

REGULATORY ASSISTANCE PROJECT

The time is now: smart charging of electric vehicles

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Executive summary

Electric vehicles (EVs) are key to the transition to zero-emission mobility and energy in the coming decade. As automakers phase out internal combustion engine vehicles and consumer demand for electric cars rises, the majority of new car purchases in all major European markets will be electric within a matter of years. Used EVs are also becoming a viable option for many more Europeans.

EV market shares are growing rapidly, and so is a broad spectrum of technologies allowing smart charging. That means charging at times when costs for the user, the grid and climate change mitigation are lowest – with automated actions making it hassle-free for users. Smart charging allows users to save money, contributes to an efficient and resilient energy network, increases the use of renewable energy and enables earlier fossil fuel power plant exits, thus lowering emissions. What Europe needs now are services and regulatory measures that make the most of this valuable resource to help its transport and energy sectors meet their climate targets. In the context of the current energy crisis in particular, a more broadly established market for smart charging tariffs and services will help to reduce the need for fossil fuels in both the transport and the electricity system.

This report¹ provides a unique, comprehensive overview of 139 residential smart charging tariffs and services already available in Europe, and makes recommendations to ensure the benefits of smart charging extend to all EV users at all locations. Making smart charging the default drives down costs for all electricity system users, not just the EV drivers directly benefiting from smart charging. By contrast, the costs of unmanaged charging would be carried by all.

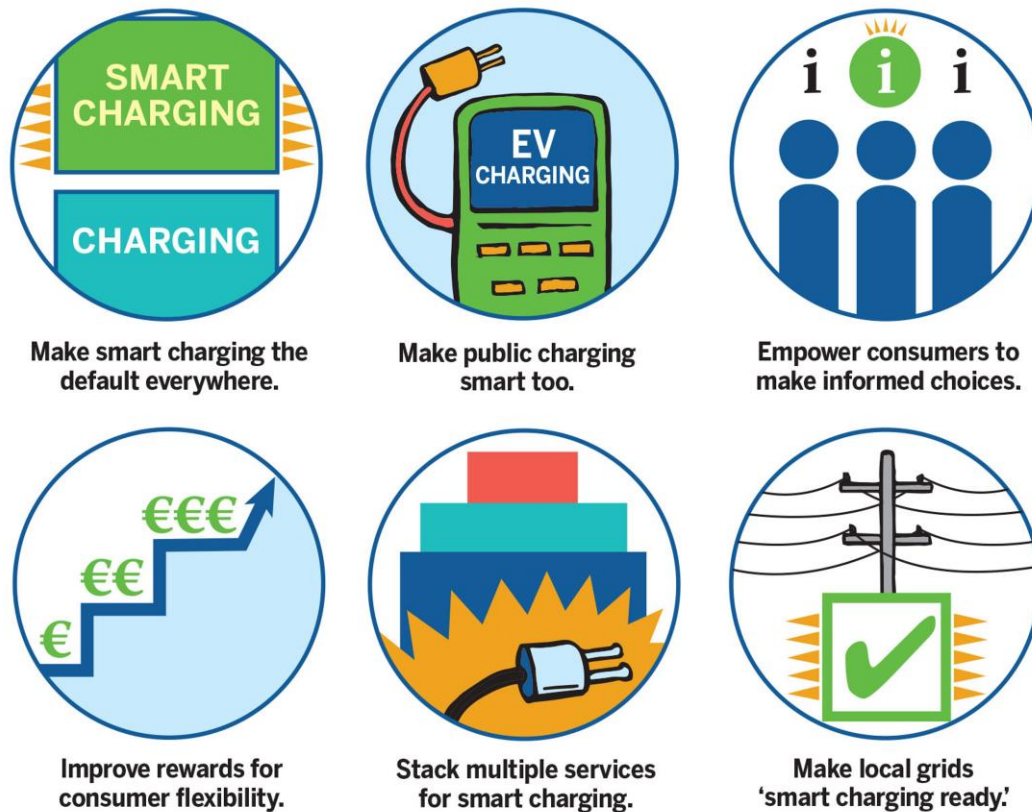
Starting now, policymakers need to lay the groundwork for a solid regulatory framework that facilitates a market for smart charging services and optimally prepares transport systems and the grid for mass vehicle electrification. By designing policy measures in a consistent manner across Europe, legislators can help ensure that the European EV services market can prosper and capture the benefits smart charging offers.

To ensure that all Europeans can charge smartly wherever they are on the continent, we recommend, as shown in Figure 1 on the next page, that policymakers:

- Make smart charging the default everywhere.
- Make public charging smart too.
- Empower consumers to make informed choices.
- Improve rewards for consumer flexibility.
- Stack multiple services for smart charging to increase individual and system benefits.
- Make local grids ‘smart charging ready.’

¹ The authors would like to acknowledge and express their appreciation to the following people who provided helpful insights in to drafts of this paper: Marie Rajon Bernard, The International Council on Clean Transportation (ICCT); Jaume Loffredo, BEUC The European Consumer Organisation; Marion Malafosse, smartEn Smart Energy Europe; Arjan Wargers, ElaadNL; Thomas Willson, European Climate Foundation; and Mark LeBel, David Farnsworth, Rick Weston, Louise Sunderland and Sophie Yule-Bennett from RAP. Deborah Bynum provided editorial assistance.

Figure 1. Recommendations for accelerating smart charging



Introduction

The electrification of passenger transport is now fully underway, and electric vehicles (EVs) are replacing petrol and diesel cars at unprecedented rates. In 2021, 10.3% of all cars sold across Europe were fully electric (with a further 8.9% rechargeable hybrids), up from 6.2% (and 5.2%) in 2020.²

EVs offer a powerful opportunity for the transition to a fossil-free energy system because they consume less energy, can charge on renewable energy, and can support the power grid. An electric car is three to four times more energy-efficient than a car with an internal combustion engine running on fossil fuels.³ What's more, energy that is not used in the first place does not need to be decarbonised — making the transition to a renewable energy system easier and faster. The electricity used in EVs can come from a variety of renewable energy sources, such as wind and solar power.

In the transition “from a world where we forecasted demand and scheduled supply to a world where we will forecast supply and schedule demand,”⁴ EVs provide a model

² European Automobile Manufacturers' Association numbers for the European Union, UK, and European Free Trade Association countries. ACEA. (2022). *Fuel types of new cars*. [Press release]. <https://www.acea.auto/fuel-pc/fuel-types-of-new-cars-battery-electric-9-1-hybrid-19-6-and-petrol-40-0-market-share-full-year-2021>

³ U.S. Department of Energy. (n.d.). *Where the energy goes: electric vehicles / gasoline vehicles*. <https://www.fueleconomy.gov/feg/atv-ev.shtml>

⁴ Trabish, H. (2022, 31 January). Breakthroughs in generation and system integration are driving the utility of the future, analysts say. *Utility Dive*. <https://www.utilitydive.com/news/breakthroughs-in-generation-and-system-integration-are-driving-the-utility/616579>

example of schedulable demand: Cars are parked for long periods of time during the day and night, and are used for trips that are often predictable. If charged smartly, EVs can help integrate renewable energy sources into the grid more effectively, thus reducing the number of times wind and solar are curtailed, meaning their generation is reduced. This also prevents firing up additional fossil fuel power plants. EVs can be a highly valuable flexible resource: smart charging means adjusting the power flow to (and from) EVs when it is most beneficial for consumers, the power system and climate change mitigation. In practice, users charge when carbon emissions from electricity are low, during times when there is less stress on the power system, and when electricity is cheaper.

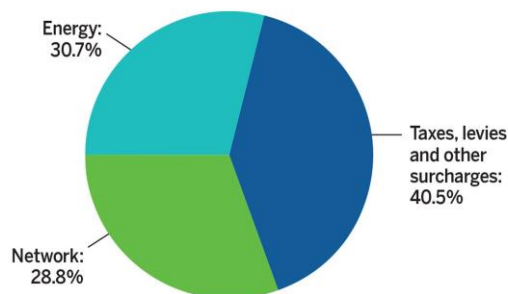
But this will not happen automatically; the right incentives must be put in place.

Smart EV tariffs and services are a key policy tool to incentivise consumers to engage in smart charging. Put simply, smart tariffs can be retail electricity prices — for energy or for use of the power network, as listed on the user’s electricity bill — that vary depending on the time of day to provide an economic incentive to consumers for adapting their charging routines. If consumers charge during hours with lower electricity prices, they can benefit from the cost savings of these ‘time-of-use’ tariffs.

Elements of retail electricity prices

Retail electricity prices consist of three main components for all types of consumers: the energy component, the network component, and the taxes and levies. The first component relates to the cost of electricity production and the second to the delivery of this electricity to the final consumer. Taxes and levies are effectively the costs for specific policies and fiscal instruments. In this paper, we discuss the energy and network components, while the taxes and levies are outside of its scope. For the majority of European consumers, the network tariff is included in the energy bill they receive from their electricity supplier. On average, network costs make up 28.8% of a household’s electricity bill and the energy supply 30.7%, although there is significant variance across Member States. Figure 2 shows the weighted average breakdown in 2020.⁵ The more pricing elements that are flexible, the stronger the price signal to consumers to shift and adjust their consumption.

Figure 2. Breakdown of energy bill for typical European household in 2020



Source: Agency for the Cooperation of Energy Regulators and Council of European Energy Regulators. (2021). *Annual report on the results of monitoring the internal electricity and natural gas markets in 2020*.

Other smart tariffs and services offer cash bonuses or a discounted flat charging rate instead of time-dependent prices, in exchange for permission to manage the EV charging process smartly and in accordance with the user’s preferences. The power

⁵ Agency for the Cooperation of Energy Regulators (ACER) and the Council of European Energy Regulators (CEER). (2021b). *Annual report on the results of monitoring the internal electricity and natural gas markets in 2020: energy retail markets and consumer protection volume*, p. 81. <https://www.acer.europa.eu/electricity/market-monitoring-report#135>

system also benefits from these arrangements because the charging puts less strain on the grid and requires less power generation capacity. In recent years, many energy companies have started to offer smart EV tariffs; new smart charging service operators have emerged, and a significant share of customers are taking advantage of them.

Fortunately, smart EV charging is simple – as participating consumers can attest. This paper provides an overview of smart EV charging programmes and practices across Europe. We highlight the most successful offers, products and tariffs currently on the market, and explore the benefits to consumers and the energy system overall that would result if smart charging tariffs and services were made the default for all users, whether at home or at a public station. The paper concludes with recommendations at European and Member State levels to accelerate the transition at the lowest possible cost, providing input into the legislative framework underpinning private and public EV charging.

In the next section of this report, we set out the case for smart charging in more detail, and explain why it is beneficial to consumers and essential for the power system. An introduction to different types of smart charging tariffs and services follows in [Chapter 2: What are smart charging tariffs?](#), illustrated with real-world examples. Then we present a unique, comprehensive overview in [Chapter 3: Smart charging tariffs and services in Europe](#), before we close with policy recommendations in [Chapter 4: How can smart charging be accelerated?](#) and [Conclusions](#).

Chapter 1: The case for smart charging

When the charging of EVs is optimised to lower costs, to accommodate the integration of renewable energy sources and to minimise the impact on the power grid, it's known as smart charging. Smart charging can deliver significant cost savings to consumers by using time-varying tariffs which offer lower electricity prices at certain times of day, or by rewarding flexibility through bonus payments. Managing charging in this way can help increase the immediate use of rooftop solar generation, for example, and respond to other household demands to ensure fuses do not blow. In addition, some EVs can store this solar energy for later use in the home and grid and can provide backup power during outages. Technology and automation make smart charging user-friendly, and can provide additional benefits such as ensuring the car and its battery are at the right temperature at the set departure time, improving comfort and range.

Smart charging is a tool to make the use of existing resources more efficient: power generation assets, grid infrastructure and the batteries in EVs. EVs use electricity which is stored in their batteries, and there is potential to optimise the way in which these are charged. Signals from the grid or building to steer charging can cover a range of grid levels and time horizons, e.g., to prevent temporal congestion in a distribution or transmission system, to coincide with an increase in forecasted renewable energy supplies, or to relieve pressure on a substation in the neighbourhood when capacity limits are approaching.⁶ With increasing shares of renewable energy being produced

⁶ We intentionally use a very broad definition of grid inputs here to cover a wide temporal and locational scope, as well as a multitude of system operators. A more detailed overview of these inputs is presented in Hildemeier, J., Kolokathis, C., Rosenow, J., Hogan, M., Wiese, C., & Jahn, A. (2019). *Start with smart: Promising practices for integrating electric vehicles into the grid*. Regulatory Assistance Project. <https://www.raponline.org/knowledge-center/start-with-smart-promising-practices-integrating-electric-vehicles-grid>

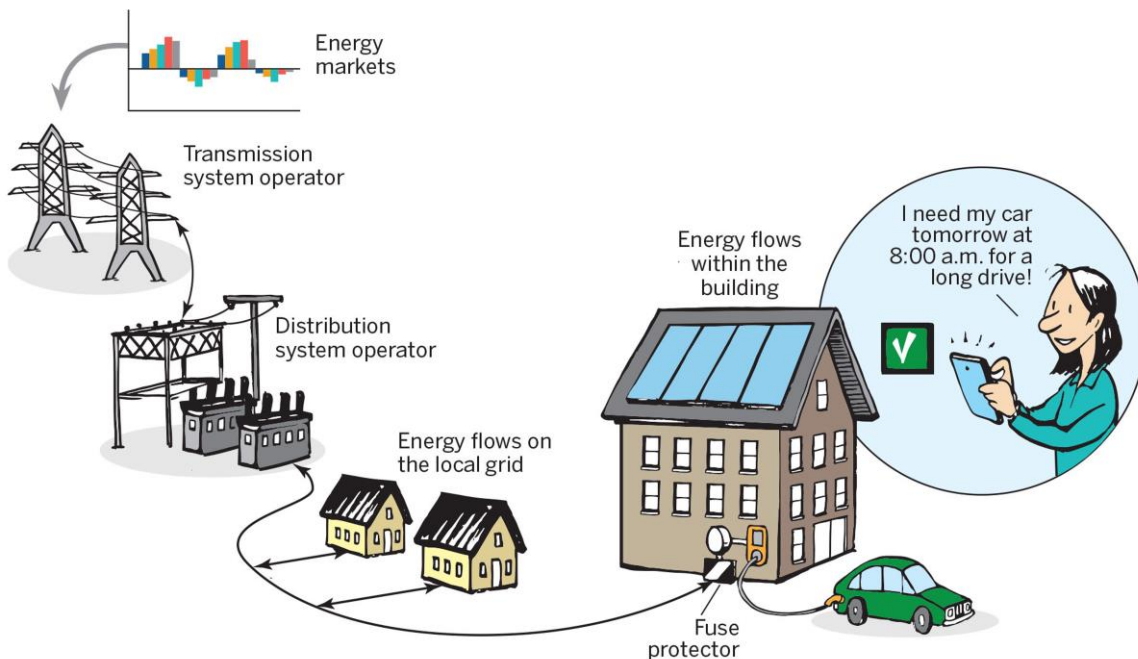
from various distributed locations, these grid inputs can help shift the charging of EVs to absorb local surpluses, as well as to prevent increases in the existing peak demand on the grid.

When the charging of EVs is optimised to lower costs, to accommodate the integration of renewable energy sources and to minimise the impact on the power grid, it's known as 'smart charging.'

But smart charging is more than just an asset for the power system. Smart charging services also benefit EV owners by rewarding them with financial savings for adapting their charging behaviour, without compromising on their transportation needs. These savings can come from lower-priced electricity or network usage, for instance, or as a bonus for participating in a flexibility scheme.⁷ Smart tariffs and services can achieve user and system benefits simultaneously, for instance by shifting demand away from an existing evening peak to lower-priced hours in the night, thereby reducing the grid's peak load.

These aspects of smart charging are illustrated in Figure 3.

Figure 3. The elements of smart charging



⁷ For a review of the principal elements of smart charging tariffs and an overview of initial smart charging tariffs in Europe, see Hildermeier et al., 2019. This report gives an updated overview of available offerings and recent market developments.

Benefits for EV drivers

As is shown in Figure 4, smart charging offers tangible benefits for EV drivers, with financial savings being a main incentive. Comfort and ease of use are additional advantages, plus a user's EV can even power their home. And although the primary focus of this report is on consumers using electric passenger cars, emerging new offerings and use cases such as mobility-as-a-service, electrified taxi fleets, company car fleet operators, carsharing providers and others with distributed fleets can benefit as much as individual car owners from improved access to smart tariffs and services.

We explore the benefits related to cost savings and reliable electricity supply in more detail below.

Comfort, ease of use

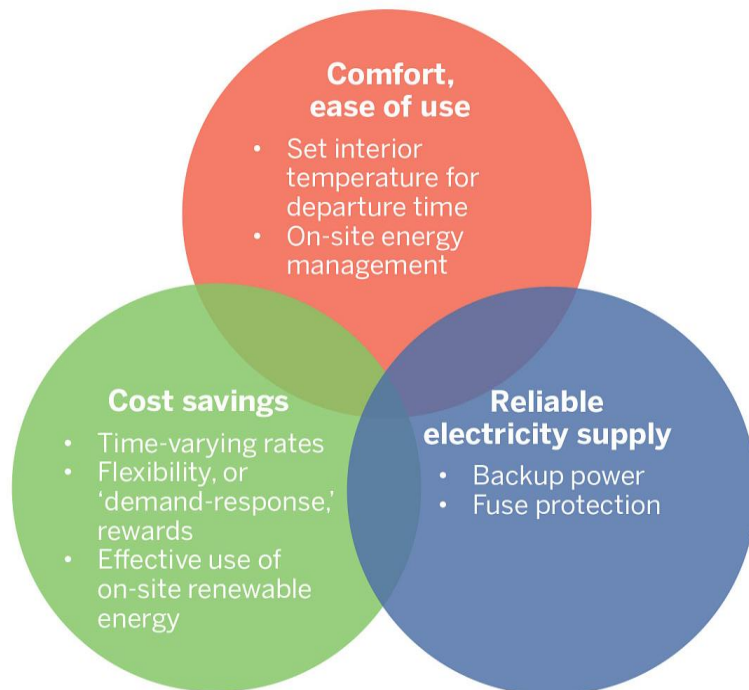
Much of smart charging can be automated to ease the complexity of the process: Setting the desired departure time is often sufficient input from the driver. The system automatically adjusts to changing signals such as energy prices and the battery charge level of the car. The EV driver reaps the cost savings (explained in more detail in the next section) without needing further day-to-day interaction with the charging equipment or app. They do not need to worry about setting the proper charging speed to avoid overloading the fuses or about plugging in the vehicle in the middle of the night to benefit from the savings from cheaper rates.

The technology also makes it easy to manage on-site energy without compromising charging needs. This could mean pausing the charging session when another household appliance has a more urgent need, directly using rooftop solar energy or sharing available capacity amongst multiple vehicles in an apartment building's shared parking area. Using a smart charging system that can communicate with the vehicle comes with the additional benefit of using the pre-heating or pre-cooling function of the car, so that the interior temperature is comfortable by the pre-set departure time.

Cost savings for EV users

Smart charging can deliver sizable cost savings to consumers when it's coupled with tariffs that offer lower electricity prices at certain times of the day. For example,

Figure 4. Benefits of smart charging for EV drivers



experience from Ireland shows that overnight charging can cut costs by 80% compared to daytime charging (see also [Static time-of-use pricing](#)). Similarly, French EV drivers can save an average of 150 euros per year by charging at off-peak times.⁸ Having access to time-varying electricity prices is a key factor in reducing the charging costs of an electric car. Even during periods of high energy prices, there is still considerable price variability on wholesale markets at different times of the day, week and year – and time-varying consumer electricity prices reflect this (see [Types of time-varying charging tariffs](#)).

An additional way to help EV users save money is offered in some markets, where network tariffs are designed to avoid seasonal peak hours while supporting the grid by avoiding increases to peak electricity load. The Danish distribution system operator (DSO) Radiusnet offers an example of a network tariff that works in this way (see text box on [Denmark](#)).

Smart charging can deliver sizable cost savings to consumers when it's coupled with tariffs that lower electricity prices at certain times of the day.

An increasing number of EV smart charging offerings are combining savings on time-varying electricity and network prices with additional flexibility rewards from demand-response programmes⁹ that help to balance energy markets and grids. An example of such integration is OVO Drive in the UK (see text box on the [United Kingdom](#)), which allows drivers to benefit from yearly savings of 225 pounds using a managed smart charging offering. As we'll show in this report, combining the savings from different sources increases the benefits for drivers and grids.

One possible way of saving on charging costs is to directly use on-site renewable energy.

Effective use of on-site renewable energy

It is often more beneficial for consumers to use the electricity from on-site solar panels directly, rather than exporting it to the grid. If smart charging is combined with rooftop solar, users can make optimal use of their own power generation, further reducing their energy bills. With the right technology, charging an electric car with up to 99% rooftop solar energy is possible within the usage patterns of typical drivers.¹⁰

Some charging systems like myenergi Zappi (see text box below) include a solar self-consumption priority option as a core functionality. Other home chargers offer similar functionality when linked to a home energy management system or a solar inverter. Some manufacturers of solar inverters have even extended their business to home charging, while a couple of the digital smart charging services (see text box on

⁸ RTE. (2019). *Enjeux du développement de l'électromobilité pour le système électrique* [Challenges to the development of electromobility for the electricity system]. Réseau de Transport d'Électricité. <https://www.rte-france.com/actualites/developpement-du-vehicule-electrique-et-systeme-electrique-une-faisabilite-sereine-et>

⁹ Demand response refers to consumers shifting the timing of their electricity consumption (from the grid) in response to signals, such as lower prices or market incentives.

¹⁰ Martin, H., Buffat, R., Bucher, D., Hamper, J., & Raubal, M. (2022). Using rooftop photovoltaic generation to cover individual electric vehicle demand — A detailed case study. *Renewable and Sustainable Energy Reviews*, 157, 111969. <https://www.sciencedirect.com/science/article/pii/S1364032121012326>

market-based DSO flexibility procurement in the United Kingdom) are integrating solar forecasting into their services.

Increasing solar self-consumption through smart charging

Increasing self-consumption of rooftop solar by using the power to charge an EV reduces the costs for using the grid, both for feeding in solar electricity and for drawing electricity from the grid. User benefits can include:

- Higher solar returns – if solar production would otherwise need to be capped, e.g., because of feed-in restrictions, in the respective region.
- Lower EV charging costs.
- Higher charging capacity – if the grid capacity is constrained.
- A trusted and sustainable energy source for charging their electric car.

The Zappi home charger from myenergi comes with equipment that measures the power flows on the grid connection in real time, allowing users to charge a vehicle in a solar-surplus mode, reducing net imports and exports. Other options include the booster mode, which allows users to charge at a higher capacity.

When connected to myenergi's online platform, the Zappi also works with time-varying tariffs, including the UK's Agile Octopus dynamic time-of-use electricity pricing.¹¹

In a recent demonstration project, the charger proved able to respond to changes in the grid's frequency (normally stable at 50 hertz) based on a remotely set profile, paving the way for future services to contribute to power system stability.¹²

Reliable electricity supply

Just like a home battery, an EV can, in principle, provide power to homes, e.g., from solar energy stored for later use, or to ensure electricity is available during outages. This offers users various advantages: it allows them to benefit from preferential prices for their own solar energy as described above, it provides them with a transparent and renewable source of power, and it increases their self-sufficiency and resilience. The size of the battery in an EV is larger than most home batteries currently on the market and, if it's fully charged, it can provide enough electricity for several days while still meeting daily mobility demands.

Using the electricity in the EV battery for uses other than driving requires bidirectional charging technology (see text box below). Until recently, this was not widely supported in cars or charge points. For a long time, only the CHAdeMO DC charging technology utilised by Japanese car makers supported bidirectional charging, although most pilots in the last decade have worked with the technology. From 2022 onwards, an increasing number of car models will support bidirectional charging using the ISO 15118-20 standard and the European standard plug; these include all Volkswagen EVs with a

¹¹ Chapter 2 explains in detail existing types of time-varying rates, including an explanation of dynamic energy prices.

¹² Evergreen Smart Power. (2021). *FRED flexibly-responsive energy delivery smart charging trial findings*. <https://evergreensmartpower.co.uk/domestic-dsr-fred-trial>

larger battery type.¹³ The benefit most often marketed to consumers is that it improves the self-consumption of solar energy in the home: for example, the electricity is stored during the daytime and released in the evening to power the house. In the United States, the Ford F-150 electric pick-up truck's ability to power homes during outages is a key marketing feature.¹⁴ Most residential bidirectional charging applications have so far been released on a trial basis, delivering insights about the user-service interaction and the type of services bidirectional charging vehicles can provide. However, given recent advances in vehicle and charger technology, and assuming the right regulatory framework can be put in place, the time has come to move beyond pilot and trial stages.

Bidirectional charging

Bidirectional charging encompasses a number of potential energy services for a building or for the grid. 'Vehicle-to-home' (V2H) is the common term for bidirectional charging which benefits a house's energy balance. Use cases include storing excess solar energy to be used later at night, or to provide backup power during outages, much like any other battery storage application. EV batteries can also provide services to the grid such as storing energy when prices are low and discharging it when prices are higher, or balancing the grid by adjusting electricity usage upward or downward. These use cases are called 'vehicle-to-grid' (V2G).

The added financial benefits of these V2G services for users are currently limited by the higher hardware costs of the charger, and future system-side revenues might be lower than today once more flexibility from all types of smart charging is widely available.¹⁵ The V2H benefits alone, however, can be substantial enough to make it worthwhile for users to choose the technology, in which case the V2G services are simply an added bonus.

Being able to reduce energy consumption when prices are high and increase it when prices are low can make time-varying electricity prices, time-varying network tariffs and the design of grid flexibility products even more important for bidirectional charging. Bidirectional charging technology can work in sync with the grid's frequency of 50 hertz and help to stabilise it, or it can work on its own in 'island' mode. However, the electronics in the car or charger and the national grid codes might limit the bidirectional power flow to just one of these modes: this should ideally be addressed on a European level to widen the market, in terms of services as well as geography. Interoperability of services and technology should ensure that V2H use cases can be easily extended with V2G services. To achieve this, countries should remove barriers, such as double taxation of energy stored and later fed back into the grid, and allow small-scale energy consumers to participate in flexibility markets at the national and local grid levels.

Effective smart charging policies and tariffs should also be suitable for advancing bidirectional charging, which consists of smart charging and discharging. This is why we do not differentiate further between 'unidirectional' and 'bidirectional' smart charging in this report.

¹³ Volkswagen. (2021). *Convenient, networked and sustainable: new solutions for charging electric Volkswagen models*. <https://www.volkswagen-newsroom.com/en/press-releases/convenient-networked-and-sustainable-new-solutions-for-charging-electric-volkswagen-models-7695>

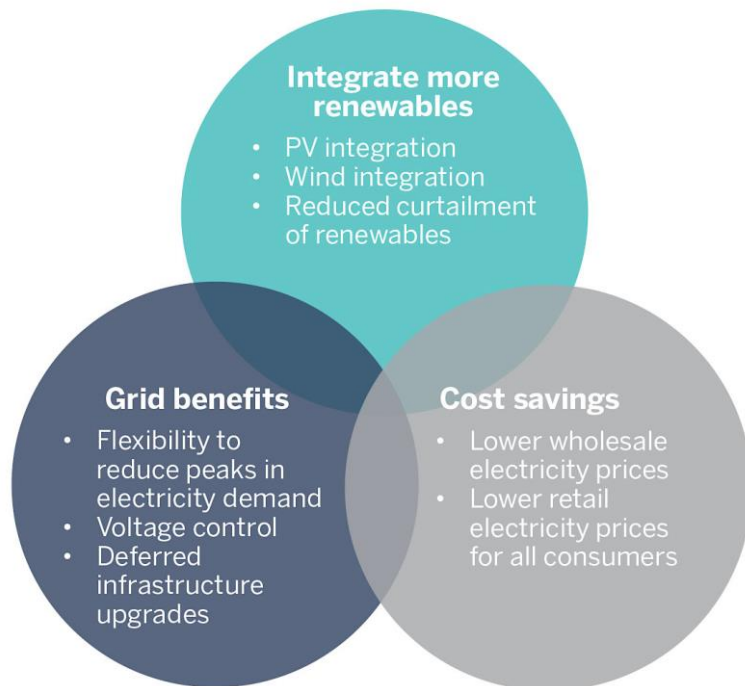
¹⁴ Ford. (2022). *Ford intelligent backup power*. <https://www.ford.com/trucks/f150/f150-lightning/2022/features/intelligent-backup-power>

¹⁵ Element Energy. (2019). *V2GB vehicle to grid Britain project report*. <http://www.element-energy.co.uk/2019/06/element-leads-world-class-transport-and-energy-stakeholders-on-v2g-feasibility-study>

Benefits for the power system

Charging EVs smartly not only brings benefits for users, but it also offers a whole suite of power system benefits. These fall broadly into three categories, as shown in Figure 5 — grid benefits, electricity cost savings and renewable energy integration. These elements combine to save power system costs by reducing the need for grid reinforcement and through backup power generation, which also contributes to energy sector greenhouse gas emissions savings.

Figure 5. Benefits of smart charging for power system



We explain each of the three categories of benefits below. A more detailed look at the system benefits of flexibility in electricity demand is presented in our *Joy of Flex* report.¹⁶ It is important to stress that by improving system efficiency, EV smart charging reduces costs not only for EV users, but for all users of the system. In other words, EV smart charging should be of interest to everyone, whether or not they own an EV. In [Annex 1: Smart charging benefits within the local community](#), we discuss use cases where EVs provide benefits for the user and the system within local communities.

**By improving power system efficiency,
EV smart charging reduces costs not only for
EV users, but for all users of the system.**

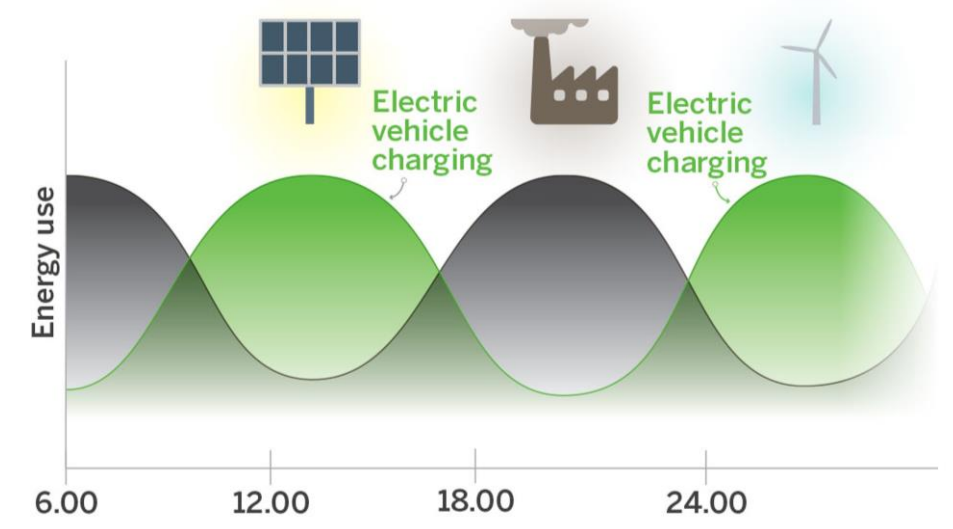
Integrate renewables

The output from renewable energy generation from sources such as solar and wind varies over the course of a day and between days. Often when there is more renewable energy on the grid than normal, wholesale market prices can be quite low. Shifting EV charging to such periods, as shown in Figure 6 below, can mitigate uneconomic curtailment (or ‘output reduction’) of renewable energy. In turn, shifting charging to

¹⁶ Yule-Bennett, S., & Sunderland, L. (2022). *The joy of flex: Embracing household demand-side flexibility as a power system resource for Europe*. Regulatory Assistance Project. <https://www.raponline.org/knowledge-center/joy-flex-embracing-household-demand-side-flexibility-power-system-resource-europe>

periods of high renewable energy generation allows more renewable electricity to be used than would otherwise be the case.

Figure 6. Smart EV charging integrates more renewable energy



With the further build-out of renewable energy across Europe, being responsive on the demand side becomes increasingly important. As we show in [Chapter 3: Smart charging tariffs and services in Europe](#), EV smart charging is already helping to displace fossil fuels as consumers shift demand to periods with a higher share of renewables in the electricity mix.

Grid benefits

A key challenge for power network operators at both the transmission level (high-voltage lines connecting generators, regions and countries) and the distribution level (local-level networks including substations and the low-voltage grids extending to end users) is to manage peaks in demand and supply. This is true both in the long term for operational planning purposes and in the short term to keep the grid's voltage and frequency within narrow limits.

EVs are at times depicted as a threat, as their introduction – and the consequent influx of new demand for electricity – was not foreseen when most of today's power grids were planned and built. Unmanaged charging of EVs would result in increased peaks of electricity demand, especially in the evenings when people charge their cars after returning from work, and this could cause 'congestion': the grid can only deliver a certain amount of electricity without exceeding the thermal, voltage and stability limits put in place to ensure its reliability. With EV adoption on the rise, such problems could occur increasingly frequently on the distribution grid if unmanaged charging became the default.

A 2019 study shows that smart charging could reduce the necessary investment in distribution grids by at least 50% by 2030.

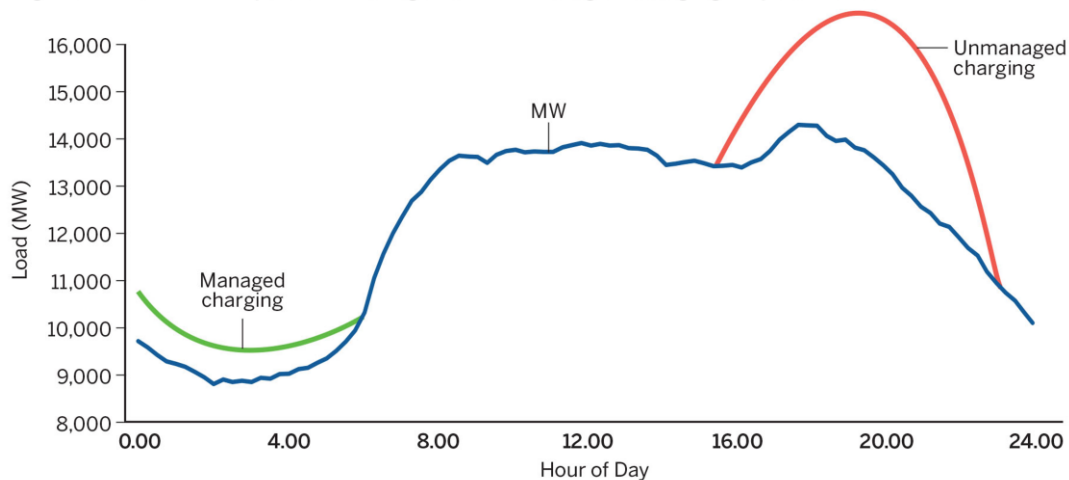
One option to address this challenge would be simply to upgrade the existing power network as needed. But much like road traffic, an increase in electricity demand

requires more than just a simple expansion of the physical infrastructure – which would also tie up grid operator resources that could be used more effectively elsewhere.

This is where smart charging can provide direct and sizable grid benefits. Many EV smart charging pilots have demonstrated that increased peak demand from EV charging can be effectively managed.¹⁷ Previous work shows that smart charging could reduce the necessary investment in distribution grids by at least 50% by 2030.¹⁸ A recent large-scale investigation on dynamic time-of-use electricity tariffs shows that households (especially those with EVs) are able to significantly reduce their demand during the evening peak.¹⁹ While this might not completely remove the need for grid reinforcements, the ability to postpone them in some areas can help operators to build out the existing network more efficiently.

Figure 7 shows the impact smart charging would have on peak demand. The blue line depicts the load curve in a large distribution area in Germany on a peak day;²⁰ it shows a clear morning and evening peak. This evening peak would increase if all EV users plugged in their EV when coming home (illustrative red line) – and evidence from Europe’s most mature EV market, Norway,²¹ shows that this is what happens if we do not provide consumers with incentives to shift their charging while still offering the same level of service. Instead, we want to shift charging to hours when it is better for the grid, for example midday (in summer) or night hours, when electricity is cheaper and, most likely, cleaner (illustrative green line).

Figure 7. Illustrative impacts of managed and unmanaged charging on peak demand



Based on data from Westnetz. (2017). Peak day.

¹⁷ Hildermeier, J., & Shipley, J. (2020). *EV tariff design can optimize grid resources and save drivers money — selected examples and lessons learned from the U.S. and Europe* [Conference paper]. 33rd World Electric Vehicle Symposium and Exposition, Portland, Oregon, United States. <https://www.raonline.org/knowledge-center/ev-tariff-design-optimize-grid-resources-save-drivers-money>

¹⁸ Agora Verkehrswende, Agora Energiewende, Regulatory Assistance Project. (2019). *Distribution grid planning for a successful energy transition – focus on electromobility*. <https://www.raonline.org/knowledge-center/distribution-planning-for-successful-energy-transition-electromobility>

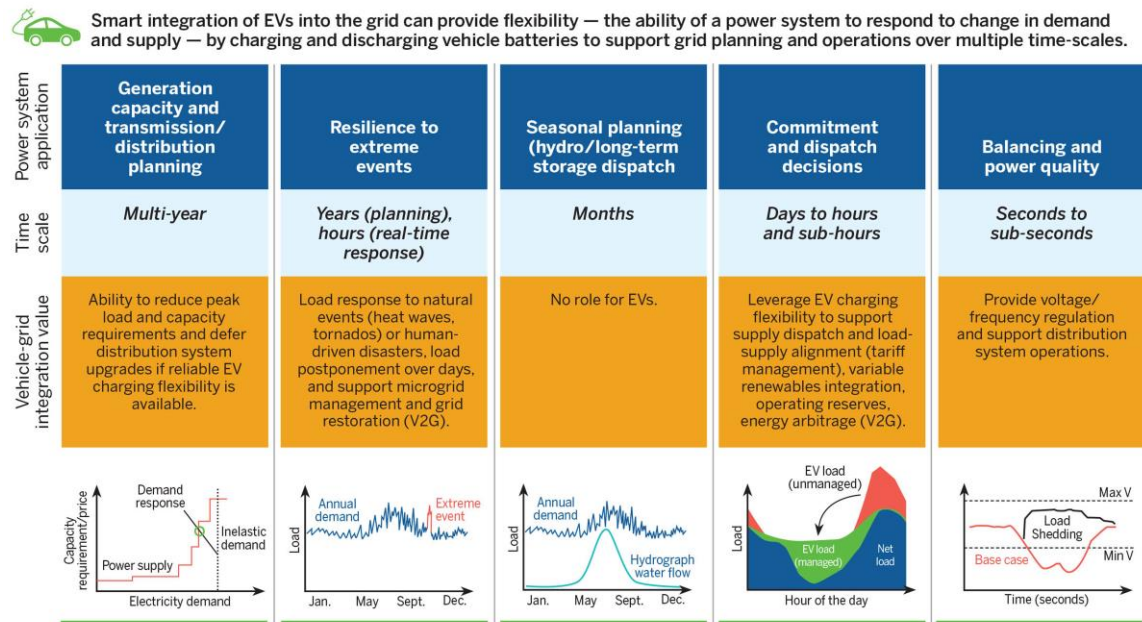
¹⁹ nationalgridESO. (2021). *CrowdFlex – phase 1 report*. https://smarter.energynetworks.org/projects/nia2_nqeso001

²⁰ The red and green curves are illustrative. Data source: Westnetz. (2017). *Peak day*. <https://www.westnetz.de/de/ueber-westnetz/unser-netz/netzkennzahlen/netzrelevante-daten-strom.html>

²¹ A 2018 survey among Norwegian EV owners showed they customarily plug in at 6:00 p.m. if not offered incentives to do otherwise. Hildermeier et al., 2019.

The benefits from managed EV charging for the grid range from long-term, multi-year optimisation, such as from the deferment of distribution system upgrades mentioned above, to millisecond-interval responses to voltage or frequency deviations.²² Figure 8 gives an overview of various applications from a grid perspective. In short, smart EV charging can help manage the grid.

Figure 8. Beneficial role of EV smart charging for power system applications



Source : Anwar, M. B. et al. (2022). *Assessing the value of electric vehicle managed charging: a review of methodologies and results.*

The more EVs are connected to smart charging services, the more flexibility becomes available for the grid. Combining energy wholesale market prices with time-varying network prices can further amplify the effectiveness of both. Having distributed, large-scale, aggregated flexibility available to the power system can drive down costs for operating networks and the energy system, thereby reducing costs for all users, not just those with smart charging EVs.

Electricity cost savings for all consumers

An important feature of wholesale electricity markets is that the average electricity costs passed on to consumers through retail prices are lowered if consumption of electricity during peak hours is reduced and if more electricity is being consumed during periods of low, or even negative, prices. In other words, all electricity consumers, including those who do not use an electric vehicle, benefit if EV drivers charge their vehicles smartly. The same is true for the costs of operating the grid: by shifting EV charging to periods of lower demand – and possibly increased local renewables production – grids can be operated more efficiently, reducing costs for all network users.²³

²² Anwar, M. B., Muratori, M., Jadun, P., Hale, E., Bush, B., Denholm, P., Ma, O. & Podkaminer, K. (2022). Assessing the value of electric vehicle managed charging: a review of methodologies and results. *Energy & Environmental Science*, 15, 466-498. <https://pubs.rsc.org/en/content/articlelanding/2022/EE/D1EE02206G>

²³ Kühnbach, M., Stute, J., Gnann, T., Marwitz, S., & Klobasa, M. (2020). Impact of electric vehicles: Will German households pay less for electricity? *Energy Strategy Reviews*. 32, S. 100568. <https://www.sciencedirect.com/science/article/pii/S2211467X20301218>

As this section has shown, multiple benefits of smart EV charging accrue to the EV owner, other energy consumers and the power system at different levels. But smart charging is not going to happen by itself – it will require sufficient incentives to be offered. This is where smart EV tariffs come in. The next chapter explains what these are and their variations in more detail.

Chapter 2: What are smart charging tariffs?

Smart charging tariffs are retail electricity prices that vary across the day and allow consumers to save electricity costs if they are willing to shift their consumption to periods of low prices. In their simplest form, smart charging tariffs are static and set at a lower rate during certain hours of the day. More sophisticated types of dynamic tariffs vary more frequently and will be different during different hours on different days. The prices can be those of the electricity supplier (electricity prices) or of the distribution system operator (network tariff). Most European consumers pay for both via one consolidated bill, and for reasons of simplicity we refer to both here as well. As shown in Figure 2 on [page 4](#), for an average European household the electricity prices form 30.7% of the electricity bill and network costs 28.8%. These percentages vary, however, by country and user profile. Generally speaking though, increasing the share of dynamic pricing elements in the bill will increase the signal to shift and adjust electricity use.

Smart charging services offer EV drivers automated ways to benefit from time-varying prices and to participate in demand-response services: in reaction to a signal (not necessarily price), EV charging power is adjusted in power level or direction (to or from the car battery). For readers wanting to understand better what demand-response entails, our *Joy of Flex* report provides deeper insight.²⁴

This section explains the main types of smart charging tariffs, other flexibility benefits and the required user input.

Types of time-varying charging tariffs

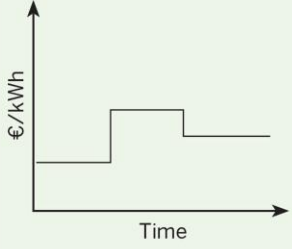
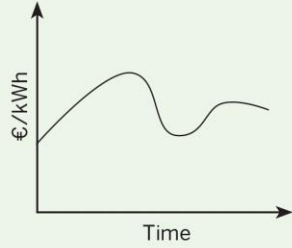
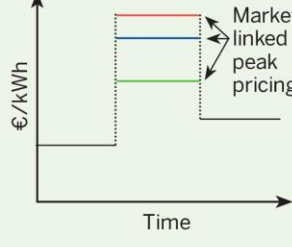
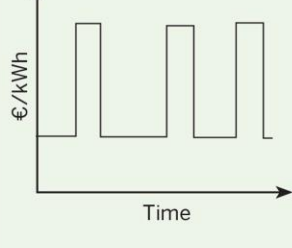
Figure 9 on the next page shows the four main types of time-varying tariffs, of which the first type, a static time-of-use (TOU) tariff, is the most commonly used.²⁵

Each of the tariff options provides different incentives for smart charging and has advantages and disadvantages for consumers and the system.

²⁴ Yule-Bennett & Sunderland, 2022.

²⁵ IRENA – International Renewable Energy Agency. (2019). *Innovation landscape for a renewable-powered future*. <https://www.irena.org/publications/2019/Feb/Innovation-landscape-for-a-renewable-powered-future>

Figure 9. Forms of time-of-use tariffs

Type of tariff	Nature of pricing	Illustrative graphical representation	Features
Static TOU pricing	Static		<p>This typically applies to usage over large time blocks of several hours, where the price for each time block is determined in advance and remains constant.</p> <p>It can use simple day and night pricing to broadly reflect on-peak and off-peak hours, or the day can be split into smaller segments, allowing several slack periods.</p> <p>Seasonality can also be taken into account.</p>
Real-time pricing	Dynamic		<p>Prices are determined close to real-time consumption of electricity and are based on wholesale electricity prices. Electricity prices are calculated based on at least hourly metering of consumption, or with even higher granularity (e.g., 15 minutes).</p> <p>Such tariffs are mostly composed of the wholesale price of electricity plus a supplier margin.</p>
Variable peak pricing	Combination of static and dynamic		<p>A hybrid of static and dynamic pricing, where the different periods for pricing are defined in advance, but the price established for the on-peak period varies by market conditions.</p>
Critical peak pricing	Combination of static and dynamic		<p>A rate in which electricity prices increase substantially for a few days in a year, typically during times when the wholesale prices are the highest.</p> <p>E.g., The French Tempo tariff varies by time of day, with notably higher prices on 22 days during the winter. Customers are notified in advance of the prices for the coming days.</p>

Source: IRENA – International Renewable Energy Agency. (2019). *Innovation Landscape Brief*. Adopted from smartgrid.gov (n.d.) and EURELECTIC. (2017).

Static TOU pricing offers predictability and simplicity to consumers but may not offer them the full potential of cost savings that other, more sophisticated tariff options do; nor does it provide the same level of power system benefits.

Real-time pricing means more fluctuation in pricing, which can mean very low and even negative prices but also significantly higher prices at peak times (unless capped). This exposes consumers to more risk but also offers higher potential cost savings for users capable of shifting the demand from loads such as EV charging. In this paper,

we often refer to this type of pricing as dynamic. In Europe, these dynamic price contracts are based on the day-ahead spot market prices.²⁶

Critical and variable peak pricing are similar to static TOU pricing, but the peak price is designed more like a speeding ticket: its price signal should be strong enough to ensure a solid response, avoiding consumption in that time where possible. This type of pricing is not very common in Europe, but there are some examples of seasonal critical peak pricing – such as the one from Denmark described below.²⁷

Denmark

Seasonal critical peak pricing to reduce winter evening peaks

In Denmark, distribution system operators such as Radiusnet in the Copenhagen area set significantly higher prices for a limited number of ‘critical peak’ periods announced in advance. The network tariff has an on-peak volumetric charge – in the evening hours (5 p.m. to 8 p.m.) of the winter season from October through to March – that is nearly three times as high as the rate for off-peak hours. The on-peak rate is 63.07 øre/kWh compared to 23.63 øre/kWh for off-peak hours [approximately 8.5 and 3.1 euro cents/kWh, respectively].²⁸

These types of prices allow users to adjust their consumption, shifting from higher- to lower-priced periods. Most of these prices are communicated well in advance, set either for the year or season, or are shared at the latest a day ahead of time. The following two sections explain how the main features of time-varying tariffs, and the automated services working with them, create benefits for consumers from smart charging.

Other features of time-varying tariffs

Short-term signals to adjust demand

Increasing the variability of pricing often means that both the reward potential and risks for consumers grow, as illustrated in Figure 10 on the next page.²⁹ Prices that go up and down mean that consumers will want to better manage how much electricity they consume at particular times. When automating charging, the risk-reward trade-off can skew towards the reward side. The smart charging system – whether managed by a remote smart charging service or locally on a charge point – can make the choices for the consumer, protecting them from higher costs. Managed charging services, such as OVO Drive Anytime and Elli Naturstrom Connect, even take away the price volatility completely, combining a smart charging service with a fixed low price. Others, like Jedlix and Leaseplan Energy, give the users a bonus payment or price reduction for

²⁶ CEER. (2020a). *Recommendations on dynamic price implementation*. Council of European Energy Regulators. <https://www.ceer.eu/documents/104400/-/-/2cc6dfac-8aa7-9460-ac19-4cdf96f8ccd0>

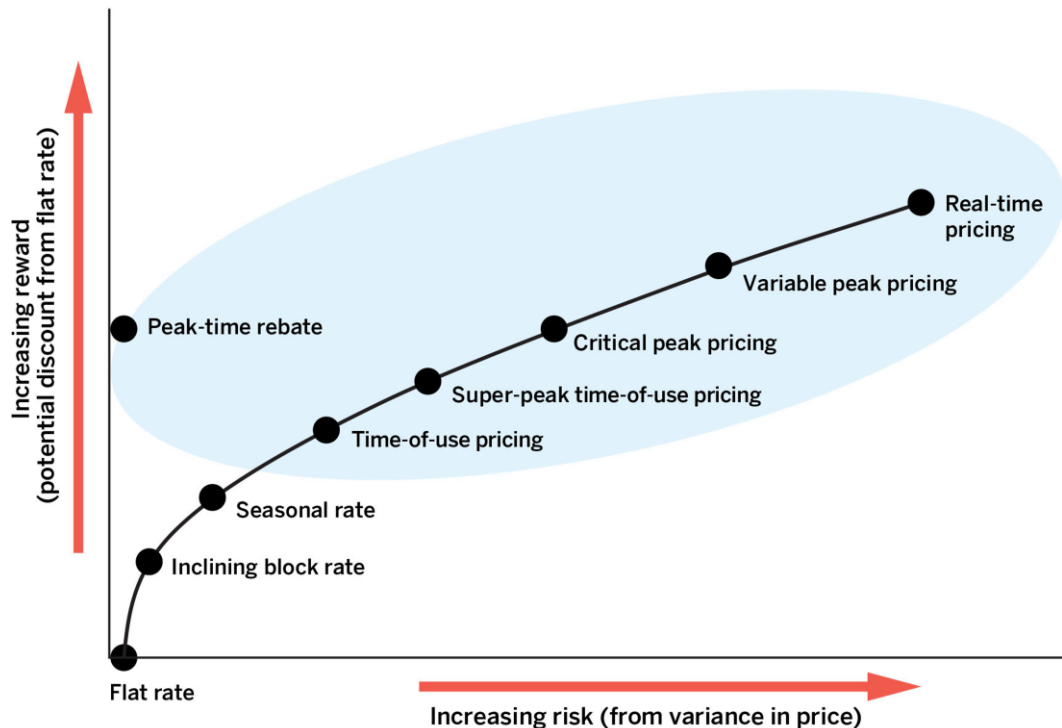
²⁷ For more detail on how smart pricing can help optimise use of existing electricity networks, see Hogan, M., Kolokathis, C., & Jahn, A. (2018). *Treasure hiding in plain sight: Launching electric transport with the grid we already have*. Regulatory Assistance Project. <https://www.raonline.org/knowledge-center/treasure-hiding-in-plain-sight-launching-electric-transport-with-the-grid-we-already-have>

²⁸ Currency conversion as of 25 April 2022.

²⁹ Faruqui, A., Hledik, R., & Palmer, J. (2012). *Time-varying and dynamic rate design*. Regulatory Assistance Project and The Brattle Group. <https://www.raonline.org/knowledge-center/time-varying-and-dynamic-rate-design>

every kWh charged actively using their smart charging service. These smart charging services often optimise charging with both time-varying prices and shorter-term signals.

Figure 10. Representation of customer risk-reward trade-off in smart, time-varying tariffs



Source: Faruqi, A., Hledik, R., and Palmer, J. (2012). *Time-varying and dynamic rate design*.

The time-varying prices provide signals ahead of time, with ‘real-time’ pricing based on day-ahead wholesale energy market prices. That means that prices are set and communicated a day in advance. Energy suppliers forecast the likely response by their customers to these price signals. There is value in adjusting demand beyond that forecast, especially when changes in energy supply and overall demand cause deviations. These lead to price dynamics on the intraday energy market (which is a shorter-term energy market) or within a balancing mechanism (where national system operators level out supply and demand in real time). Other inputs and incentives for smart charging can be the flexibility needs from a system operator at the national or local level, signals that are provided directly to consumers or through an aggregator. Responding to these flexibility needs is often part of a demand-response contract, in which remuneration, at a fixed or per-event rate or combination of the two, is agreed in advance, and technology delivers and confirms a response to operator signals.³⁰

Automation to meet user needs

To optimise the charging and still fulfil the user’s mobility needs, it helps to know when and for how long a driver wants to use their car. If the signals for smart charging are

³⁰ More on this in our *Joy of Flex* report on demand-side flexibility, Yule-Bennett & Sunderland, 2022.

simple, such as a day/night tariff, only a persistent timer is needed to charge at off-peak. In fact, this is how many French EV drivers already charge.³¹

For more sophisticated electricity tariffs, automation is an easy-to-use solution. Software can translate the user's mobility needs into the data needed to optimise energy flows, such as the required volume in kilowatt-hours, time and charging power. The driver benefits from the vehicle being charged, and even heated or cooled, at the desired time of departure – with very little effort on their part. For this to happen, consumers and service companies acting on their behalf need open access to relevant battery and vehicle information and, ideally, charging control.³² Smart charging can then even be as simple as downloading an app (see text box).

Start smart charging just by downloading an app

An increasing number of phone apps from various smart charging service providers allow EV drivers to start smart charging by connecting the EV to their platform. These services benefit from the digital connectivity offered by most EVs. Starting with Tesla and later introduced to other brands, apps like Jedlix and ev.energy allow drivers to start smart charging without the need for new hardware, such as a charge point, and even without switching energy supplier. With just a few clicks, users can enable smart charging and start benefiting – with these services providing financial benefits to all users in some markets, regardless of their energy supplier or contract. Others work with specific suppliers, such as Barry Energy, Tibber, Kraftem and vandebron, or with all dynamic price energy contracts based on wholesale energy markets, such as True Energy, stekker.app and Gridio.

Danish startup Monta is offering a similar app-based service to connect existing home chargers, allowing EV drivers to upgrade their existing charging system to one with a smart charging option. Many of the above car-focused apps also work with a limited number of home chargers.

More information on the intended car usage, gathered from direct user input or perhaps calculated through a self-learning mechanism, means the system can develop a better charging plan. Analysis of usage patterns can help predict future needs, reducing the need for active user interaction with the smart charging process on a day-to-day basis. This is what most smart charging services do: ask the user once for a minimum charge level (to which the vehicle is typically immediately charged) and preferred departure time. This information is retained but can be overruled or changed to reflect changing user needs. The UK's 'The Electric Vehicles (Smart Charge Points) Regulations 2021'³³ show how this can be made a standard step in setting up new home chargers. These regulations require both the technical capabilities to support smart charging and for it to be set as the default charging mode (see text box below).

³¹ Enedis. (2021). *Utilisation et recharge: Enquête comportementale auprès des possesseurs de véhicules électriques* [Use and charging: Behavioural survey of electric vehicle owners]. <https://www.enedis.fr/sites/default/files/documents/pdf/enquete-comportementale-possesseurs-de-vehicules-electriques.pdf>

³² As proposed in the revision of the Renewable Energy Directive.

³³ UK government. (2021). The Electric Vehicles (Smart Charge Points) Regulations 2021. No. 1467. <https://www.legislation.gov.uk/uksi/2021/1467>

United Kingdom

Smart home and workplace charging: off-peak default or dynamic smart charging

The Electric Vehicles (Smart Charge Points) Regulations 2021 are a set of requirements introduced in the UK to advance off-peak and smart charging. In addition to requiring charge points to have the proper technological capabilities, they must also be set to off-peak charging mode by default and provide instructions for the user. This shifts EV charging away from defined peak hours of the day. The user can always override this setting, either on a one-off basis or by programming new default charging settings. Suppliers of EV charge points may also opt to deliver a more advanced smart charging service that allows the station to respond to dynamic signals based on the actual conditions on the grid, rather than setting the off-peak charging mode to a static range of hours. To enable these digital smart charging services, new charge points must be able to support connectivity with the relevant systems.

There are many variations of smart charging tariffs, ranging from simple static TOU tariffs to much more sophisticated dynamic pricing and demand-response approaches. They all provide incentives for people to shift their electricity consumption, including EV charging. But where do such tariffs exist and what kinds of tariff models have been adopted? The next chapter provides a rare comprehensive overview of smart EV tariffs in Europe to answer that question.

Chapter 3: Smart charging tariffs and services in Europe

Offerings for smart charging for EV drivers are expanding across Europe. This section gives a unique, comprehensive overview of the existing smart charging tariffs and services in Europe. Recent events have put energy prices in the spotlight.³⁴ The price increases and dynamics make being able to flexibly adjust demand from EV charging even more important in managing costs for consumers.

Overall, we found 139 tariffs and services across Europe³⁵ specifically incorporating EV smart charging.³⁶ In addition, eight markets, including Norway, Denmark and Finland, have a wide availability of dynamic TOU tariffs for all consumers, not just EV users. Multiple smart charging services exist that can easily work with these tariffs, as all of the prices are based on the day-ahead market. The total number of tariffs compatible with smart charging is therefore greater than 139.

Most smart charging tariffs and services work with dynamic prices. The ability to automate charging makes this a perfect match.

³⁴ A caveat here: some of the examples used are based on prices from before the energy price surges in Europe. The ratio between prices for various times of the day still remains intact.

³⁵ Included in the analysis are the 27 EU Member States, Iceland, Liechtenstein, Norway, Switzerland and the UK.

³⁶ Data was collected until end of 2021.

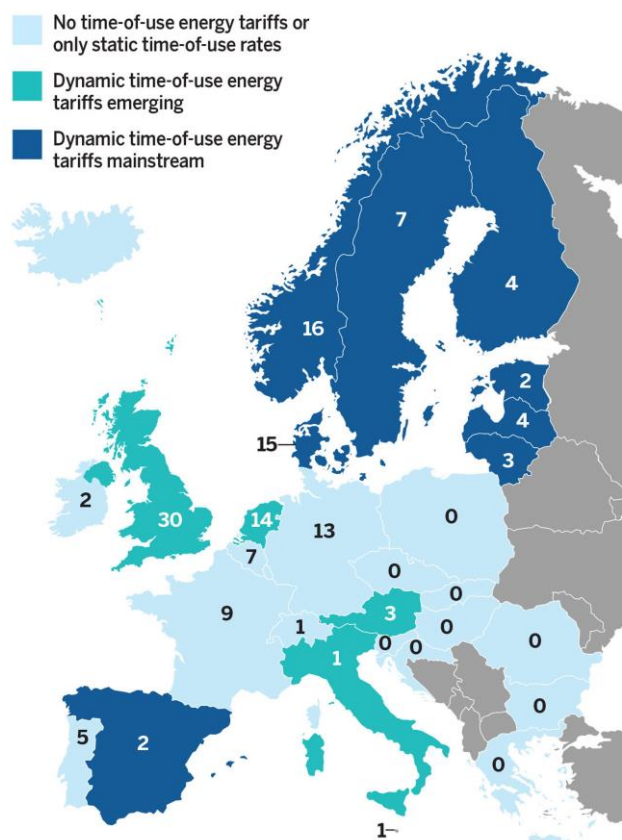
This review of EV smart tariffs only considers rates that are marketed as EV charging offers or can be specifically integrated with EV smart charging services for additional benefits, with some of the electricity tariffs even requiring EV drivers to provide evidence of vehicle ownership. However, we do not generally see a need to have EV-specific electricity or network tariffs – as the example of most Nordic countries shows, EV smart charging services are perfectly able to work with ‘generic’ dynamic tariffs. In fact, most of the smart charging tariffs and services work with dynamic prices. The automation in EV smart charging makes these a perfect match. For this reason, in its *Future Energy Scenarios*, the UK’s National Grid sees the switch to an electric car as a trigger point for consumers to change to a dynamic TOU electricity tariff.³⁷

The map in Figure 11 shows the state of development of these two types of tariffs supporting smart EV charging. The digits (in each country) indicate the number of tariffs and services targeted to smart EV charging available in different European countries. The second indicator, the colour shadings on the map, indicates the general availability of dynamic TOU tariffs, not just those specific for EV charging.³⁸ The specific EV tariffs show a geographical and functional breadth that we will explore in more detail in the following sections.

There is significant geographical variance across Europe, with some countries offering many smart charging tariffs and services. The UK, for example, boasts 30, and even has a dedicated price comparison tool for EV drivers, while other countries do not have a single EV tariff. EV uptake

appears to be a logical reason for electricity providers to start introducing tariffs targeted at home charging and for start-ups to develop smart charging services. Car manufacturers increasingly acknowledge the potential of smart charging. Renault is a shareholder of the smart charging service Jedlix, which offers branded versions of its service to Renault and Hyundai drivers. Volkswagen is currently the only car brand offering a smart energy tariff – at the moment only in Germany under its Elli brand. Notably not included in the overview because it does not include EV charging is Tesla’s

Figure 11. Smart charging tariffs and services across Europe



Source: own research, see Annex for details.

³⁷ nationalgridESO. (2021). *Future energy scenarios 2021*. <https://www.nationalgrideso.com/future-energy/future-energy-scenarios/fes-2021>

³⁸ The colour code indicating the availability of generic dynamic TOU tariffs is based on Agency for the Cooperation of Energy Regulators (ACER) and the Council of European Energy Regulators (CEER), 2021b.

own smart energy plan in the UK, which aggregates consumers' home batteries in a virtual power plant.

EV market leader Norway has the second highest number of tariffs and services at 16. An even stronger indicator for the number and the sophistication of smart tariffs and services, however, is the advancement of energy market legislation, particularly the options for active consumers to market the flexibility in their electricity consumption. For instance, in Germany, the rollout of smart meters is only slowly advancing, as are the offerings for dynamic pricing from energy suppliers and network operators. Smart services here have a strong focus on adapting to the renewables share in the current energy mix, without using any direct price signal.

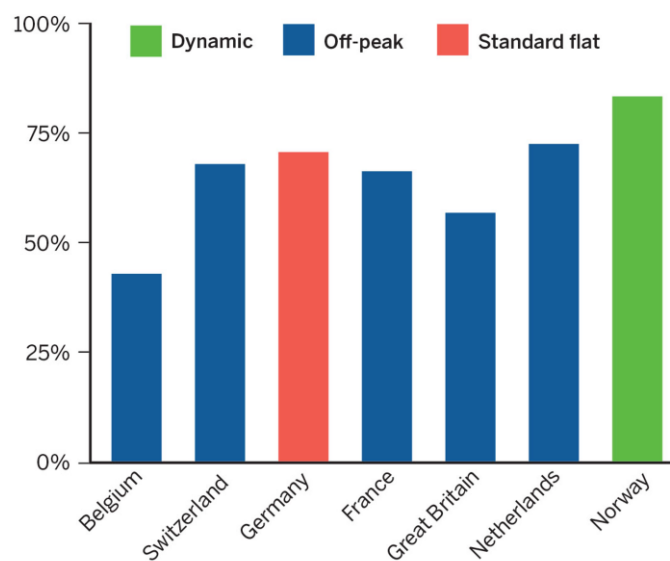
In markets with higher shares of smart meter rollout, such as in the Nordic region, dynamic TOU pricing is much more common. Multiple dedicated smart tariffs as well as services compatible with any day-ahead-market-based electricity contract (see text box on the [Nordic region](#)) are available. Data from smart charging service Jedlix in Figure 12 illustrates the dominant type of electricity rate for its users in different markets: in Norway 84% of its users are on a dynamic TOU tariff, while in Germany 71% have a standard flat electricity rate.³⁹

Although recent EU electricity market reforms – the Clean Energy for All Package – were designed to help develop residential smart tariff offerings across the EU, the level of ambition and speed of implementation of these provisions still differ widely across Member States, depending on their national regulatory frameworks.⁴⁰ As Table 1 on [page 28](#) shows, not all European countries have fully transposed the Energy Market Directive that aims to increase the active role of consumers in the energy system. Given the increasing

numbers of EVs, not allowing consumers to respond to dynamic price signals or provide flexibility to grids at local or national level means policymakers ignore a sizeable and readily available asset that can drive down overall energy system costs.

As the following overview shows, there are already many smart tariff offerings available for charging at home: these can serve as inspiration for other markets and

Figure 12. Dominant type of energy tariff for users of smart charging services



Jedlix. (2022). *A sneak peek into tariff rates across countries*.

³⁹ Jedlix. (2022). *A sneak peek into tariff rates across countries*. <https://www.jedlix.com/en/blog/a-sneak-peek-into-tariff-rates-across-countries>

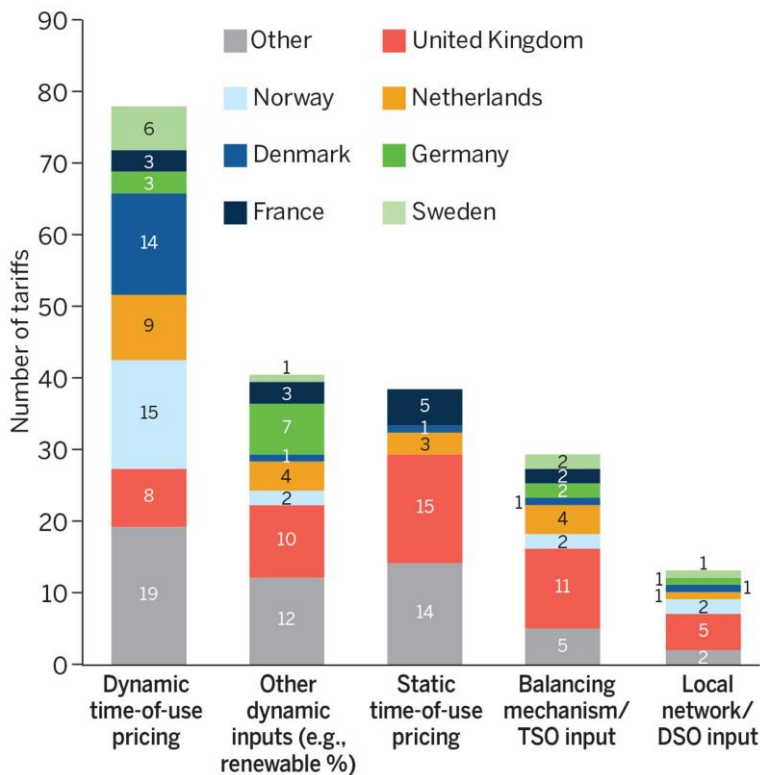
⁴⁰ smartEn. (2022). *The implementation of the electricity market design*. *smartEn Monitoring Report 2022*. <https://smarten.eu/report-the-implementation-of-the-electricity-market-design-2022-smarten-monitoring-report>

policymakers. Smart charging should not, however, be exclusively offered to EV drivers living in single-family houses. Legislative proposals attempting to harmonise EU-wide public and private EV charging should require all infrastructure to have smart charging capabilities and ensure smart charging services have access to this infrastructure, so that more EV users can use dynamic tariffs. More detailed policy recommendations are discussed in the final chapter.

Smart charging should be available to all EV users.

In the next section, we provide more detail on the different types of tariffs and services on offer in Europe, with examples of each type. The tariffs and services can be categorised into five distinct groups, as shown in Figure 13, according to the different types of information (input) on which they are based. We start by looking at static TOU pricing, with cheaper prices for charging at set, off-peak hours. We continue with dynamic time-varying prices, which are set according to day-ahead energy markets. After that, we look at real-time tariffs, with various dynamic inputs that optimise charging for grid carbon intensity or availability of (local) renewable energy. The last two categories of tariffs illustrate how EVs can provide flexibility either to help balance the national grid based on inputs from a transmission system operator (TSO), or the local network or distribution system operator (DSO).

Figure 13. Basis for smart tariffs and services



These categories are not mutually exclusive; in fact, they can be mutually beneficial. Stacking these services increases the benefits to the EV user. The wider energy system benefits from increased participation of flexibility in various markets and locations are harder to attain if targeted on their own, or providers could even end up competing for the same user and EV charging flexibility. In total, 38 tariffs and services combine inputs from two or more of these categories. Within the TOU categories, both electricity prices and network prices can vary. Combining time-differentiated network prices with time-dependent electricity prices can make a compelling offering for consumers. Recent research found that, together, these rates provide a higher incentive to charge off-peak on a day-to-day basis than any potential value from local flexibility tenders,⁴¹ and are a solid basis for many smart charging tariffs and services. On top of these savings, there's additional value in providing flexibility on a near-real-time basis to a TSO or DSO. Our research found 25 tariffs combine time-varying prices with providing near-real-time flexibility at a national level, and 12 tariffs at a local level. Finally, 10 tariffs operate on both levels.

Stacking smart charging services increases the benefits for the user and the power system.

Static time-of-use pricing

The majority of EVs come with a charge timer in the vehicle, allowing a postponed start to charging. By setting that timer, users can plug in their vehicles when arriving home, for example in the early evening, but still charge at low-cost periods overnight. The EV will start charging only at a certain time, making sure the user benefits from lower off-peak prices in their electricity supply contract or network tariff.

Most French EV drivers use a timer for charging at home,⁴² as it can deliver clear and predictable savings.⁴³ Ireland and the UK offer some of the highest price differences through static TOU rates – in Ireland, for example, overnight charging can cut costs by 80% compared to daytime charging. This category of static TOU pricing is often a combination of electricity prices and network tariffs, following the same set blocks of time. In some countries like Germany, however, TOU rates (from energy suppliers or in network tariffs) are almost non-existent. In others, such as the Netherlands, the network tariff does not contain a time-differentiated price component. As a result, static TOU electricity rates, which are the default for most consumers, only yield small savings of around 5%.

The cost for using the power network can vary considerably – typically, off-peak tariffs are 50% lower.⁴⁴ TOU network tariffs are therefore one of the most important inputs for smart charging, as network costs represent an important share of household electricity costs. EV drivers wanting to optimise costs will likely respond to time-

⁴¹ Gonzalez Venegas, F., Petit, M., & Perez, Y. (2021). *Participation of electric vehicle fleets in local flexibility tenders: Analyzing barriers to entry and workable solutions*. EUI Working Paper RSC 2021/12. Florence School of Regulation. <https://cadmus.eui.eu/handle/1814/69860>

⁴² Enedis, 2021.

⁴³ RTE, 2019.

⁴⁴ ACER. (2021). *Report on distribution tariff methodologies in Europe*. <https://documents.acer.europa.eu/Media/News/Pages/ACER-reports-on-electricity-distribution-tariff-methodologies-in-Europe-and-recommends-how-to-improve-them.aspx>

varying network prices. That allows TOU network tariffs to combine effectiveness in reducing peaks on the grid with clear savings for the user.⁴⁵

Ireland

Static TOU rates offer predictable savings

Irish EV drivers with off-street parking can count on considerable savings by opting for overnight charging. With Pinery's EV Drive Time Tariff, the price between 2:00 a.m. and 5:00 a.m. every night is 0.0568 euros/kWh. At all other times, the charge is 0.3214 euros/kWh, which is also the unit price on the default tariff for all times.

A typical EV driver with 2,500 kilowatt-hours of home charging can save 661 euros a year if they are able to shift all of their charging to the cheaper three-hour time window.

Time of day	Price	Savings at 2,500 kWh/yr
2:00 a.m.-5:00 a.m.	0.0568 euros	661 euros
All other hours	0.3214 euros	0 euros

The fact that most French EV drivers already use charge timers shows how static TOU tariffs are a good start for smart charging. However, the additional benefits for the user and the grid of having real-time smart charging are within easy reach with digitally connected charge points and cars.

This is where dynamic smart charging – responding in real time to various signals – and dynamic tariffs (both electricity prices and network tariffs) come into play. Some digital smart charging services are able to shift charging to user-configurable off-peak times and respond to more dynamic signals. In the next section, we look at other dynamic inputs for smart charging – these are often the current carbon intensity of the energy production, or (local) renewable energy production. The last two categories use the flexibility in EV charging to provide real-time balancing power to the grid at a national level (within a balancing mechanism or with input from a TSO), or at a local level (with input from a DSO).

Dynamic time-of-use pricing

Dynamic or 'real-time' TOU prices are the most common input for smart charging, present in 77 of the 139 smart charging tariffs and signals we surveyed. This is a clear sign that the automation in charging EVs is a good match for dynamic prices, making it attractive for an increasing share of consumers to change to a dynamic TOU electricity tariff.

⁴⁵ In our report *Start with smart: Promising practices for integrating electric vehicles into the grid*, we describe the interaction between the network costs and electricity tariffs in more detail. Hildermeier et al., 2019.

In some European countries, dynamic price contracts have become quite common over the past years. Largely based on the day-ahead electricity market, energy suppliers in Nordic countries such as Denmark, Norway, Finland and Estonia have introduced dynamic TOU electricity contracts in one-hour time blocks,⁴⁶ with an increasing number of customers using these tariffs.

As recommended by the Council of European Energy Regulators, dynamic price contracts in the EU are based on the day-ahead spot market prices.⁴⁷ That makes it simple for digital services to implement smart charging, as the input for all contracts within a market stays the same. That's why EV drivers in the region covered by the market platform Nordpool – including the countries mentioned above – can benefit from a choice of digital smart charging services that are compatible with any tariff and supplier (see text box below), but also from smart charging services integrated into their energy supplier's app (e.g., as Tibber does). Increasingly, digitally connected home chargers are able to use dynamic TOU prices as well, requiring no additional technology for users. Some energy suppliers, such as Krafthem, offer a dynamic price electricity contract with a smart charging service that integrates flexibility to balance energy on a national level too.

Nordic region

Smart charging with any tariff and supplier

In Scandinavian and Baltic countries, dynamic price energy contracts have become common in recent years. Most of these have hourly changing prices that are based on the respective Nordpool day-ahead spot market for their location (some countries are split into multiple zones). The similar design of the contracts and of the platform for price-setting (Nordpool) make launching smart charging services that work with all suppliers in all regions relatively easy. Digital-first services can take advantage of this and scale quickly.

Smart charging service providers Gridio, True Charge and Monta have their origins in this region and can work with any dynamic price electricity contract, with Monta also accounting for the critical peak network tariff in some regions in Denmark. True Charge and Jedlix follow the spot market price as the basis for their smart charging services, with which services to balance the grid at the national level and – in pilots only – local level are bundled.

In the UK, Agile Octopus is used almost as a synonym for dynamic pricing, with many of the smart charging services present there, such as ev.energy and Ohme, able to optimise charging at these prices.

For other markets, the availability of dynamic TOU prices for charging is more limited. The European Energy Market Directive⁴⁸ entitles all consumers with a smart meter

⁴⁶ All European countries use these one-hour blocks, except the UK, which uses half-hour blocks.

⁴⁷ CEER. (2020a). Recommendations on dynamic price implementation. Council of European Energy Regulators. <https://www.ceer.eu/documents/104400/-/-/2cc6dfac-8aa7-9460-ac19-4cdf96f8ccd0>

⁴⁸ European Parliament and Council of the European Union. (2019). Directive (EU) 2019/944 of the European Parliament and of the Council of 5 June 2019 on common rules for the internal market for electricity and amending Directive 2012/27/EU (recast). <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32019L0944>

installed to enter into a dynamic price contract. The rollout of smart meters is still limited, however, resulting in minimal availability and limited choice of such contracts (see Table 1 on the next page for the smart meter rollout status and other indicators).

Some European countries have had dynamic price contracts in place, albeit not necessarily in the mainstream, for a couple of years.⁴⁹ A possible explanation for the lack of dynamic smart charging services in these markets, such as Spain, is their current low share of EVs. The first dynamic price offers are emerging in Austria, Germany, the Netherlands, France and Belgium. Smart charging service Jedlix has established partnerships with electricity suppliers in these markets, allowing consumers to save money on their charging sessions, often in combination with additional benefits from providing flexibility to balance the grid at a national level.

Table 1 below provides an overview of European countries and the key indicators for smart charging potential: plug-in vehicle share,⁵⁰ number of EV tariffs and services, the conditions for effective dynamic retail prices, and smart meter rollout.⁵¹ Barriers to effective dynamic retail prices include the availability of smart meters and a high proportion of inflexible network prices and taxes and levies that dampen the varying prices from wholesale markets.⁵² The ideal conditions for expanding smart charging exist in regions with a high share of EVs, combined with the availability of smart meters and dynamic or smart EV tariffs.

Table 1 also illustrates that the smart meter rollout is uneven across European countries. Only in 11 EU Member States can consumers opt for a dynamic energy contract with real-time or hourly energy pricing.⁵³ Most of the countries with a high plug-in vehicle share of new car sales last year also rank highly for the availability of hourly energy pricing (dynamic TOU) and smart meter rollout. A notable exception is Germany, where the smart meter rollout is still below 50% for residential connections and is currently barely progressing. For Norway and Sweden, the Agency for the Cooperation of Energy Regulators (ACER) finds that a relatively high and inflexible share of network tariffs in the energy bill acts as a limited barrier to dynamic energy prices, as these fixed costs obscure the more dynamic electricity supply prices.

⁴⁹ Enefirst. (2020). *Using time-of-use tariffs to engage customers and benefit the power system*. <https://enefirst.eu/examples>

⁵⁰ Battery-electric vehicles and rechargeable hybrid vehicles. See also European Automobile Manufacturers' Association, 2022.

⁵¹ Higher than 80% is considered advanced, 50%-80% is deemed middle, and less than 50% is considered early. Agency for the Cooperation of Energy Regulators (ACER) and the Council of European Energy Regulators (CEER), 2021b. Figure iii, p. 13.

⁵² Agency for the Cooperation of Energy Regulators (ACER) and the Council of European Energy Regulators (CEER). (2021 a). Annual report on the results of monitoring the internal electricity and natural gas markets in 2020: Electricity wholesale markets volume. Table i, p. 15. <https://www.acer.europa.eu/electricity/market-monitoring-report#135>

⁵³ Agency for the Cooperation of Energy Regulators (ACER) and the Council of European Energy Regulators (CEER), 2021b. Figure 37, p. 61.

Table 1. Overview of European countries and key EV, EV tariff and dynamic pricing indicators

Country	2021 new plug-in vehicle share	Number of EV tariffs/services found	Barriers to effective dynamic retail prices	Stage of smart meter rollout	Products with real-time or hourly energy pricing
Norway	86.2%	17	Minimal	Advanced	Yes
Iceland	54.7%	0	N/A	N/A	N/A
Sweden	45.0%	7	Minimal	Advanced	Yes
Denmark	35.3%	15	Not restrictive	Advanced	Yes
Finland	30.8%	4	Not restrictive	Advanced	Yes
Netherlands	29.5%	15	Not restrictive	Advanced	Yes
Germany	26.0%	13	Moderate	Early	Yes
Switzerland	22.5%	3	N/A	N/A	N/A
Luxembourg	20.5%	0	Not restrictive	Advanced	No
Austria	20.0%	3	Moderate	Early	Yes
Portugal	19.7%	5	Minimal	Middle	No
United Kingdom	18.5%	32	N/A	Early	Yes
Belgium	18.4%	7	Moderate	Early	Yes
France	18.3%	9	Not restrictive	Advanced	No
Ireland	15.7%	2	Minimal	Early	No
Italy	9.4%	1	Not restrictive	Advanced	No
Spain	7.8%	2	Not restrictive	Advanced	Yes
Romania	7.3%	0	Moderate	Early	No
Hungary	7.0%	0	Moderate	Early	No
Greece	6.9%	0	N/A	N/A	No
Croatia	4.1%	0	Moderate	Early	No
Latvia	3.9%	4	Not restrictive	Middle	Yes
Lithuania	3.7%	1	Moderate	Early	No
Poland	3.7%	0	Moderate	Early	No
Slovenia	3.5%	0	Not restrictive	Advanced	No
Czech Republic	3.2%	0	N/A	N/A	No
Slovakia	3.0%	0	Moderate	Early	No
Estonia	2.9%	2	Not restrictive	Advanced	No
Malta	1.7%	1	Not restrictive	Advanced	No
Cyprus	1.7%	0	Minimal	N/A	No
Bulgaria	1.7%	0	N/A	Early	No

In dynamic energy price contracts, the electricity supply component changes by the hour (or by the half-hour in the UK). No network tariffs currently follow this same method, apart from a trial by German DSO Mitnetz.⁵⁴ Mitnetz's trial demonstrated well that dynamic time-varying network prices with a locational element can reduce peak load from EV charging as well as help to better integrate locally produced renewable energy (by increasing EV charging incentivised by lower network prices). As a result, consumers who can charge flexibly gain additional savings, but all consumers benefit from lower network costs from the more efficient grid operation.

⁵⁴ MITNETZ / E-Bridge. (2020). *Zeitvariable Netztarife und intelligentes Energiemanagement für flexible Netzkunden. Innovatives Konzept zur Förderung und Nutzung von Flexibilität im Verteilnetz* [Time-variable network tariffs and intelligent energy management for flexible grid customers. Innovative concept for the promotion and use of flexibility in the distribution network]. <https://www.enviam-gruppe.de/presse/pressemitteilungen/2020/mitnetz-strom-und-e-bridge-veroeffentlichen-studie-fuer-die-umsetzbarkeit-zeitvariabler-netztarife>

A common counterargument against introducing dynamic network tariffs is their perceived complexity. Yet, as suggested by the Council of European Energy Regulators, dynamic time-varying network tariffs could be a logical and understandable option for consumers who are already on a dynamic price electricity contract.⁵⁵ These consumers already have experience with time-varying prices, which allow them to easily save significantly by automatically shifting their charging to lower-priced periods of time. The technology that facilitates dynamic price energy contracts is equally responsive to dynamic network tariffs, making them a perfect fit for smart charging. Combining dynamic energy prices with a dynamic network tariff allows for further alignment of wholesale markets and (local) grid optimisation.⁵⁶ Regulators and grid operators should investigate this possibility as an option for consumers,⁵⁷ especially while EV numbers are still relatively low, to make the best use of this potential to integrate higher numbers of EVs into the grid.

Services to help reduce carbon emissions

A quarter of the smart tariffs and services surveyed use dynamic input signals other than price to manage the charging process. Their common feature is that they charge at times with the lowest carbon intensity. Most use market data on the current grid mix per country or region, often combined with a forecasting mechanism that allows a charge to be scheduled. Some apps offer daily alerts to inform drivers of the best time to plug in to benefit from these periods, such as the UK's National Grid WhenToPlugIn, France's adapt and Netherlands-based GreenCaravan,⁵⁸ while others automate the process. Some apps also use specific forecasting, e.g., based on wind or local solar production. An individual solar forecast enables EV drivers to increase use of their on-site solar (as detailed earlier in the user benefits section).

Services to help balance the national grid

A third (35) of the tariffs and services surveyed use the flexibility in the smart charging process to help balance the grid on a national level, as a real-time service. Pausing charging, or increasing or decreasing charging power, can contribute to correcting the balance between national energy production and supply based on signals from the TSO and other energy system actors. Table 2 shows whether national regulatory frameworks allow active consumers, who could be EV owners, to participate in flexibility mechanisms. Currently, only nine European countries have enabling policies in place.

Table 2 below gives an overview of the extent to which the distributed flexibility from EV charging may participate in relevant energy markets in European countries. As in Table 1, it shows the share of plug-in vehicles in new vehicle sales in 2021 and the number of smart EV tariffs and services found. The third indicator reflects whether consumers, such as EV users, have the right to participate in flexibility and efficiency

⁵⁵ Council of European Energy Regulators (CEER), 2020a.

⁵⁶ Council of European Energy Regulators (CEER). (2020b). *CEER Paper on Electricity Distribution Tariffs Supporting the Energy Transition*. <https://www.ceer.eu/documents/104400/-/-/fd5890e1-894e-0a7a-21d9-fa22b6ec9da0>

⁵⁷ European consumer organisation BEUC has made recommendations to incentivise flexible consumption while safeguarding consumers' interest. BEUC. (2019). *Consumers and the future electricity grids. How to make flexible consumption a win-win*. <https://www.beuc.eu/publications/consumers-and-future-electricity-grids>

⁵⁸ GreenCaravan and adapt also work in European markets outside their country of origin.

schemes that reward them for adjusting their electricity consumption.⁵⁹ The fourth indicator shows how the access to energy markets is organised for residential consumers: through direct access, through an end-user residential aggregator⁶⁰ independent of the energy supplier, or no access.⁶¹ These indicators illustrate favourable conditions for developing EV-based demand response markets.

Table 2. Overview of European countries and indicators on consumer participation in (flexibility) markets

Country	2021 new plug-in vehicle share	Number of EV tariffs/services found	Consumer right to participate in flexibility and efficiency schemes in national law	End-user residential aggregator, customer participation in markets
Norway	86.2%	16	N/A	Neither
Iceland	54.7%	0	N/A	N/A
Sweden	45.0%	7	No	Neither
Denmark	35.3%	15	Yes	Both
Finland	30.8%	4	Yes	Neither
Netherlands	29.5%	14	No	Neither
Germany	26.0%	13	Yes	Both
Switzerland	22.5%	1	N/A	N/A
Luxembourg	20.5%	0	No	Aggregator only
Austria	20.0%	3	Yes	Both
Portugal	19.7%	5	Yes	Both
United Kingdom	18.5%	30	N/A	Aggregator only
Belgium	18.4%	7	No	Aggregator only
France	18.3%	9	Yes	Both
Ireland	15.7%	2	N/A	Aggregator only
Italy	9.4%	1	Yes	Both
Spain	7.8%	2	Yes	Neither
Romania	7.3%	0	Yes	Both
Hungary	7.0%	0	Yes	Both
Greece	6.9%	0	No	Neither
Croatia	4.1%	0	No	Neither
Latvia	3.9%	4	No	Both
Lithuania	3.7%	3	No	Aggregator only
Poland	3.7%	0	No	Aggregator only
Slovenia	3.5%	0	Yes	Both
Czech Republic	3.2%	0	No	Neither
Slovakia	3.0%	0	No	Neither
Estonia	2.9%	2	Yes	Neither
Malta	1.7%	1	No	Neither
Cyprus	1.7%	0	No	Aggregator only
Bulgaria	1.7%	0	N/A	Neither

⁵⁹ Agency for the Cooperation of Energy Regulators (ACER) and the Council of European Energy Regulators (CEER), 2021a. Table 32, p. 132.

⁶⁰ Aggregators combine smaller distributed energy resources into one larger controllable unit that can deliver services, for example, to transmission system operators to balance the grid.

⁶¹ Agency for the Cooperation of Energy Regulators (ACER) and the Council of European Energy Regulators (CEER), 2021b. Figure 38, p. 62.

The absence of an organised, consumer-focused framework doesn't necessarily mean that EVs can't contribute to flexibility mechanisms, but doing so might require a larger-scale combination of flexibility from consumers by aggregators in combination with energy suppliers. This can, however, limit the choice of offerings for consumers.

As well as the savings from time-varying rates, most smart charging tariffs and services that participate in a national balancing mechanism offer a per-kWh bonus to EV drivers for smart charging, which allows service providers to market their flexibility.

A similar approach is taken by Volkswagen in Germany, where its Elli Naturstrom Connect contract offers drivers credits for smart charging. This is a different approach from dynamic price energy contracts or static TOU rates, but it offers predictable savings for the EV driver. In the UK, OVO Drive Anytime offers a fixed low rate for all EV charging, provided the smart charging service is activated (see text box).

United Kingdom

Multiple services, one preferential charging rate

With its Drive Anytime electricity tariff, energy supplier OVO offers a different approach to smart charging. Consumers signing up for the tariff allow OVO to manage the charging of their EV in accordance with their app preferences the user sets in an app. The smart charging service operated by OVO learns from the user's plug-in and departure times and energy needs to further optimise the charging based on various inputs and markets, such as wholesale day-ahead markets, intraday markets and the balancing mechanism.

In return, consumers pay a lower rate of 5 pence/kWh charged using the service. For all charging events where users opt out – which they may do at any time – the normal rates are applied. This service requires a compatible home charger.

A typical EV driver with 2,500 kWh of home charging can save approximately 225 pounds annually compared to a regular off-peak rate.

Services to help balance the local grid

Time-varying network tariffs can incentivise charging behaviour that is beneficial for the local grid. Adding locational elements based on actual grid constraints can help DSOs to more effectively manage their grids. We're now going to look at two other options that in many cases complement TOU network pricing and include a locational element: procuring market-based flexibility and DSO-controlled network contracts. In the smart charging tariffs and services we surveyed, local network signals were used the least for smart charging optimisation (see Figure 13 on [page 23](#)).

Using flexibility from producers or consumers, whether directly or through suppliers and independent aggregators, can help DSOs prevent congestion and manage grids more effectively, reducing cost. TSOs frequently use competitive tenders to procure market-based flexibility for balancing energy and for providing ancillary services. A DSO could use this flexibility as an alternative to, or deferral of, grid upgrades. It's a tool complementary to a tariff design that encourages efficiency. The EU's Energy Market Directive⁶² requires Member States "to provide the necessary regulatory

⁶² European Parliament and Council of the European Union. Directive (EU) 2019/944 of the European Parliament and of the Council of 5 June 2019 on common rules for the internal market for electricity and amending Directive 2012/27/EU (recast), Article 32. <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32019L0944>

framework to allow and provide incentives to distribution system operators to procure flexibility services, including congestion management in their areas, in order to improve efficiencies in the operation and development of the distribution system.” DSOs should procure these services in a fair, transparent way through flexibility markets and use the services where they are a cost-effective alternative to upgrades. A market monitor on demand-side flexibility concluded last year that “no state has taken steps to adequately remunerate the use of flexibility by DSOs, and no standardised market products for flexibility exist in Europe.”⁶³ Recent research on the participation of EV fleets in local flexibility tenders has found that while EV charging is an increasingly available resource for flexibility, there are still barriers to its effective utilisation.⁶⁴ DSOs often still require high minimum bids in their flexibility procurement, and have metering and connection requirements that suit medium and large customers, rather than those at the scale of (aggregated) individual EVs.⁶⁵

In fact, as of 2021, the only country in Europe in which all DSOs utilise flexibility procurement on a business-as-usual basis is the UK.⁶⁶ Residential flexibility such as that provided by EV charging is increasingly part of successful bids,⁶⁷ and many of the UK’s smart charging services – such as ev.energy, Ohme and Electric Miles – participate in local flexibility markets, as well as optimising for time-varying energy prices. This is a clear sign that opening local flexibility markets will induce smart charging services to respond.

United Kingdom

EV smart charging with market-based DSO flexibility procurement

ev.energy offers a smart charging service to EV drivers by acting as an aggregator, interacting with the DSO. In addition to responding to time-varying prices from their energy supplier (or local solar forecast), consumers can sign up to ev.energy’s smart charging services and benefit from price- and/or carbon-optimised charging processes and be rewarded for participating in the demand-response scheme. As well as optimising charging based on market price and carbon intensity signals, ev.energy responded to flexibility requests for specific areas from the DSO as part of a further research project.⁶⁸ The first innovation is that now residential flexibility is being used where typically only larger consumers or producers could participate in flexibility tenders. The second change addresses the needs of low-voltage grids, at the level of a feeder or substation, not just the medium-voltage grid infrastructure.

Outside the UK, there are two regional pilots integrating flexibility for a DSO within existing smart charging services: in Denmark, EVs using True Energy’s smart charging service help to alleviate congestion in the region of DSO Radius, and provide balancing

⁶³ smartEn / Delta-EE. (2020). *EU market monitor for demand-side flexibility 2020*. <https://smarten.eu/eu-market-monitor-for-demand-side-flexibility-2020>

⁶⁴ Gonzalez Venegas et al., 2021.

⁶⁵ In our *Joy of Flex* report on demand-side flexibility, these barriers are presented in more detail. Yule-Bennett & Sunderland, 2022.

⁶⁶ Energy Networks Association. (2021). *Flexibility in GB Timeline*. <https://www.preceden.com/timelines/523803-flexibility-in-gb-timeline>

⁶⁷ ev.energy. (2020). *ev.energy wins UK’s first commercial tender using electric vehicles to manage the electricity network*. <https://ev.energy/news/ev-energy-wins-uks-first-commercial-tender>

⁶⁸ UK Power Networks. (2021). *Project Shift. Trialling market based incentives for domestic smart electric vehicle charging. Progress report January 2021*. <https://innovation.ukpowernetworks.co.uk/projects/shift>

services to the TSO at national level.⁶⁹ In Germany's south-western state of Baden-Württemberg, Jedlix partners with DSO Netze BW and TSO Transnet to provide EV charging flexibility for these grid operators.⁷⁰ This shows that, across the EU, regulatory conditions and transparency requirements for network operators need to be improved to allow local flexibility markets to develop more widely (for more policy recommendations, see [Chapter 4: How can smart charging be accelerated?](#)).

Network tariffs with direct DSO control of charging

Home charging will likely take place through the same grid connection, meter and energy contract as other household consumption. There are, however, two notable examples from Germany and Malta which separate EV charging from residential electricity consumption, using an additional grid meter solely for EV charging and a contract for DSO control of the connection in return for reduced rates.

Germany

'Controllable loads' network tariff limits charging and user benefits

Many German DSOs offer a 'controllable loads' network tariff for flexible loads such as EV charging and heat pumps. The largest, Westnetz, installs a new connection of this type for free (in addition to an existing residential grid connection that covers all other electricity demand).

The connection is active in one or two blocks of time; with Westnetz these are from 4:00 p.m. to 4:45 p.m. and from 7:45 p.m. to 7:45 a.m. the next morning (small variations in time stagger the start of charging). Other periods do not allow consumption. Instead of time-varying prices, this connection type is time-varying capacity (down to zero) in exchange for a discounted tariff.

In Germany, network costs are mostly charged per kWh. On Westnetz's controllable loads tariff, users get a reduced rate of 3.4 euro cents versus the regular household rate of 8.5 euro cents.⁷¹ A typical EV driver (2,500 kWh home charging) can save 127 euros/year on the lower tariff. However, due to yearly metering costs of 100 euros, the limited availability may outweigh the savings, as a rigid control structure limits access to other flexibility markets. These high metering costs mean a German EV owner will likely not benefit from the cost savings of the network tariff.⁷² Not surprisingly, the take-up rate for this kind of connection has been very low.⁷³

Regulatory attempts to increase or oblige the use of controllable loads connections have until now been unsuccessful because they fail to properly address consumer choice.⁷⁴

As described in the text box, Germany's 'controllable loads' grid connection is a network tariff with timed grid access without an override option. The DSO might, for example, curtail this connection up to three times for two hours per day, at varying

⁶⁹ True Energy. (2021). *True Energy and Radius test EVs' flexibility*. <https://www.trueenergy.io/radius>

⁷⁰ Jedlix. (2021). *Leisten Sie einen wertvollen Beitrag zur Energiewende und zur Integration erneuerbarer Energien: Smartes Laden im Praxistest in Baden-Württemberg* [Make a valuable contribution to the energy transition and to integrating renewable energy sources: Smart charging in practice in Baden-Württemberg]. <https://www.jedlix.com/de/transnetbw-project>

⁷¹ Westnetz. (2021). *Netzentgelte Strom* <https://iam.westnetz.de/ueber-westnetz/unser-netz/netzentgelte-strom>

⁷² Rutschmann, I. (2022). *Autostrom Wie Du Dein E-Auto zuhause günstig auflädst* [How you can charge your EV cheaply at home]. <https://www.finanztip.de/autostrom-portalvergleich>

⁷³ Recent market monitoring from the German energy regulator suggests many DSOs that offer this type of connection currently lack the technical ability to actually control the capacity. Bundesnetzagentur. (2021). *Monitoringbericht 2021* [Monitoring report 2021]. <https://www.bundesnetzagentur.de/DE/Fachthemen/ElektrizitaetundGas/Monitoringberichte/start.html>

⁷⁴ Jahn, A., Burger, J., & Rosenow, J. (2021). Trust, not control: Germany, EVs and the power of consumer choice. *Euractiv*. <https://www.euractiv.com/section/electricity/opinion/trust-not-control-germany-evs-and-the-power-of-consumer-choice>

local times. In exchange for this DSO control, the network tariff is considerably reduced.

Solutions based on user trust rather than user control, combined with submetering solutions like OVO Drive's managed charging offering (see text box on the [United Kingdom](#)), can reduce costs and scale up quicker, and therefore provide greater user and system benefits.

In Malta, an integrated network tariff and electricity supply contract gives EV owners access to reduced off-peak charging rates during the night (midnight-6:00 a.m.) and afternoon (noon-4:00 p.m.). To benefit from these rates, users request the installation of a separate meter and an EV control box that switches the power feed off and on at set times. With a button on the EV control box, users can override and charge at their regular residential rates when they need to.⁷⁵

A third example of a DSO-controlled network connection is from Sweden. In response to a parliamentary push for more flexible network tariffs,⁷⁶ DSOs can now experiment with new tariffs that encourage flexible energy consumption to reduce peak loads at various grid levels. DSO Ellevio (active in Stockholm, among other regions) introduced a network tariff for public charging stations with reduced rates in exchange for the option to reduce capacity to 6 amps for a yearly maximum of 175 hours.⁷⁷ This DSO control option replaces static TOU network tariffs with reduced overall rates for network utilisation for the charge point operator (plus an additional discount based on the control events that occur). Compared to procuring market-based flexibility, this type of DSO-controlled network capacity is more difficult to combine with other sources of flexibility because of the lack of visibility between the actors. The DSO controls the charge point without being able to see the actual utilisation or charging session needs. As a result, this type of flexibility procurement might also produce less certain results for the DSO than those that can be provided by an aggregator within a local flexibility market.

In the previous sections, we looked at examples that show how static and dynamic TOU pricing, rebate or bonus systems and increasing solar self-consumption can provide user and grid benefits, and are often combined. Providers should aim to bundle multiple smart charging inputs, such as energy supply and local grid conditions, on-site solar energy and national balancing mechanisms. If done well, stacking multiple services doesn't increase complexity for the user, but it can increase (financial) benefits. From a system perspective, it means additional flexibility can be accessed at lower costs.

Tariffs and services at public charging stations

Having looked at smart charging at home, we now shift our focus to EV drivers without access to off-street parking. In the previous section, we looked at an example from

⁷⁵ Enemalta. (2021). *Electric vehicle charging electricity tariffs*. <https://www.enemalta.com.mt/electric-vehicle-charging-electricity-tariffs/>

⁷⁶ Energimarknadsinspektionen. (2019). *Pilotprojekt för att testa nya elnätstariffer* [Pilot project to test new electricity network tariffs]. <https://www.ei.se/sv/for-energiforetag/el/Elnat-och-natprisreglering/pilotprojekt-for-nya-elnatstariffer>

⁷⁷ Ellevio. (2022). *Elnätpriser och villkor för Ellevio Smart Laddabonnemang för alla Ellevios nätområden från och med 1 januari 2022 lokalnät max 0,4 kV* [Electricity network prices and conditions for Ellevio Smart Charging subscription for all Ellevio network areas from 1 January 2022 onwards local network max 0.4 kV]. <https://www.ellevio.se/foretag/om-er-el/forsta-er-elnatskostnad/det-har-betalar-ni-for/ert-pris>

Sweden where the DSO offers a discounted network tariff for public charge points in exchange for control of charging processes. In this section, we want to dive deeper into EV users who rely on public charging infrastructure.

A large share of European citizens, especially those in urban areas, fall into this category. To enable these drivers to switch to electric mobility, access to public charging is vital – but those who rely on public charging can rarely access the benefits of cheaper off-peak or smart charging electricity rates. This has a negative impact on the affordability of EVs for consumers, especially those who drive second- or third-hand EVs where the operational costs are a larger share of the car cost.⁷⁸

In Ireland, off-peak charging rates are as low as 6 euro cents/kWh, while public charging rates are almost four times as high at 23 euro cents/kWh. This can create an affordability gap between users with and without access to off-street parking, which policymakers should address.

Providing access to time-varying pricing and the option of smart charging to users of public charging stations can bridge this affordability gap. With time-varying rates, what's cheapest for EV users often aligns with what's best for the grid. Especially in urban residential areas, for example, grid constraints associated with EV charging can potentially be solved through smart charging on public charging stations, combining benefits for the user and the grid.⁷⁹ Giving users control over their charging session also facilitates smart charging optimisation as they share information valuable for the smart charging process, such as their expected departure time and their charge need. This allows for a more granular and effective smart charging process, increasing user and system benefits.

Pricing based on day-ahead spot markets is being trialled in Germany for fast chargers.⁸⁰ The most advanced integration of dynamic inputs for public smart charging – local substation conditions and dynamic energy prices – is currently being trialled in the UK. As part of the 'Beyond Off Street Smart Meter Electric Vehicle Charging' competition,⁸¹ two consortiums aim to address the affordability gap between home off-peak charging and public charging. Users can control their own public charging session, opting in for optimised charging at reduced rates.

A pilot in the Netherlands⁸² and a recently introduced voluntary option for charge point operators in Germany⁸³ give users the option to select their energy supplier at a public

⁷⁸ Element Energy. (2021). *Electric cars: Calculating the total cost of ownership for consumers. Final report for BEUC* (The European Consumer Organisation). <https://www.beuc.eu/publications/electric-cars-calculating-total-cost-ownership-consumers-technical-report>

⁷⁹ Element Energy. (2022). *Charge Collective final report*. UK Power Networks. <https://innovation.ukpowernetworks.co.uk/projects/charge-collective>

⁸⁰ E.ON. (2022). *E.ON Innovation and LEW launch fast charging stations with dynamic pricing model*. <https://www.eon.com/en/innovation/innovation-frontline/innovation-news/eon-innovation-and-lew-launch-fast-charging-stations.html>

⁸¹ Department for Business, Energy and Industrial Strategy. (2020). *Beyond off street smart meter electric vehicle charging competition – winning projects*. <https://www.gov.uk/government/publications/smart-meter-electric-vehicle-charging-competition-winning-projects/beyond-off-street-smart-meter-electric-vehicle-charging-competition-winning-projects>

⁸² Provincie Groningen. (2021). *Dat belaadpaal ik zelf wel* [the charging is for me to decide]. <https://datbelaadpaalikzelfwel.themasites.provinciegroningen.nl>

⁸³ Bundesnetzagentur. (2021). *Netzzugangsregeln zur Ermöglichung einer ladevorgangsscharfen bilanziellen Energiemengenzuordnung für Elektromobilität (NZR-EMob)* [Grid access rules to enable a charging-process-oriented allocation of balancing energy from electromobility (NZR-EMob)]. https://www.bundesnetzagentur.de/DE/Beschlusskammern/1_GZ/BK6-GZ/2020/BK6-20-160/Anlagen%20Beschluss/Anlage%206.html

charging station. Network tariffs are outside the scope of these models, but the German model does acknowledge the potential of dynamic TOU electricity pricing. However, as of 2022, neither of these schemes makes TOU pricing available for EV drivers. The only European country with such a framework for public charging is Portugal. The electricity supply to public charging stations, as well as the network tariff, are decoupled from the charge point operator and covered by a regulated central operator (see text box). This allows EV drivers to save on public charging costs by charging at off-peak times, helping their wallets and the grid.

Portugal

Bring your own electricity supply to public charging stations

All Portuguese public charging stations are connected to a regulated operator (EGME – Entidade Gestora da Rede de Mobilidade Elétrica, Electric Mobility Network Managing Entity) which manages transactional flows. The e-mobility service provider pays, through EGME, the grid fees, EGME's fees and the charge point operator's fee, in addition to the costs for the electricity supplied.⁸⁴ The costs for using the electricity network are solely volumetric and are structured in two – or depending on the grid area, in three – time blocks. The prices are structured to provide cost recovery similar to the network tariffs for other users.

E-mobility service providers offer their customers an integrated package for public charging, and many offer time-varying prices. EV drivers save on average 6 euro cents/kWh for charging off-peak.

This section has provided an in-depth overview of available tariffs and services for EV smart charging. To make smart charging the default option for all EV drivers in Europe, a regulatory framework is needed that helps these types of tariffs and services to develop more broadly.

Chapter 4: How can smart charging be accelerated?

This section sets out six recommendations for accelerating the use of smart charging and making smart charging tariffs and services a standard option Europe-wide. Particularly in the context of the current energy crisis, a broadly established market for smart charging tariffs and services will help to reduce the need for fossil fuels in both the transport and the electricity system. Although smart charging technology is already available and – to a lesser extent – in use, it is now important for policymakers to make smart charging services and tariffs accessible for all types of consumers and charging situations through an enabling framework.

This framework will benefit from collaboration between European, national and local policymakers and the energy and transport industry as well as consumer groups. In particular, as EV sales grow, joint planning is key to integrate EVs into our power grids in a way that maximises benefits for users and the energy system, minimises cost and

⁸⁴ Entidade Reguladora dos Serviços Energéticos. (2021). *Functioning*. <https://www.erse.pt/en/eletric-mobility/functioning>

accelerates the move to renewable energies. Although the following recommendations leverage the potential of electric passenger cars and consumers, they also support the optimal integration of electric commercial and heavy-duty vehicles and fleets.

Make smart charging the default everywhere

To maximise the benefits of smart charging, it should be the default option for charging infrastructure everywhere, in public and private settings alike. New EV drivers in particular might not be aware of smart charging and its benefits, so for private charging this information should be provided during the purchase and installation of a home charger. One best practice example is from the UK (see text box on the [United Kingdom Electric Vehicles \(Smart Charge Points\) Regulations](#)), where installers are asked to set the – overridable – default to off-peak charging mode, or to connect the home charge point to a smart service offered by an energy supplier or other provider. This goes a step beyond requiring the technical capabilities to support smart charging, and extends the requirement to its actual use.

Policymakers have the opportunity to guarantee that smart charging⁸⁵ is included in several of the legislative proposals under discussion:

- **By including the necessary requirements in the renewed building codes** (Energy Performance of Buildings Directive⁸⁶). Most EV drivers will charge at home or at work; charging points at both should support smart charging.
- **By including a solid definition of smart charging, including its benefits for consumers, for carbon mitigation and for the grid, in the Renewable Energy Directive recast.** The current proposal⁸⁷ suggests putting smart charging in public infrastructure on an equal footing with smart charging in private infrastructure. The legislation could be improved, however, by specifying the broader grid benefits of doing so. The proposal establishes a user-centric model for smart charging, ensuring that control of the charging process and access to energy markets remain in the hands of the customer. As charging systems expand, economies of scale and standardisation will further boost the effectiveness of smart charging and drive down costs. More users charging smartly also means more flexible resources available for the grid, especially in urban areas.

A suitable definition should refer to optimising charging of an electric vehicle by adjusting the power level and timing, based on user or external input. It should also include integration of electric vehicles into the power system, increase the potential to use renewable energy sources and promote the use of time-varying tariffs and smart charging services to lower user and system costs. The agreed definition should also be referred to in the Alternative Fuels Infrastructure

⁸⁵ As noted previously, we do not further differentiate between unidirectional and bidirectional charging.

⁸⁶ European Parliament and Council of the European Union. (2021c). Proposal for a Directive of the European Parliament and of the Council on the energy performance of buildings (recast). <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52021PC0802&qid=1649680671416>

⁸⁷ European Parliament and Council of the European Union. (2021a). Proposal for a Directive of the European Parliament and of the Council amending Directive (EU) 2018/2001 of the European Parliament and of the Council, Regulation (EU) 2018/1999 of the European Parliament and of the Council and Directive 98/70/EC of the European Parliament and of the Council as regards the promotion of energy from renewable sources, and repealing Council Directive (EU) 2015/652. <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52021PC0557>

Regulation⁸⁸ (see the next recommendation) and Energy Performance of Buildings Directive proposals, making it consistent across all related legislation.

Make public charging smart too

Given that smart charging reduces system costs, making public charging smart will benefit all electricity consumers, including those who do not own an EV. In fact, a substantial number of Europeans don't have access to off-street parking, especially in urban areas. Drivers who rely on public charging often do not have the option to pay less by responding to TOU pricing. A recent study for the European consumer organisation BEUC finds that the lack of smart charging offerings at public charging stations makes EVs less affordable, and thus less attractive, for consumers.⁸⁹ Most existing public infrastructure offers only limited choice, and therefore only limited consumer control.

To allow all Europeans to benefit from public smart charging, EU decision-makers should:

- **Require smart charging capabilities in all public charging points.** This would apply to all charging points covered by the new Alternative Fuels Infrastructure Regulation, including high-power chargers – and not only 'normal' lower-speed chargers, as the EU Commission suggests in its legal proposal. All chargers, slow and fast, are easier to use and integrate into the grid if they are smart. In addition, setting smart charging requirements through the Alternative Fuels Infrastructure Regulation for all chargers will lay the foundation for market growth of innovative charging services that include public charging infrastructure. These services not only make it easier for EV drivers to reap the benefits of smart charging, but also enable grid operators and energy markets to use the inherent flexibility in EV charging to run their grids more efficiently.

Empower consumers to make informed choices

Users often lack clear information on potential savings along with more general information on the importance of smart charging⁹⁰ which would enable them to make informed choices. Users who already drive an EV, own a charge point and want to benefit from smart charging services need a different approach to get them to use such a service than users with a new charge point (as in the example from the UK). The good news is an increasing number of smart charging services are emerging that allow users to connect their existing car or charger and gain smart charging functionality. Not all cars support this remote control of the charging process. For most existing chargers, connecting them to a different platform to gain smart charging functionality is a rather technical process. Sometimes it requires technical support from the supplier, or worse, the specific charge point is locked in to a supplier platform. Policymakers and suppliers can ease these difficulties by paying attention not only to the importance of standards

⁸⁸ European Parliament and Council of the European Union. (2021b). Proposal for a Regulation of the European Parliament and of the Council on the deployment of alternative fuels infrastructure, and repealing Directive 2014/94/EU of the European Parliament and of the Council COM/2021/559 final. <https://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX%3A52021PC0559>

⁸⁹ Element Energy, 2021.

⁹⁰ BEUC The European Consumer Organisation. (2019). *Fit for the consumer? Do's and don'ts of flexible energy contracts*. <https://www.beuc.eu/publications/fit-consumer-dos-and-donts-flexible-electricity-contracts>

for ensuring the interface can interact remotely with a charge point, but also by requiring interoperability so users can easily switch platforms.⁹¹

Smart charging services should keep the user in control and provide maximum transparency at all times. Automation can increase the attractiveness of smart EV products and services through easier day-to-day charging. The most popular apps automate functions to require as little or as much attention from the user as they choose, making sure the EV is charged when they need it and reacting to various price signals based on the user's preferences. In addition, many current automations are highly responsive to even minor signals from the power system. This allows a provider of smart charging services to participate in real-time balancing of the energy system. Users don't need to make these balancing adjustments themselves, but they should be comfortable with the service doing it for them.⁹² By contrast, smart charging models that shift the control over consumers' charge points to the grid operator, as is the case in Germany, are not likely to increase the attractiveness of smart charging or to achieve true cost reductions.⁹³

Policymakers, planners and providers of smart charging services, such as electricity suppliers, grid operators, dedicated smart charging service companies, aggregators, and charge point operators, need to collaborate to make EV smart charging tariffs and services more attractive for users – and more effective for all. Two aspects in particular need improvement: drivers' understanding of smart charging, and the actual day-to-day usage.

- **Providers should incentivise drivers to use smart tariffs and services by clearly communicating their benefits.** These include explaining how much money drivers can save by charging at the right times or how to make better use of energy from renewable sources.
- **Providers need to design easy-to-use apps or chargers** that provide the user with the relevant information to meet these objectives and support the user's preferences for charging and driving. This would give drivers confidence in the smart charging process while meeting mobility needs. Users who understand the benefits of flexible, smart charging are more inclined to participate in demand response and provide services to the grid.⁹⁴
- **Policymakers and planners can enhance these improvements by requiring transparency and better information,** backing consumer education campaigns and supporting innovative pilot projects.

Improve rewards for consumer flexibility

It is important to provide consumers with dynamic pricing structures and reward schemes that reflect the true system value of their flexibility. Introducing smarter electricity contracts and network tariffs to a broad consumer base now, when the

⁹¹ More on standards for smart charging and charger platform interoperability in ECOS. (2020). *Electric vehicle smart charging. The key to a renewable and stable grid.* <https://ecostandard.org/publications/electric-vehicle-smart-charging-the-key-to-a-sustainable-grid>

⁹² A deeper investigation into consumer needs in interacting with demand-response services is provided in UsersTCP. (2021). *Social license to automate. Emerging approaches to demand side management.* <https://userstcp.org/publications>

⁹³ Jahn et al., 2021.

⁹⁴ Evergreen Smart Power, 2021; and UsersTCP, 2021.

percentage of EVs is still low, creates an opportunity for all stakeholders to benefit and learn, to improve offerings and to adjust as needed as the number of EVs grows. In all cases, customers should be given clear information on how they can accrue rewards and benefits through the use of dynamic tariffs.

Not all consumers will like the idea of being exposed to dynamic TOU pricing, as rewards will vary along with grid conditions and consumption. But examples like OVO Drive or Volkswagen Naturstrom (see example from [United Kingdom](#)) show how a managed charging service can reassure consumers about pricing and mobility while still dynamically optimising their charging sessions. As the range of dynamic tariffs and associated smart charging services grows, consumers will be able to choose their preferred degree of flexibility and type of reward.⁹⁵ Some may want to use different tariffs for EVs than for their general household consumption, which would require submetering.⁹⁶ However, the more dynamic tariffs are used, the greater the overall benefits from flexible consumption – including better utilisation of on-site renewable energy generation. In other words, EVs don't require separate tariffs – they can pave the way for smarter energy use all round.

- To better reward consumer flexibility, **policymakers and regulators should improve electricity market design, in particular to enable residential flexibility** in advance rather than waiting until the need becomes urgent. This may go against some DSOs' current strategies, which tend not to reward system flexibility ahead of time.
- In addition, it will be important to **remove barriers that prevent small-scale assets such as EVs from participating in flexibility markets**. This includes addressing minimum thresholds, metering and interoperability requirements.

Stack smart charging services to increase benefits

As regulators advance electricity market reforms in all Member States, it is important to ensure that smart charging services can be stacked to amplify their individual and system benefits. Interoperability allows services to interact and share information across the various actors involved. Benefits such as increasing the use of on-site solar PV or better load management in multi-dwelling buildings can easily be 'topped up,' or stacked with, other services from energy suppliers through dynamic TOU pricing or through aggregators that provide dynamic flexibility to the local grid and the energy system. Europe's Clean Energy package gives consumers the freedom to choose their services from energy suppliers and independent aggregators; the technology underpinning smart charging should reflect this freedom of choice and ensure compatibility of services.

⁹⁵ More on these options in our *Joy of Flex* report. Yule-Bennett & Sunderland, 2022.

⁹⁶ A trial by DSOs in the Netherlands has shown that built-in meters from charge points can be used for these purposes. Liander. (2022, 2 March). *Verbruiksdata delen maakt verschillende energieleveranciers mogelijk zonder extra meters* [Sharing consumption data enables different energy suppliers without extra meters]. <https://www.liander.nl/nieuws/2022/03/02/verbruiksdata-delen-maakt-verschillende-energieleveranciers-mogelijk-zonder-extra>

Regulators and policymakers should encourage stacking of smart charging services by ambitiously implementing electricity market reforms. This includes:

- **Improving interoperability and data exchange** between market actors and system operators for communicating clearly how flexible charging processes will be deployed within the power system.
- **Reassessing and simplifying metering requirements for demand response**, for instance by allowing submetering through the existing meters in charge points and households.
- **Enabling safe sharing and use of data from home chargers and cars to allow more granular insights for a smart energy system.** This requires consumer access to their vehicle, charge point and energy consumption data to optimise the operation of smart charging services on their behalf and consumer control over (anonymised) data sharing to support efficient operation of grids.

Make local grids ‘smart charging ready’

DSOs should make use of market-based smart charging services which can help avoid unnecessary and costly grid upgrades. The flexibility of many smaller assets, like EVs, can be aggregated to create a powerful energy system resource. Transmission system operators and legislators already recognise the potential for smart charging to support system balancing and the reduction of peak demand on the grid through demand response. Smart charging offerings for EV drivers are now slowly emerging, with electricity suppliers and TSOs driving the change – directly or in cooperation with new smart charging service providers – through integrated services. Because the services are digital, DSOs risk missing opportunities if they delay digitalising their grids and grid management: this would drive up costs and make ensuring reliability more difficult, reducing the value proposition for flexible customers, including EV users.

In addition, local flexibility markets should include distributed, small-scale residential flexibility from smart charging EVs.

Ideally, regulators and policymakers:

- **Encourage and support DSOs in digitalising grids and grid management**, with a view to using real-time grid data as much as possible. This includes obligations on system operators to share local grid utilisation data so third parties can offer solutions to congestion, including demand response from EVs.
- **Encourage interaction with distributed flexible resources** through (local) flexibility markets to defer costly grid upgrades.
- **Facilitate network tariff reform** to better reflect real-time and local conditions.

Conclusions

Our in-depth Europe-wide review of available EV smart charging tariffs and services concludes that smart charging has the potential to achieve a wide array of user and system benefits alike. It also underscores how all electricity consumers benefit from flexibility in charging EVs, not just the vehicles' users.

Driving an EV reduces carbon emissions compared to cars with internal combustion engines. Smart charging can amplify these emissions reductions by helping to integrate increasing shares of renewable energy into the power system and by shifting demand for electricity to times when these resources would otherwise be curtailed. The fact that EV smart charging avoids periods of peak electricity demand means it can reduce the need for expensive peak-demand generators, which often run on fossil fuels. In light of the current energy crisis, making smart EV charging services broadly available will help reduce Europe's dependency on energy from fossil fuels.

Our analysis reveals that, although a large number of EV tariffs and services are already available and easy to use, they are not distributed evenly across Europe. Some countries, such as the UK, have established favourable energy market conditions, allowing EVs to participate as flexible resources in markets, even at the local level, thus generating greater rewards for consumers. In many Northern European countries, the prevalence of dynamic tariffs is helping integrate the rapidly growing number of EVs into their energy systems. Other countries, by contrast, are only in nascent stages of establishing the framework to reward residential flexibility, or existing models depend on grid operator control, which stands in the way of developing consumer-driven smart charging services. The development of smart charging services is hindered by a lack of transparent grid data, and slow and heterogeneous smart meter rollout.

Our recommendations for policymakers in Europe address current barriers in European and national transport and energy market regulation. They include putting users in control by making user-centric smart charging the default for public and private infrastructure. This requires amending the Alternative Fuels Infrastructure Regulation, the Energy Performance of Buildings Directive and the Renewable Energy Directive to include a comprehensive definition of smart charging to ensure its consistent application. We also recommend empowering consumers and improving rewards by providing clear, comprehensive information. It's also important to ensure easier access to energy markets and effective participation of EVs in flexibility markets at national and local levels. Finally, we advise making power grids 'smart charging ready' by requiring more transparency for grid usage data, encouraging collaboration between grid operators and market-based flexibility providers, and introducing time-varying network tariffs.

Smart charging is the fast lane as the transport and energy sectors move towards zero emissions. With the transition to EVs fully underway and accelerating, now is the time to ensure smart charging works for all Europeans, at all locations and at all levels of the energy system. The related benefits are within easy reach: the technology is ready and smart tariffs and services have demonstrated that they can deliver – we now need to extend existing best practices for consumers to all European markets.

Annex 1: Smart charging benefits within the local community

The advantage of lower electricity rates or using on-site renewable energy should not be exclusively available to single-family house owners. Regulatory frameworks that follow European energy legislation extend the benefits of using your 'own' renewable energy to renters in apartment buildings, such as Germany's 'Mieterstrom' concept,⁹⁷ or to energy communities at a local scale. The frameworks encourage consumers to adjust their electricity demand to the actual renewable energy supply, making smart charging of EVs a powerful and logical tool (see Figure A on the next page for an explanation of how smart charging within energy communities can combine community and grid benefits). For EV users in apartment buildings, installing a charge point could be more complex than for users living in a single-family house. However, a 'right to plug,' such as that introduced in France for apartment owners and renters, can remove procedural barriers, while smart charging technology can help ensure smooth integration with the building and the power system. Both are currently under discussion for the revision of the EU's Energy Performance of Buildings Directive.⁹⁸

Energy communities

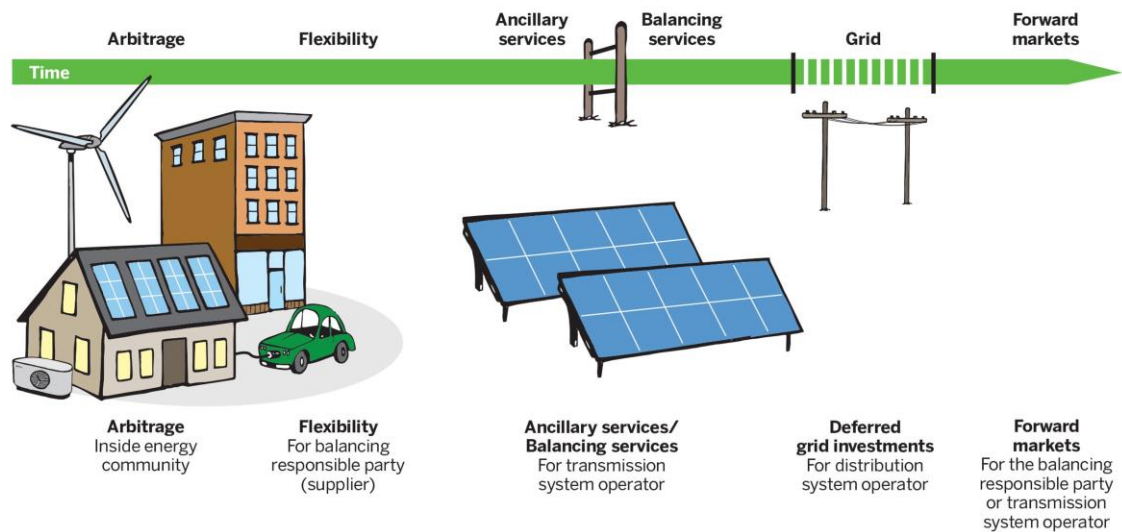
Energy communities allow organised groups of citizens to jointly become so-called prosumers, active consumers and producers of renewable energy who can adjust the amount of energy they draw from (or feed into) the grid. European legislation is enabling these collectives of individuals to become active in the energy world to increase energy democracy, alleviate energy poverty through broader access to money-saving projects, and facilitate the deployment of decentralised renewable energy. Perhaps most importantly, energy communities can drive positive social cohesion and innovation, in addition to providing grid services.⁹⁹ Figure A on the next page provides an overview of these grid services, with arbitrage (consuming energy within the community where it is produced) as the basis on top of which other services can be provided, e.g., to a local distribution system operator or towards balancing power at the national level. Some of these services provide long-term grid benefits, such as deferring grid investments, whereas others depend on short-term responses that can easily be delivered through smart charging.

⁹⁷ For more information on this concept, see Bundesministerium für Wirtschaft und Klimaschutz. (n.d.). *Häufig gestellte Fragen zum Mieterstrom* [Frequently asked questions about on-site renewable energy sources on rented premises]. <https://www.bmwi.de/Redaktion/DE/FAQ/Mieterstrom/faq-mieterstrom.html>

⁹⁸ Burger, J., & De Bruyckere, L. (2021). EU's building directive should give EV owners the right to a smart plug. *Euractiv*. <https://www.euractiv.com/section/energy/opinion/eus-buildings-directive-should-give-ev-owners-the-right-to-a-smart-plug>

⁹⁹ Claey's, B. (2021). *Energy communities with grid benefits: A quest for a blueprint*. Regulatory Assistance Project. <https://www.raonline.org/knowledge-center/energy-communities-with-grid-benefits-a-quest-for-a-blueprint>

Figure A. Value propositions for community energy flexibility



In Belgium, carsharing cooperative partago and local energy communities have joined up for a carsharing project called CEDAN, with electric cars integrated into the local energy community. This is an example of increasing self-consumption within the energy community. France has introduced the concept of ‘autoconsommation collective’ (collective self-consumption) in the network tariff structure. This way, the consumption and production of renewable energy on the same low-voltage grid within the same time window (there are four differentiated time periods) are subject to a reduced network tariff.¹⁰⁰ France is the first Member State to introduce this concept from Europe’s Clean Energy Package into the network tariff structure. Other Member States still need to follow, enabling and structuring the way energy communities can provide balancing services on a local level.

¹⁰⁰ Commission de Régulation de l’Énergie (CRE). (2021). *Délibération N°2021-13. Délibération de la Commission de régulation de l’énergie du 21 janvier 2021 portant décision sur le tarif d’utilisation des réseaux publics de distribution d’électricité (TURPE 6 HTA-BT)* [Deliberation N°2021-13. Deliberation of the Energy Regulatory Commission of 21 January 2021 concerning the tariff for the use of public electricity distribution networks (TURPE 6 HTA-BT)]. <https://www.cre.fr/Documents/Deliberations/Decision/tarif-d-utilisation-des-reseaux-publics-de-distribution-d-electricite-turpe-6-hta-bt>

Annex 2: List of tariffs and services analysed

We considered the following collection of smart EV tariffs and services for this report. The information was collected during 2021. Some of these are active in multiple countries and are therefore counted multiple times in the overview section of this report.

Provider	Product name
adapt	adapt
Agva	Agva Spotpris
Andrae	LadeChecker
aWATTar	Hourly
Barry Energy	Barry
Bluecharge	Bluecharge
Bornholms Energi & Forsyning	TIME-FLEX
British Gas	Electric Drivers
Bulb	E V tariff
cDiscount Énergie	cDiscount Énergie
Corrently	Autostrom + GrünstromBonus
E.On	Drive
E.On	E.ON Next Drive
Ecotricity	Fully Charged
EDF	Vert Électrique Auto
EDFenergy	GoElectric 35
EDFenergy	GoElectric 98
ekWateur	ekWateur
Electric Miles	Electric Miles
Ellevio	Smart Laddabonnemang
Enemalta	EV Charging
Energeia	EV
EnergyZero	ANWB Energie
EnergyZero	EnergyZero
EnergyZero	Laadje
Engie Electrabel	other tariffs

Provider	Product name
Engie Electrabel	Dynamic
eprimo	Öko Zuhause & eMobil
Equiwatt	Equiwatt
Essent	LaadVoordeel
ev.energy	ev.energy
Factorenergia	Factorenergia Card
Fjordkraft	Fjordkraft
FlexifAI	Youree
Fortum	Fortum 360
Frank Energie	Frank Energie
Freeloadr.io	Freeloadr.io
GenGame	EV app
GenGame	Home & Roam
GNP Energy	Fordel plus el
GNP Energy	Marked Web
go-energi	GO SPOT ENERGI
Good Energy	EV Driver 4
Good Energy	Zap Flash
Green Caravan	CO2smartcharging
Green Energy UK	TIDE
Greenpeace Energy	Mobilstrom Plus
Gridio	Gridio
Gudbrandsdal Energi	Gundbrandsdal Energi
Hiven	smart charging
Iberdrola	Plan Vehículo Eléctrico
Igloo Energy	Pioneer
Jedlix	BW
Jedlix	Jedlix
Krafthem (now: Flower)	Virtual Power Plant
Krafthem (now: Flower)	Krafthem

Provider	Product name
Kraftriket	Kraftriket
Lampiris	eMobility
LeasePlan Energy	LeasePlan Energy
LOS	spotpris
MijnDomeinEnergie (EnergyZero)	Flex
Mobilitectric	Kilo
Mobismart	Plano Power
Modstrøm	Klimapakke
Moixa	e:PROGRESS
Monta	Monta
nationalgrid	WhenToPlugIn
newmotion	newmotion
Nieuwe Stroom	FullFlex Stroom
NRGi	KØR-VEL-EL
ø-strøm	SpotEL
Octopus Energy	Octopus Go
Octopus Energy	Intelligent Octopus
Octopus Energy	Agile Octopus
Octopus Energy	CrowdFlex
Ohme	Ohme
Ovo Energy	Ovo Drive
Ovo Energy	Drive Anytime
Øvre Eiker Strøm	Eiker Smart
Pinery	Drive
Plüm énergie	Plüm énergie
Polarkraft	Polarkraft
Polarstern	Autostrom
Prio	Prio Electric
Re.alto	Connect EV

Provider	Product name
Samstrøm	REN SPOT
Schlaustrom	Spot-Plus
ScottishPower	SmartPower EV Tarif
SEF Energi	EL FleksVIND
SENEC	SENEC Cloud to go
Shell Energy	Charge and Drive
Smart Energi	Spot Time
SO Energy	EV
Stekker.app	Stekker.app
Tibber	Tibber
TotalEnergies	Plan Vehículo Eléctrico
TotalEnergies	Heures Super Creuses pour votre véhicule électrique
True Energy	True Charge
vandebrom	SlimLaden
Virta	Virta Home
Volkswagen	Elli Naturstrom Connect



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