Plugging into potential: unleashing the untapped flexibility of EVs

Why smart charging is essential for a more sustainable and resilient energy system

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Contents

Executive summary

We know the story.

Europe's energy landscape is undergoing irreversible change.

On the supply side, the rapid shift towards renewables and low-carbon power generation accompanies greater diversification to enhance energy security. But the variable nature of renewable energy also introduces new risks, which must be managed. They include a mismatch in demand and supply, overloaded transmission and distribution lines, and challenges with grid integration.

On the demand side, the growing load from the electrification of industrial processes, heat pumps, data centres and, of course, transport creates unpredictability and introduces new peaks at different times of the day.

At the same time, customers are becoming more engaged with their individual energy consumption. As their expectations shift towards greater transparency and control, the way in which they interact with the grid is changing too. Meanwhile, the rising threat of cyber attacks, extreme weather events and grid systems that are already constrained in some regions make it more critical than ever to balance and manage energy supply and demand in real time.

The future is already smart, but it must get smarter

So what's the definitive answer to managing these converging challenges? How can we balance the grid, optimise the use of renewables and lower costs for consumers?

In large part, the solution already exists today. Unidirectional smart charging is a proven way of encouraging users to consume energy intelligently and to shift load from congested periods or to cheaper periods. But now, with exponential growth in electricity demand, especially as consumers charge their electric vehicles (EVs) at home, unidirectional charging is becoming an even bigger imperative.

Instead of everyone plugging in when they return home from work, coinciding with peak demand from other energy-hungry devices, EV charging is becoming smart. Algorithms optimise the charging process based on preferences set by EV drivers. They might, for instance, want their car charged to 80% overnight at the cheapest rate, or to be fully charged by 8:00 a.m. Once their preference is set, communication between the EV, the charger and a management system automatically starts and stops the charging process. When functioning optimally, it can take into account the price of electricity, grid utilisation, availability of renewable energy and the state of charge of the EV battery.

Consumers and grid companies are the primary beneficiaries of unidirectional charging, also known as first-generation vehicle-to-grid (or V1G). It revolves around a simple time of use (ToU) energy tariff and does not require a significant overhaul of existing infrastructure or regulations.

The exception — and a major barrier to accruing flexibility benefits from V1G — is the need for data sharing and interoperability legislation. Yet to be implemented, Article 20a of the Renewable Energy Directive (RED III) will ensure that in-vehicle data is made available to any third-party stakeholder, subject to driver consent. Without free and fair access to data, smart charging for flexibility services cannot be fully adopted.

> "The general perception is that V2G is the ultimate solution to address grid balancing challenges and optimise renewable energy use. But it all starts with what we have available already today — which is unidirectional smart charging — which controls when EVs can charge at maximum possible power and when the charging power should be reduced. V2G is a good next step for further optimisation, and can take off once other fundamentals, such as regulations, tax and surplus renewables capacity, and multi-layer grid capacity improvements have matured and are properly in place.
>
> **Suthalan Gnanes**
> Managing Director, GreenFlux

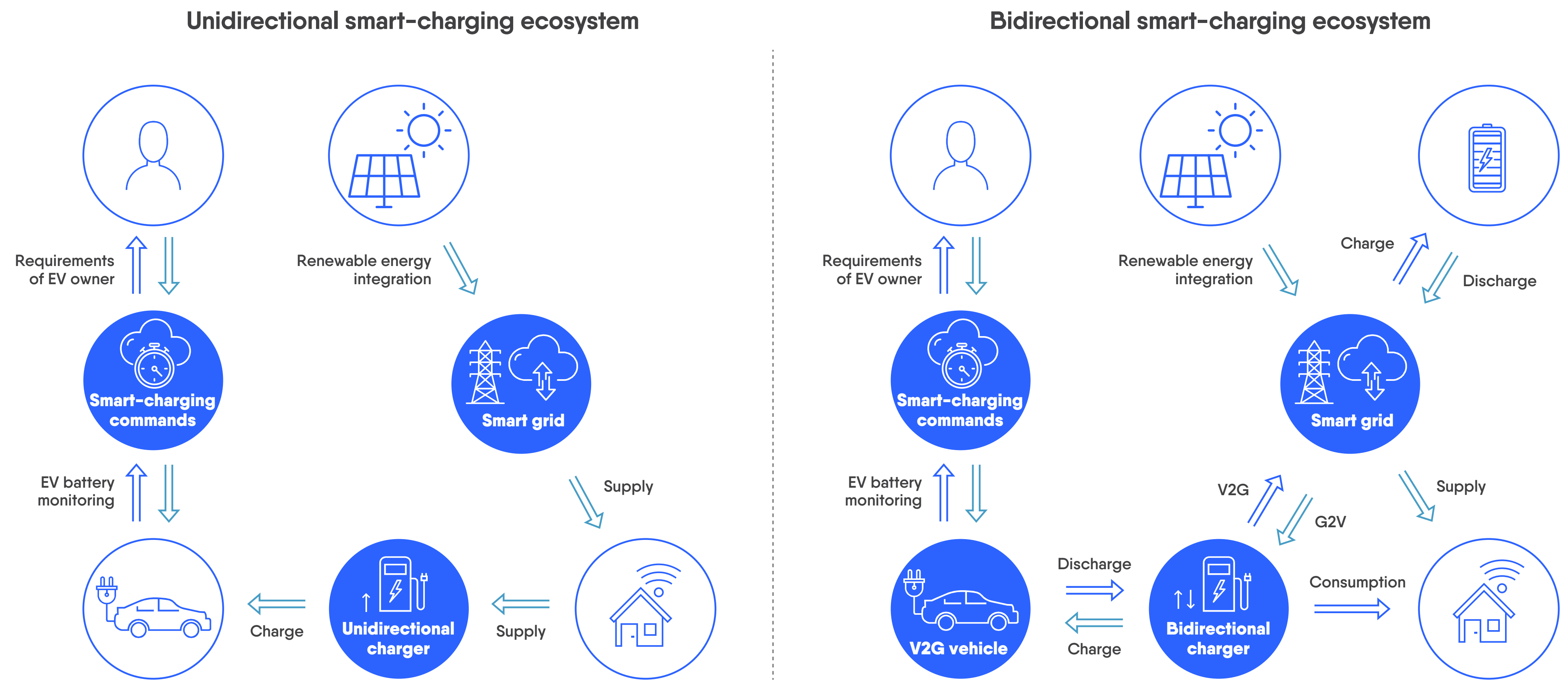
Vehicle-to-grid: local response to local energy problems

Fast-forward a few years from now. Current data-sharing and interoperability limitations for V1G have been addressed. Specialised bidirectional chargers and a remote management system allow power to flow in two directions. It will go from the grid to the vehicle and back again (this is known as vehicle-to-grid (V2G)) or directly from the vehicle battery to the home (vehicle-to-home (V2H)), reducing energy bills and increasing user self-sufficiency.

Of course, the success of V2G depends on having sufficient bidirectional-enabled EVs on the road. The technology, which is already being piloted in some countries, is demonstrating real potential. Ultimately, it can enable thousands of EVs to work in unison as a large, distributed energy system, providing valuable flexibility services to the power grid.

Bidirectional power flow is inherently more complex than V1G. But get it right, and V2G could stabilise the grid by effectively reducing peaks in electricity demand at the grid level and lowering electricity costs for vehicle users.

Smart-charging ecosystem



Source: EY Insights.

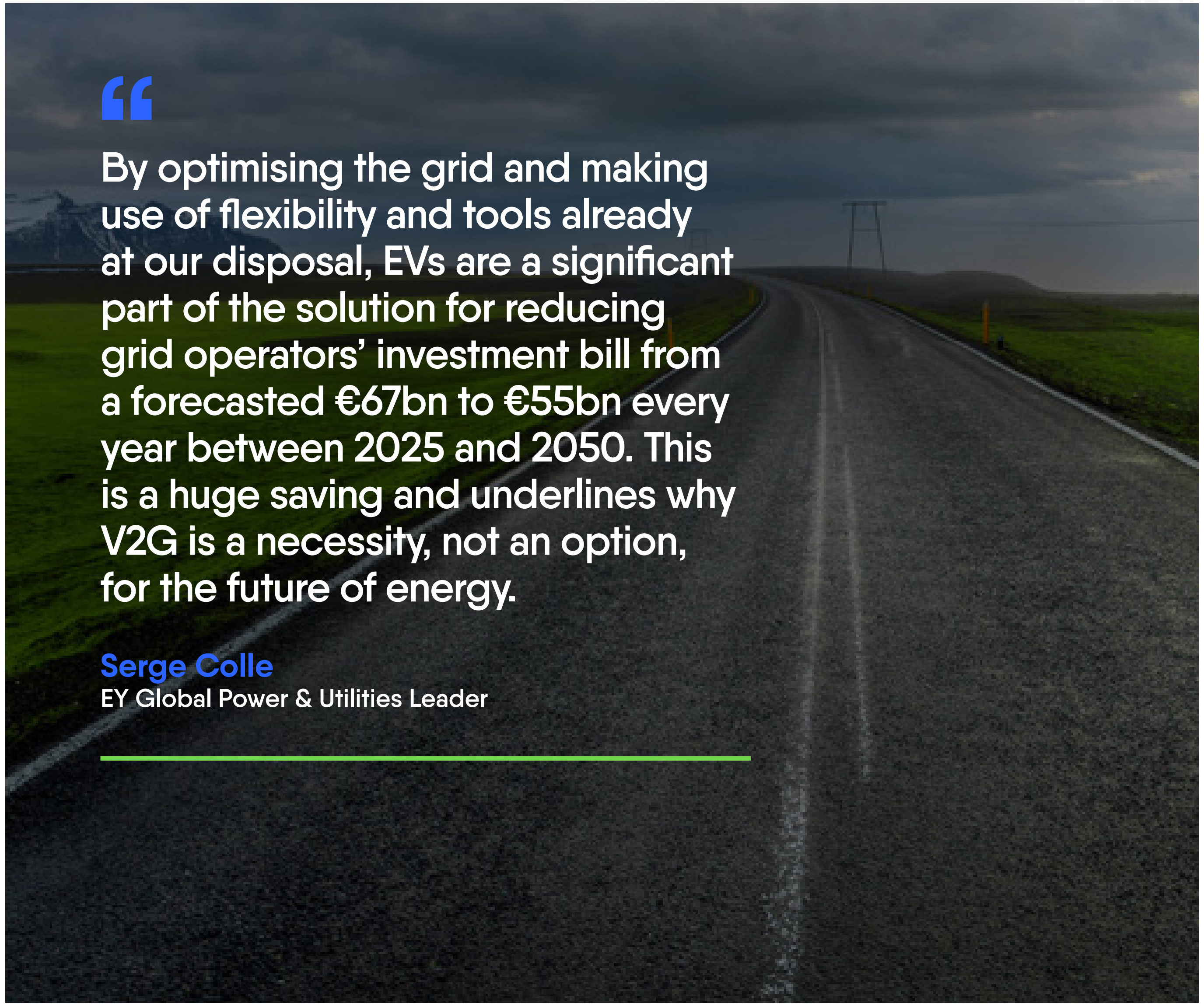
In 2024, annual EV sales reached 22.7% of total vehicle sales in Europe. As we move closer to 2035, the de facto ban on the sale of new petrol and diesel vehicles will come into effect in some jurisdictions, creating even greater momentum around EV uptake. In local communities, the number of EVs will be largely commensurate with the number of dwellings. V2G could allow vehicles to plug and charge in their neighbourhoods, and also discharge, creating a relevant and available flexibility resource to balance the local network.

From an energy system perspective, V2G could allow EVs to perform as decentralised energy storage units. Effectively, given the variable output of wind and solar, EV batteries become buffers, holding renewable energy until it is needed by the grid.

Of course, there are unresolved challenges, not least the lack of a standardised open interface or connection between the vehicle, the charger and the grid. The current scarcity of V2G-enabled EVs and chargers, and the inability to synchronise precisely all V2G-enabled vehicles to provide grid services, such as frequency regulation, present obstacles. An abundance of tax and regulatory hurdles, as well as the need for driver consent, further hinder V2G rollout.

On balance, however, whether using V1G or V2G, smart charging offers a compelling economic justification. As identified in Eurelectric's 2024 Grids for Speed study, making use of flexibility from available assets could contribute to a projected €4bn in savings every year for European grid operators. Combined with optimising the grid and anticipatory investments, flexibility can be considered part of a set of strategies to lower the overall grid investment cost from an anticipated €67bn to €55bn annually between 2025 and 2050.[1]

This, we believe, makes V1G and V2G not so much options but necessities. They have the potential to deliver among the most affordable, scalable and flexible solutions to localised energy needs, while driving down the price tag for network investment to some degree. They turn EVs into integral components of the energy solution, rather than stranded assets sitting idle whenever they're not being driven.

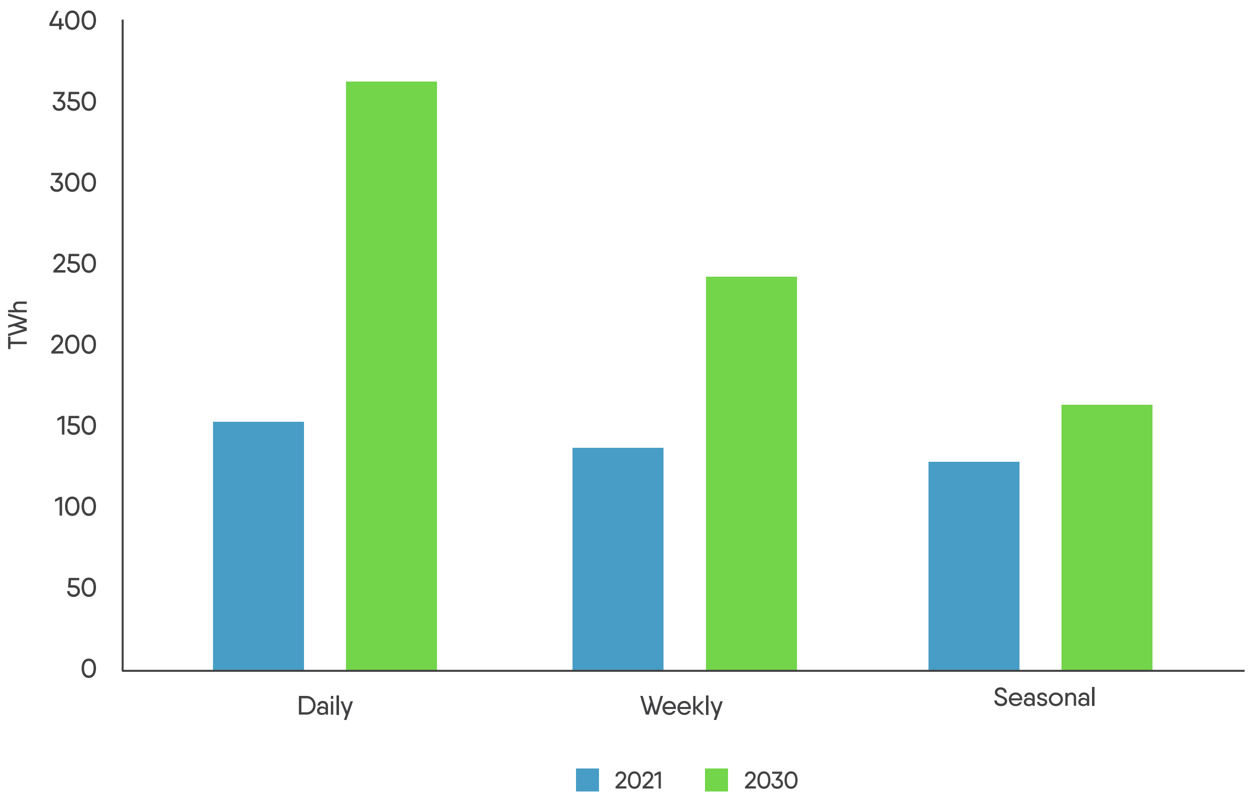


"By optimising the grid and making use of flexibility and tools already at our disposal, EVs are a significant part of the solution for reducing grid operators' investment bill from a forecasted €67bn to €55bn every year between 2025 and 2050. This is a huge saving and underlines why V2G is a necessity, not an option, for the future of energy.

Serge Colle
EY Global Power & Utilities Leader

[1] "Grids for Speed," Eurelectric website, accessed 16 January 2025.

Europe's growing flexibility needs, 2021 vs. 2030



Source: "Flexibility solutions to support a decarbonised and secure EU electricity system," EEA/ACER Report, September 2023.

Pressure on the grid

- In the past 40 years, electricity demand has grown by **500 TWh** to **2,500 TWh**.
- Over the next 25 years, the rate of change will be four times faster, with electricity demand anticipated to top **4,500 TWh** by **2050**.

"At E-REDES we are testing the potential of local flexibility markets. In this business model, EVs will have a valuable role as they benefit from having a flexible load profile while being well distributed across the grid.

João Rafael
Senior Project Manager, E-REDES

Flexibility value propositions: the winners

If flexibility from EVs is to scale and enter the mainstream, the value proposition must deliver across the entire ecosystem.

Consumers to participate in flexibility

Smart charging allows consumers, who sit at the heart of the energy transition, to participate directly in providing flexibility. They can play an active role in relieving grid congestion, which lowers, in turn, the cost of electricity and increases reliability and security for users. However, EV drivers who agree to participate must be able to trust the companies to which they provide flexibility and be rewarded for their contribution.

Equally important is the need for relevant and easy-to-use smart-charging propositions, with clear benefits for consumers to maximise engagement and adoption. For drivers to consider their EVs as both a source of mobility and a potential financial asset, companies must explain how they can turn ToU and smart energy tariffs to their advantage. They should demonstrate how consumers can save money by charging when prices are low and make money by selling energy back to the grid.

The economics of EV ownership will also improve where flexibility from unidirectional smart charging and V2G is optimised. Total cost of ownership (TCO) includes the cost of the vehicle, energy, tax, maintenance and insurance. Savings will vary by country and the electricity tariffs available. They will be informed by solar photovoltaic (PV) ownership, vehicle battery size, distance travelled and frequency of charge.

On a TCO basis, when the vehicle is optimally charged and benefits from V2G, EY estimates that the owner of a compact EV in the UK can save up to 19% (€1,270) annually compared with the cost of an internal combustion engine (ICE).[2] In the large or sports utility vehicle (SUV) segment, the annual saving can be as much as 26% (€2,460).

In Germany, Sweden and Spain, the TCO for a small vehicle could be reduced by as much as 14%. In France and the Netherlands, savings of 8% and 9% respectively may be realised.

Grid operators to secure benefits from avoided curtailment

V2G will provide significant day-to-day benefits for grid operators, but only if they can implement smart control, and actively control and optimise electricity consumption and charging to make best use of grid integration.

Currently, the EU power grid is congested in many constituencies. Grid congestion occurs when the transmission capacity of the power grid is insufficient to meet demand. This is mainly driven by the rapid increase in decentralised generated energy, such as solar and wind. These sources of renewable energy, often generated by households and businesses, feed energy back into the grid, contributing to fluctuations and spikes that are difficult to manage.

The EU Agency for the Cooperation of Energy Regulators (ACER) Market Monitoring Report shows that the need for congestion management jumped 14.5% in 2023, driving up system costs. It estimates that the costs of managing congestion in the EU power grid exceeded €4 billion, with 60% of these costs borne by the German system.[3]

Increasingly, congestion management results in renewable energy being curtailed. In most EU Member States, this often means that fossil fuel generation fills the gap. A more effective way to manage grid congestion is to smartly manage energy assets. This requires intelligent use of available energy resources, energy storage and programmes to encourage or reward consumers for matching their energy usage to grid availability. Given the vastness of the grid, and the numbers of EVs that already and will ultimately connect to it, flexibility could become one of the cheapest and most effective ways to resolve localised congestion, avoiding curtailment.

The potential is huge. In terms of avoided curtailment of renewables, EVs could, in theory, contribute 4% of Europe's annual power supply by 2030. Estimated at 114 TWh battery capacity, it is enough to power 30 million homes every year. And, by 2040, that potential becomes even more significant, as V2G could store more than 10% of Europe's overall power needs and reinject when needed.[4]

[2] See appendix for methodology.
[3] "Transmission capacities for cross-zonal trade of electricity and congestion management in the EU 2024 Market Monitoring Report," ACER, 3 July 2024.
[4] EY modelling suggests that, by 2040, the potential becomes 10%.

Other market participants are also integral to a functioning flexibility system and are poised to accrue significant value from participation:

- **Charge point operators (CPOs)** could benefit from new revenue streams by operating their portfolios of public charging points to provide flexibility services to grid operators. Services might include V1G overnight charging on the alternate current (AC) or fast-balancing services for high-power charging (HPC). By offering attractive pricing plans to EV owners willing to participate in smart-charging programmes, such as V1G or V2G, CPOs could also increase customer loyalty and market share.
- **Fleet operators** may turn their plugged-in vehicles into revenue generators by enrolling in smart-charging programmes. By undertaking wholesale arbitrage and providing grid-balancing services, with V2G specifically, they can reduce their own operating costs, improve energy efficiency and benefit from better energy management. In fact, studies suggest that EV bus fleets could reduce their charging costs, a primary component of their operating expenditure, by more than 90% with V2G.[5]
- **Other third parties (including providers of energy management systems, automakers, energy suppliers, retailers and independent aggregators)**, if they acquire the right skill sets, might shift their business models to include monetising charging and flexibility services.

Monetising smart charging

Smart charging, including V2G, is critical for balancing energy supply and demand. It should drive down total system costs and, with the right framework, avoid the need for some network investments. However, flexibility must be monetisable. Flexibility markets and better pricing must reward providers and support trade in the commodity. But first, several mechanisms must be in place:

- Smart-charging data interoperability and information sharing between the vehicle, the distribution system operator (DSO) and CPO or aggregator, and standardised communication protocols to link all participants within the ecosystem
- Appropriate investment and regulation, on both the demand and supply sides, to effectively manage flexibility output from weather-dependent resources, such as wind and solar
- Scaled flexibility solutions that adjust electricity supply or demand in response to changing conditions
- Price signals to prompt EV drivers to charge or discharge, relieving congestion on local networks
- The establishment of effective local flexibility markets for DSOs to procure flexibility to avoid network congestion and improve network asset utilisation
- The removal of regulatory hurdles, such as double taxation, for mobile and stationary storage
- The implementation of pending technical standards, such as ISO 15118-20, in vehicles and charging infrastructure, and increased availability of interoperable vehicles and charging infrastructure for bidirectional charging
- Market rules for market participation, enabling DSOs to compensate users for helping to balance the grid with V2G

[5] "A comparative analysis of charging strategies for battery electric buses in wholesale electricity and ancillary services markets," ScienceDirect website, April 2023.

Urgency to turn EVs into flexibility assets

Swift action is needed. By 2030, 15% of vehicles on Europe's roads will be EVs.[6] If EVs continue to charge at will, in an unmanaged way, there will be implications not only for a functioning power grid but also for EV drivers and all stakeholders within the ecosystem.

However, the ubiquitousness of EVs also makes them part of the energy solution. Insights from CPOs in this study reveal that EVs are stationary, on average, 23 hours every day. It means they are huge and available assets for the entire energy system, effectively becoming batteries on wheels. By getting consumers on board with flexibility, and rewarding them appropriately, we will have an abundance of EVs ready to be connected to the grid, able to participate in managed charging and deliver flexibility solutions to local energy needs.

Flexibility, properly managed, will support confidence in both the energy and mobility systems. Supported by a relevant technical and regulatory framework, flexibility could deliver whenever and wherever it is needed, with defined and simple market rules, clear signals and economic incentives that encourage participation.

> "We need a functioning market, with lots of connected customers and assets, to create trust in flexibility. The thing about EV batteries is that the customer is in charge; enabling their participation and engagement is therefore key to success.
>
> **Martin Olin**
> Head of e-Mobility, Swedenergy

Inevitably, using vehicle battery assets as a source of flexibility will bring challenges as well as opportunities. However, our conversations with industry leaders have allowed us to identify six prerequisites, which we explore in this study. They must be in place to unlock value from EVs as flexibility assets and support commercialisation.

For players bold enough to participate, the real value — environmental, social, financial and commercial — sits at the intersection where the electricity grid and e-mobility meet.

Six prerequisites to unlock flexibility from EV

1. Customer acceptance
2. Economic viability
3. Customer segmentation
4. System planning
5. Data, visibility and market integration
6. Simple and accessible managed charging

[6] EY Mobility Lens Forecaster. Assumptions based on cumulative EV sales as a percentage of the total vehicle stock in Europe.

About this report

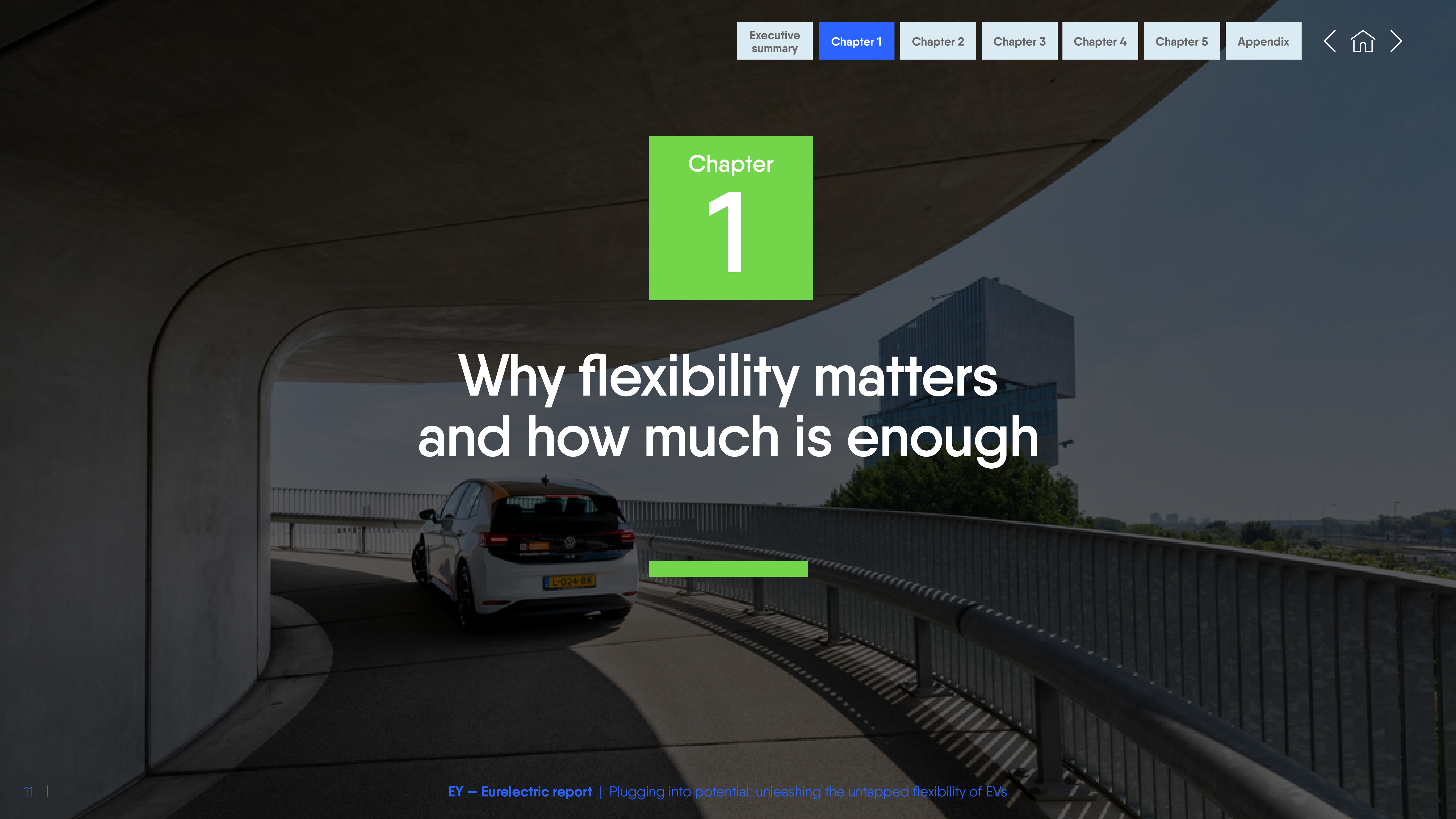
This report delves into the EV flexibility value proposition. It explores the reasons why we must unlock the flexibility potential in EV batteries as part of a wider strategy to decarbonise energy systems.

It considers how the current EV ecosystem is set up to administer flexibility, the roles of key players, the importance of regulation, and the need to overcome technical and economic barriers and societal resistance. As the transition to EVs gathers pace, in parallel with unprecedented changes to our energy system, we must build the foundations for a flexible, intelligent and digital grid that enables consumer participation.

Curated by EY professionals with extensive experience in the energy, automotive, government and technology sectors, this study is based on interviews with automakers, CPOs, flexibility providers, energy retailers, DSOs and industry bodies. It draws on the insights of professionals at the European energy industry body Eurelectric and its members.

With thanks to Ampeco, BDEW, EDP, E-Redes, ElaadNL, EnBW, Enel X, ENGIE, E.ON, EV Belgium, FEBEG, GLP, GreenFlux, Ignitis, Motus-E, PPC, Schneider Electric, Spirii, Swedenergy, Volvo Energy and Volvo Cars.

For the purposes of this study, Europe denotes the EU 27, plus Norway, Switzerland and the UK.



Chapter
1

Why flexibility matters and how much is enough

Today, the electricity system meets flexibility needs mainly through fossil-based dispatchable electricity generation in most EU Member States. Our need for energy flexibility stems largely from the variability inherent in the shift to a decentralised, renewables-based power system. Over the next decade, however, the biggest driver of flexibility demand will be the sheer speed and scale of electrification.

Within five years, just to keep up with changing electricity supply and demand, Europe will need more than double today's flexibility resources. Compared with 2021, demand for flexibility will increase sharply, up 2.4-fold on a daily basis (from 153 TWh), 1.8-fold on a weekly basis (from 137 TWh) and 1.3-fold on a seasonal basis (from 132 TWh).[7,8] From 2030 to 2050, the need for flexibility is projected to triple.[9]

What do we mean by flexibility?

Flexibility denotes the energy system's ability to adjust energy supply, demand or storage in real time to balance the grid.

Flexibility keeps the system stable and functioning, despite fluctuations in renewables supply or changes in demand.

Massive escalation in electricity demand

To meet the European Commission's goal of a 90% reduction in carbon dioxide (CO_2) emissions by 2040, electrification, as a percentage of energy consumption, must increase from 23% today to 50% within the next 15 years.[10]

To put it into perspective, in the next 25 years, electricity demand in Europe will increase four times faster than in the previous 40 years, taking it to more than 4,500 TWh.

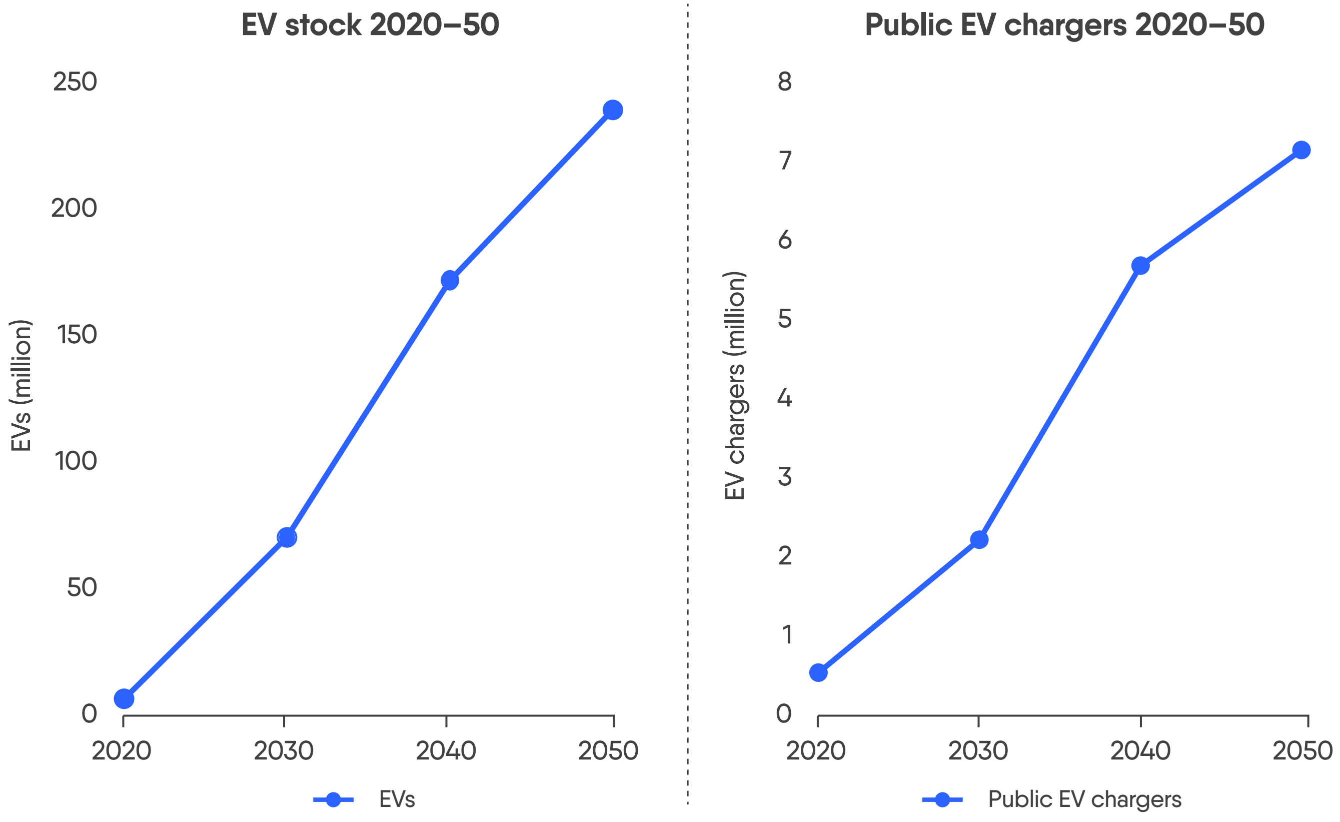
Whether end-use electrification comes from EVs and their chargers, heat pumps, data centres or industrial electrification, it is expected to add significantly to the load currently on our grids today.

In 2023, the electric light-duty market, which includes passenger cars and small delivery vans and commercial vehicles, saw 3.2 million new vehicles take to the road.[11] In 2024, the market continued to grow, albeit at a slower pace than in previous years, with European battery and plug-in hybrid EV sales hitting 3.1 million.

Though European sales have slowed, supportive regulatory policies are easing supply-demand economics. And this should position the market for a rebound. While there has been a 20% surge in demand for hybrids in 2024, it is still expected that EVs will make up 50% of sales in Europe by 2030, two years later than previously projected.[12] By 2050, EVs will reach approximately 250 million — roughly 20 times up on today. At the same time, seven million public EV chargers are anticipated, a near 60-fold increase.[13]

[7] "Flexibility solutions to support a decarbonised and secure EU electricity system," EEA/ACER Report, September 2023.
[8] Daily flexibility: morning and evening demand peaks and day-night generation difference. Weekly flexibility: weekday-weekend demand difference and wind pattern fluctuations. Seasonal flexibility: heating-cooling periods and seasonal weather patterns.
[9] "Flexibility requirements and the role of storage in future European power systems," JRC Publications Repository, European Commission website, 14 March 2023.
[10] "Decarbonisation Speedways," Eurelectric, 20 June 2023.
[11] "How is Europe's EV slowdown affecting its market forecast?," EV Volumes website, 25 June 2024.
[12] "How to retake the momentum in the EV transition," EY website, accessed 16 January 2025.
[13] "Decarbonisation Speedways," Eurelectric, 20 June 2023.

European EV and public EV chargers outlook 2020–50



Source: EY Insights analysis of "Decarbonisation Speedways," Eurelectric, 20 June 2023.

How many public chargers are there?

By the fourth quarter of 2024, there were, according to the European Alternative Fuels Observatory, 821,773 public charging points in Europe serving 10 million EVs, up 30% compared with 2023. Over 15% of all charging points offer fast-charging capabilities, meaning they can deliver power above 22 kW. But the pace of charging infrastructure rollout must be accelerated in some EU Member States. Getting to the European Commission's 3.5 million target by 2030 means 450,000 new charging points must be installed each year, the equivalent of 8,600 every week.

Source: "Infrastructure 2024," European Commission, accessed 16 January 2025.

Slower to get off the mark, but making progress, is the electrification of Europe's light-medium and heavy-duty trucks. At the end of 2023, electric medium-duty trucks represented 7% of the overall e-mobility market, rising to 8.3% in the first nine months of 2024. In the heavy-duty electric trucks market, above 16 tonnes gross vehicle weight, new electric sales have increased from 1% in 2023 to 1.3% by the end of October 2024.

But the pace of vehicle adoption must accelerate too. In February 2024, the European Commission increased its target emissions reductions for heavy-duty commercial vehicles. In 2030, levels must be 45% lower than in 2019, rising to a 65% reduction in 2035 and a 90% reduction in 2040.[14]

National strategy frameworks, which implement EU regulations on the bloc's expansion of charging and hydrogen infrastructure, also support the trucking sector with the rollout of fast chargers to reduce charging times.

[14] "Heavy-duty vehicles: Council signs off on stricter CO2 emission standards," European Council website, 13 May 2024.

Grid flexibility is key to managing surge in renewables

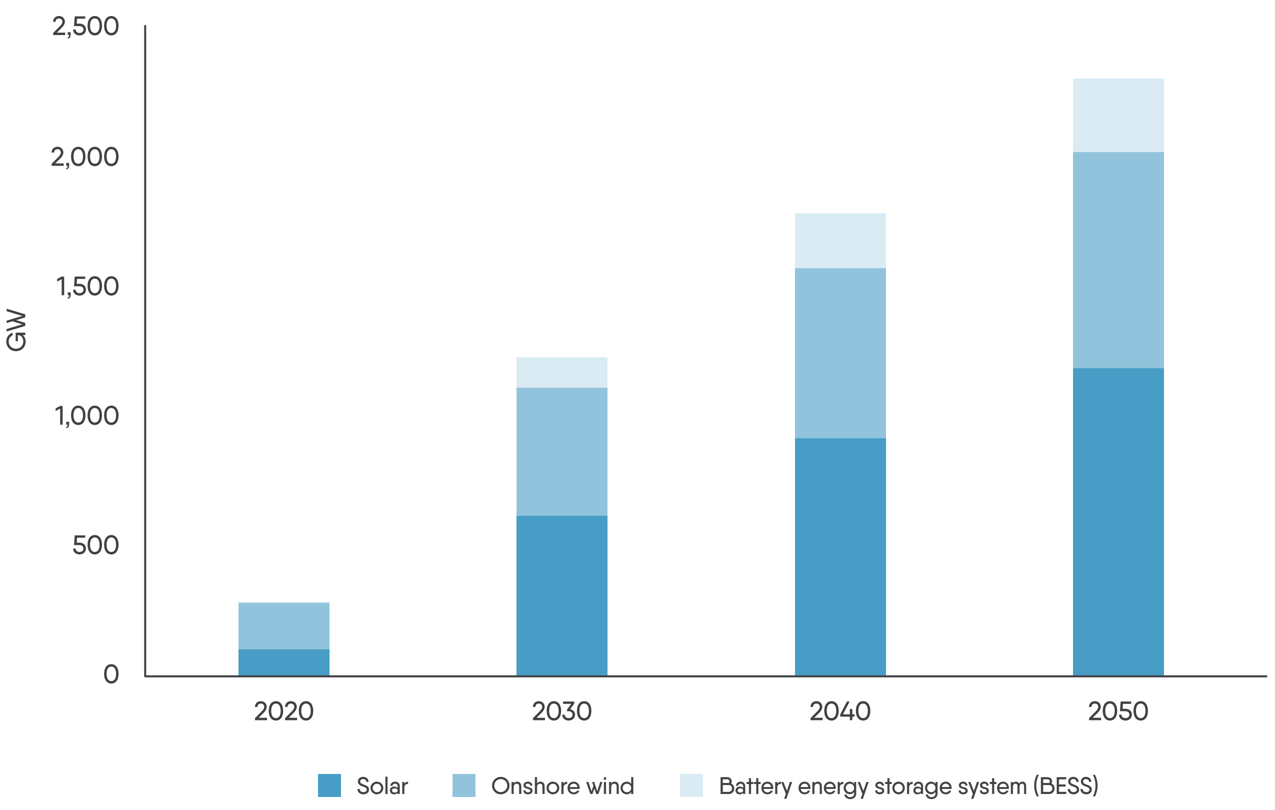
As electricity demand surges, renewables and low-carbon resources will mainly bridge the supply gap. However, the inherent variability of wind and solar makes it challenging to maintain consistent and reliable supply. To secure output, backup systems, storage, significant over-instalment of excess capacity or flexibility solutions are needed.

Today, renewables, including hydropower, make up 45% of electricity production in Europe. In the past five years, solar PV capacity has jumped from 127 GW to 301 GW, while wind power capacity has grown from 188 GW to 279 GW in the same period.[15]

Wind and solar now make up, on average, 27% of electricity production in Europe, overtaking gas for the first time. Nine countries already operate above the European average. The European Union's REPowerEU plan, which aims to reduce dependence on Russian fossil fuels, targets 72% power from renewable sources by 2030, with wind and solar more than doubling to over 50%. In practice, this would require variable renewable generation to increase by an average 111 TWh every year — double the average annual growth (+56 TWh per year) recorded between 2010 and 2023.[16]

Around 70% of future renewable generation and electricity storage will be connected to the distribution grid. Distributed renewable capacity in Europe will grow nearly six-fold between 2020 and 2050.[17] This represents a massive increase in variable capacity.

Renewable energy capacity in the EU, 2020–50



Source: "Decarbonisation Speedways," Eurelectric, 20 June 2023.

[15] "European Electricity Review 2024," Ember website, accessed 16 January 2025.
[16] EY analysis of data from bp, the IEA and Ember.
[17] "Grids for Speed," Eurelectric website, accessed 16 January 2025.

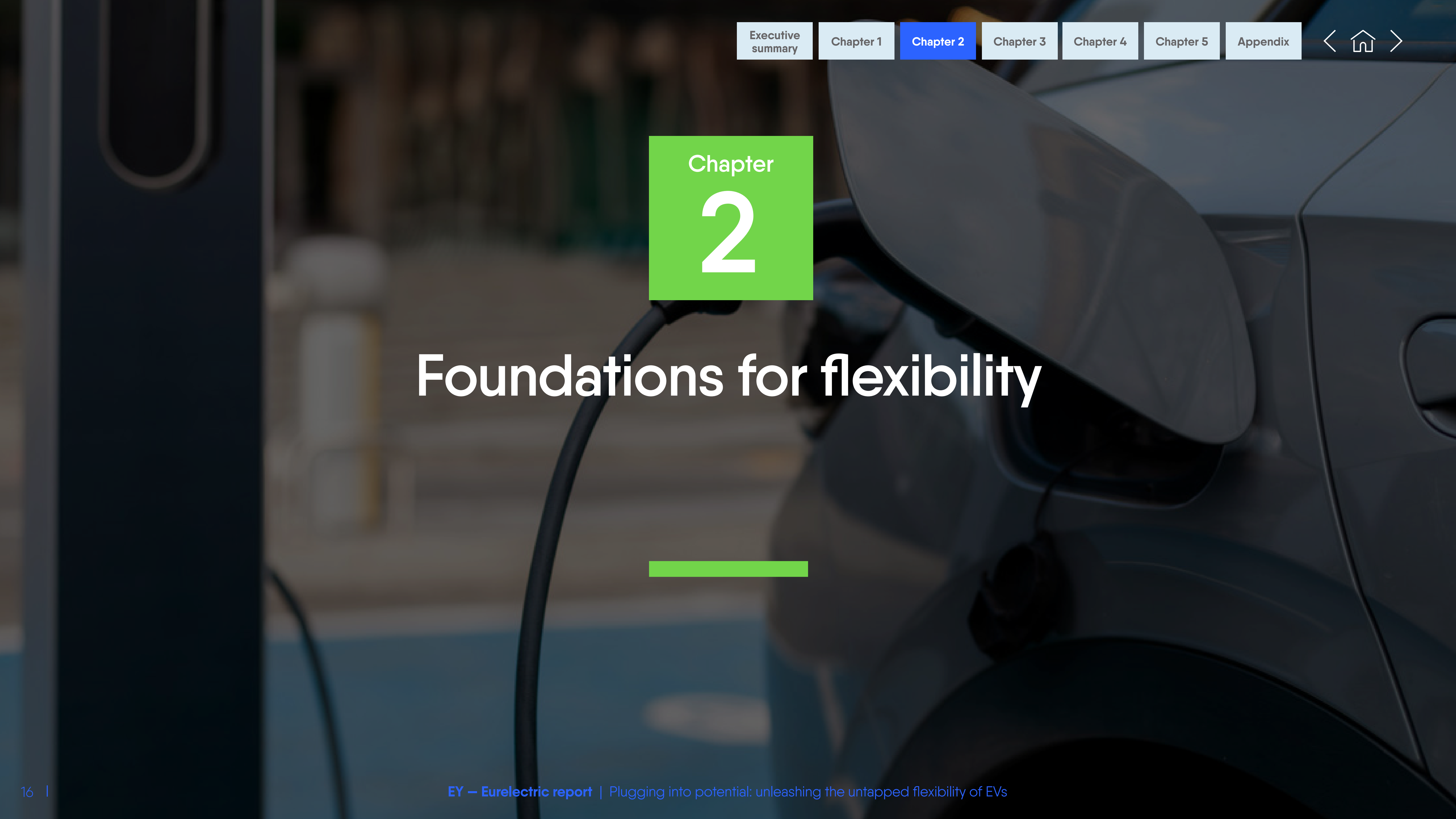
As the penetration of renewable energy increases, generation will not always align with consumption patterns. Currently, without widespread battery energy storage systems, the grid can neither absorb nor store excess power. It means system operators must resort to curtailment to reduce or restrict energy production. Not only is this a potential waste of clean and cheaper energy but it also undermines the investment case for new renewable energy projects, especially if prices turn negative.

Negative pricing, a signal of low demand and surplus generation, is becoming more commonplace, particularly in regions with plentiful wind and solar. In the first eight months of 2024, Europe reported 7,841 negative price hours, up more than 160% on 2023, with prices dropping below minus €20/MWh in some instances.[18, 19] Negative prices were registered in nearly every European electricity market. In the UK, negative price hours jumped 40% in 2024 to 149 hours, with forecasts of 1,000 hours by 2027. This is driven by growth in subsidised, price-insensitive generation capacity, such as nuclear and rooftop solar, combined with low demand.[20]

But it is also symptomatic of markets that have underinvested in grid infrastructure, and those where conventional power stations cannot respond to variable generation and flexible load. Delays in constructing storage technologies, along with market design and regulations that fail to keep pace with renewable deployment, also contribute to negative energy pricing.

Given these actual and impending scenarios, the case for flexibility and the need for real-time adjustments in energy supply, demand and storage become more acute across Europe. Workable solutions must be found and deployed as the speed and scale of electrification increases.

[18] "Negative European energy prices hit record level," Financial Times website, accessed 16 January 2025.
[19] "Power Barometer 2024" Eurelectric website, accessed 16 January 2025.
[20] "Negative prices: Why do they happen and why will they continue to grow?," Modoenergy website, 18 September 2024.

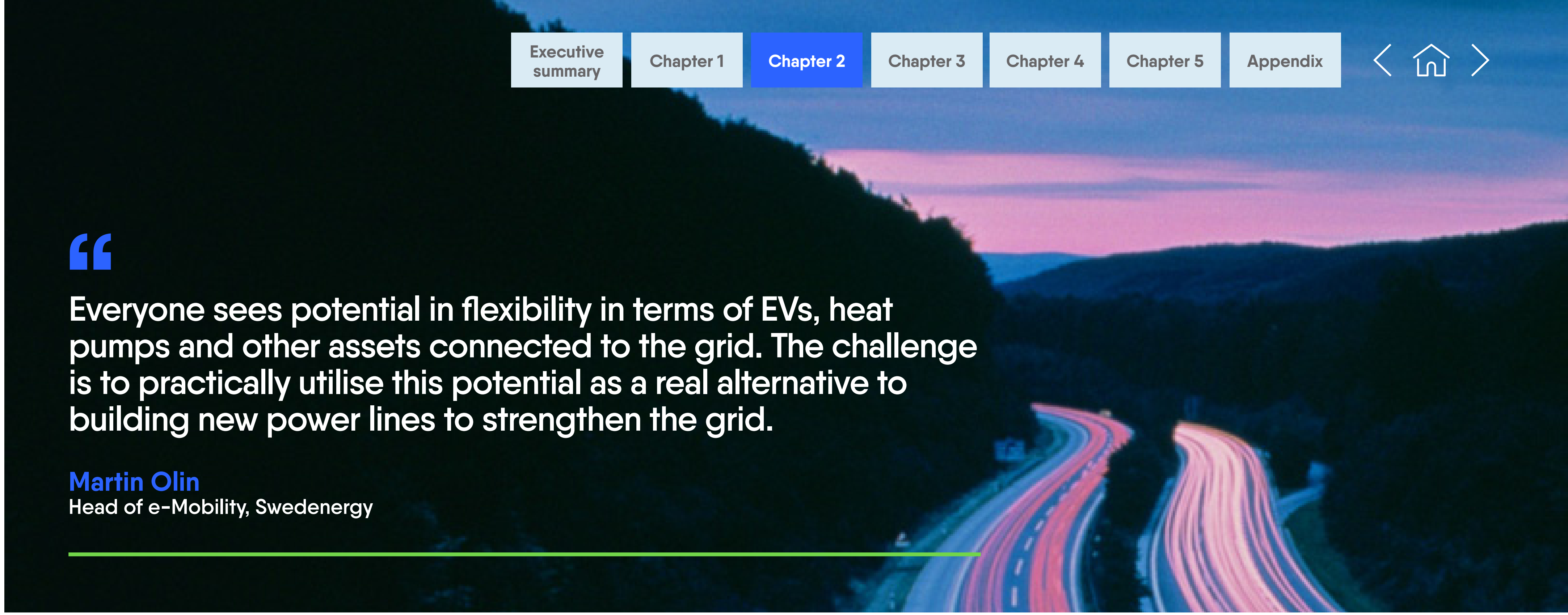


Chapter
2

Foundations for flexibility

As more variable renewables come online, and as demand for electricity escalates, bigger challenges emerge for grid operations. Reliance on conventional interconnections between regions for the transfer of electricity may no longer be sufficient to maintain grid stability and security of supply. The need for widespread storage and grid-balancing capabilities becomes more urgent.

This is where flexibility and smart-charging solutions, such as V1G, and V2G in particular, could compensate. Flexibility spreads energy demand over time and across locations, reducing stress on the grid. It has scope to delay or mitigate the need for investment in grid reinforcement, which Eurelectric's Grids for Speed study[21] estimates at €67bn per year from 2025 to 2050.



> **Everyone sees potential in flexibility in terms of EVs, heat pumps and other assets connected to the grid. The challenge is to practically utilise this potential as a real alternative to building new power lines to strengthen the grid.**
>
> **Martin Olin**
> Head of e-Mobility, Swedenergy

Market conditions are ideal, right now, for the development of smart grids to enable and support flexibility. Vast improvements in communications means that complex multidirectional power flows can be monitored and balanced across decentralised systems. Digitisation of energy interactions, and advances in data interoperability, provide insights into when, where and why energy is used.

The vision is to deliver flexibility anywhere within the electricity system, whenever it is needed, enabling real-time balancing of energy supply and demand.

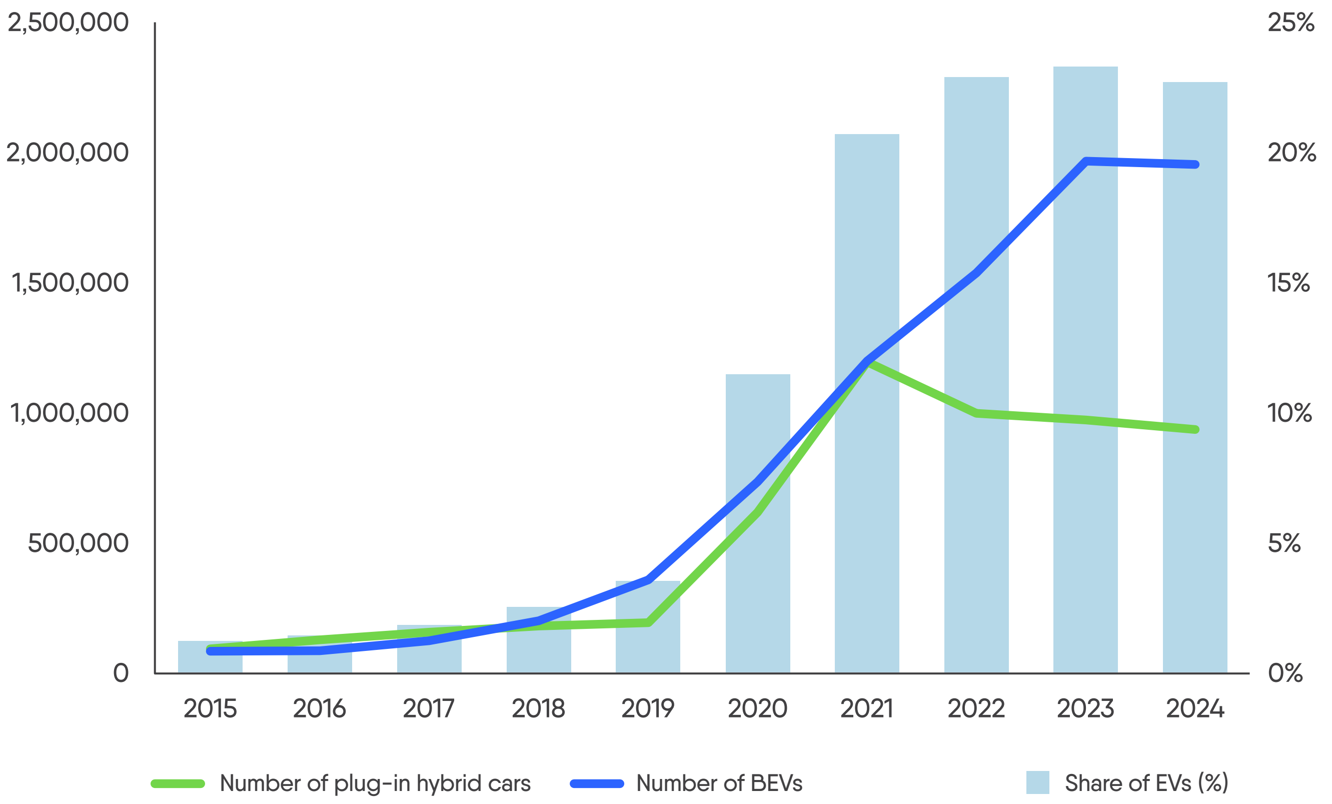
For flexibility to become a mainstream solution to balancing the grid, value propositions must deliver commercially, socially and environmentally right across the e-mobility ecosystem. For the purposes of this study, we consider the value of flexibility in the context of both the consumer and the grid.

Value proposition: the consumer

The slowdown in the growth of EV sales in 2024 is a reminder that the value proposition must be right to persuade consumers to make the transition away from ICE vehicles. Overall, EVs accounted for 22.7% of new car registrations and 8% of new van registrations in Europe in 2024. In total, 2.94 million new electric cars were registered, marginally down from 2.98 million in 2023.[22]

[21] "Grids for Speed," Eurelectric website, accessed 16 January 2025.
[22] "New car registrations European Union," Press release, ACEA website, 21 January 2025.

New registrations of electric cars, Europe, 2015–24



Source: EY Insights analysis of data from https://www.acea.auto/.

Though the pace of growth has slowed as we enter mass-market adoption, our analysis reveals that buyer interest in EVs remains high — 58% of car buyers say they intend to buy a fully electric, plug-in hybrid or hybrid vehicle rather than an ICE alternative within the next 12 months.[23]

The reality is that EV sales are now at a transition point. Sales to more affluent, early adopter enthusiasts have peaked. In 2023, 70% of global BEV sales were within the large and premium car segments.

For the time being, sales to more mainstream consumers, constrained by budgets and affordability, are yet to take off. Some traditional automakers have been slow to recognise that the next phase of growth will be driven by consumers who want affordable prices and value. They want more choice of EV models; they want smaller passenger cars and premium features.

> **The price gap between EVs and ICE vehicles in the higher-value segments is narrowing. But in the lower segments, the price differential is as much as €10,000. Some EVs are almost double the cost of ICE alternatives. That's a major obstacle to take-up.**
>
> **Dr. Jan Strobel**
> **Head of Regulation, Market Communication and Mobility, BDEW**

Though upfront cost is a very real barrier to buying an EV, reduced operating costs from smart charging at home, or at the workplace, could make a robust long-term economic case for EV adoption.

The simple value proposition is that EV drivers can save money by charging during off-peak hours when electricity rates are lower. By optimising EV charging, customers can gain greater control over their energy usage and costs.

[23] "How to retake the momentum in the EV transition," EY website, 9 September 2024.

Analysis: how to save money by EV charging at home

Though the price of an EV may seem high today compared with ICE alternatives, it is important to consider not just the initial purchase price but also the running costs, including the cost of electricity or fuel over the vehicle's lifetime. Our analysis reveals that by optimising the time of charge and selling energy back to the grid, the TCO of EVs can be lowered significantly.

To illustrate the cost benefits to consumers, we explored annual and lifetime costs for owning and charging an EV at home in France, Germany, the Netherlands, Spain, Sweden and the UK. We also identified ways to reduce costs by shifting charging times with ToU tariffs (V1G) and selling energy back to the grid with V2G.

For this calculation, we make assumptions about vehicle type, purchase price, battery size, annual distance travelled and charging behaviour, with variations by country.

We also consider variances in retail electricity prices over time and different tariff structures available in the countries.

A straightforward TCO analysis compares the total running costs for two typical vehicle owners: one with an EV and one with an equivalent ICE vehicle.

Our analysis finds that, despite the increase in electricity demand that comes with EV ownership, the owner of a compact EV will make savings. This ranges from an average 2% (€101) in Spain to 5% (€347) in the UK, off the annual cost of the vehicle.[24]

In the family car segment, the savings are greater. In the UK, the average annual saving is approximately 6%, equivalent to €485 per year. In Germany, the saving is 11%, or €850 per year. In the Netherlands, the saving can be as high as 16%, or €1,375 per year. These increased savings denote the difference between the battery size of the family car compared with the compact segment, the greater distance travelled on a single charge, reduced road taxes and fuel expenses, versus fuel for the ICE vehicle.

Consumers can achieve further cost savings by timing when and how they charge their EVs.

Off-peak charging: By simply shifting charging from expensive peak hours (early evenings) to low-price periods (10:00 p.m. to 8:00 a.m.), the average EV owner of a compact car can save a further €21 (the Netherlands) to €99 (the UK) each year off their home energy bill. In the family vehicle segment, savings are on average between €100 to €150 per year, and €110 to €190 per year in the large or SUV vehicle segment.

ToU charging: Savings are amplified under a cost-reflective ToU tariff scenario, where charging is automatically shifted to take advantage of expected market conditions and off-peak prices. Although dynamic ToU tariffs can provide prices that indicate real-time market conditions, Eurelectric's 2021 report found that static ToU tariffs are much better managed by DSOs and better suited for shifting consumer behaviour.[25] Savings in the compact car segment jump a further €30 (France) to €110 (the UK) each year, boosting the TCO of the EV over the ICE equivalent.

V2G charging: By using V2G or V2H and selling energy back to the grid, while also benefitting from a dynamic ToU tariff, the average owner of a compact EV could save between €285 (the Netherlands) to €885 (the UK) each year, rising to €1,760 in the large or SUV segment.

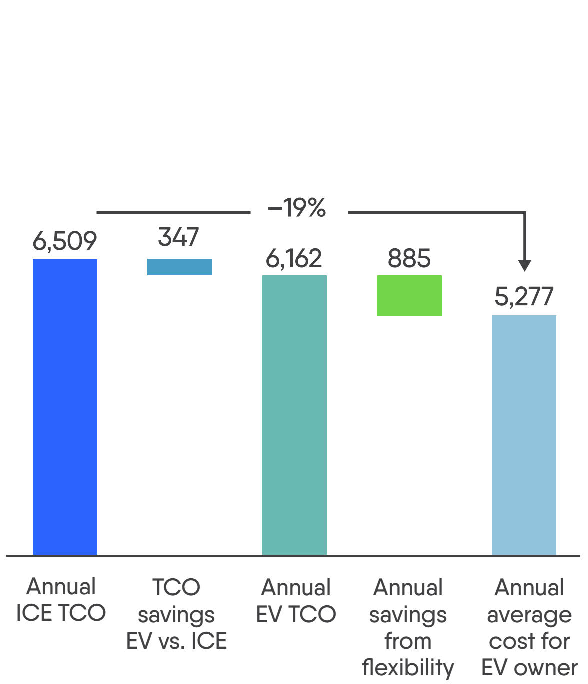
When the total value of flexibility is accounted for in the TCO calculation, an annual 19% (compact) to 26% (large or SUV) total saving over the ICE vehicle equivalent could be realised in the UK. The saving works out at €1,230 to €2,700 a year.

In the Netherlands, the average annual savings could range from 9% (€515) in the compact segment to 26% (€2,700) in the large or SUV segment. In Spain, the annual savings are equivalent to 13% (€780) to 25% (€2,500) and, in Sweden and Germany, 14% (€800) to 29% (€2,900). In France, the average annual savings could range between 7% (€450) in the compact segment to 19% (€1850) in the large or SUV segment.

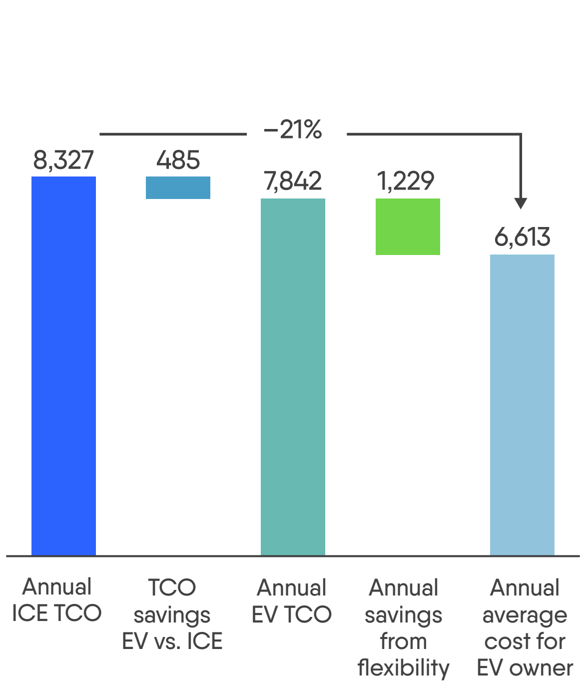
[24] EY Insights based on the cost of electricity to charge an EV or fuel for the ICE vehicle, over the lifetime ownership of the vehicle.
[25] "Powering the Energy Transition Through Efficient Network Tariffs," Eurelectric Report 2021.

Country comparison of annual TCO (€ '000) and savings by vehicle segment and flexibility solution

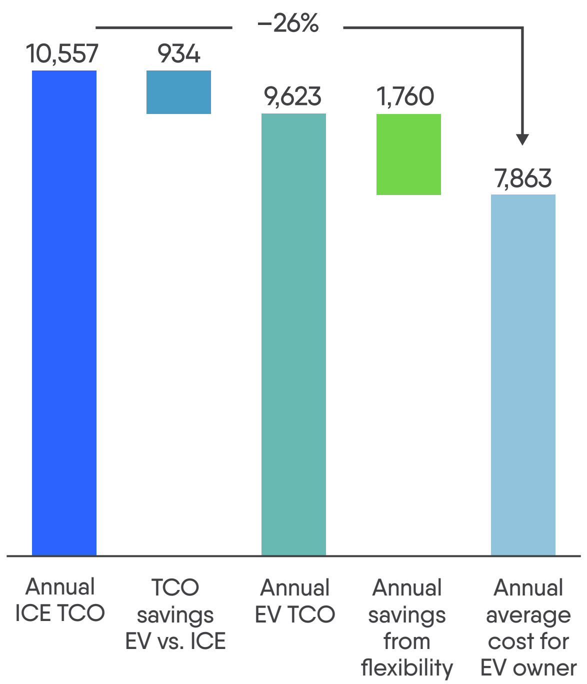
UK compact vehicle segment



UK family vehicle segment



UK large vehicle segment

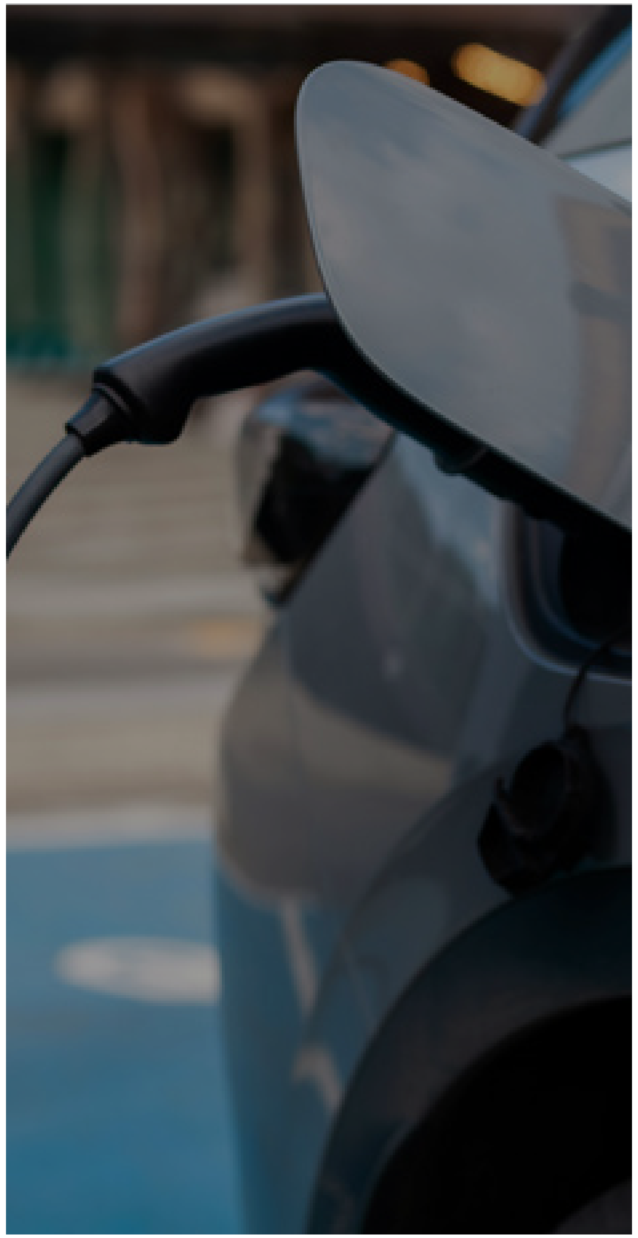


UK market selected as an example comparison.

In (€)	UK			Germany			France			Netherlands			Sweden			Spain		
Annual TCO savings EV vs. ICE	347	485	934	158	852	1,583	152	677	1,105	231	1,375	2,001	303	632	1,793	101	419	945
Annual flex savings	885	1,229	1,760	614	967	1,388	304	525	744	285	499	708	493	790	1,126	675	1,060	1,529
Annual net saving % of ICE TCO	19%	21%	26%	13%	23%	29%	7%	15%	19%	9%	22%	26%	14%	19%	29%	13%	20%	25%

Compact | Family | Large

Source: EY Insights.



Value proposition: the grid

Smart charging is a necessity for the grid. It could deliver one of the largest, most affordable, scalable and flexible solutions to balance the network at the local level and resolve bottlenecks.

It has the potential to mitigate the need for grid investment because EVs already exist. And they are set to become even more abundant due to various factors, not least the de facto ban on new ICE sales from 2035. Recognising that different countries are at different stages of EV maturity, and with the current slowdown in EV sales in favour of hybrids, we expect the total European market to still reach 55 million battery electric and plug-in hybrid vehicles by 2030, rising to 116 million by 2035. These vehicles will be parked in localities where energy demand is created and where variable generation from renewables risks creating congestion.

Though flexibility could be on tap, it requires a connection or open interface between the vehicle, the charger and the grid to enable the bidirectional flow of energy and data. Plugged in, EVs will consume energy when generation is high and prices are low. Under a suitable technical and regulatory framework, and with attractive but simple offers for consumers, EVs could be used to both store energy and send energy back to the grid, when needed, to keep it in balance.

Some studies reveal that up to 6% can be shaved off peak load where proper energy management systems are combined with V2G technology.[26] Eurelectric's Grids For Speed study calculates that by investing ahead to meet future demand, and by optimising the grid and making use of flexibility from available assets, European grid operators could benefit from a projected €4bn saving every year. In fact, flexibility could be considered an inherent part of the solution to reduce operators' anticipated annual €67bn investment bill to €55bn.[27]

Smart-charging solutions shift the time of charge to support the network

Flexibility is enabled by innovations in both charging infrastructure and the vehicle itself to intelligently manage the car battery to benefit the network.

Smart charging delivers demand-side flexibility (DSF) by remotely shifting, interrupting, fluctuating or ramping demand up or down. The aim is to charge EVs at the optimal time, from the perspective of the EV driver, the CPO or the grid operator. The EV responds to price signals from wholesale markets to schedule charging when:

- Electricity prices are low
- A high supply of renewable energy risks creating local congestion
- The network has sufficient capacity to support charging

At the system level, shifting charging times from high- to low-cost times of day delivers multiple benefits. It can smooth out demand peaks and absorb surplus renewables on the grid. It can ensure more efficient energy usage and contribute to grid stability. When EV numbers are aggregated, flexibility from smart charging could help to balance supply and demand, mitigating the need for some investments in distribution infrastructure.

> **Smart EV charging can be defined as charging at times when the cost to the user, the power grid and the planet are lowest, without compromising the consumer experience, all enabled by automation.**
>
> **Andrew Horstead**
> EY Global Power & Utilities Lead Analyst

To convince EV drivers to participate and support the efficient integration of EVs into the energy ecosystem, smart charging must be both straightforward and as seamless as conventional fuelling. Drivers simply sign up to an EV charging service that bills them on the cost per kilowatt hour, determined by the specific time of their energy consumption.

[26] "Vehicle-to-grid impact on battery degradation and estimation of V2G economic compensation," ScienceDirect website, 1 January 2025.
[27] "Grids for Speed," Eurelectric website, accessed 16 January 2025.

EV load can be controlled via aggregators, CPOs or retailers with more complete, data-enabled information. The charging process, which may happen late at night or in the early hours of the morning, requires no driver intervention. Users set their own preferences — e.g., charge to 80% by 7:30 a.m. — but they can easily override the system so that the vehicle is available if their circumstances change.

> **We can accept power limitation messages from grid operators, aggregators or flexibility market players. Based on that, the system controls the charging power of EVs.**
>
> **Natalia Aleksandrova**
> Project Manager, AMPECO

How smart EV-charging business models are evolving

Case study: partners to transform charging with dynamic tariffs

AMPECO and Octopus Energy formed a strategic partnership to enhance EV charging services. This collaboration offers a suite of dynamic electricity tariffs that aim to provide flexible and cost-effective charging solutions to both CPOs and EV drivers.

"AMPECO and Octopus Energy: Powering CPO flexibility with dynamic tariffs," AMPECO website, 7 November 2023.

Case study: UK feasibility trial to test EV charging flexibility

More than 2,000 joint British Gas and Pod Point customers were recruited to trial EV charging as a valuable flexibility resource for the electricity system operator's balancing mechanism. The first phase of the pilot, in February 2024, focused on delivering flexibility services to customers using Centrica's demand-side response platform. It encourages customers to move their electricity use out of peak times to give them access to a cheaper and more sustainable supply.

"Feasibility trial launched in UK to test EV charging flexibility, Smart Energy International," Smart Energy International website, 19 April 2024.

Case study: UK feasibility trial into dynamic pricing and smart charging

Shift 2.0 is testing how dynamic prices influence smart charging, enabling EV drivers to maximise their use of cheap green energy without overloading local electricity networks. The trial by UK Power Networks, Octopus Energy and ev.energy involves more than 1,500 EVs all responding to dynamic network price signals to help manage demand and shift energy usage out of peak times. UK Power Networks sends a "day-ahead" ToU price signal to Octopus Energy and ev.energy. They combine this with the wholesale price of electricity and other information to schedule EV charging in line with the availability of cheap power and network capacity. Early results show that EVs started charging during the early evening when wholesale electricity prices were low due to an increased supply of wind energy.

"UK-first trial shows shifting EV charging can help manage renewable energy," UK Power Networks website, 24 June 2024.

V2G balances the grid with bidirectional energy flows

V2G is an alternative to V1G smart charging. But it goes further. It allows EVs to not only draw electricity from the grid but also feed stored energy back into it when needed, to support peak demand, provide backup emergency power, and balance frequency and voltage on the grid.

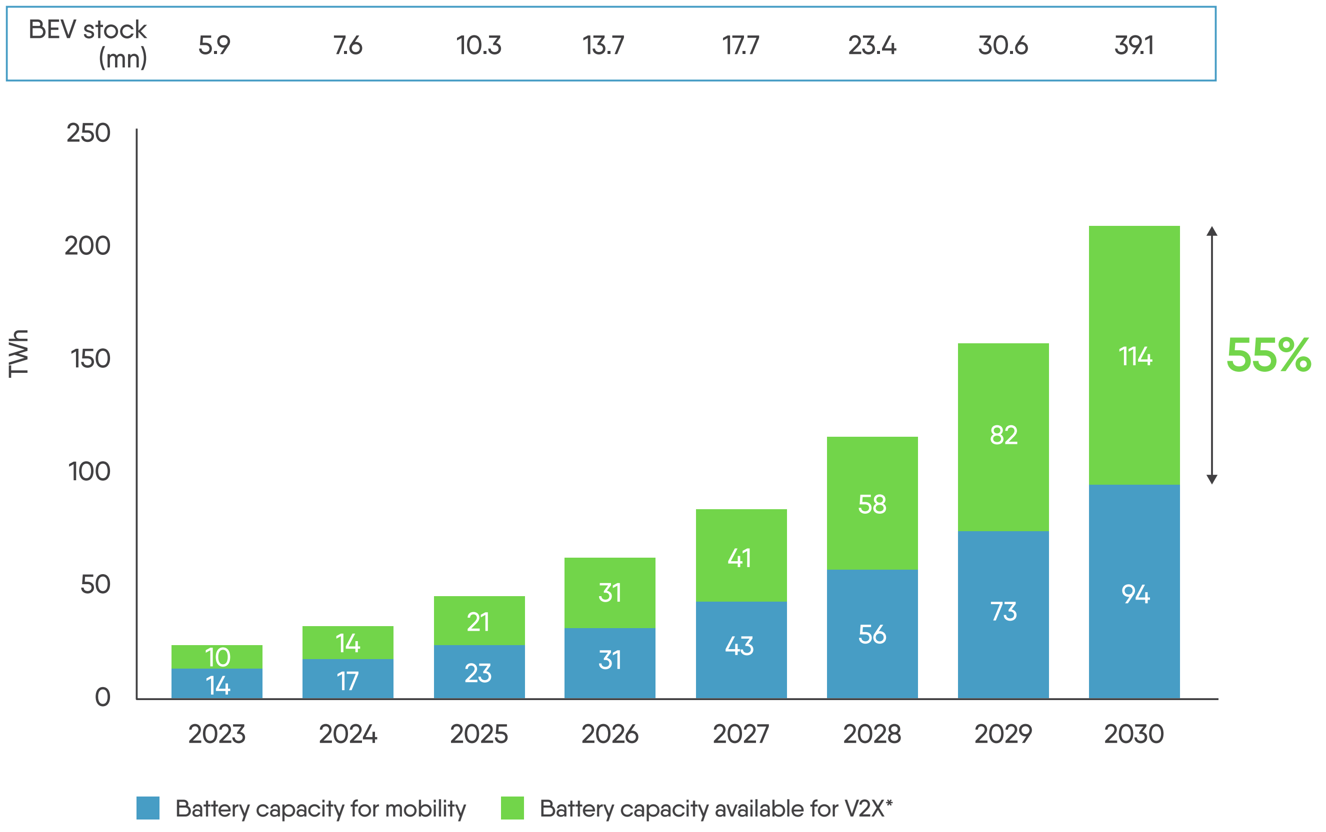
For the grid operator, the V2G value proposition is significant. By 2030, based on projections of EV uptake and battery size, we calculate that the total usable EV battery capacity in Europe, estimated at 114 TWh — approximately 4% of Europe's overall electricity demand — could be sufficient to power 30 million homes every year. And by 2040, if all EVs are capable of bidirectional charging, V2G could store over 10% of Europe's power needs and reinject when it is needed.[28]

114 TWh
BEV battery capacity available for grid purposes, equivalent to **4%** of Europe's electricity demand by 2030

55%
of the cumulative BEV battery capacity available for V2X purposes

Potential scale of energy stored in EV batteries

Cumulative battery capacity by usage



*V2X stands for "vehicle-to-everything". It's a term that describes a system of wireless communication between vehicles and other entities, such as infrastructure, and other vehicles.

Source: EY Insights.

V2G technology is still at a nascent stage. Around 72% of projects currently run on a trial basis. Globally, 10 proprietary projects are commercially operated in Europe, and one in Australia.[29] However, if allowed to scale, the technology promises significant benefits:

- **Grid flexibility:** Grid services, such as frequency regulation, peak load management and congestion mitigation, could enhance grid stability and reduce the need for costly grid reinforcements.
- **Energy autonomy:** Enabling integration of renewable energy sources, V2G supports the drive towards climate neutrality and energy autonomy.
- **Revenue streams:** EV owners can earn revenue by feeding energy stored in EV batteries back into the grid, further enhancing the overall e-mobility value proposition.
- **Cost savings:** Grid operators could optimise the use of existing infrastructure and reduce the need for new investments. Savings can be passed on to consumers.

[28] EY Insights.
[29] "V2G around the world," V2G Hub website, accessed 16 January 2025.

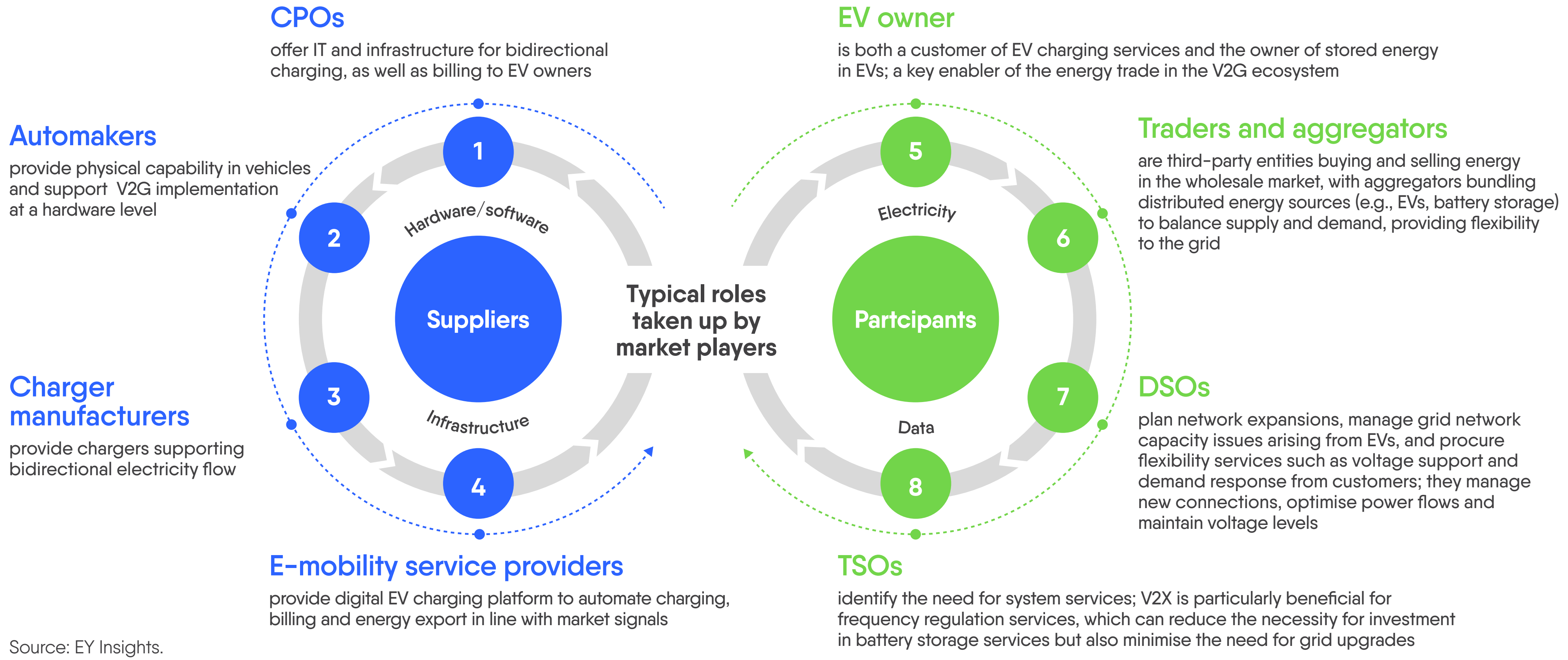
V2G differs from unidirectional smart charging due to its ability to inject power back into the grid. Strength is in numbers and quality: The more EV assets smartly connected to the grid, the greater the potential to predict and service the demand for flexibility.

However, EV availability depends, rightly, on human considerations, such as owner consent, driver behaviour and willingness to participate in flexibility. It also hinges on system readiness (e.g., charger availability), technical constraints (e.g., risk of battery degradation), market readiness, cooperation between transmission system operators (TSOs) and DSOs, market access and regulations on critical issues such as data sharing and double taxation.

V2G business models in Europe

The V2G ecosystem is a dynamic and collaborative network of players. They aim to work together to optimise the use of EVs, as both consumers and suppliers of energy. Each player contributes unique value, facilitating interactions that maximise both economic and environmental benefits. Fair and transparent data sharing between market participants is crucial to V2G's success.[30]

The interconnected V2G ecosystem



Source: EY Insights.

[30] Article 20a of RED III already obliges car manufacturers to share relevant vehicle data (state of charge, state of health, battery power set point, battery capacity and, where appropriate, location of EVs) with vehicle owners and third parties acting on the owners' and users' behalf at no cost. Through a revision of RED III or an in-vehicle data act, additional vehicle data needs to be added to Article 20a, and the data needs to be defined to ensure a common understanding by all market participants. The data needs to be available via API or open interfaces (during and outside of the charging process).

Potential V2G energy services

Load balancing:

- Peak shaving — sending power to the grid when demand is high
- Regulating load — increasing or decreasing charging power to reduce load peaks
- Valley filling — charging EVs at night when demand is low

Frequency regulation

- Keeping voltage and frequency stable — providing services to meet sudden demands for power

Backup power:

- Providing power in emergencies — EVs can provide backup power during blackouts and other emergencies

Case study: EV fleets get green light for V2G in France

RTE, the French TSO, has certified the use of EV batteries in company fleets for V2G charging. The practice allows real-time balancing of supply and demand to provide frequency control services, smoothing the operation of the French (and European) electricity system.

"CHAdeMO V2G certified to participate in the real-time balancing of the electricity system (FCR) in France," CHAdeMO website, 29 March 2022.

Case study: EV fleet batteries aggregated for frequency regulation in Denmark

V2G technology company Nuvve aggregates multiple EV batteries to provide a primary frequency controlled reserve (FCR) service to Energinet, the Danish TSO. Vehicles are connected to 10 kW bidirectional direct current (DC) chargers, controlled by Nuvve's V2G GIVeTM platform. Nuvve's software bids available capacity in EV batteries in the FCR market, while ensuring that the vehicles retain sufficient energy to operate when needed. Fleet owners use Nuvve's management app to set their driving needs for any given day.

"Nuvve Corporation Announces Four Years of Consecutive V2G Operations of Electric Vehicle Fleet in Denmark," NUVVE website, 29 September 2020.

Case study: Danish V2G success story sees revenues returned to EV drivers

The Parker project in Denmark uses a commercial V2G hub and EVs to provide frequency regulation services. The project reveals that individual cars can each supply thousands of hours of frequency services, generating annual revenue of €1,860 per car.

"Parker," V2G Hub website, accessed 16 January 2025.

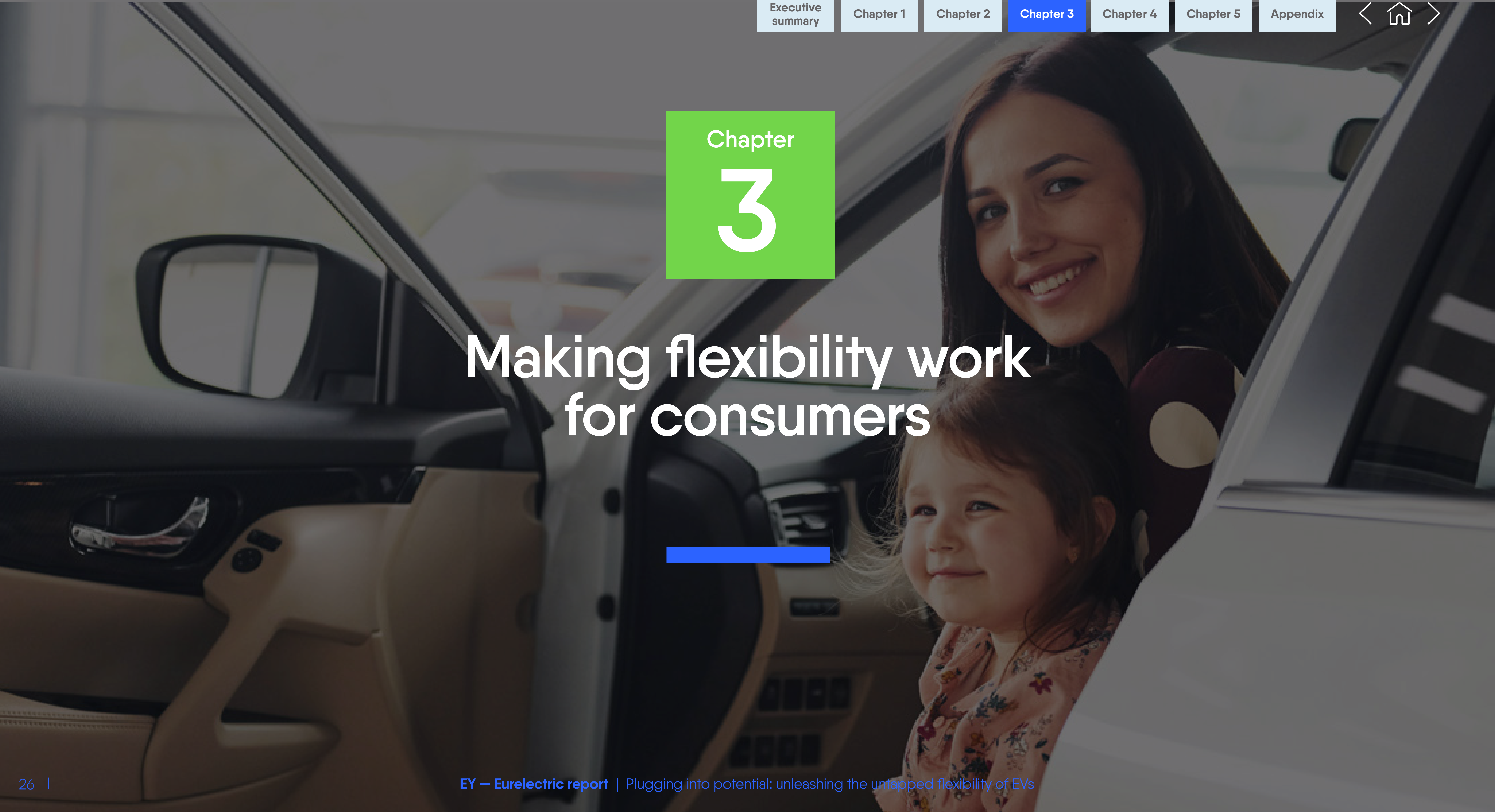
The future of smart charging, and especially V2G, hinges on enabling data sharing and interoperability to allow different systems, interfaces and providers to communicate with one another. This will support the fair and transparent exchange and interpretation of data, and enable the commercialisation of EV services and enhanced customer experiences.

However, until existing regulations, such as Article 20a of RED III are fully implemented and supported by a technical and regulatory framework, much-needed data sharing and interoperability will be compromised.

Flexibility from EVs depends on:

- Charging points connected to the electricity grid
- Identifiable and communicable needs for flexibility
- EVs and charging points able to respond to flexibility demand signals
- Accurate price signals and other incentives to secure flexibility when needed
- EV users being able and willing to charge flexibly

> **The collective opportunity for EVs to align charging with grid needs, or to provide other services to grid operations, is huge. But customers must remain central to load management programme development. And their transportation needs must be paramount.**
>
> **Thierry Mortier**
> EY Global Energy Digital & Innovation Leader



Chapter 3

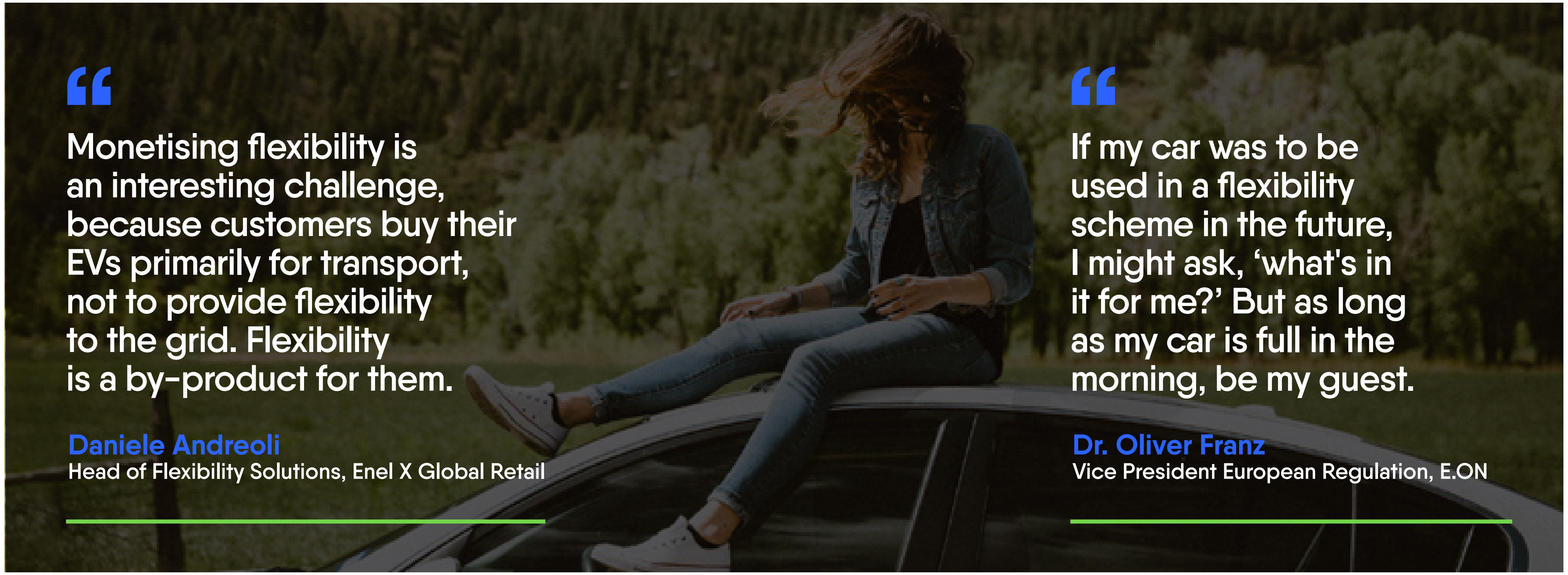
Making flexibility work for consumers

Consumers sit at the heart of the energy transition. By allowing their vehicles to be used for flexibility, they become both participants and enablers. But they are also beneficiaries of the system. To make flexibility work for consumers, and for the society and environment in which they live, services must be easy to use and offer the types of benefits they want.

The e-mobility ecosystem must help consumers to get on board with flexibility. Time is running out, because flexibility resources must double within the next five years to match the speed and scale of electrification.[31]

Already, the consumer group extends beyond early EV adopters, some of whom have benefited from ToU tariffs or participated in V2G pilots and value their potential. It now includes EV drivers, at different levels of acceptance, who are prepared to hand over control of their vehicles to third parties.

Some trust the V2G process and are willing to be part of the experiment. Others may be motivated by potential rewards. And some simply want their vehicle to be charged and available when it's needed, but don't really care too much about what happens while it is plugged in.



> "Monetising flexibility is an interesting challenge, because customers buy their EVs primarily for transport, not to provide flexibility to the grid. Flexibility is a by-product for them.
>
> **Daniele Andreoli**
> Head of Flexibility Solutions, Enel X Global Retail

> "If my car was to be used in a flexibility scheme in the future, I might ask, 'what's in it for me?' But as long as my car is full in the morning, be my guest.
>
> **Dr. Oliver Franz**
> Vice President European Regulation, E.ON

Consumer relevance: What's in it for me?

Flexibility must work for everyone, including those yet to be persuaded of its merits. And for that, users need clear information, reason and reward for participation. And so the value proposition must quantify flexibility benefits and directly address the question, "what's in it for me?"

Inevitably, V2G creates anxiety for some EV drivers. They want to know who controls their vehicle. They want assurances that it will be always available on demand. As they learn more about their EVs and V2G, drivers' concerns will include battery degradation and impact on warranties if manufacturers' limits on charging and discharging cycles are exceeded.

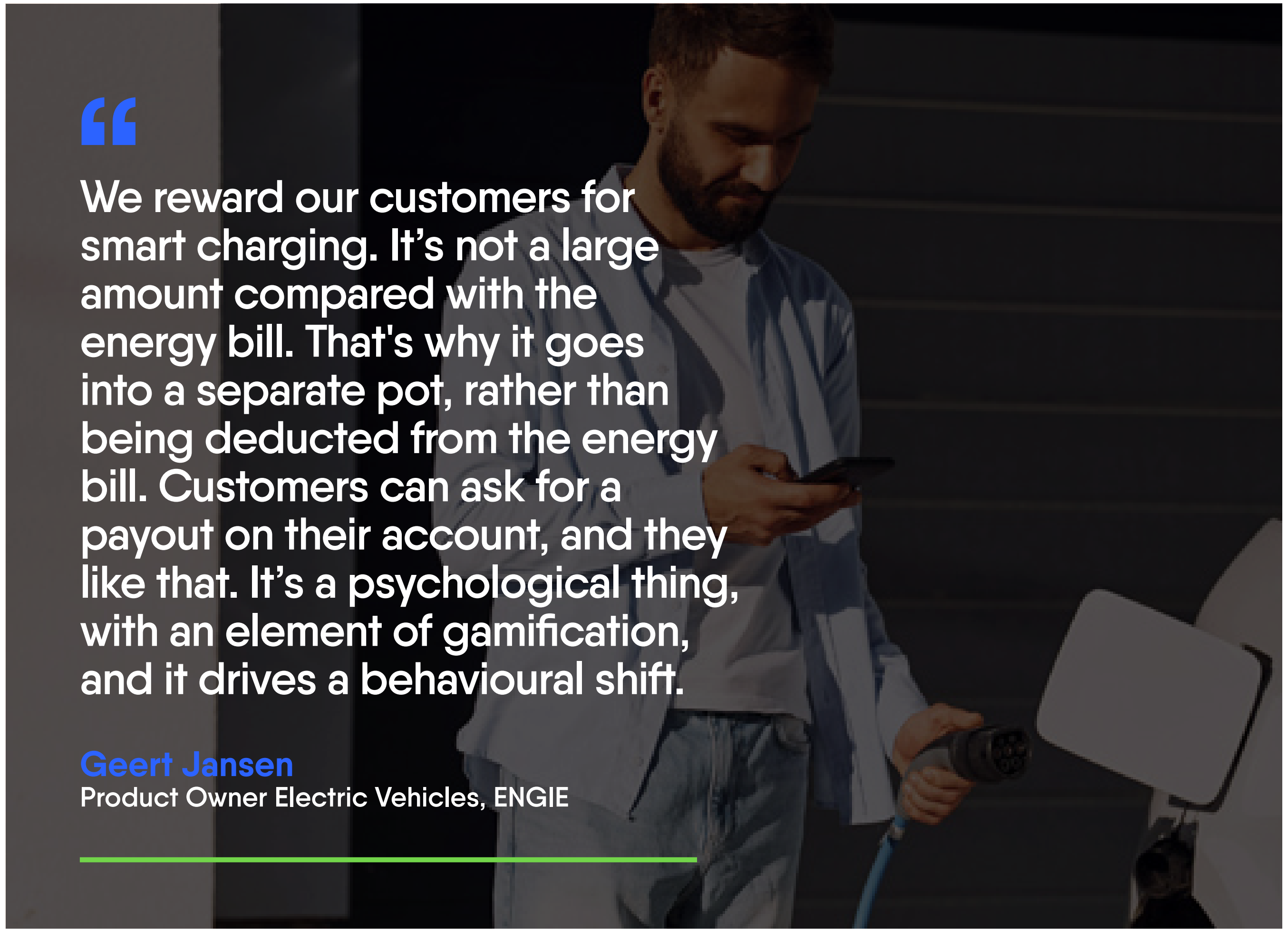
They are valid concerns. Industry has an integral role to play in liaising with insurers to quantify and mitigate the risks of degradation and in helping consumers to understand the benefits and risks of participation.

However, it is equally important that industry shares accurate information with drivers to mitigate their concerns. For instance, recent studies find that smart charging and bidirectional charging can actually extend EV battery life.[32]

Consumers also expect economic reward for allowing their vehicle to be used as a flexibility asset — perhaps monthly or annual reimbursement, or reductions on their energy bill.

[31] "Flexibility solutions to support a decarbonised and secure EU electricity system," EEA/ACER Report, September 2023.

[32] "Quantifying the impact of V2X operation on electric vehicle battery degradation: An experimental evaluation," ScienceDirect website, accessed 16 January 2025.



"We reward our customers for smart charging. It's not a large amount compared with the energy bill. That's why it goes into a separate pot, rather than being deducted from the energy bill. Customers can ask for a payout on their account, and they like that. It's a psychological thing, with an element of gamification, and it drives a behavioural shift.

Geert Jansen
Product Owner Electric Vehicles, ENGIE

There is no one-size-fits-all incentive mechanism, as our conversations with industry experts reveal. But if there is no clear win for the consumer, there will be no win for other players either.

Leasing as flexibility gateway

Europe's large leasing market offers scope to scale V2G from pilot phase to real-world test bed.

Around half of all new cars in Europe are leased — most on company schemes. Getting leasing companies on board and overcoming fears of battery degradation and violating car warranty conditions, while supporting with V2G education and installation, could secure the numbers needed to take V2G from pilot and into practice.

Fleet participation

Though it is early days, there is scope for electric fleet vehicles and electric heavy-duty vehicles (eHDVs) to participate in flexibility too.

When eHDVs, which have much larger battery capacity than passenger cars, plug into chargers at depots overnight, stored capacity could be used to provide balancing and flexibility services to the grid. However, the commercial vehicle market is very different from the passenger car market, and an idle fleet cannot generate revenue. Tailored smart-charging and V2G solutions for different industries, e.g., school buses, are needed to optimise vehicle downtime and the cost of electricity consumed by electric fleet vehicles and eHDVs.

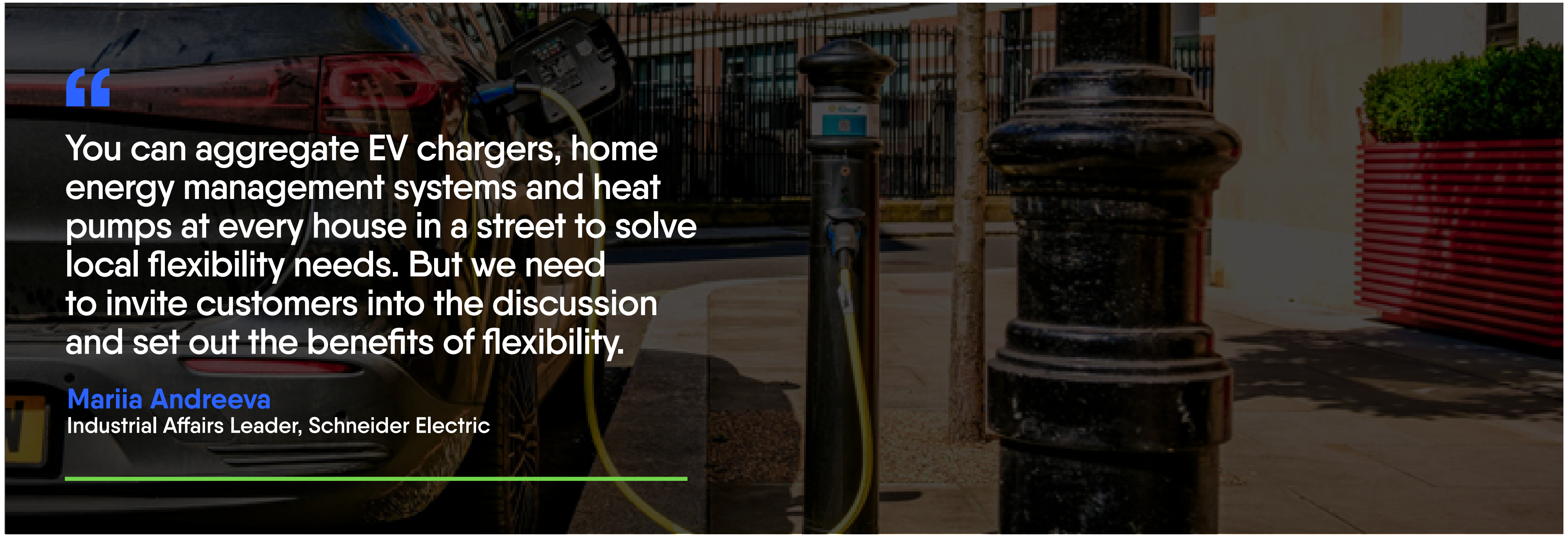
"In commercial operations, vehicle up-time makes money, and dwell-time costs money. You can't assume that the fleet market is the same as the passenger-vehicle market when it comes to V2G.

Magnus Broback
Head of Volvo Energy Charging & Infrastructure Business Development, Volvo Energy AB

Simplify the customer experience

Simplifying the customer experience, providing help when there's a concern or when new technology makes an existing product redundant, must come from the extended EV ecosystem.

Retailers, CPOs, automakers, leasing and distribution companies have a joint responsibility to get the customer experience right and to bring participants on board with V2G.



"You can aggregate EV chargers, home energy management systems and heat pumps at every house in a street to solve local flexibility needs. But we need to invite customers into the discussion and set out the benefits of flexibility.

Mariia Andreeva
Industrial Affairs Leader, Schneider Electric

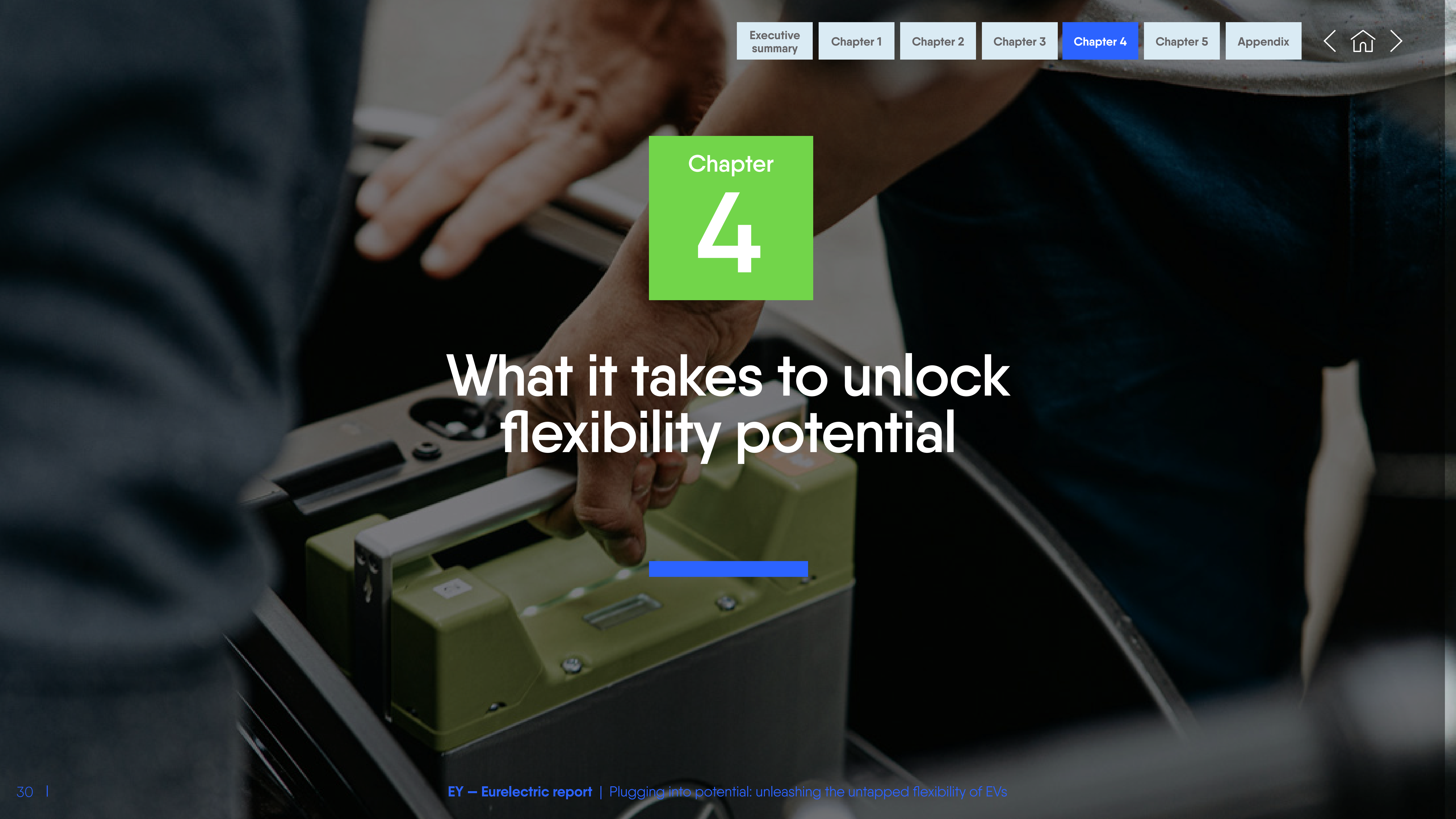
Manage the equity gap

A potential equity gap must be closed. EVs, and their perks, must be available across all demographics to enable the transition to a clean e-mobility system.

Currently, e-mobility favours drivers with access to off-street parking, ToU home energy tariffs and potential rewards from V1G or V2G services. Yet 42% of European EV drivers live in cities without access to home charging points. Reliant on public charging stations, they pay more to charge. They cannot benefit as much from smart charging. And they are not always plugged in for long enough periods for battery capacity to be discharged to the grid.

To ensure public buy-in, remedies might include subsidised public charging, community charging hubs in urban or multi-dwelling facilities, and future expansion of V2G infrastructure.

Currently, EV drivers with private charging privileges are poised to be the biggest beneficiaries of smart-charging services. Further policy interventions are needed if all consumers are to participate in flexibility programmes.



Chapter
4

What it takes to unlock flexibility potential

Our conversations with cross-industry experts, supplemented by our analysis of external research, confirm that EVs can indeed play a role in delivering flexibility.

However, the size of the opportunity is contingent on several factors, including the speed of rolling out charging infrastructure, making EVs available at an affordable price, compatibility between EVs and chargers, addressing regulatory challenges and convincing customers of the value available to them. Commentators flag that failure to resolve five key challenges could block the inherent potential of flexibility.

Challenge 1
Energy system readiness for flexibility

Readiness is largely a function of market access, including regulations and compensation mechanisms, price signals to prompt EVs to charge or discharge, in-country sociopolitical support, and grid and technology availability.

Our assessment of the state of readiness across leading markets in Europe shows that there are barriers to full market integration. They include high minimum bid sizes, restrictive aggregation conditions and low remuneration potential. Full implementation is now needed of Europe's Electricity Market Design Reform,[33] which reduces the minimum bid sizes for trading in day-ahead and intraday markets to 100 kW or less. This change will make it easier for small, decentralised assets to participate in all electricity markets.

There is recognition, too, of fragmentation within Europe when it comes to the maturity and readiness of flexible energy systems. The Nordics and Northwest European markets continue to be the most advanced, with countries in Southeast Europe slower to adapt.

Some countries are making progress:

- France and Germany have relatively advanced frameworks but still face challenges, such as restrictive market conditions, technical requirements and economic barriers that hinder full participation of smaller distributed energy resources (DERs). Germany notes challenges with double taxation, slow smart meter rollout, and an absence of fair and transparent data sharing pending revisions to Article 20a of RED III.
- The Netherlands supports a more active role for DSF but is yet to fully integrate V2G into its grid adequacy assessments.
- The UK is making progress, particularly with the introduction of new standards for aggregators. Meanwhile, there is recognition that current obstacles when adding V2G-enabled EVs to the Balancing Market (BM) as an aggregated unit will be solved in the coming years. The issue relates to operational metering and the discrepancy between the current metering standards for the BM and the standard of metering being installed at charge points.[34]

To realise the potential of smart charging, both V1G and V2G, European market frameworks must adapt further to allow for broader participation of decentralised flexibility resources in grid services.

> **By 2030, we will have 2.1 million EVs in Belgium. Imagine if just 100,000 of these EVs, with bidirectional capabilities, connected to the grid, each delivering 40 kW flexibility. You're talking nuclear plant-scale capacity.**
>
> **Philippe Vangeel**
> Operational Director, EV Belgium

[33] "Electricity market design" European Commission website, accessed 16 January 2025.
[34] "Powerloop: Trialling Vehicle-to-Grid technology," ESO & Octopus Energy group, June 2023.

Country-level flexible energy and key transition factor ratings

Countries / Parameters	Market access (regulations, compensation and costs)	Sociopolitical support (transparency on system needs, socioeconomic impact, and political alignment)	Technology potential (grid accessibility, EV infrastructure and charging, digitalisation and innovation)
Norway	5	4	5
Denmark	4	5	4
Belgium	4	5	4
Finland	4	4	4
Sweden	4	4	4
Ireland	4	4	3
France	3	4	4
Netherlands	4	4	4
UK	3	4	3
Germany	3	4	3
Italy	3	4	3
Spain	3	4	3
Switzerland	3	2	3
Poland	2	3	2

Low — High

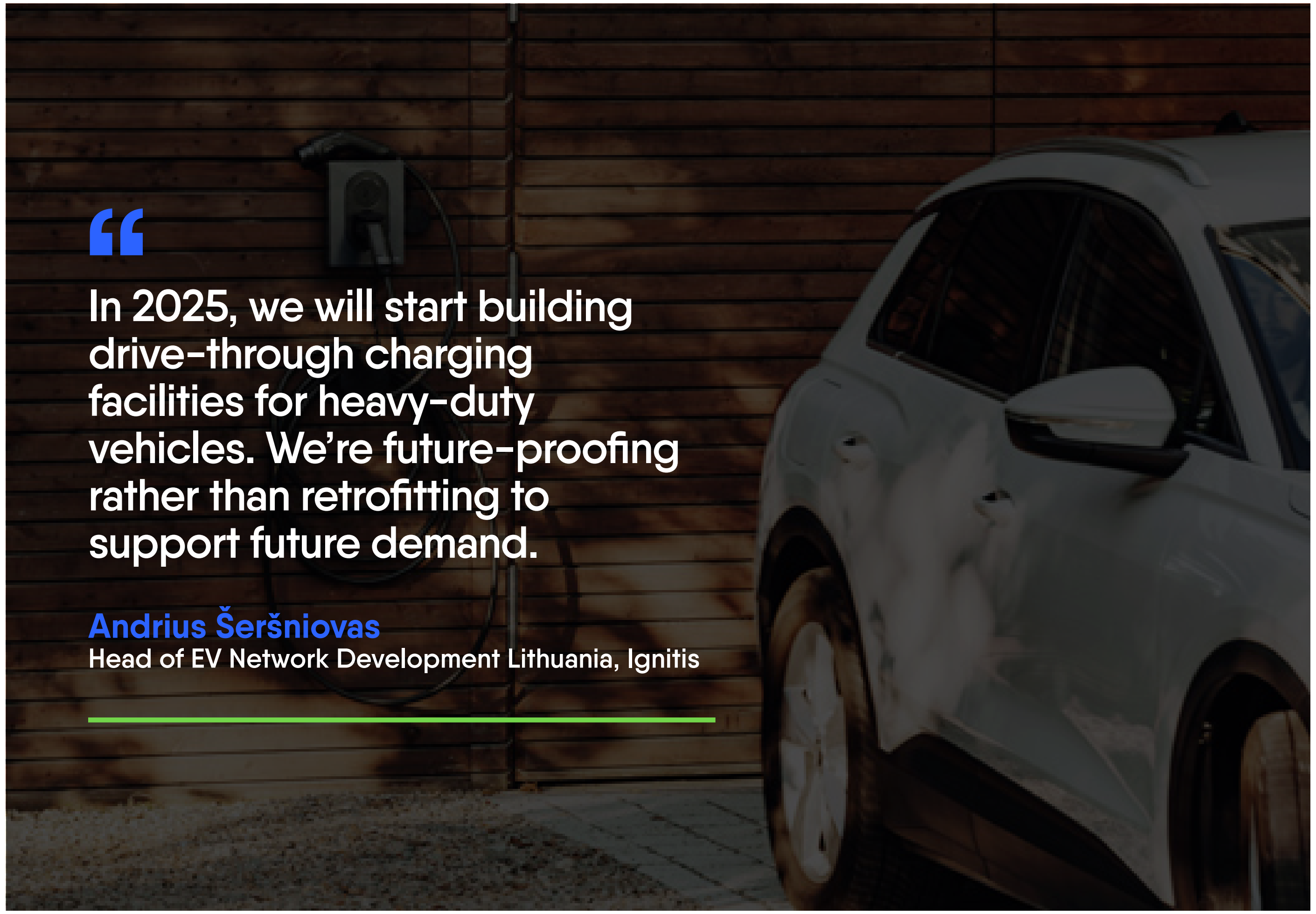
Market attractiveness for flexible energy services

Source: EY Insights analysis of the REA Energy Transition Readiness Index 2022.

Challenge 2
Complexity of operating the grid

The addition of EVs and other DERs will both expand the control surface of the grid and increase complexity for grid operators.

Every load brings different considerations and constraints. Load can range from single residential EV chargers to highway hubs with dozens of chargers, and fleet depots charging hundreds of trucks. All compete for the right to charge.



> "In 2025, we will start building drive-through charging facilities for heavy-duty vehicles. We're future-proofing rather than retrofitting to support future demand.
>
> **Andrius Šeršniovas**
> Head of EV Network Development Lithuania, Ignitis

While the supply of megawatts for large, concentrated load requires advanced planning to mitigate voltage fluctuations and thermal overloads, not all load is predictable. Individually, home chargers create small and dispersed load. Collectively, however, that residential load could be equivalent, in wattage terms, to a single large load from a fleet-charging hub.

Without effective network price signals and flexibility markets, high EV adoption could double the peak load pressure on the low-voltage grid, compared with low take-up scenarios. Although traditionally the role of TSOs, expansion in DERs will require DSOs to perform balancing services.

For this reason, DSOs must invest in real-time digital monitoring and network modelling to achieve granular visibility over the low-voltage grid. It will allow them to:

- Identify available grid capacity at the local level and streamline connections of smart and V2G chargers in areas where the network is less constrained.
- Procure short-term flexibility services, creating additional revenue streams from smart charging, including V2G.

To be deployed at scale, V2G must be integrated into a smart energy system capable of communicating with EVs in real time. A V2G optimisation algorithm is needed to help operators manage the complex bidirectional interactions between EVs and the grid. Acting as a smart decision-maker, the algorithm determines when EVs charge, discharge or stand idle, while accommodating user preferences. This process of integration, already deployed for existing technologies such as heat pumps and air conditioning, could help to ease grid congestion and local voltage variations. It can also be used to support more complex load management strategies, subject to user consent.

Challenge 3
Customer awareness and engagement

The technical complexity of bidirectional power flows, especially for consumers unfamiliar with the electricity system, means public appetite and awareness of V2G are currently low.

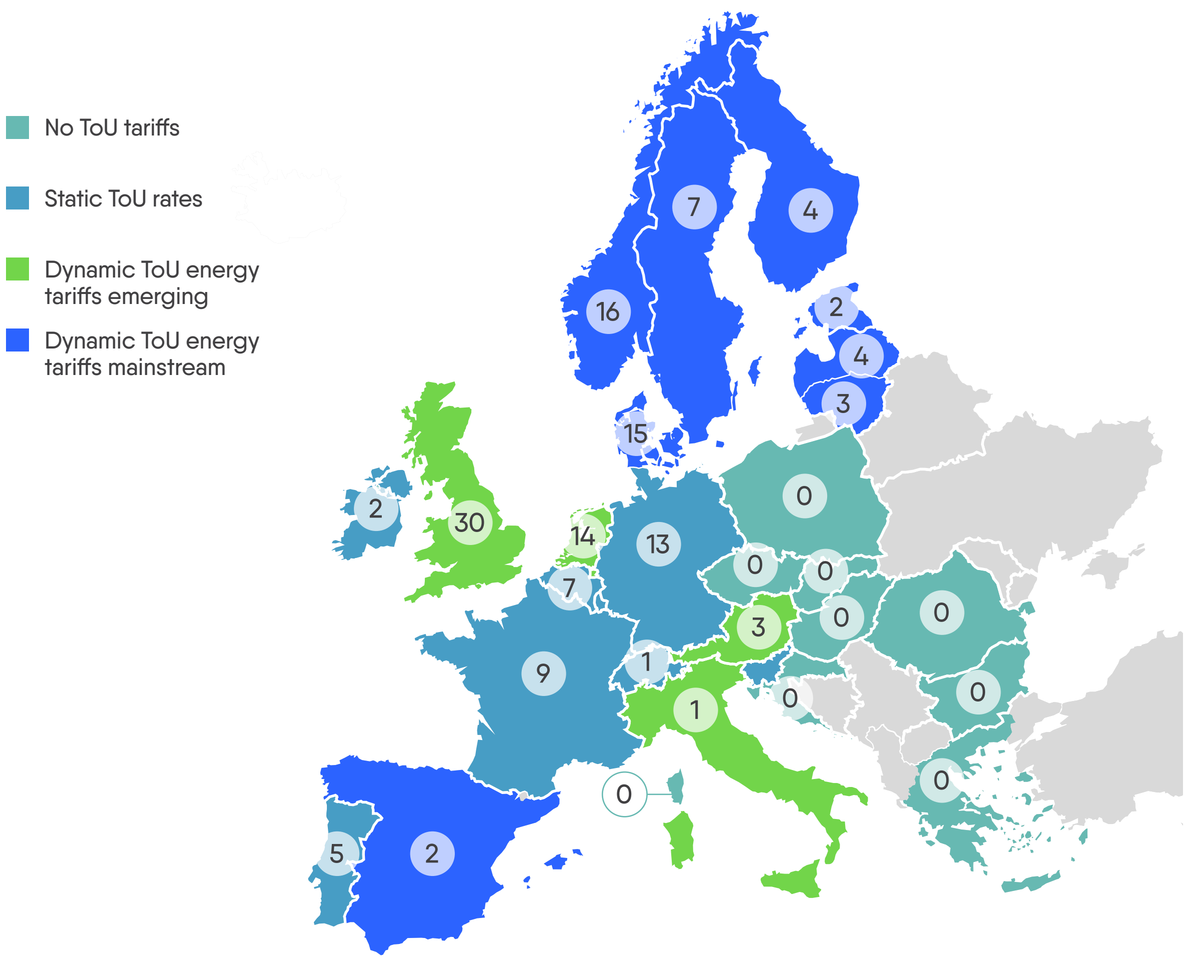
Cost and compatibility are additional barriers. The availability of V2G-compatible cars today is limited, but more vehicles are expected to feature bidirectional charging capabilities in the future. V2G-capable chargers cost, on average, five to 10 times more than unidirectional chargers. Furthermore, most V2G chargers available on the market are direct current (DC), which, as standard, have higher prices than alternating current (AC) chargers. While AC V2G-capable chargers have recently been launched, they are only compatible with EV models equipped with onboard V2G chargers.

Meanwhile, the number of EV offerings, charging options and tariffs add to the complexity. To persuade consumers to make the switch to EVs, charging and discharging must be as simple as refuelling at the pump.

> **We need to help customers understand V2G, and the various tariff options and benefits that are available to them, if we want to get them on board.**
>
> **Mariia Andreeva**
> Industrial Affairs Leader, Schneider Electric

Across Europe, different countries adopt different smart-charging solutions, and distribution is far from equal. The rollout of pan-European solutions is further hampered by the lack of standardised policies and underdeveloped regulations, which hinder the commercial feasibility of V2G across geographies.

Distribution of EV charging tariffs and services across Europe



EY Insights analysis of ["A Review of Tariffs and Services for Smart Charging of Electric Vehicles in Europe,"] MDPI website, accessed 16 January 2025.

There is growing recognition that being "technically capable" of providing flexibility services is no guarantee of successful mass V2G rollout or take-up of ToU tariffs.

Among the blockers, according to our industry commentators, is consumer consent and appropriate rewards for the use of EVs as flexibility resources.

The functionality of smart-charging systems is deeply influenced by user behaviour and pricing structures. Market-specific pricing models must engage customers and persuade them of the benefits of V2G.

It will be put to the test this year, when European legislation mandates that major electricity suppliers provide consumers with ToU tariffs, whether dynamic or static, alongside the usual fixed-rate options.[35]

Currently, however, customer education and awareness fall short of the levels required to change behaviours, while different tariff structures provide varying levels of engagement. Better coordination between stakeholders, such as utilities, charging providers and automakers, is important for raising consumer awareness.

As the technology becomes more widely available, and as standards and regulations are rolled out, consumers must be made aware of the long-term cost savings of participating in V2G and the potential revenue-making opportunities available to them.

[35] "Dynamic pricing energy contracts to harness price volatility and get loyal customers," Maxbill website, 22 June 2024.

Challenge 4
Market design and the need for adequate reward structures

Where residential consumers sell excess energy from EVs and other grid-edge assets, such as rooftop solar PV generation, back to the grid, they become active participants in the flexibility market.

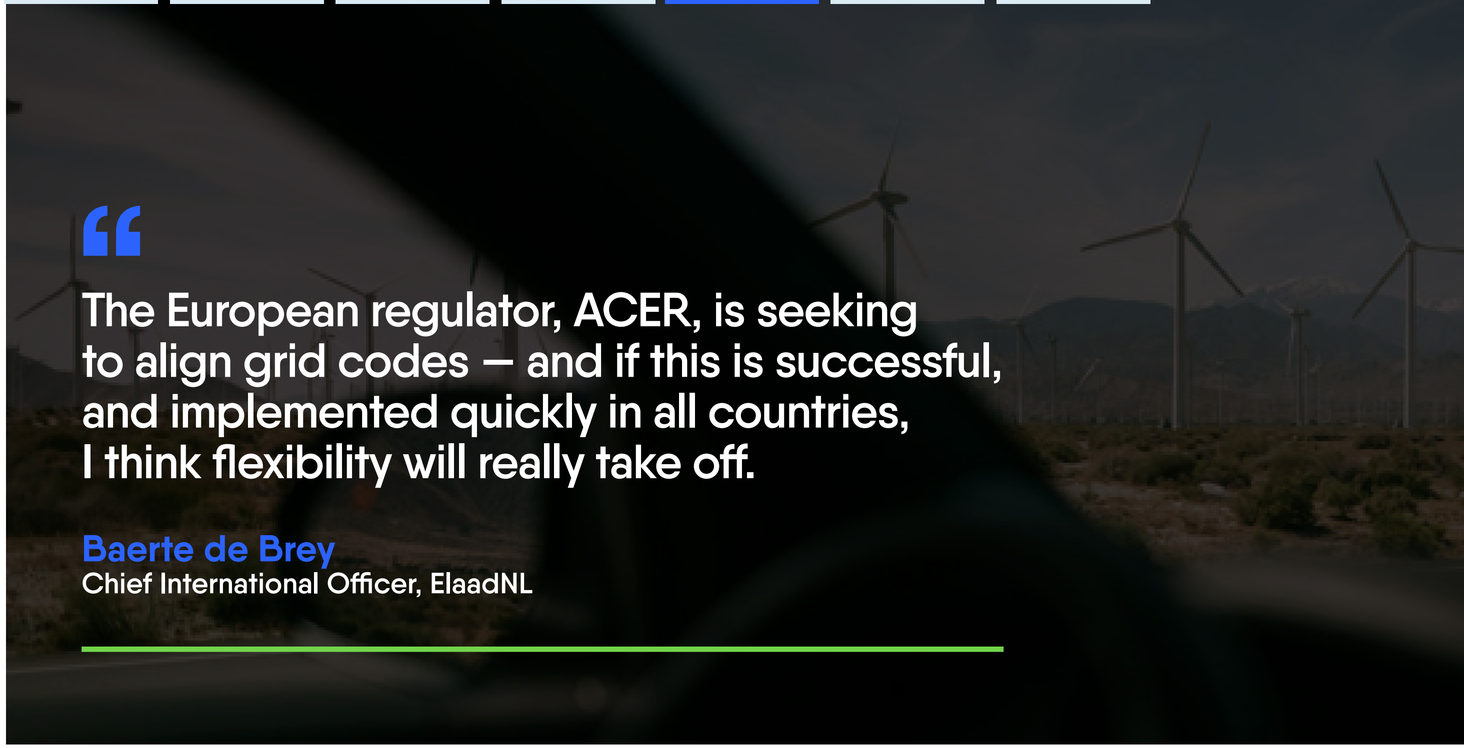
Pricing signals that flag potential congestion or constraints on the system, and which prompt EVs to charge or discharge, are needed if V2G is to help balance the local grid. However, if grid performance is, in part, reliant on EV owners' contribution, there must be rules around participation and accountability, as well as adequate rewards for allowing their EV batteries to be used for balancing purposes.

Currently, no legal barriers prohibit the feed of electricity from the EV to the power grid. RED III requires EU Member States to ensure that charging points support smart-charging functionality. This includes the ability to adjust electricity delivered to the vehicle in real time, based on data received electronically, and, where appropriate, support bidirectional charging.

Nor is there any V2G-specific regulation. The business case for V2G relies on regulated flexibility markets, on top of revenues from energy arbitrage and the ancillary services markets. Currently, however, flexibility services procured by TSOs and DSOs seldom incorporate V2G.

As a result, V2G relies primarily on electricity arbitrage for revenue generation. This limits diversification of revenue streams and potential stacking of revenue sources from other energy flexibility solutions, such as battery energy storage. An adequate regulatory framework, with rules on accessibility, as well as appropriate legislation, regulation and policy to support bidirectional charging, are fundamentals of market design and critical to the future of flexibility.

Industry commentators say adequate regulation, with standardised EU network codes to support widespread adoption of V2G technologies, is critical. They must allow technical and operational interactions between EVs, charging infrastructure and the grid to prevent overloads and maintain frequency.



> “The European regulator, ACER, is seeking to align grid codes — and if this is successful, and implemented quickly in all countries, I think flexibility will really take off.
>
> **Baerte de Brey**
> Chief International Officer, ElaadNL

Compatibility between EVs and chargers is challenging. In Europe, most infrastructure uses the Combined Charging System standard, and only chargers that meet the 2022 ISO 15118-20 can support V2G. Delays by automakers and charging providers in adopting these standards are slowing V2G implementation.

Germany is progressing with V2G through ISO 15118-20, facilitating communication between EVs and charging stations.

Other standardisation is also needed to support interoperability in V2G-capable vehicles and chargers, including:

- Electrical safety and cross-manufacturer interoperability between grid connection points, charging devices and the vehicle
- Uniform requirements for the use of legally compliant billing systems
- Communication protocols for control and digital market connections

> If we're to use flexibility, and to market it, we need to see standardisation. If you change your car, you must change your wallbox too, because it's not compatible. It compromises seamless smart charging and adds costs to the customer.

Dr. Jan Strobel
Head of Regulation, Market Communication and Mobility, BDEW

Though the Netherlands has advanced bidirectional charging infrastructure and smart-charging stations, monetisation of flexible load, such as V2G, is still limited. Most incentives take the form of reduced charging costs rather than direct financial compensation for grid services.

The UK permits bidirectional charging, but infrastructure is sparse. In 2023, there were fewer than 1,500 V2G-enabled public charging points (less than 5% of total infrastructure). However, government investment of £500mn is helping to grow the market.

> We need to make anticipatory grid investments. Yes, we can optimise and digitalise and do stuff with the current network. But we need to make decisions now, so we've got what we need five, 10 or 15 years down the line.

Magnus Broback
Head of Volvo Energy Charging & Infrastructure Business Development, Volvo Energy AB

One significant barrier to V2G deployment, raised by several industry commentators, is double taxation of energy storage. Some countries, such as Spain and Sweden, have already eliminated this tax. Others, including Denmark, the UK and Germany, are still grappling with ways to address it. Though the European Commission is discussing revisions to the 2003 Energy Taxation Directive, efforts have stalled, making the tax regime a key area for improvement.

> In the current landscape, V2G is not reaching its full savings potential due to double taxation. You pay tax and a grid fee when you charge your car; you often pay tax and a grid fee when you discharge your car. Much of the value you create from that cycle is lost, due to fees. Double taxation is, I would say, the biggest barrier to V2G.

Linus von Sydow
Volvo Cars Energy Solutions

Commentators also stress that regulatory barriers relating to stationary storage must be addressed. They call for it to be treated equally to mobile storage, as both present viable solutions for the energy system.

Challenge 5
Transparency, data exchange and access to information

The energy grid is reliant on information and data. Historically, that data was held by utilities to operate their systems and had little relevance to external parties. Now, as EVs and other DERs are integrated into the energy system, data that originates outside the utility becomes a valuable new component of grid planning and operational performance.

Data, as we identified in our 2024 data interoperability study,[36] should be interoperable across the entire EV value chain. It should be exchangeable across roaming networks, grid congestion heatmaps and common platforms, with standardised interfaces to break down data silos.

Priorities include relevant vehicle data, communication protocols, security, networked grid and control algorithms for EV charging stations, as well as planning and grid optimisation capabilities.

Standards and protocols are essential to support two-way communication and interoperability at multiple levels:

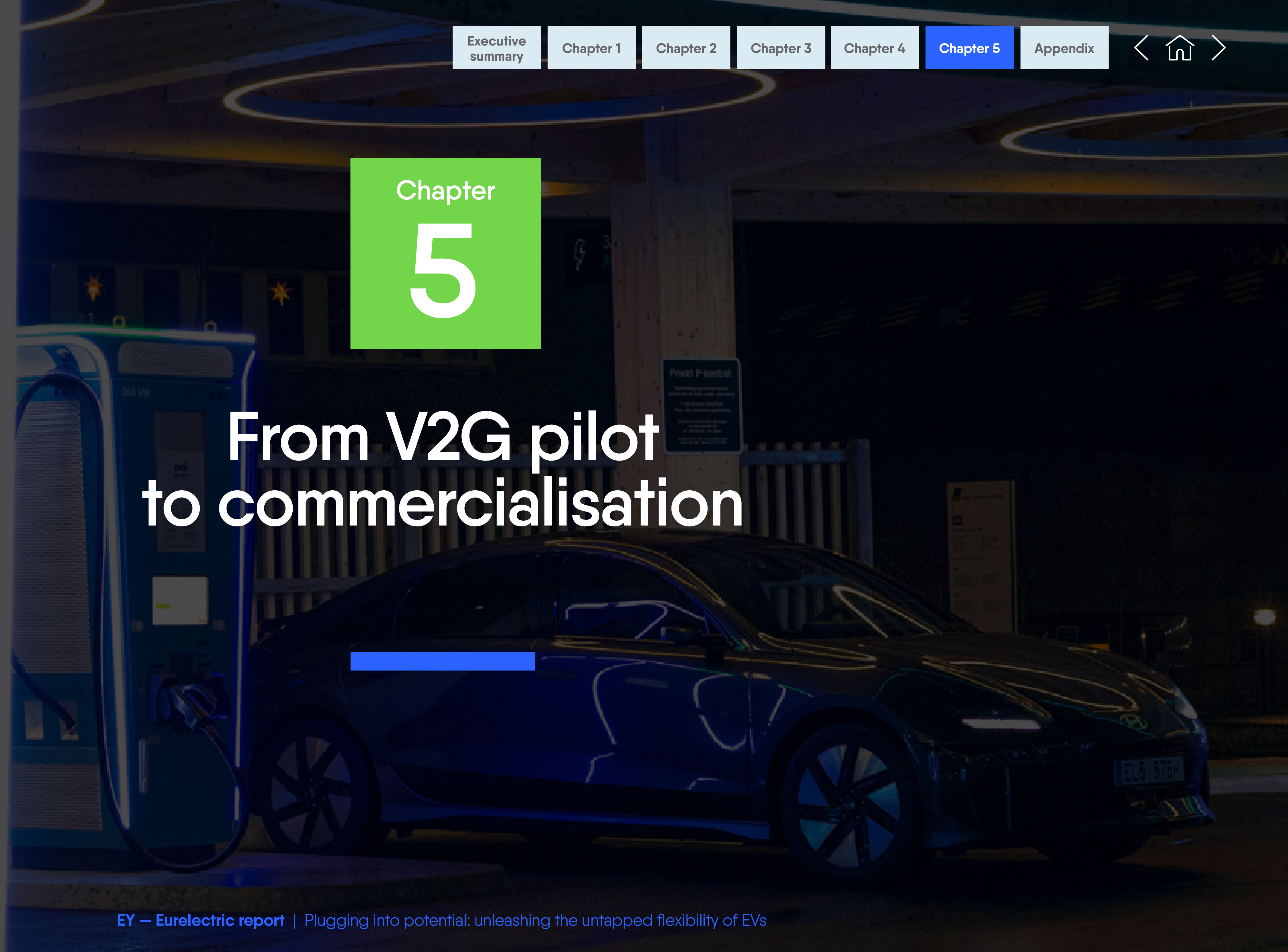
- Grid to charger
- Vehicle to charger and vice versa
- CPO to charger
- Among CPOs
- Aggregator to grid
- CPO to aggregator
- Aggregator to charger
- Customer, and third parties acting on behalf of the customer

Efforts are being made to develop standards that support multiple communication protocols between vehicles and charging stations. However, the proprietary nature of some automakers' telematics for communicating information between vehicles and aggregators remains a hurdle.

Looking ahead, a clear regulatory framework for mandatory data exchange must be established. And EU Member States must implement Article 20a of RED III, which requires automakers to share key vehicle data, such as state of charge, battery capacity and vehicle location, with vehicle owners and specified third parties at no cost.

Additional vehicle data, either by revisions to RED III or an in-vehicle data act, should include clear definitions to enable common understanding by all market participants. Furthermore, vehicle data should always be available via an API or open interface.

[36] "How do we solve the challenge of interoperability in e-mobility?," Eurelectric 2024.



Chapter
5

From V2G pilot to commercialisation

Smart charging, including V2G, is a necessity for unlocking the full flexibility of EVs. It has the potential to deliver the most affordable and scalable solution to localised energy needs, while driving down the costs of network investment. But without consumer consent, and aggregation of EV assets, traction for V2G may be lost.

Our conversations with participants across the ecosystem reveal growing recognition and support for EVs as part of the flexibility solution. Yet this is a nascent market, with multiple players trying to establish robust business models, but not necessarily in a standardised way.

V2G scalability and profitability depend on clear pricing signals, adequate investments, proper regulations, transparent market rules, and high data interoperability among stakeholders. Policymakers must make sure that the transition to V2G is inclusive so that users of public charging can also benefit.

So how do we take V2G from pilot phase to full commercialisation?

We have identified six prerequisites to unlock the value of EVs as flexibility assets, along with measures to evidence success and action points for industry participants.

Prerequisite 1
Customer acceptance

Consumers are at the heart of the energy transition. Their consent and participation are crucial for the success of V2G. This can be achieved through a seamless and cost-effective customer experience, increased awareness of the benefits of smart charging, and clear economic benefits.

Action points for consumers: Embrace cost-reflective ToU energy tariffs and participate in smart charging (e.g., V2G) programmes to save money, and contribute to system stability. Be mindful that each mechanism comes with unique burdens and opportunities for consumers. Though each is essential, together they can help to secure best value, as long as robust customer protections are in place, particularly for vulnerable users, and information is available and accessible by all.

Prerequisite 2
Economic viability

The economics of EV ownership need to improve under a well-functioning value proposition. For instance, in the UK, the owner of a compact EV could save up to 19% annually compared with an ICE equivalent. Of course, the proposition is dependent on available deals and initiatives, with some UK tariff providers even offering EV charging for free.

Robust business models that articulate the financial viability of V2G are essential. Simple to use, with benefits that are easy to understand and access, they should also include incentives for user participation.

Action points for automakers and CPOs: Develop and promote user-friendly V2G-enabled vehicles and charging infrastructure, and collaborate with other stakeholders to ensure compatibility and interoperability.

Action points for regulators: Abolish barriers, such as double taxation, and facilitate mandatory data sharing. When removing regulatory barriers to mobile storage, do not discriminate against stationary storage, which is also crucial for the integration of renewable energy.

Prerequisite 3
Customer segmentation

Different customers have different needs and behaviours. Commercial vehicle operations, for instance, have different requirements from those of passenger vehicle operations. Understanding how consumers respond to different flexibility solutions, and ensuring robust user security and privacy to enhance trust, are key success factors.

Action points for automakers, grid operators, aggregators and retailers: Develop business models that articulate the financial viability of V2G and offer incentives for user participation. Also facilitate data sharing and market integration.

Prerequisite 4
System planning

The grid needs to be prepared for the large influx of EVs and the variable nature of renewable energy. Flexibility can deliver a local response to local energy problems. Building future electrification needs into utilities' planning processes, and enabling efficient energy management, is crucial.

Action points for grid operators: Consider the value proposition of V2G in terms of more efficient and reliable system operations, reduced peak load, lowered emissions, and deferred generation and storage capacity investments. Grid infrastructure investment should target and support V2G rollout, including monitoring to better identify and predict congestion on low-voltage networks.

Action point for regulators: Establish a regulatory framework to incentivise low-voltage visibility by installing real-time network monitoring.

Prerequisite 5
Data, visibility and market integration

The energy grid relies heavily on data. Policymakers should ensure that data is interoperable across the entire EV value chain and break down data silos. This includes making data exchangeable across automakers, roaming networks, grid congestion heatmaps and common platforms. Collaboration across the ecosystem, information sharing and partnerships between utilities, automakers and third-party aggregators are essential to enabling EVs as flexibility resources.

Action points for regulators: Establish regulatory frameworks to support smart charging, including V2G; mandatory data exchange, including the standardisation of communication protocols; and the removal of barriers such as double taxation.

Additionally, to ensure common understanding by all market participants, a clear regulatory framework for mandatory data exchange must be established. It should include implementation of Article 20a of RED III, and revisions to it, or the introduction of an in-vehicle data act.

Prerequisite 6
Simple and accessible managed charging

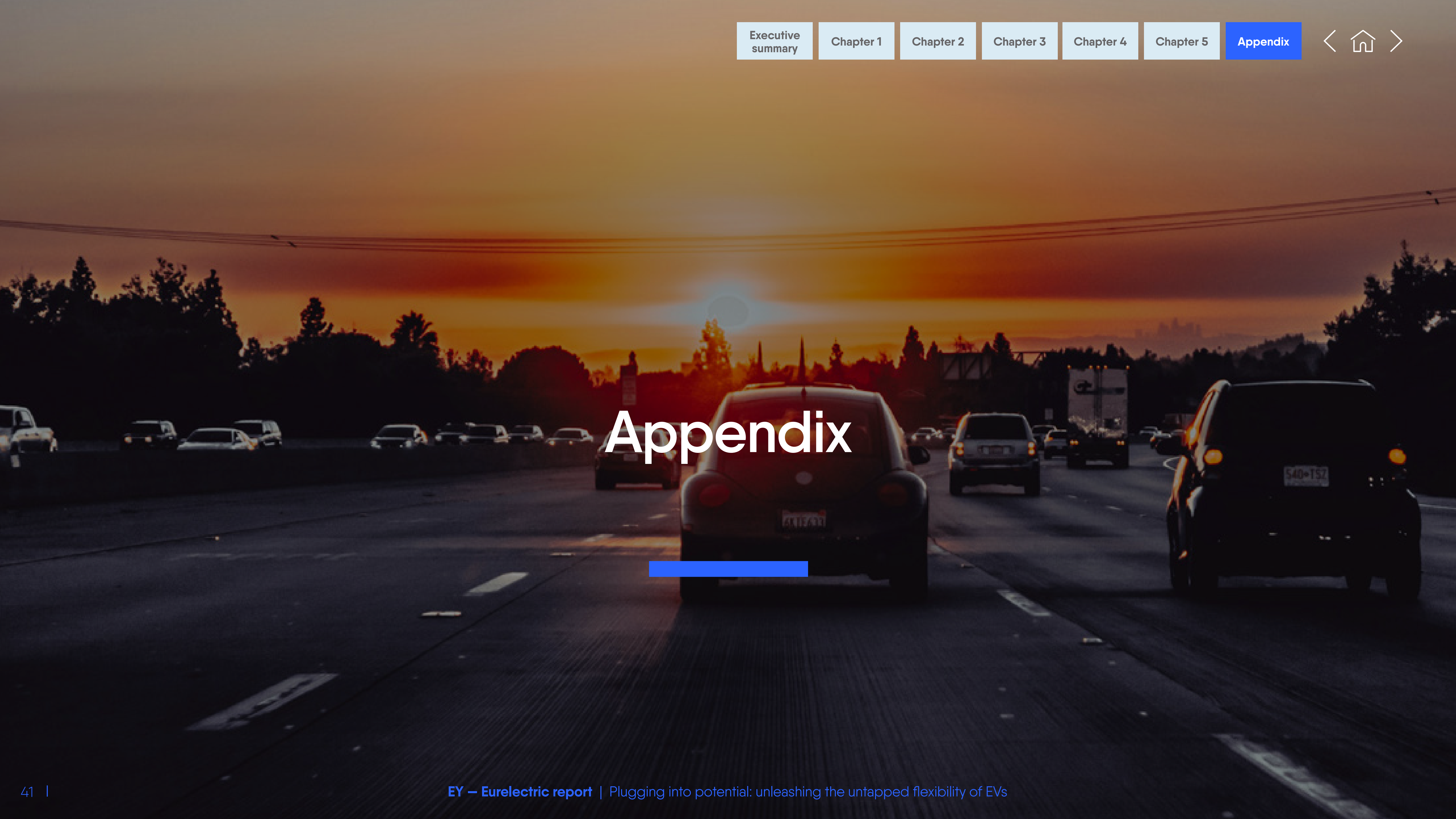
Simple and accessible smart charging is key to V2G technology. Smart-charging solutions must be able to shift the time of charge to support the network and the electricity system more broadly. Smart charging should be enabled by automation and innovations in both charging infrastructure and the vehicle itself. This means creating simple programmes to support mass adoption, and ensuring that disadvantaged and low-income communities are part of the process.

Action points for grid operators and regulators: Ensure cost-reflective pricing signals when the grid is congested. Incentivise the local flexibility markets through regulatory frameworks so that DSOs can procure flexibility to manage congestion. Allow consumers to choose which third party controls their EV (e.g., independent aggregator, the automaker, CPO or retailer). Provide appropriate compensation mechanisms and use market-based mechanisms and price signals to prompt EVs to charge or discharge. And ensure that V2G benefits are accessible across all demographics, including disadvantaged and low-income communities.

Available, flexible and scalable: the smart-charging solution

Unlocking smart charging, notably V2G, has the potential to pave the way to a more sustainable and resilient energy system. But it requires concerted effort from all stakeholders, including consumers, grid operators, automakers, regulators, policymakers and energy retailers. By first addressing the prerequisites for unidirectional smart charging, the actions necessary for V2G commercialisation can be unlocked. This will help to position both V1G and V2G technology as potential cornerstones of our future energy landscape.

Because if it's not smart charging, what else can take advantage of the abundance of EVs ready and available at comparatively low cost, already proven, flexible and scalable? We conjecture that smart-charging solutions are the necessities that a cleaner and more efficient energy system is waiting for.



Appendix

Energy cost benefit analysis of flexibility for EV consumers: introduction

The EY EV cost benefit forecasting model calculates the value proposition for customers through flexibility services participation.
The model covers various vehicle segments, multiple archetypes and key EU markets

Three key objectives

1. Estimate the total flexible energy available in the BEV fleet across Europe by 2030.
2. Compare TCO cost of ICE vs. EV across different European regions.
3. Assess consumer benefits in annual savings on energy bills from flexibility.

The model does this by analysing

Three vehicle segments

Compact vehicle
PV with a fuel consumption of **~7L** or an electricity consumption of **~14kWh** per **100km**

Family vehicle
PV with a fuel consumption of **~10L** or an electricity consumption of **~16kWh** per **100km**

Large vehicle
PV with a fuel consumption of **~13L** or an electricity consumption of **~18kWh** per **100km**

Five archetypes

- **ICE vehicle owner** TCO (fixed + variable)
- **Fixed tariff**: EV owner TCO on fixed tariff plans with no grid participation
- **Static ToU**: EV owner participating in static ToU tariff with fixed day and night prices
- **Dynamic ToU**: EV owner with more optimised ToU tariff on hourly basis
- **V2X**: EV owner further participating in V2G/V2H flexibility offerings

Six geographies

- UK
- Germany
- France
- Netherlands
- Sweden
- Spain

Our approach and methodology for calculating the four key outcomes across six markets and three vehicle segments

1 TCO for an ICE vehicle

A. Fixed cost:
- ICE cost
- Taxes

B. Variable cost:
- Maintenance
- Registration/insurance
- Fuel cost

C. Other variables:
- ICE depreciation
- Inflation

Net present value (NPV) of ICE TCO (cumulative/ annual) across vehicle segments

2 TCO for an electric vehicle

A. Fixed cost:
- EV cost
- Subsidies/taxes

B. Variable cost:
- Maintenance + registration/ insurance
- Electricity requirement in a year (calculated)
- Charging (home vs. public)
- Electricity prices (fixed tariff)

C. Other variables:
- EV depreciation
- Inflation

NPV of EV TCO (cumulative/ annual) across vehicle segments

Key outcome (1 + 2): Average annual saving of EV owner vs. ICE (TCO benefits)

3 ToU savings

Further adjustments in charging behaviour:
- Charging (home vs. public vs. office)
- Percentage of charging under off-peak vs. peak period
- Peak hours rate
- Non-peak hours rates
- Public charging cost

NPV of EV electricity cost under static ToU

Key outcome (2 + 3): Average annual saving of EV owner for off-peak tariff against fixed rate

4 Dynamic (optimised) ToU

EVs on dynamic ToU tariffs shift charging to off-peak hours when electricity rates are lower:
- Charging (home vs. public vs. office)
- Percentage of charging under dynamic rates vs. peak period
- Peak hours rate
- Non-peak hours rates
- Public charging cost

With rates fluctuating hourly based on demand, 10–15% more saving with dynamic ToU tariffs

Key outcome: Additional saving with more optimised ToU on top of static ToU

5 V2X savings

V2G revenue potential:
- V2G participation per year
- Average battery capacity
- Discharge rate of battery per hour
- Charging cost per hour (off-peak)
- Discharging cost per hour (grid defined)

NPV of the difference between charging and discharging of battery in a year

Key outcome: Additional revenue generation and savings from V2X

Key inputs | Calculations | Key outcome

Key assumptions

Vehicle segment assumptions	Compact	Family	Large
Vehicle segments	**Compact vehicle** PV with a fuel consumption of ~7L or an electricity consumption of ~14kWh per 100km	**Family vehicle** PV with a fuel consumption of ~10L or an electricity consumption of ~16kWh per 100km	**Large vehicle** PV with a fuel consumption of ~13L or an electricity consumption of ~18kWh per 100km
Average travel distance covered in a year (km/year)		15,000km	
Consumption kWh/100km	14	16	18
Charging frequency (full cycle/week)	1.4	1.0	0.7

Assumptions around V2X calculations	Assumptions	Remarks
V2G participation per year (hours)	182	Approx. 0.5 hours of participation every day on an average
Average battery capacity (KWh)	Compact – 40; family – 60; large – 90	Average of the models available in the market
Discharge rate of battery per hour	40%	Max. amount of battery that can be discharged every hour
Charging cost per hour (off-peak) (€/kWh)	0.18–0.3	Average prices offered by retailers in a market. UK offers the lowest average off-peak price
Discharging cost per hour (grid defined) (€/kWh)	0.27–0.40	France offers the lowest V2G price for grid participation, with other markets in range of €0.35–€0.4/KWh

Assumptions around V1G (Static and Dynamic ToU)	Assumptions	Remarks
Consumer charging location preference (home v/s public vs. office)	Home charging 60%–80% Office charging 10%–30% Public charging 2%–17%	According to EY primary research, 62%–65% consumers in Germany, France prefers home charging vs. the UK, Netherlands – 80%+
Peak hour rate (€/kWh)	0.27–0.40	France has lowest peak charges compared with other markets
Public charging cost (€/kWh)	0.4–0.6	Most of the European countries charge more than €0.55/KWh for public charging