

Cleaner, Smarter, Cheaper:

Network tariff design for a smart future

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1. Fixed charges impede the clean energy transition

Network charges—the fees paid by consumers to cover the costs for power lines and other network assets and services—form a significant part of consumers' bills. These costs have been increasing and are expected to continue increasing, especially at the distribution network level, as they are expanded to accommodate new distributed activities, such as electric vehicle charging and distributed generation, and modernised to make them smarter.

Network charges are commonly split into fixed and volumetric (or variable) components. In recent years, several states and network companies have increased the share of fixed charges, in part by lowering the volumetric rates. For example, the Netherlands eliminated volumetric payments for residential customers and instead established fixed charges only.¹ In Germany, fixed charges have increased for residential customers by approximately 50 percent from 2013 to 2016 and already account for more than 50 percent of the total network bill for low-demand households in some network areas.² In Spain, the main fixed component for households increased from 32 percent to 60 percent of the network charges in 2013 to 2014.³ A similar trend is observed in Italy, where the fixed charge is scheduled to increase threefold between 2016 and 2018.⁴

Fixed charges take the power of choice out of consumers' hands...resulting in increased costs for all by driving excessive investments in underutilised grid infrastructure

¹ The fixed charge in the Netherlands is based on the contracted capacity of a residential consumer. This type of fixed charge is called capacity-based charge; see next section for more details.

² Jahn, A. (2017). Are fixed charges an answer to tariff design challenges? [PowerPoint slides]. Retrieved from <http://www.raponline.org/wp-content/uploads/2017/07/rap-jahn-tariff-design-MN-II-2017-july-12.pdf>

³ This refers to the capacity component of the tariff for Spanish residential consumers.

⁴ For more information, see, for example, Verhaeghe, C. (2016). Distribution charges: Review of experiences on tariff structure and new challenges [PowerPoint slides]. Retrieved from <http://www.eprg.group.cam.ac.uk/wp-content/uploads/2016/05/C.-Verhaeghe.pdf>

These developments are counterproductive, especially given the European Union's (EU's) commitment to the clean energy transition with consumers at its centre.⁵ Fixed charges take the power of choice out of consumers' hands and are contrary to the EU vision of broad deployment of energy efficiency, demand response, and distributed generation. They promote consumption at times of stress on the grid and overconsumption generally, resulting in increased costs for all by driving excessive investment in underutilised grid infrastructure. Given the need to decarbonise the transport and heat sectors in large part through electrification, fixed charges will exacerbate the problem of underutilised grid infrastructure and higher costs for the energy transition. The incentives created by further shifts to fixed charges will lead to the need to over-build distribution infrastructure and in so doing will create a significant hurdle for the deployment of beneficial electrification of the heat and transport sectors.⁶

Purpose of this paper

This paper provides recommendations for network tariff design that will support the realisation of the European Union's clean energy vision in a timely fashion, at least cost, and with an equitable distribution of the costs and benefits among consumers. In the next section we briefly present the state of play for network charges in Europe. In Section 3 we explain why fixed charges are undesirable. Sections 4 and 5 describe our recommendations for the high-level principles of smart tariff design and provide concrete examples of such tariffs, along with practical recommendations about the appropriate tariff design for different consumer classes and uses.

2. Network charges in Europe – state of play

The amount European consumers pay for network charges has increased every year since 2008 and is expected to continue to do so. Reasonable increases in overall network costs are anticipated given the increased investment necessary to replace aging assets and enhance the capabilities needed to enable the European Union's clean energy vision, particularly on the distribution network. However, increasing the share of those costs levied through fixed charges should not be treated as necessary or advisable. Indeed, doing so would represent a serious threat to consumers' ability to actively participate in a smart energy future.

In 2015, network charges accounted for just over a quarter (or 54 €/MWh) of the bill for the average European household, having increased steadily since 2008 (by 3.3 percent on average per year).⁷ Small industrial consumers⁸ also paid approximately one quarter of their electricity

⁵ See, for example, European Commission. (2016, November 30). Commission proposes new rules for consumer centred clean energy transition. Retrieved from <http://ec.europa.eu/energy/en/news/commission-proposes-new-rules-consumer-centred-clean-energy-transition>

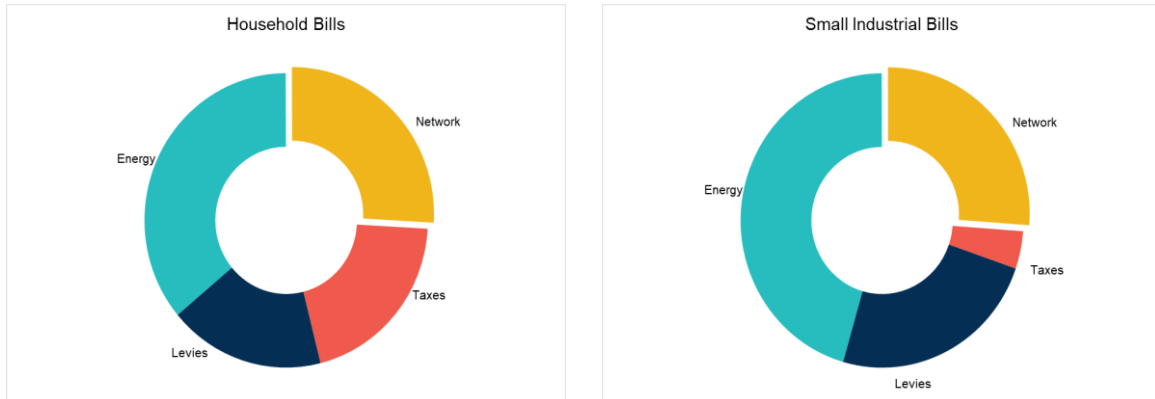
⁶ For more information on the concept of beneficial electrification, see, for example: Colburn, K. (2017). Beneficial electrification: A growth opportunity (blog). Montpelier, VT: The Regulatory Assistance Project.

⁷ Although the absolute cost of network charges has increased from 2008 to 2015, its relative share in the bill has remained constant in the same period, as the total bill has also increased. Regarding the other components of the bill, the cost for the purchase of energy has decreased significantly while the taxes and levies have increased. European Commission. (2016). *Energy prices and costs in Europe*. Brussels, Belgium. Retrieved from https://ec.europa.eu/energy/sites/ener/files/documents/com_2016_769.en.pdf

⁸ Small industrial consumers are defined by Eurostat as consumers who have an annual consumption in the range of 20 MWh to 500 MWh. Commercial consumers fall into one of the two categories, households or small industrial, depending on their size and consumption.

bill (around 38 €/MWh) for use of the networks. Figure 1 shows a breakdown of the average bills for these two customer classes. Although these charges include the cost for the use of both transmission and distribution networks, the bulk of the charges are for distribution. Distribution charges comprise approximately 80 percent of the total network charges⁹ for households and small industrial consumers.^{10,11}

Figure 1. Bill Breakdown for Average European Household and Small Industrial Consumers



Data as of 2015

Network charges are commonly split into a fixed and a volumetric component. A fixed charge is usually assessed based on the number of consumers in a network company's area and the class of customer being assessed. The size of the fixed charge can be evenly allocated across the number of customers in a given class, based on the size of the customer's connection to the distribution grid (usually called a capacity-based charge), or the customer's peak demand over a specified period of time, typically a month or a year (usually called a demand charge).¹² Fixed charges are commonly denominated in € per period or €/kW per period.^{13,14} The volumetric (variable or usage-based) part of the bill reflects how much the consumer used and is denominated in a per-unit cost, that is, c€/kWh.

Fixed charges for households tend to be capacity-based, whereas for small industrial customers they tend to be demand-based. On average, 30 percent of the network charge for households is fixed, although in some countries (i.e., the Netherlands, Spain, and Sweden) it represents 80 percent or more of network charges. For small industrial consumers, the fixed component represents almost half of their network charges, with significant variability among Member

⁹ For this reason, the focus of this paper is mainly on distribution network charges.

¹⁰ European Commission, 2016.

¹¹ This is the key reason that large industrial consumers, often connected directly to the transmission network, tend to face low network charges (16 percent of the electricity bill for the average European large industrial consumer), as they only pay for the use of transmission networks. Large industrial consumers are outside the scope of this paper.

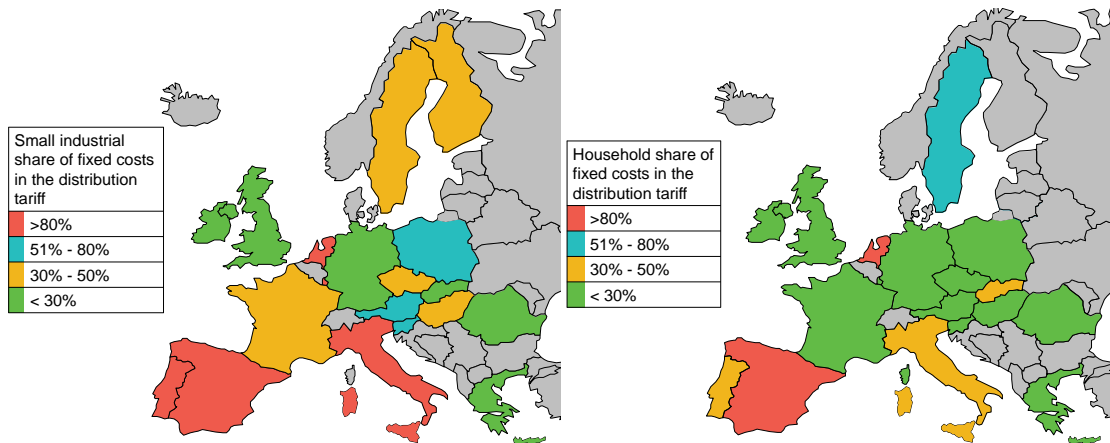
¹² In European Member States, this is usually defined with regard to the individual's peak demand and does not take into consideration whether this demand charge occurred at the time of system peak demand (also called a non-coincident peak demand charge). A variation of this type of tariff is the coincident peak demand charge, where the charge is determined based on the customer's consumption at the time of system peak and represents a better design. There are also other variations of this tariff type.

¹³ Network companies often charge a fixed fee for other purposes which are not related to the use of the network, such as for billing.

¹⁴ European Commission. (2015). Study on tariff design for distribution systems. Brussels, Belgium. Retrieved from https://ec.europa.eu/energy/sites/ener/files/documents/20150313_Tariff_report_fina_revREF-E.PDF

States.¹⁵ Figure 2 presents the proportion of network charges that are fixed for household and small industrial consumers in Member States where data are available. Network charges are uniform in some Member States (e.g., France and Hungary), whereas in others tariffs are differentiated by network company or by geography.

Figure 2: Proportion of Fixed Fees in Network Charges for Household and Small Industrial Consumers in Different Member States



Data as of 2013

3. Fixed charges drive higher costs for everyone

Network tariff design is critical for both the efficient short-term usage and long-term evolution of the grid. It sets the prices consumers pay for their use of the network infrastructure and influences their consumption and investment choices. Tariffs are also the means by which network companies expect to recover their allowed costs, as these are approved by National Regulatory Authorities (NRAs).¹⁶ In the majority of European Member States, NRAs are responsible for determining the tariff design and level of tariff. In other Member States, NRAs and distribution system operators (DSOs) share responsibility for setting network tariffs; in those Member States, NRAs are generally responsible for setting methodologic aspects of tariff design (e.g., the mathematical and other rules by which tariffs are calculated) and approving the tariffs themselves, whereas the DSOs propose the tariff structure and level.¹⁷ European legislation sets high-level principles for tariff design.

Fixed charges take the power of choice out of consumers' hands. Because they are unavoidable they undermine economic efficiency, in both the short and long run. Consumers pay the same amount independently of whether they consume a little or a lot, and independently of whether

¹⁵ European Commission, 2015.

¹⁶ The first step in the process of determining the level of tariffs is the evaluation of the allowed revenues for the network company. This is outside the scope of this paper. For more information, see, for example: Lazar, J. (2015). Dividing the pie: Cost allocation, the first step in the rate design process. Montpelier, VT: *The Regulatory Assistance Project*. Retrieved from: <http://www.raponline.org/knowledge-center/dividing-the-pie-cost-allocation-the-first-step-in-the-rate-design-process>

¹⁷ European Commission, 2015.

they use the grid at times when network capacity is abundant or scarce.¹⁸ Fixed charges discourage energy efficiency, neutralise demand response, and undermine the potential benefits of self-generation. They don't provide any of the information consumers need in order to save money, optimise utilisation of existing grid, and drive efficient investment in new equipment, by either shifting energy consumption toward times when networks are underutilised or by decreasing overall consumption (e.g., by investing in more efficient appliances).

Consumers pay the same amount independently of whether they consume a little or a lot, and independently of whether they use the grid at times when network capacity is abundant or scarce. Fixed charges discourage energy efficiency, neutralise demand response, and undermine the potential benefits of self-generation

On the contrary, fixed tariffs encourage consumption at times of stress on the grid and overconsumption in general, resulting in increased costs for all by driving excessive investment in underutilised grid infrastructure. The disincentive for energy efficiency is well recognised. For example, when the Netherlands changed their network tariffs from volumetric to completely fixed (capacity-based) charges,¹⁹ the government increased the imposed tax per unit of consumption, thus sharpening the signal to consumers through energy taxation in order to counter the effect.²⁰

Fixed charges impose a disproportionate and unfair burden on low-usage customers

Efficiency and equity are best served when the price a customer pays for shared infrastructure reflects as closely as possible the costs that consumer imposes. Fixed tariffs do not promote efficiency or equity. Consumers who use the grid efficiently (e.g., consumers who need less shared network capacity) pay the same for the use of shared grid infrastructure as those who do not. Customers whose consumption is highest during hours of lower network utilisation pay the same amount for shared infrastructure as those whose highest consumption contributes directly to peak system demand. Peak demand conditions are particularly important, as they determine the size of the grid, that is, the network is designed to accommodate the highest demand experienced collectively, not the sum of each individual customer's highest demand.²¹

¹⁸ In the extreme, if a consumer is only charged a fixed fee, the bill would be the same whether they consume no power or consume power 24 hours per day, seven days per week.

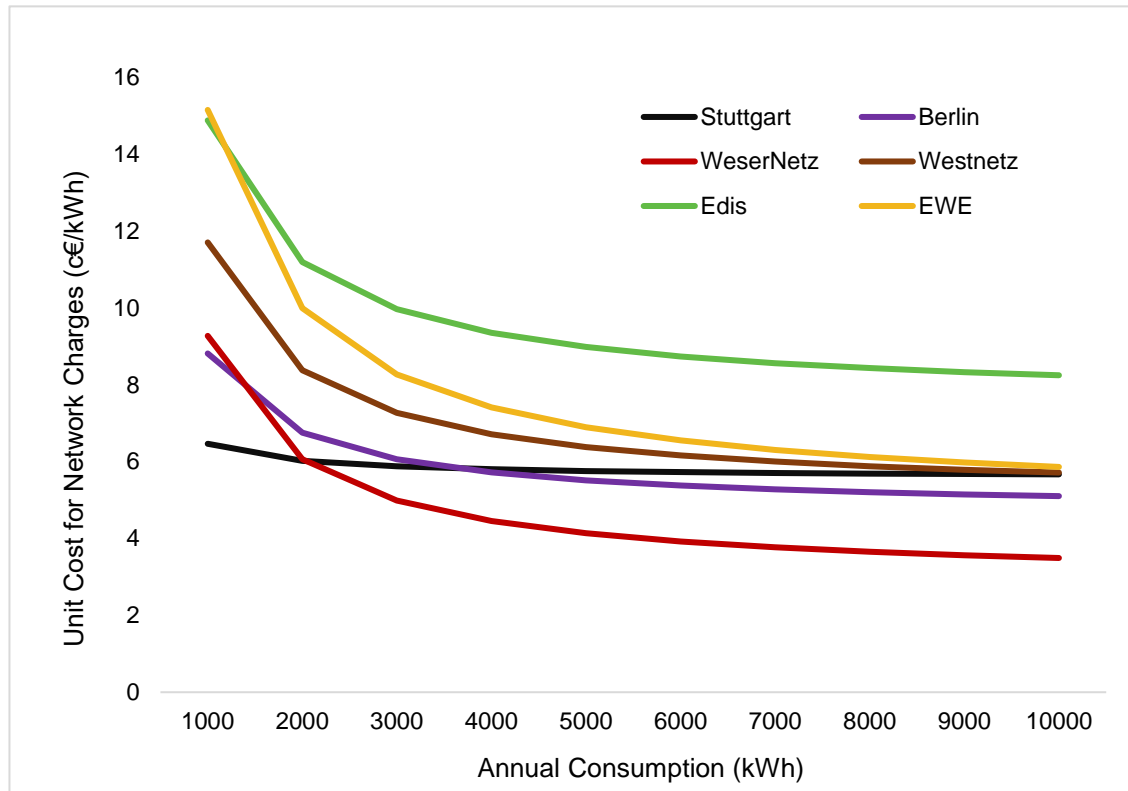
¹⁹ The Netherlands Authority for Consumers and Markets (ACM) changed the design of network tariffs in 2009, which, up to that point, were volumetric. Dutch consumers now pay a fixed charge, based on the size of their connection capacity (or a so-called capacity charge). Council of European Energy Regulators (CEER). (2017). Electricity distribution network tariffs - CEER guidelines of good practice. Brussels, Belgium. Retrieved from <https://www.ceer.eu/documents/104400/-/-/1bdc6307-7f9a-c6de-6950-f19873959413>

²⁰ CEER, 2017.

²¹ The grid, or parts of it, normally reach close to full utilisation at times of peak, *whereas* utilisation *is* lower at other times. Efficient operation of the network means that the use of grid capacity over a given period is as close as possible to the maximum amount of energy the network could practically be expected to carry over that period.

A uniform fixed tariff tends to shift costs from the high-usage customers in a customer class to the low-usage ones. This is evident for example in Germany, where low-usage consumers in the same distribution territory can pay up to two and a half times as much per unit of energy delivered to their premises compared to high-usage consumers, as is evident in five of the six distribution areas depicted in Figure 3.²² Low-usage customers receive equitable treatment compared to high-usage customers in only one out of the six distribution territories, the Stuttgart area, which does not apply any fixed charges for shared infrastructure.

Figure 3. Network Costs per kWh as a Function of Annual Electricity Consumption



The financial stability of network companies does not depend on fixed charges; it can easily be achieved with usage-based pricing

Economic theory and practical experience both demonstrate there is no reason pricing for electric grid services should be based on fixed tariffs; in the long run, all costs are variable. Competitive industries, even those with comparably high capital cost structures, rely on volumetric prices instead of fixed to recover their costs, both investment and operating. Hotels, petrol companies, airlines, and grocery chains – all highly capital-intensive industries – recoup their investment costs by charging for the volume of product sold.²³ The fact that these industries operate in competitive environments while network companies are regulated

²² Bundesnetzagentur [German National Regulatory Authority]. (2017). Monitoringbericht 2017 [Monitoring Report 2017]. Bonn, Germany. Pp 230–238. Retrieved from https://www.bundesnetzagentur.de/SharedDocs/Downloads/DE/Allgemeines/Bundesnetzagentur/Publikationen/Berichte/2017/Monitoringbericht_2017.pdf?__blob=publicationFile&v=4

²³ In some cases, such as with airlines, companies change their price with time, *for example*, prices tend to spike during peak periods, reflecting a TOU tariff, which we discuss in the next sections.

businesses in no way justifies using inefficient pricing for regulated enterprises.

The financial stability of network companies can be served by economically efficient pricing structures and appropriate regulatory frameworks. Smart tariff design and regulation can deliver both long-term financial sustainability and public policy objectives – to pursue efficient use of electricity, meet environmental goals, and minimise adverse social impacts. Appropriate regulatory frameworks include revenue-regulation and decoupling, which is widely in place in Europe, and performance-based regulation (PBR).²⁴ Revenue regulation and decoupling break the link between sales and profits for the network company while ensuring the network company will recover its allowed costs plus a reasonable return on investment. PBR, often an overlay on revenue-based regulation, links the returns for network companies to the achievement of certain predetermined goals (e.g., achieving a certain utilisation rate for grid infrastructure, reduced outage rates, achievement of energy efficiency targets).

Moreover, fixed charges are not justified even on a limited basis. If fixed charges are applied discriminately to new distributed energy activities, such as solar panels and electric vehicle charging, they may unnecessarily impede adoption of these technologies. For example, the regulator of Wallonia (Belgium) has announced that solar panel owners will pay an annual grid-fee from 2019, ranging from €330 to €560, presumably in a misguided effort to prevent cross-subsidisation.²⁵ There is no evidence these charges actually reflect the costs these consumers will impose on the system, and consumers engaged in these activities have no economic incentive to minimise their use of the network during peak demand periods. Consumers engaging in these new activities are deprived of the opportunity to save money and benefit the system at the same time. In an environment in which traditional sources of demand growth are under increasing pressure, this punitive approach to charging for new sources of demand seems self-defeating at best.²⁶

4. Smart network tariff design – the principles

The challenge of designing economically efficient tariffs has occupied regulators and policymakers since the dawn of utility regulation. It is widely accepted that tariffs should not encourage or reward unnecessary investment, and that the concept of customer cost causation

²⁴ The discussion on appropriate regulatory frameworks is beyond the scope of this paper. For more information on revenue-regulation and decoupling, see: Lazar, J., Weston, R., & Shirley, W. (2011). [Revenue regulation and decoupling: A guide to theory and application](#). Montpelier, VT: The Regulatory Assistance Project; and on PBR, see: Littel, D., Kadoch, C., Baker, P., Bharvikar, R., Dupuy, M., Hausauer, B., Linvill, C., Rosenow, J., & Wang, X. (2017). [Next-generation performance-based regulation: Emphasizing utility performance to unleash power sector innovation](#). Golden, CO: National Renewable Energy Laboratory.

²⁵ Bellini, E. (2017, April 11). Belgium: Wallonia's regulator imposes grid-fee for solar starting from 2019. PV Magazine. Retrieved from <https://www.pv-magazine.com/2017/04/11/belgium-wallonias-regulator-imposes-grid-fee-for-solar-starting-from-2019/>

²⁶ Increasing fixed tariffs could also be detrimental to the long-term financial sustainability of network companies. As the cost of batteries is getting cheaper, consumers might find it more economic to invest in solar systems complemented with batteries or other self-sufficiency options, instead of depending on the network and paying the fixed charges imposed by utilities. This could cause a death spiral for network companies through increased consumer defection from the grid and is a potential risk for the longer term. For example, a Rocky Mountain Institute and Cohn Reznick analysis shows that *approximately* 20 million consumers in parts of the United States could find it more economic to rely on a solar-battery system in a scenario of moderate technology improvements; see Rocky Mountain Institute, Cohn Reznick, & Homer Energy. (2014). The economics of grid defection. Boulder, CO. Retrieved from https://www.rmi.org/wp-content/uploads/2017/04/RMIGridDefectionFull_2014-05-1-1.pdf. This could be the case for some areas in Europe, especially in the south of the continent.

(i.e., that customers should bear the costs associated with their use of the network, in other words the costs that their usage imposes on the system) should underpin tariff design. Applying this principle is complicated by the shared nature of all but the most site-specific network infrastructure.²⁷

The elements of an economically efficient tariff, fit for the purpose of addressing current and expected network challenges, can be derived from long-established principles of good tariff design.²⁸ Those principles dictate that tariffs should: (1) be simple, predictable, and understandable, (2) reflect long-run marginal costs, (3) focus on usage-driven components, (4) give consumers the information, the opportunity, and the incentive to consume in a manner that optimises utilisation of grid infrastructure, and (5) where possible and appropriate, provide for the recovery of system costs based on how much a customer uses, when they use it, and where they are located.²⁹ In practice, these principles can push the design of tariffs in a number of directions; for example, greater time-of-use (TOU) differentiation complicates the task of designing a simple tariff.³⁰ As a result, designing tariffs is a balancing exercise and requires the use of judgment to meet several objectives.

Drawing from these principles, we recommend that the following three fundamental principles underpin network tariff design for a future consistent with the European Union's vision.

High-level principles for smart network tariff design

1. A customer should be able to connect to the grid for no more than the cost of connecting to the grid.³¹
2. Customers should pay for grid services in proportion to how much and when they use the grid.
3. Customers who produce their own electricity should cover their fair share of grid costs by paying more to use the grid when it is heavily loaded, but less when it is not.³²

²⁷ The shared nature of the network is where its added value comes from, *that is*, it is less costly to provide electric service by means of a shared asset and, as a result, everyone's costs are lower than they would otherwise be (i.e., if they were providing their own electricity).

²⁸ See, for example: Bonbright, J. (1961). Principles of public utility rates. New York, NY: Columbia University Press; or Weston, F. (2000). Charging for distribution utility services: Issues in rate design. Montpelier, VT: The Regulatory Assistance Project. Retrieved from <http://www.raonline.org/knowledge-center/charging-for-distribution-utility-services-issues-in-rate-design/>

²⁹ For more information see Lazar, J., & Gonzalez, W. (2015). Smart rate design for a smart future. Montpelier, VT: The Regulatory Assistance Project. Retrieved from <http://www.raonline.org/wp-content/uploads/2016/05/rap-lazar-gonzalez-smart-rate-design-july2015.pdf>

³⁰ At the same time, technologic progress through automated systems makes it possible to introduce more complex tariffs and makes it easier for consumers to control their consumption.

³¹ This aspect of network tariff design is outside the scope this paper. The focus of this paper is the use of shared infrastructure, which falls under principles 2 and 3.

³² The use of the grid applies to usage in both directions, that is, buying from and selling to the grid.

Overall, tariff design should reflect the fact that different consumers contribute differently to the demand for, and therefore the cost of, shared network infrastructure, depending on how and when they use it and where they are located, shaped by the value of simplicity.

5. Smart tariff design in practice

Smart tariff design enables customers to optimise the use of existing infrastructure while limiting future system costs. To the extent additional demand can be accommodated with existing infrastructure, grid costs can be spread over a larger volume of consumption, thus reducing bills for all customers instead of driving unneeded new investment and higher costs.

Smart tariffs range from TOU tariffs, in which the consumer pays a different, predetermined fee for specified blocks of time based on historical usage patterns (such as a day and night tariff, or a weekday and weekend tariff), to the most granular real-time-pricing (RTP), in which price is determined by actual conditions on the system from one interval to the next. In between the two, critical peak pricing (CPP) sets significantly higher prices for a limited number of pre-notified “critical peak” periods.

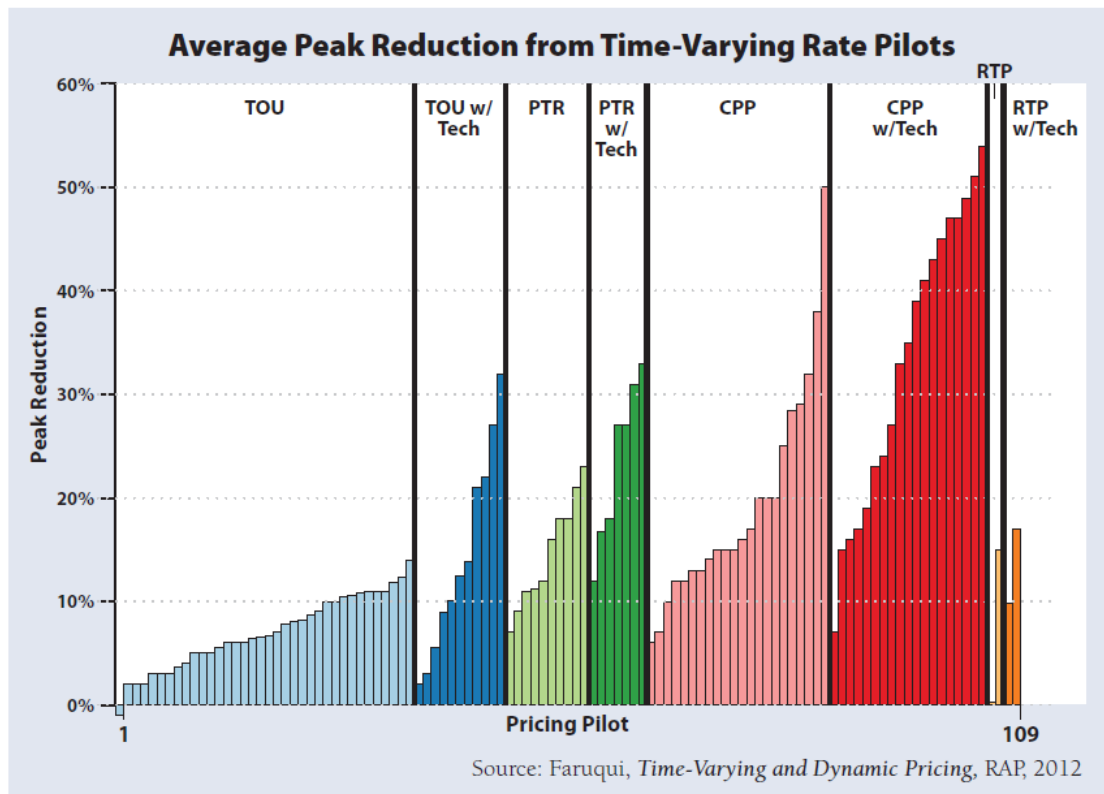
Figure 4 presents the levels of peak demand reduction achieved for a number of smart tariff pilot programmes. The figure demonstrates that smart tariffs lead to reductions, although the effectiveness of different approaches can vary considerably.³³ The effectiveness of a smart tariff increases with the use of smart technology, such as automated systems through smart phone applications and smart thermostats. The deployment of smart technologies without commensurately smart tariffs will have limited effectiveness and vice versa – smart tariffs need to be complemented by deployment of smart technologies to be fully effective.³⁴

These pilot programmes provide clear evidence customers respond to prices. With prices that reflect system value, consumers are incentivised to adopt behaviours that in time will reduce the overall costs of running the system and thus benefit all consumers. In addition, smart tariffs help to allocate costs in a more equitable way across consumers. Customers who contribute more to peak system demand will pay more, whereas customers who adopt measures enabling them to avoid using the grid at times of system stress will pay less.

³³ The pilot projects above refer to tariffs encompassing costs for both the production of electricity and the use of the networks. They suggest the more impressive scale of reductions achievable with dynamic pricing for both energy and network charges compared with dynamic pricing for energy alone, which is a widely recognised goal. Eventually consumers face the sum of the charges for the different costs that relate to the provision of the service (plus any add-ons such as taxes).

³⁴ Faruqi, A., Hledik, R., & Palmer, J. (2012). Time-varying and dynamic rate design. Montpelier, VT: *The Regulatory Assistance Project* and Brattle Group. Retrieved from <http://www.raonline.org/wp-content/uploads/2016/05/rap-faruquihledikpalmer-timevaryingdynamicratedesign-2012-jul-23.pdf>

Figure 4. Average Peak Reduction From Time-Varying Tariff Pilots



Note: "Tech" refers to the availability of smart technology

In addition, the costs that network companies face can vary significantly from area to area. For this purpose, locational signals can be provided by varying tariffs between different areas to reflect these costs (e.g., long-term marginal costs). Areas with excess capacity face low marginal costs of delivering power through the grid, while constrained areas may have significant marginal costs for incremental consumption and subsequently grid use.³⁵

In theory, the smartest tariff is the best, however in practice this is not necessarily the case. The right approach will depend on the specific conditions (e.g., the extent to which these new uses have been adopted, the roll-out of smart technology or consumer education about smart technology, and tariffs). The level of smartness of a tariff should be matched to its likely benefit, with an expectation that it can be enhanced as the energy transition progresses.

Currently, smart network tariffs are still at an early stage of development. For example, the Portuguese DSO planned to introduce a pilot project of dynamic network tariffs for industrial consumers in 2017.³⁶ Another example of a smart network tariff is the Sunshine tariff in Cornwall, United Kingdom; the pilot project commenced in 2014 and was completed in early 2017. The objective of the tariff was to relieve congestion on the distribution network at the hours of peak solar production in the summer. To achieve this, it offered a significantly lower network price during these hours, which aimed at incentivising higher residential

³⁵ Ultimately prices are to some extent averaged, at the cost of some efficiency, but with the benefits of administrative simplicity and added fairness.

³⁶ CEER, 2017.

consumption.³⁷ We present here three real-life examples of smart tariff design.

Critical peak pricing in France – the Tempo tariff

France has been an innovator when it comes to the design of smart tariffs. In the early 1980s, Électricité de France (EdF) implemented a form of CPP with its “peak days step back” project, which applied a high tariff for the days with highest demand.³⁸ The “peak days step back” project was replaced by the Tempo tariff, which has been in place for more than two decades.³⁹

The Tempo tariff combines features of a CPP and a TOU tariff offered to low-usage consumers, such as households and small commercial consumers. The days of the year are split in three different type-colours – blue, white, and red. The colour reflects the expected balance between demand and supply; on the one end, blue days reflect a greater margin of available supply over demand, and at the other end, red days indicate a tighter balance between the two. The charge for a day varies accordingly, from the lowest for blue days to the highest for red ones. Most of the days (300 days) are of blue type, while there is also a maximum of 22 red and 43 white days. The utility determines a day’s colour a day in advance and notifies its customers accordingly (e.g., via text or e-mail). The tariff is further split into day (from 6AM to 10PM) and night periods (the remaining hours). The “day” tariff is higher than the “night” one, independent of the colour, although the difference is significantly higher for red days than for blue and white days. Figure 5 presents the charges for the different colour-days and times of the day.

In effect the Tempo tariff incentivises consumers to shift their demand away from red day peak hours and, to a lesser extent, from day-time in general. Consumers have shown significant responsiveness to the price signals – consumers in the pilot project reduced their electricity consumption by 15 percent on white days and 45 percent on red days, compared to their consumption on blue days.⁴⁰ The early implementation of the tariff also showed that customers were satisfied with it and that they managed to reduce their bills by an average of ten percent.⁴¹ Tariff-based demand response is estimated to have reached approximately 6 GW in the 1990s (the contribution of tariff-driven demand response has decreased to just under 1 GW today,⁴² as EdF is phasing out the tariff to comply with new legislation).⁴³

³⁷ For more information, see Regen, S.W. (2014). Retrieved from <https://www.regensw.co.uk/sunshine-tariff>

³⁸ Lapillonne, B. (2012). Energy savings calculations for selected end-use technologies and existing evaluation practices in France. Published in the context of the International Energy Agency’s Demand Side Management (IEA DSM) programme. Retrieved from <http://www.ieadsm.org/wp/files/Tasks/Task 21 - Standardisation of Energy Savings Calculations/harmonised ESC report/Report on Energy savings calculation final version.pdf>

³⁹ The Tempo tariff is not solely a network tariff, it contains an energy component too. The Tempo tariff also includes a fixed fee, which we do not explore in this report.

⁴⁰ For more information, see Giraud, D. (2004). The tempo tariff [PowerPoint presentation]. Retrieved from <http://www.sintef.no/globalassets/project/efflocom/edf.pdf>

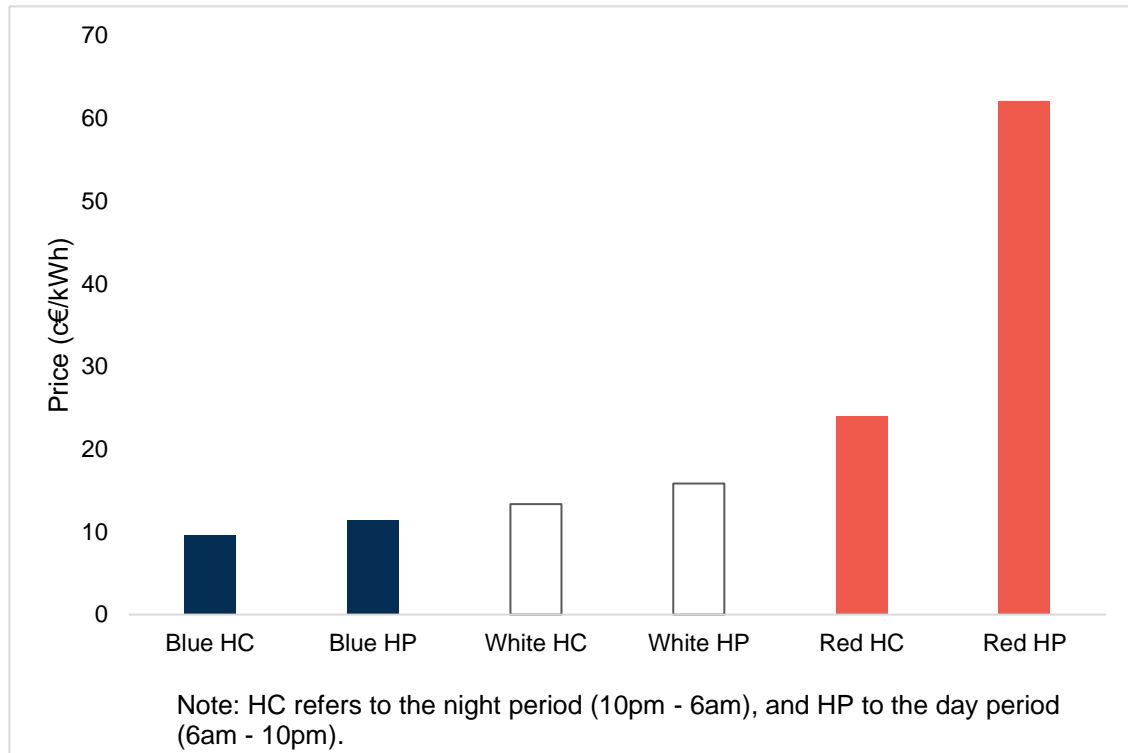
⁴¹ Giraud, 2004.

⁴² Réseau de transport d’électricité (RTE). (2016). Generation adequacy report on the electricity supply-demand balance in France. Retrieved from http://www.rte-france.com/sites/default/files/bp2016_complet_va.pdf. It is not clear from this report whether the tariff-based demand response considers other tariffs than the Tempo tariff.

⁴³ The Tempo tariff was discontinued for new consumers in 2009. The French market has taken up other ways to counterbalance the decrease in demand response through tariffs. These include supplier-driven and market-based demand response, such as bilateral contracts between suppliers and consumers, and market auctions organised by the transmission system operator.

While the Tempo tariff has been effective in delivering the traditional role for smart demand – reducing demand a few times a year – it is a simplistic instrument that is less likely to deliver the wider range of demand flexibility expected to be valuable in the future. As the power system becomes increasingly decarbonised, reducing or shifting demand on a weekly or even daily basis in response to the availability of variable energy sources is expected to deliver maximum benefit. For that to work for consumers, tariffs and technology will need to become smarter over time.

Figure 5. The Tempo Tariff in France ⁴⁴



TOU tariffs in Hawaii

An example of an incremental increase in “smartness” can be found in the U.S. state of Hawaii, where the penetration of variable renewables is reaching levels at which a smarter demand-side can provide significant value. Hawaii has embarked on an ambitious plan to source all of its electricity from renewable resources by 2045. The state has experienced significant deployment of renewable technologies in the past few years, particularly solar power and to a lesser extent wind power and biomass. Hawaii is currently the state with the highest penetration of residential solar power per household in the United States.⁴⁵ This fact, combined with the lack of interconnection with a larger regional system, makes it a laboratory for adaptation to an environment with high penetration of variable resources. The total installed capacity of photovoltaic (PV) solar has increased from negligible levels in the beginning of the decade to

⁴⁴ Électricité de France. (EdF). Electricity. Retrieved from <http://residential.edf.com/energy-at-home/offers/electricity/tarif-bleu-56121.html>

⁴⁵ For more information on the power sector in Hawaii, see Hawaii State Energy Office. (2017). Hawaii energy facts & figures. Honolulu, HI. Retrieved from https://energy.hawaii.gov/wp-content/uploads/2011/10/HSEOFactsFigures_May2017_2.pdf

680 MW in 2017,⁴⁶ and renewable energy represents approximately 26 percent of total installed capacity in the state.⁴⁷

In some rural areas of the local distribution grid, installed solar exceeds the minimum daytime load. As a result, it will become a more common occurrence that local production exceeds consumption and, as a result, power flows from the local distribution grid upstream.⁴⁸ More and more grid investments on the distribution and transmission level are caused by distributed energy resources (DER). The penetration of solar PV has created significant challenges for the operation of the network. These challenges include voltage regulation issues and the risk for overloading lines and other equipment caused by reverse flows.⁴⁹

The state regulator introduced two options in 2017, smart export and controllable customer generation, to deal with issues related to reverse flows.⁵⁰ In addition, the utilities have embarked on a plan to modify the grid to address present and future challenges, including the installation of smart inverters with solar panels,⁵¹ installation of smart communication systems, and upgrades to substations. The Hawaiian utilities identified the development of demand response, including electricity storage and electric vehicle integration, as one of the solutions to the challenges they face. Figure 6 shows part of the DER roadmap developed by the utilities.

As shown in Figure 6 (highlighted by red box), tariff design was identified as one of the ways to promote demand response in the short and longer term. The utility offers an optional TOU tariff, among others, which is presented in Figure . The tariff consists of three different charges: an off-peak charge during off-peak hours (mostly during the late evening/night), a mid-day or super off-peak charge during the hours around noon, when solar production is at its highest, and a peak charge during the afternoon and early evening hours. This rate is targeted at customers who do not have solar systems installed, and are able to concentrate their usage of grid power during the daytime hours. Enrollment in the pilot TOU tariff has exceeded original projections.

⁴⁶ Installed capacity as of the end of September 2017. For more information, see Hawaiian Electric, Quarterly installed PV data. Retrieved from <https://www.hawaiielectric.com/clean-energy-hawaii/going-solar/quarterly-installed-pv-data>

⁴⁷ In some parts of the state, such as the region covered by Hawai'i Electric Light, the penetration of renewable energy exceeds 50 percent of total installed capacity. For more information, see Hawaiian Electric. (2017). Power facts. Retrieved from https://www.hawaiielectric.com/Documents/about_us/company_facts/power_facts_2017.pdf.

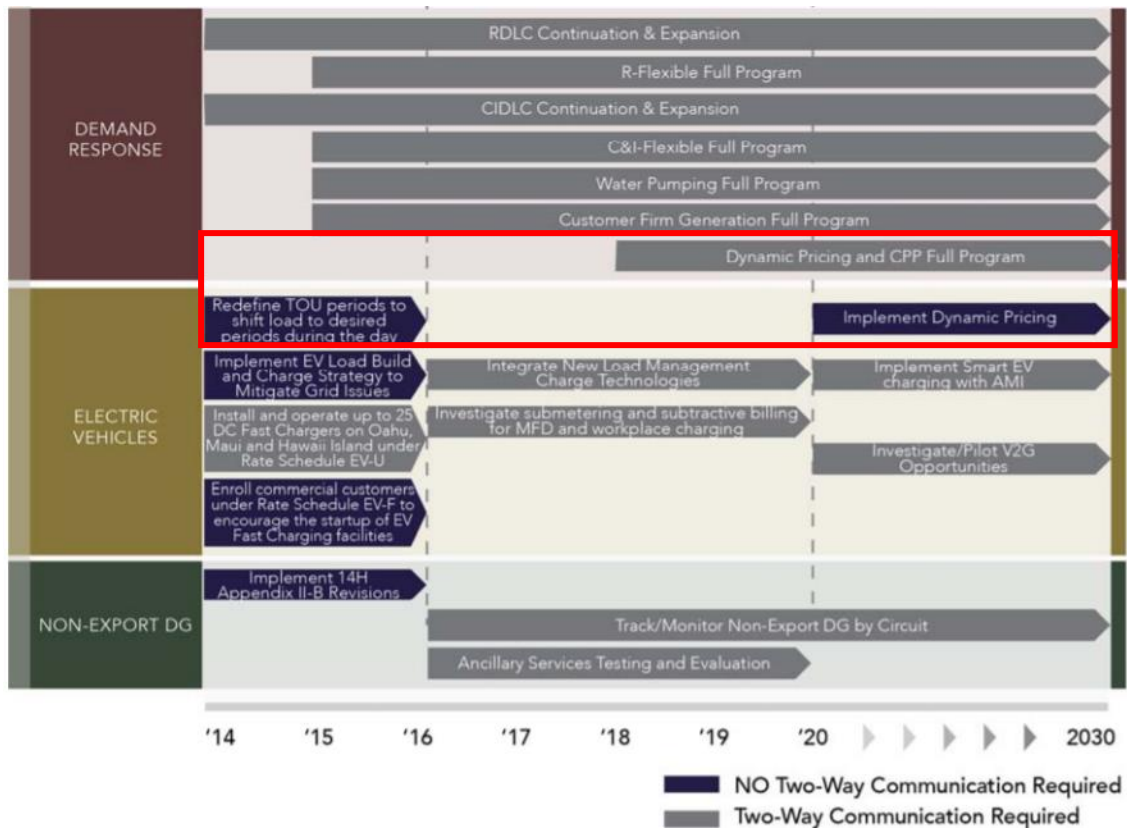
⁴⁸ In the traditional configuration of power systems, power flows from centralised power stations to the end-consumer through the transmission and, subsequently, distribution networks.

⁴⁹ Hawaiian Electric Company. (2014). Distributed Generation Interconnected Plan (DGIP). Retrieved from [http://files.hawaii.gov/puc/4_Book_1_\(transmittal_ltr_DGIP_Attachments_A-1_to_A-5\).pdf](http://files.hawaii.gov/puc/4_Book_1_(transmittal_ltr_DGIP_Attachments_A-1_to_A-5).pdf)

⁵⁰ For more information, see Hawai'i Public Utilities Commission. (2017). HPUC expands options for customers to install rooftop solar and energy storage [press release]. Retrieved from <https://puc.hawaii.gov/wp-content/uploads/2017/10/Hawaii-PUC-Rooftop-Solar-and-Storage-Press-Release-10-20-17-FINAL.pdf>

⁵¹ Smart inverters are more expensive than traditional inverters, but they can continue to operate through system disturbances - thus not triggering generators tripping off - and provide ancillary services.

Figure 6. Extract From Roadmap for the Development of DER in Hawaii⁵²

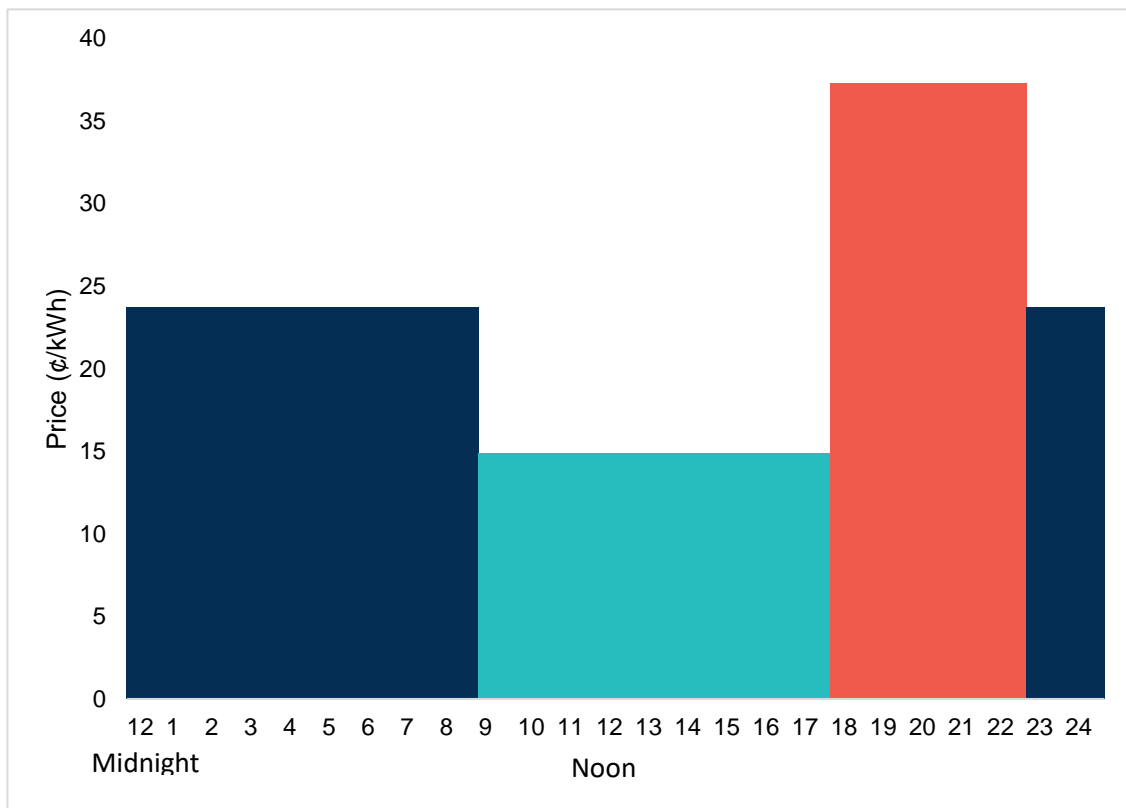


The peak-hours charge is more than twice as high as the mid-day or super off-peak one. This tariff structure incentivises consumers to shift their consumption from the traditional evening peak hours to the hours when cheap solar production on the distribution network is the highest. If such a tariff is coupled with new loads, such as electric vehicles, at the location of excess generation, it can help to relieve stress on the network and avoid or defer expensive network investments. It can also help to reduce carbon emissions by promoting the use of clean energy to power the transport needs of consumers (instead of fossil fuels such as gasoline and oil-fired power generation) and avoiding the curtailment of renewable energy. Smart tariff design can ensure that any additional costs associated with the adoption of these new, large, controllable end-uses are borne by those who fail to adapt their usage to reflect conditions of supply and demand, rather than by consumers who respond to market conditions or who have not or cannot adopt these technologies. For the longer-term, Hawaii has plans to implement more dynamic pricing for all tariff classes, and to recognise the reality of low-cost, mid-day power in all rates.⁵³

⁵² Hawaiian Electric Company, 2014.

⁵³ Hawaii is also completing a two-year pilot programme of dispatchable water heating load (new water heaters and control systems installed in a pilot apartment complex). The control system allows the utility to concentrate water heating during low-cost hours, using the storage tanks to carry customers through higher cost hours. The system allows control in four-second intervals, making it also possible to use the water heaters as a controllable load for ancillary services, such as local voltage support, system frequency regulation, and spinning reserve.

Figure 7. TOU Tariffs in Hawaii



Note: As of October 2016

TOU network tariff for controllable heating loads in Germany

The German government introduced a law in 2005 enabling DSOs of the right to adjust the consumers' demand from their controllable loads when the network is stressed.⁵⁴ The law targets mainly heat pumps and heating storage systems, but it is also open to electric vehicle participation.⁵⁵

Consumers get a significant discount for charging their controllable loads during off-peak hours when the system is not stressed. For example, the Westnetz DSO offers a 70-percent discount for the use of the network during predetermined, off-peak hours (1.5 c€/kWh) compared to peak hours (5 c€/kWh).⁵⁶ According to anecdotal evidence, the scheme has helped to electrify heating and improve grid utilisation. The key challenge is how to use such tariff instruments in a highly intermittent system in the longer-term.

⁵⁴ Bundesministerium für Justiz und Verbraucherschutz [German Federal Ministry of Justice and Consumer Protection]. (2005). Gesetz über die Elektrizitäts- und Gasversorgung (EnWG) [Energy Industry Act]. Para. 14a (in German). Retrieved from https://www.gesetze-im-internet.de/enwg_2005/_14a.html

⁵⁵ A law similar in spirit was first implemented in the 1970s and 1980s in Germany to fill in the electricity demand troughs during the night by electrifying heating. The objective was to increase the utilisation rate of networks and supply resources.

⁵⁶ Westnetz. Information retrieved from: <https://iam.westnetz.de/ueber-westnetz/unser-netz/netzentgelte-strom>, accessed on 13/12/2017.

Tariff structure for different consumer classes

Below we give an overview of tariff design options for different customer classes based on the principles discussed in the previous sections and present realities.⁵⁷

- **Residential consumers.** For residential consumers the tariff design should be based on a volumetric charge only. This will provide incentives to residential consumers to consume power efficiently. Residential consumers should also be provided with the option to choose a TOU tariff. As smart and automated controls, and metering and billing become more widespread, the roll-out of such tariffs can be expanded further.⁵⁸
- **New controllable loads, such as electric vehicles and heat pumps.** For these kinds of loads with significant potential to flex consumption, we recommend that volumetric TOU tariffs are used as the default option, preferably with locational signals. This will help to ensure that these new technologies make best use of existing networks and hence minimise the need for new investment in grids. CPP could also be a suitable option, especially where smart technology is available.
- **Small industrial and commercial consumers.** For small industrial (and commercial) consumers, we recommend that a volumetric TOU tariff is the default option, as these types of consumers tend to have better control of their electricity consumption and a greater interest in managing their bills. As shown earlier, if smart technology is available, CPP could be an appealing option too.

6. Conclusions

Network costs constitute a significant share of the bill for residential and small industrial consumers. They are normally split into fixed and volumetric components. Several Member States have shifted from volumetric charges to fixed ones in recent years. Currently, the fixed charge forms a considerable amount of the overall network charges, especially for small industrial consumers. These practices raise concerns about the alignment of tariff design with the vision of the European Union for a consumer-centred power system.

Consumers respond to price signals. Fixed charges take the power of choice out of consumers' hands and disincentivise the adoption of elements for a consumer-centred, clean energy transition (such as energy efficiency, demand response, and distributed generation). They lead to higher costs for all by promoting underutilisation of existing infrastructure and excessive investment in new infrastructure. Fixed charges are inefficient, do not promote equity across users of the grid infrastructure, and are contrary to economic theory and practice.

The design of network tariffs should empower consumers to make good decisions while ensuring that everyone pays their fair share. Smart tariffs that recognise how much, when, and where consumers use the grid can help to maximise the utilisation of existing infrastructure and

⁵⁷ As discussed earlier, the best type of tariff depends on the conditions in a system, such as the rollout of smart technology. In addition, the rollout of the type of tariffs recommended in this section will require educating consumers accordingly to raise awareness about how the tariffs work and how to take advantage of them.

⁵⁸ It is possible that residential consumers might not want to adopt a smart tariff, such as a TOU rate, hence they should have the option to choose a flat volumetric tariff.

limit the need for new investment, thus helping to minimise bills for everyone. They can also help to achieve equality and fairness in the distribution of the costs across consumers, while ensuring that network companies recover their allowed revenues.

Our central conclusion is that network prices should be volumetric in nature – that is, incurred when the grid is used and avoided when it is not – to best meet the longstanding objectives of good tariff design. The complexity of the tariffs, that is, their differentiation by time- and location-related cost drivers, can increase with the magnitude and flexibility of consumption. As the availability of automated, flexible, and smart end-uses expands, and as consumers become increasingly familiar with more sophisticated approaches to pricing, the “smartness” of tariffs can further increase with the adoption, for example, of TOU, CPP, and other pricing designs that will maximise customers’ ability to derive value from, and provide value to, the grid.



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