested areas and nodal points.[79]

[79] Consentec, 2015

7.4 Dynamization of taxes and levies

In most Member States the impact of policy costs on the retail power price is comparatively small, especially when VAT is excluded. The policy costs are scattered across many different taxes and levies. Consequently, a recommendation in favour of dynamic policy costs on European level is problematic and complex; potential benefits of dynamic taxes and levies could outweigh the transaction costs. We recommend that every Member State should decide on its own whether it wishes to implement dynamic policy costs. In this case, we recommend that the policy costs should be aggregated into one single levy, comparable to Spain, in order to maximise the effect of price variations and keep the administration simple.

7.5 Dynamization roadmap

The design of the RTP tariffs should be specified at MS level, reflect the national framework conditions and first experiences with RTP. For instance, design options can include the implementation of a price floor or price cap. Based on the experiences in the USA, price caps can protect households from massive price increases in cases of exceptional events such as blizzards and avoid lengthy lawsuits between households and energy companies in the aftermath. Judging on the experience in Spain, price caps should be sufficiently high to avoid budget deficits in case of rising power prices. Moreover, price caps should provide sufficient room for price variations to encourage demand response.

For example, in the whole of 2016 the German-Austrian day-ahead spot prices surpassed only in 5 hours their threefold average value. The highest peak was 3.6 times higher than the average. During the weeks of extreme cold weather in Pennsylvania, the so-called polar vortex, in January 2014, the day-ahead prices soared up to around $900/MWh compared to around $50/MWh in the milder weeks of January. This constitutes an 18-fold increase which resulted in a threefold increase of the monthly electricity bill for some residential consumers.[80] In order to shelter residential customers from such extreme events and to accommodate usual price variations, a price cap around its eight-to-tenfold average value from the previous year seems appropriate. These views are generally in line with the initial draft for the Internal Market Directive. According to the directive, supply price regulation should only be encouraged in defined circumstances such as extreme weather events and have a limited duration.

Similarly, potential price floors, fixed cost or margins should be minimal (or even absent) and only serve to cover the fixed cost such as administration as well as decrease the overall risk in the market. Otherwise, these could hamper potential energy efficiency efforts and lead to unfair cost allocation between different consumption groups. Overall, it is highly important that electricity tariffs are structured as simple and transparent as possible.

In line with the Internal Market Directive, we believe that dynamic power pricing should move towards RTP at intervals equal to the market settlement frequency, as this tariff option can offer the greatest benefit, assuming a smart metering infrastructure is in place. We recommend a three-step implementation approach, shown in the figure below.

[80] PJM, 2014, PR Newswire, 2016

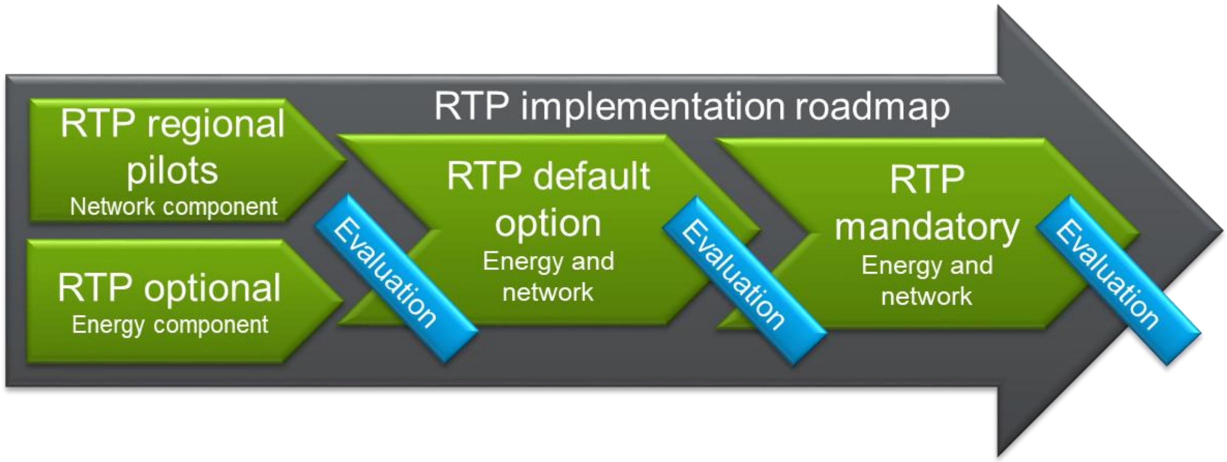

Figure 31: RTP implementation roadmap towards dynamic pricing

As a first step, consumers should get the option to install a smart meter and be able to choose a RTP tariff for the energy component of their power price. Consumers that do not decide in favour of a RTP tariff should not be penalised for their choice. Instead, they should be informed about the dynamic pricing and potential benefits through energy suppliers, regulators and associations. Switching should be further facilitated through shorter minimum contract periods, supporting switching procedures and price comparison tools that illustrate the individual cost impacts of switching. In these points, we agree with the recommendations in the Internal Market in Electricity Directive Draft.

While the price elasticity and interest for electricity tariffs of households is limited, SME and small industries are more likely to act quicker to achieve electricity bill savings. As it was shown before, dynamic electricity prices can lead to overall lower costs for the power system and consumers. Dynamic electricity prices will be particularly beneficial for consumers with flat load profiles; however, consumers with peaky load profiles could experience higher electricity costs and have possibly an incentive to choose a flat rate. The 'cross-subsidies' between consumers with flat and peaky load profiles would decrease and flat rates would need to be adjusted.

For a dynamization of the network component, we recommend precursory regional pilot projects in specific regions in order to gain more insight in local threshold values, consumer behaviour that might be cultural dependent, system operator requirements and market dynamics. Moreover, more insight can be gained in how a local congestion charge could be introduced. Such pilot projects would typically be at a national or international level including a few countries.

After these first steps, we suggest going beyond the recommendation in the Internal Market Directive and pursue the implementation of RTP more firmly. After experience with dynamic tariffs has been gained and the awareness of dynamic pricing has been raised, RTP should be made the default option for all consumers, for both the energy and the network component. Since consumers can hardly choose their grid operator (as opposed to their electricity supplier), a RTP per default for the network component could immediately be introduced after the pilot projects. Consumers that would not have switched on their own and therefore benefited from RTP because of inertia or a lack of information, get automatically a RTP tariff. Only if consumers explicitly decide against RTP, they should be able to return to their former tariff or an equivalent. This second step would particularly target households that show little interest for electricity prices. Consumers would be liberated from the requirement to actively pursue the cheapest tariff. Instead they would automatically get a dynamic tariff that would lead to savings for most consumers and energy system benefits.

Ultimately, all consumers equipped with smart metering devices should be exposed to price variations at the wholesale market, as this is the most efficient and optimal pricing method. The final step would be a mandatory RTP for all consumers, for both the energy and the network component.

In addition, we recommend conducting an evaluation after each step to fully understand the impacts of the roll-out of RTP and adjust the specific requirements and price setting methodology to increase effectiveness and efficiency of RTP.

8 REFERENCES

ACER/CEER, 2015: Annual Report on the Results of Monitoring the Internal Electricity and Natural Gas Markets in 2014. Online at: https://www.acer.europa.eu/Official_documents/Acts_of_the_Agency/Publication/ACER_Market_Monitoring_Report_2015.pdf

ACER/CEER, 2016: Annual Report on the Results of Monitoring the Internal Electricity and Natural Gas Markets in 2015. Online at: https://www.acer.europa.eu/Official_documents/Acts_of_the_Agency/Publication/ACER%20Market%20Monitoring%20Report%202015%20-%20ELECTRICITY%20AND%20GAS%20RETAIL%20MARKETS.pdf

AECOM, 2011: Energy Demand Research Project: Final Analysis. Online at: https://www.ofgem.gov.uk/ofgem-publications/59105/energy-demand-research-project-final-analysis.pdf

AECOM et al., 2011: Energy Demand Research Project: Final Analysis (English). Online at: https://www.ofgem.gov.uk/ofgem-publications/59105/energy-demand-research-project-final-analysis.pdf

Annala, 2015: Households' willingness to engage in Demand Response in the Finnish retail electricity market: an empirical study (English). Online at: http://www.doria.fi/bitstream/handle/10024/113819/Salla%20Annala%20A4.pdf;sequence=2

BET, Frontier, 2016: Kosten und Nutzen einer Dynamisierung von Strompreiskomponenten als Mittel zur Flexibilisierung der Nachfrage (German). Online at: https://www.bmwi.de/Redaktion/DE/Publikationen/Studien/kosten-nutzen-dynamisierung-strompreiskomponenten.html

BMWi, 2015: Leitstudie Strommarkt 2015 (German). Online at: http://www.bmwi.de/Redaktion/DE/Publikationen/Studien/leitstudie-strommarkt-2015.pdf?__blob=publicationFile&v=9

CEER, 2017: Electricity Distribution Network Tariffs CEER Guidelines of Good Practice. Online at: https://www.ceer.eu/documents/104400/-/-/1bdc6307-7f9a-c6de-6950-f19873959413

CNMC, 2017: Boletín de indicadores eléctricos de noviembre de 2017 - 30 de noviembre de 2017 (Spanish). Online at: https://www.cnmc.es/sites/default/files/1863753_0.pdf

CNMC, 2018: Boletín de indicadores 2018 (Spanish). Online at: https://www.cnmc.es/expedientes/isde01218

Consentec, 2015: Koordination von Markt und Netz- Ausgestaltung der Schnittstelle (German). Online at: http://www.bfe.admin.ch/php/modules/publikationen/stream.php?extlang=de&name=de_968514259.pdf

Deloitte, 2017: Un modelo de transporte descarbonizado para España en 2050 - Recomendaciones para la transición (Spanish). Online at: https://cdn2.hubspot.net/hubfs/1708142/Campanas/Estudio-descarbonizacion-2017/Descarbonizacion-Transporte-Monitor-Deloitte.pdf

DG ENER and JRC, Benchmarking smart metering deployment in the EU-27 with a focus on electricity, COM(2014)356

DLR, 2015: Balancing of Intermittent Renewable Power Generation by Demand Response and Thermal Energy Storage

EC, 2015: Study on tariff design for distribution systems. Online at: https://ec.europa.eu/energy/sites/ener/files/documents/20150313%20Tariff%20report%20fina_revREF-E.PDF

EC, 2016: Impact Assessment study on Downstream Flexibility, Price Flexibility, Demand Response & Smart Metering (English). Online at: https://ec.europa.eu/energy/sites/ener/files/documents/demand_response_ia_study_final_report_12-08-2016.pdf

EC, 2017: Directive of the European Parliament and of the council on common rules for the internal market in electricity (English). Online at: https://ec.europa.eu/energy/sites/ener/files/documents/1_en_act_part1_v7_864.pdf

EC, 2018: Clean Energy for All Europeans. Online at: https://ec.europa.eu/energy/en/topics/energy-strategy-and-energy-union/clean-energy-all-europeans

EcoAlign, 2013: Consumer Preferences and the Elusive Magic of Dynamic Pricing

Ecofys, 2013: Incentives to improve energy efficiency in EU Grids. Online at: https://www.ecofys.com/files/files/ecofys-2013-incentives-to-improve-energy-efficiency-in-eu-grids.pdf

Ecofys, 2016: Prices and costs of EU energy – Final report. Online available at: https://ec.europa.eu/energy/sites/ener/files/documents/report_ecofys2016.pdf

Ecofys 2016A: Flex-Efficiency. Ein Konzept zur Integration von Effizienz und Flexibilität bei industriellen Verbrauchern (German). Online at: https://www.agora-energiewende.de/fileadmin/Projekte/2015/Flex-Efficiency/Agora_Flex-Efficiency_WEB.pdf

Ecofys, 2017: Smart-Market-Design in deutschen Verteilnetzen (German). Online at: https://www.agora-energiewende.de/fileadmin/Projekte/2016/Smart_Markets/Agora_Smart-Market-Design_WEB.pdf

Eesti Energia, 2018: View our electricity packages and find the best one for you. Online at: https://www.energia.ee/en/elekter/paketid-ja-hinnad

Elbil, 2018: Norwegian EV market. Online at: https://elbil.no/english/norwegian-ev-market/

ENEA, 2015: Energy Efficiency trends and policies in ITALY. Online at: http://www.odyssee-mure.eu/publications/national-reports/energy-efficiency-italy.pdf

energy authority, 2017: National Report 2017 to the Agency for the Cooperation of Energy Regulators and to the European Commission. Online at: https://www.energiavirasto.fi/documents/10191/0/National_Report_2017_Finland_1469-401-2017.pdf/6b783563-e997-4c4c-ace9-826d68447c9b

Esios, 2017: Active energy invoicing Price. Online at: https://www.esios.ree.es/en/pvpc

Eurelectric, 2013: Network tariff structure for a smart energy system. Online at: http://www.eurelectric.org/media/80239/20130409_network-tariffs-paper_final_to_publish-2013-030-0409-01-e.pdf

Eurelectric, 2016: Network tariffs. Online at: http://www.eurelectric.org/media/268408/network_tariffs__position_paper_final_as-2016-030-0149-01-e.pdf

Eurelectric, 2017: Dynamic pricing in electricity supply. Online at: http://www.eurelectric.org/media/309103/dynamic_pricing_in_electricity_supply-2017-2520-0003-01-e.pdf

Euroheat & Power, 2017: District Energy in Norway. Online at: https://www.euroheat.org/knowledge-centre/district-energy-norway/

European Council, 2017: Transport, Telecommunications and Energy Council, 18/12/2017. Online at: http://www.consilium.europa.eu/en/meetings/tte/2017/12/18/

Eurostat, 2017: Electricity price components

EWI, 2010: The potential of demand-side management in energy-intensive industries for electricity markets in Germany

Faruqui, Palmer, 2012: The Discovery of Price Responsiveness – A Survey of Experiments involving Dynamic Pricing of Electricity (English). Online at: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2020587

FfE, 2014: The Merit Order of Demand Response in Industry. Online at: https://www.ffegmbh.de/download/veroeffentlichungen/454_dr_industry_enerday/ffe_demand-response-industry_paper.pdf

FfE, 2015: Belastung der Stromnetze durch Elektromobilität (German). Online at: https://www.ffe.de/download/article/543/Belastung_der_Stromnetze_durch_Elektromobilitaet.pdf

Fraunhofer ISI, 2012: Variable Stromtarife aus Kundensicht – Akzeptanzstudie auf Basis einer Conjoint-Analyse (German). Online at: http://www.isi.fraunhofer.de/isi-wAssets/docs/e-x/working-papers-sustainability-and-innovation/WP01-2012_Dynamische-Stromtarife_final_v1.pdf

Giraud, 2014: The tempo Tariff. Online at: https://www.sintef.no/globalassets/project/efflocom/edf.pdf

Helen, 2017: Electricity products and prices. Online at: https://www.helen.fi/en/electricity/homes/electricity-products-and-prices/

Hobman et. al. 2014: Uptake and usage of cost-reflective electricity pricing: Insights from psychology and behavioural economics

Homburg & Partner, 2008: Smart Metering aus Kundensicht (German)

JRS, 2018: Smart Metering deployment in the European Union. Online at: http://ses.jrc.ec.europa.eu/smart-metering-deployment-european-union

Kim et. al., 2016: A Dynamic Electricity Tariff survey for Smart Grid in South Korea. Online at: http://www.iiis.org/CDs2016/CD2016Summer/papers/SA054EJ.pdf

Kitzing et. al., 2016: The residential electricity sector in Denmark: A description of current conditions. Online at: http://orbit.dtu.dk/files/121099206/The_residential_electricity_sector_in_Denmark.pdf

Klobasa et al., 2006: Demand Side Management in dezentral geführten Verteilnetzen (German)

Laveron, 2015: Electricity tariff structure – Spanish experience. Online at: https://www.iea.org/media/workshops/2015/esapworkshopiv/Laveron.pdf

Linear, 2014: Demand Response for Families. Online at: http://www.linear-smartgrid.be/sites/default/files/Linear%20Final%20Report%20-%20lr2.pdf

Maggiore, 2014: Evaluation of the effects of a tariff change on the Italian residential customers subject to a mandatory Time-of-Use tariff. Online at: https://de.slideshare.net/drsea/07-maggiore-simoneieadsmgrazoctober2014

MsbG 2016: Gesetz über den Messstellenbetrieb und die Datenkommunikation in intelligenten Energienetzen (Messstellenbetriebsgesetz - MsbG) (German). Online at: https://www.gesetze-im-internet.de/messbg/MsbG.pdf

Navigant Research, 2016: Dynamic Pricing. Real-Time Pricing, Critical Peak Pricing, Peak Time Rebates, and Variable Peak Pricing: Global Market Analysis and Forecasts

NordREG, 2015: Tariffs in Nordic countries – survey of load tariffs in DSO grids. Online at: http://www.nordicenergyregulators.org/wp-content/uploads/2015/03/Tariffs-in-Nordic-countries-survey-of-load-tariffs-in-DSO-grids.pdf

Ots, 2017: Price regulation in Estonian power sector. Online at: http://rekk.hu/downloads/events/OTS_Price%20regulation%20in%20power%20sector%20may%202017.pdf

PJM, 2014: PJM response to consumer reports on 2014 winter pricing. Online at: http://www.pjm.com/-/media/documents/reports/20140919-pjm-response-to-consumer-reports-on-2014-winter-pricing.ashx?la=en

PR Wire, 2016: Pennsylvania PUC Approves Settlement of Claims Regarding IDT Energy 2014 Polar Vortex Pricing. Online at: https://www.prnewswire.com/newsreleases/pennsylvania-puc-approves-settlement-of-claims-regarding-idt-energy-2014-polar-vortex-pricing-300293074.html

RAP, The Brattle Group, 2012: Time-Varying and Dynamic Rate Design (English). Online at: https://www.raponline.org/wp-content/uploads/2016/05/rap-faruquihledikpalmer-timevaryingdynamicratedesign-2012-jul-23.pdf

RAP, 2018: Cleaner, Smarter, Cheaper: Network tariff design for a smart future

Riigi Teataja, 2017: Electricity Market Act. Online at: https://www.riigiteataja.ee/en/eli/ee/Riigikogu/act/506072017006/consolide

S3C, 2013: TOU Italy. Online at: http://www.s3c-project.eu/News/52/ToUItaly.html

Saraiva et. al., 2016: Implementation of Dynamic Tariffs in the Portuguese Electricity System - Preliminary Results of a Cost-Benefit Analysis. Online at: https://repositorio.inesctec.pt/bitstream/123456789/3893/1/P-00K-WVM.pdf

Schneider, Sunstein, 2016: Behavioural considerations for effective time-varying electricity prices. Online at: https://doi.org/10.1017/bpp.2017.2

Statistics Norway, 2015: The overall renewable energy share for Norway. Online at: https://www.ssb.no/266658/the-overall-renewable-energy-share-for-norway.annual-figures

Statistics Norway, 2017: Almost 100 000 electric passenger cars. Online at: http://www.ssb.no/en/transport-og-reiseliv/artikler-og-publikasjoner/almost-100-000-electric-passenger-cars

Statistics Norway, 2018: Electricity prices in the end-user market, by contract type 2012K1 - 2017K3. Online at: https://www.ssb.no/en/statbank/table/09364/?rxid=3b9a3d6f-6e0c-4648-bc6c-1311bbbd1379

Strompris, 2018: Sjekk strømprisene (Norwegian). Online at: https://www.strompris.no/en/home/?

Synopia, 2017: Les Français et l'électricité (French). Online at: http://www.ifop.fr/media/poll/3661-1-study_file.pdf

The Brattle Group, 2008: Quantifying the Benefits of Dynamic Pricing in the Mass Market. Online at: http://www.edisonfoundation.net/iee/documents/quantifyingbenefitsdynamicpricing.pdf

The Brattle Group, 2010: The Impact of Dynamic Pricing on Low Income Customers. Online at: http://www.edisonfoundation.net/IEE/Documents/IEE_LowIncomeDynamicPricing_0910.pdf

The Brattle Group, 2010A: Quantifying the Benefits of Dynamic Pricing in the Mass Market. Online at: http://www.edisonfoundation.net/iee/documents/quantifyingbenefitsdynamicpricing.pdf

The Brattle Group, 2017: Workshop on Pricing Reforms. Online at: http://www.brattle.com/system/publications/pdfs/000/005/523/original/Workshop_on_Pricing_Reforms.pdf?1508353919

Université Paris-Dauphine, 2016: La tarification des réseaux électriques (French). Online at: http://www.faee.fr/files/file/aee/seminaires/2016/160128_Synth%C3%A8se_2.pdf

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