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Building a market for EV charging infrastructure: A clear path for policymakers and planners

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Executive summary

One of the key challenges for the successful electrification of the transport sector in coming years is the development of a competitive electric vehicle (EV) charging market along with sufficient, accessible and smart charging infrastructure. Charging infrastructure build-out is a crucial lever to increase e-mobility uptake and thereby strengthen the contribution that electric vehicles can make to decarbonising the transportation sector, the only sector of the economy where emissions continue to rise.[2] In addition, harnessing competition and innovation to charge "smart"[3] — at times when the costs for electricity are lower but without compromising the vehicle owner's needs — will accelerate the clean, affordable transformation of the electric sector by facilitating EV integration into the power system as flexible resources. Leveraging this potential for beneficial[4] grid integration will be an essential part of a green recovery in Europe after the economic crisis brought on by the COVID-19 pandemic.

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[2] This paper was drafted before the outbreak of the COVID-19 crisis. We acknowledge that transport emissions have fallen sharply during the pandemic restrictions, but this short-term phenomenon doesn't eliminate the need for long-term sustainable electrification solutions addressing both economic and environmental goals.

[3] Hildermeier, J., Kolokathis, C., Rosenow, J., Hogan, M., Wiese, C., & Jahn, A. (2019). *Start with smart: Promising practices for integrating electric vehicles into the grid.* Regulatory Assistance Project. https://www.raponline.org/knowledge-center/start-with-smart-promising-practices-integrating-electric-vehicles-grid

[4] By beneficial charging we mean charging that reduces costs for consumers and supports optimal integration of EVs into the grid, thereby lowering system costs and increasing low-carbon electricity use. Farnsworth, D., Shipley, J., Sliger, J., & Lazar, J. (2019, January). *Beneficial electrification of transportation: Ensuring electrification in the public interest.* Regulatory Assistance Project. https://www.raponline.org/knowledge-center/beneficial-electrification-ensuring-electrification-public-interest/

There are two opportunities for policymakers in Europe to support an EV charging market in a way that accelerates the electrification of the region's transportation sector with benefits for consumers, the environment and the power grid. The first is the upcoming review of the legislative framework for charging infrastructure. The second is the implementation of the recent electricity market reforms. Each represents an opportunity for policymakers at the EU level and in Member States to make progress towards the vision of a self-sustaining EV charging market in Europe. **In this vision, EV drivers everywhere would have ready access to sufficient, accessible and smart charging infrastructure providing a range of charging services to fit their needs, with competition driving the innovation needed to provide those services at attractive prices.**

To realise this vision, we need ambitious implementation of the provisions of the recent electricity market reforms enabling and properly rewarding demand-side flexibility; in close alignment, we also need the creation of a suitable European legislative framework through the review of the Alternative Fuels Infrastructure Directive. A key element addressing the current debate on the development of public charging infrastructure will be to require Member States to define an "essential network" of charging points, which can be developed through well-designed public tenders until the competitive market becomes sufficiently robust. The network should be designed in a way that provides equal access for all types of EV users, including those in hard-to-serve locations that are unlikely to be served by commercial providers, and optimally integrates EVs into the grid.

This paper offers a clear path for how policymakers and regulators can best take advantage of these opportunities. Key recommendations are that policymakers revising the Alternative Fuels Infrastructure Directive:

- Develop a common vision for EV charging infrastructure in Europe.
- Require Member States, by way of a binding target in a directive or as a regulation, to define an "essential charging network" with the objective of providing a minimum coverage of charging points, including hard-to-serve areas.
- Establish public tenders as the default procedure to ensure cost-effective infrastructure build-out, based on current best practices and criteria for well-designed tenders.
- Consider and develop alternative tools, such as auctioning charging point locations, to reveal the economic value of each charging point.

We also recommend ambitiously implementing electricity market reforms to:

- Clarify the roles of regulated and private actors participating in a functioning EV charging services market.
- Require tariffs that reflect the cost of energy and delivery of electricity (time-varying network prices), as well as options for reduced network tariffs, to help develop public fast and ultrafast charging services.
- Develop guidance for making EV charging prices more transparent by basing the main price elements on electricity consumed.

Introduction

The electrification of passenger cars, vans, trucks and buses is crucial for decarbonising Europe's transport sector and reducing air pollution.[5] Supporting the shift to e-mobility in line with the European Commission's Green New Deal[6] will be a key element of a green recovery strategy for the transport sector after the current economic crisis. Support for e-mobility needs to include encouraging the development of a network for public electric vehicle (EV) charging across Europe, the lack of which is currently one of the largest barriers to the spread of EVs.

The degree to which the charging infrastructure allows for cost-effective and grid-friendly charging is a key ingredient for successfully integrating EVs into the existing power system. Enabling efficient public infrastructure build-out is thus a key element of the transport and energy transitions.

Unlike other obstacles, such as high upfront costs for EVs — which are expected to decrease as the market grows — building a sufficiently dense charging network and services, accessible for all consumers including low-income communities and optimally integrated with the electricity grid, will require more comprehensive policy solutions. These solutions need to collectively address EV drivers' needs and align with transport policy objectives, as well as requirements for electricity procurement and grid planning.

The degree to which the charging infrastructure allows for cost-effective and grid-friendly charging is a key ingredient for successfully integrating EVs into the existing power system. Enabling efficient public infrastructure build-out by eliminating barriers to beneficial EV grid integration is thus a key element of the transport and energy transitions. Approaching these two transitions jointly is, in turn, critical for the overall success of each.

Today's market for EV charging services faces several challenges. Lacking a shared vision of a common EV charging market with minimum build-out requirements and integrated planning procedures, European Member States developed public EV charging infrastructure in very different ways. The lack of clarity around ownership and operation of public charging points hinders the development of a competitive market. In addition, the suppliers of public fast charging services are facing high upfront and operational costs linked to the way the pricing for electricity and network use is designed. These aspects combined leave EV drivers with disjointed and opaque charging options that are frequently inconvenient. Not addressing these uncertainties, in turn, can slow the growth of EVs.

This paper argues that Member States should be required to establish an essential network to provide a minimum density of publicly accessible charging points in optimal locations. This will allow e-mobility to develop beyond private home and workplace charging to address a wider range of use cases while not stressing the energy system. Public tenders have emerged as a promising policy tool for ensuring basic infrastructure while building a competitive EV charging

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[5] Direct electrification is the most efficient option for cars, vans and buses. For long-haul trucks, prospects are promising for battery-based systems as well as electric road systems. Other technological options, including hydrogen fuel cell technology, are outside the scope of this paper. Hacker, F. (2018). *Transitioning to zero-emission heavy-duty freight vehicles: A system perspective on zero-emission heavy-duty road freight transport and challenges for a successful market entry*. Öeko-Institut e.V. https://theicct.org/sites/default/files/Oeko-Institut_ZEHDV_Brussels.pdf

[6] European Commission. (2019). *Communication on the European Green Deal*. https://ec.europa.eu/info/publications/communication-european-green-deal_en

market. The upcoming review of the Alternative Fuels Infrastructure (AFI) Directive — the legislative framework for charging infrastructure — offers EU policymakers and governments an opportunity to accelerate the build-out of smart charging infrastructure by including this requirement.

To phase in a functioning market for EV charging, it is critical that the planning, building and operation of EV charging infrastructure is cost-effective and climate friendly and supports grid operation. This is why policymakers also need to address the grid-related barriers to EV charging to help integrate electrified road transport into Member States' increasingly flexible and decentralised power markets. This includes clarifying ownership and operation of charging points, introducing time-varying[7] network tariffs to support load shifting and encourage investments in charging services, and making charging costs transparent and understandable for consumers. To address all of these elements, the review of the AFI Directive needs to align closely with the implementation of Europe's recent electricity market reforms and the Electricity Market Regulation and Directive as they are being implemented in Member States.

This paper concentrates on developing public charging infrastructure, the focus of the AFI Directive.[8] We focus on the policy recommendations necessary to develop optimally located public charging infrastructure. Its build-out will need to accommodate different groups of (future) EV users as the market grows and employ different EV infrastructure types.[9] It should be noted, however, that expanding public infrastructure represents only one part of Member States' effective planning for EV charging needs, as studies indicate that drivers will continue to do the majority of their charging at home or work.[10] Private charging must be considered in addition to public charging to avoid stranded assets and to most effectively integrate charging into the grid, but we do not address it in detail here.

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[7] "Time varying" includes different design options for tariffs that vary depending on when the vehicle is charged. An effective design includes higher tariffs at peak hours to encourage the user to shift consumption to less congested hours with lower tariffs. This is also referred to as critical peak pricing. This form of pricing is most effective in encouraging EV customers to lower network costs by reducing the investment needed to provide peak capacity. Faruqui, A., Hledik, R., & Palmer, J. (2012). *Time-varying and dynamic rate design*. Regulatory Assistance Project and The Brattle Group. https://www.raponline.org/knowledge-center/time-varying-and-dynamic-rate-design/

[8] This includes charging services at privately owned but publicly accessible locations such as supermarkets, hotels and so on, as defined by the current directive. European Parliament and Council of the European Union. (2014, 28 October). Directive 2014/94/EU of 22 October 2014 on the deployment of alternative fuels infrastructure. *Official Journal of the European Union.* https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32014L0094&from=EN

[9] We adopt the following distinctions among infrastructure types: non-fast chargers are either single-phase AC chargers (3 to 7 kWs), which charge an EV in about seven to 16 hours, or triphase AC chargers (11 to 22 kWs), which charge an EV in about two to four hours. In addition, fast DC chargers (50 to 100 kWs) or ultrafast DC chargers (above 100 kWs) charge EVs in 30-40 or 10-20 minutes, respectively. (These three types correspond to the U.S. terminology of Level 1, 2 and 3.) See Transport & Environment. (2020a). *Recharge EU: How many charge points will Europe and its Member States need in the 2020s.* https://www.transportenvironment.org/sites/te/files/publications/01%202020%20Draft%20TE%20Infrastructure%20Report%20Final.pdf. Public non-fast charging can meet the needs of users without personal off-street parking, who require publicly accessible charging points like curbside parking in the city or commercial parking. Public fast or ultrafast charging addresses drivers needing to top up occasionally but also fleet applications or EV-based ride-hailing services with higher mileage. Some additional demand for high-power public charging infrastructure can be expected from the electric logistics sector to the extent that demand cannot be covered by depot charging. Groen, M., Verweij, K., Vos, G., Otten, M., Tol, E., Wagter, H., de Goffau, W., Nering Bogel, W., Schoo, R., Ploos van Amstel, W., Balm, S., van den Hoed, R., van den Engel, A., Kindt, M., Kin, B., Nesterova, N., & Quak, H. (2019, July). *Charging infrastructure for electric vehicles in city logistics.* Top Sector Logistics. https://www.cedelft.eu/en/publications/2356/charging-infrastructure-for-electric-vehicles-in-city-logistics

[10] Engel, H., Hensley, R., Knupfer, S., & Sahdev, S. (2018, August). *Charging ahead: Electric-vehicle infrastructure demand.* McKinsey & Company. https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/charging-ahead-electric-vehicle-infrastructure-demand

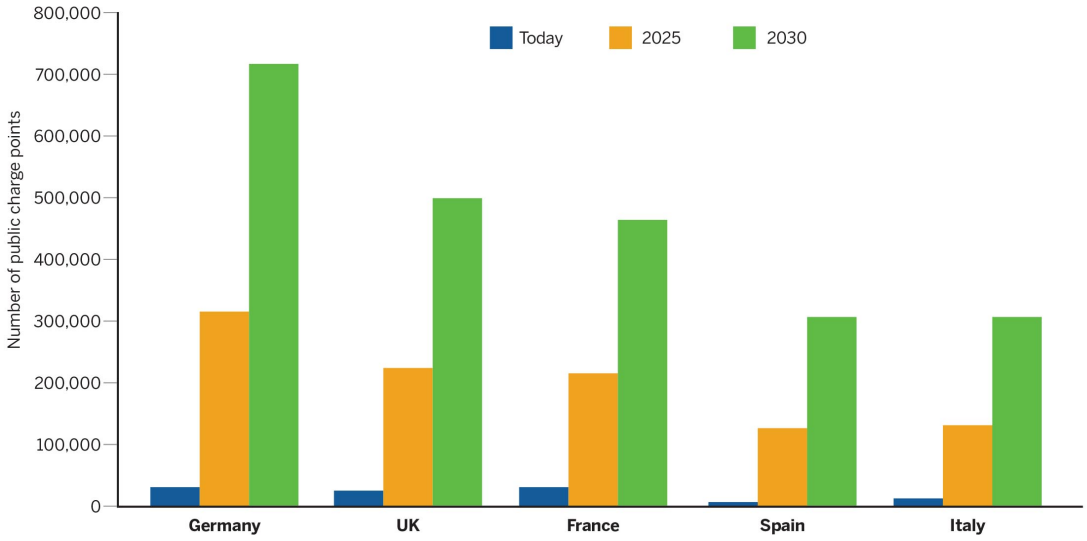
The two main sections of this paper guide policymakers through upcoming opportunities for building the market for smart EV charging. They discuss policy options for the following questions:

1. What is needed to most effectively plan EV charging infrastructure?
2. What grid-related barriers need to be addressed?

Planning electric vehicle charging infrastructure effectively

European Member States were initially cautious about supporting the build-out of an EV charging network as part of the alternative fuels infrastructure for road transport. As a result, their initial development plans in response to existing legislation, the current AFI Directive, contained large regional gaps in infrastructure coverage.[11] However, increasing carbon dioxide reductions over the vehicle life cycle and positive market prospects in all vehicle segments indicate a solid future for electric light-duty and, increasingly, heavy-duty vehicles.[12] Figure 1 shows the expected growth in the need for public chargers in the next 10 years.[13]

Figure 1. Projected need for public charging infrastructure in Europe's largest car markets



Source: Transport & Environment. (2020). *Recharge EU: How many charge points will Europe and its Member States need in the 2020s*

[11] European Commission. (2019, 13 February). *Report on the assessment of the Member States national policy frameworks for the development of the market as regards alternative fuels in the transport sector and the deployment of the relevant infrastructure pursuant to Article 10 (2) of the Directive 2014/94/EU* [Staff working document]. https://ec.europa.eu/transport/sites/transport/files/legislation/swd20190029.pdf

[12] The life cycle improvement is mainly due to improvements in battery production and technology. Transport & Environment. (2020b). *How clean are electric cars? T&E's analysis of electric car lifecycle CO_2 emissions.* https://www.transportenvironment.org/sites/te/files/downloads/T%26E%E2%80%99s%20EV%20life%20cycle%20analysis%20LCA.pdf. Electric trucks are expected to be cost-competitive with diesel trucks between 2025 and 2030. Hall, D., & Lutsey, N. (2019). *Estimating the infrastructure needs and costs for the launch of zero-emission trucks.* International Council on Clean Transportation. https://theicct.org/publications/zero-emission-truck-infrastructure

[13] Transport & Environment, 2020a.

Electrifying the vehicle fleet will reduce the EU's carbon dioxide emissions but also add to its electricity demand, in particular if charging is unmanaged. Demand from EVs in Europe is estimated to increase from approximately 0.03% of Europe's total electricity consumption in 2014 to 9.5% in 2050.[14] How much additional energy will be needed largely depends on whether EVs will be integrated successfully into the grid to use existing power network capacities as well as provide grid services, thus reducing the cost of EV grid integration. Integrated planning to optimise the type and location of charging infrastructure, including public charging infrastructure, will determine whether EVs will be charged optimally.

This projection of increasing EVs confirms the need for a common vision to provide public charging options across Europe in a least-cost, integrated manner. This section of the paper spells out the fundamental concepts underpinning a functioning EV charging market. We explore why national policymakers should be required to map out where essential charging infrastructure is needed, then we discuss public tenders as an effective planning tool.

Articulate a common vision for infrastructure rollout

European infrastructure policy should be designed with the objective of establishing a self-sustaining European market for EV charging. In this vision, EV drivers everywhere would have ready access to sufficient, accessible and smart charging infrastructure providing a range of charging services to fit their needs, with competition driving the innovation needed to provide those services at attractive prices. A well-designed charging market contains many elements that foster the integration of EVs into the electric grid while providing the most benefit to society. These include:[15]

- Equipping all public charging infrastructure with intelligent metering technology and implementing cost-reflective electricity and network pricing to ensure that EV charging occurs during the hours, and at locations, most beneficial for the grid.[16]
- Integrated planning among distribution system operators (DSOs), e-mobility service providers[17] and public authorities[18] when siting public charging points. This coordination takes into account mobility demands and available grid capacity to minimise investments.

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[14] European Environmental Agency. (2016). *Electric vehicles and the energy sector: Impacts on Europe's future emissions.* https://www.eea.europa.eu/publications/electric-vehicles-and-the-energy/download

[15] One of the benefits not detailed in this paper is unrestricted access and mobility among different user networks. Slater, S., Ferguson, N., Dodson, T., Cutter, E., & Heavey, C. (2019). *Implementing open smart charging.* ZEV Alliance. http://www.zevalliance.org/implementing-smart-charging/

[16] Public fast and ultrafast charging presents unique considerations for optimisation of charging: Faster charge speeds will enable EV drivers to spend less time at charging points, which means a reduced ability to shift the timing of charging, such as through dynamic tariffs. Additional planning measures, such as optimising charging by location, are needed to ensure beneficial EV grid integration and reduce cost. These measures can include locating fast charging points in areas where grid capacity or renewable energy production is available. An additional strategy for lowering costs is the use of storage to increase siting options, for example by equipping fast chargers with stationary batteries from used EVs. Storage also gives service providers access to cheaper energy in general, independent of specific siting. This paper does not further examine storage as a strategy to optimise grid use of EVs. For a summary with examples of best practices, see smartEn. (2020). *E-mobility as an energy resource: Collection of best practices to drive regulatory changes*. https://smarten.eu/wp-content/uploads/2020/02/smartEn-e-mobility-publication-2020_for-web.pdf

[17] The same entity may serve as both the e-mobility service provider and the charging point operator (CPO).

[18] In particular for urban EV charging in metropolitan areas, public authorities have a significant role in the siting of infrastructure. This ranges from use of public land to integration with existing transport systems (traffic management considerations, pedestrian needs, disability access, etc.).

By enshrining these elements in the legislative framework for charging infrastructure, the announced review of the AFI Directive can provide European Member States with the necessary guidance as they build infrastructure in preparation for increased need.

To support this process, many have called for binding target requirements for Member States to build sufficient public charging infrastructure.[19] The advantage of target requirements is that they provide planners and investors with more certainty for their investments.[20] They are also in line with other recently adopted policies aimed at increasing EV sales, such as stricter carbon dioxide standards, sales targets for zero-emissions vehicles and various national purchase incentives for EVs. One of the options the European Commission could investigate to strengthen these requirements on Member States and industry, and further a common vision for a single European market for EV services, is reissuing the Alternative Fuels Infrastructure Directive as a regulation.[21]

Although the need for a common vision supports a more prescriptive legislation, it's essential to avoid overbuilding based on inaccurately defined target criteria. Current practices highlight the need for careful deliberation and coordination: Several governments are currently basing the development of charging infrastructure on simple quantitative targets by defined target years,[22] while the European Commission initially recommended range-based targets, which now need review.[23] Meanwhile, EU-level research shows the need for more specific supply metrics to set targets that best meet mobility demand and avoid stranded assets.[24] Less focus has been placed thus far on the integrated planning approaches that governments will need to ensure that targets are providing sufficient and accessible charging points, without overbuilding, and integrating these effectively into the grid.

To address the current need for binding targets for EV charging infrastructure build-out while recognising different market needs, the EU should require Member States to define infrastructure that is essential to accelerate the EV market. The next part of this paper recommends that Member States develop an essential infrastructure network based on the common vision for a smart European EV charging market.

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[19] Platform for Electro-mobility. (2019). *Platform for Electro-mobility calls for revision of the Alternative Fuels Infrastructure Directive*. https://www.platformelectromobility.eu/wp-content/uploads/2018/02/Electromobility-Platform_Position-paper-AFID_final.pdf

[20] Sustainable Transport Forum. (2019). *Analysis of stakeholder views on key policy needs and options for action in alternative fuels infrastructure deployment and consumer services.* https://ec.europa.eu/transport/sites/transport/files/2019-stf-consultation-analysis.pdf

[21] A previous example of a European directive reissued as a regulation is the European Type Approval legislation that was reinforced after national type approval authorities failed to prevent vehicle emissions fraud. Regulation (EU) 2018/858 replaced Directive 2007/46/EC.

[22] For example, the energy industry viewed Germany's plan to build 1 million public charging points by 2025 as too ambitious. Stratmann, K. (2019, 4 November). Energiebranche warnt vor zu viel Ehrgeiz beim Ausbau von Ladesäulen. *Handelsblatt*. https://www.handelsblatt.com/politik/deutschland/autogipfel-energiebranche-warnt-vor-zu-viel-ehrgeiz-beim-ausbau-von-ladesaeulen/25186284.html?ticket=ST-418722-nPlStkdUl4Okz5MvKRrJ-ap6

[23] The EU Commission initially recommended a ratio of 10 vehicles to 1 charging point and recognises that this parameter will have to be refined and tailored. Thiel, C., Julea, A., Acosta Iborra, B., De Miguel Echevarria, N., Peduzzi, E., Pisconi, E., Gómez Vilchez, J. J., & Krause, J. (2019). Assessing the impacts of electric vehicle recharging infrastructure deployment in the European Union. *Energies*, *12*(12), 2409. https://www.mdpi.com/1996-1073/12/12/2409/htm. This finding is confirmed by an expert group advising the commission on Alternative Fuels Infrastructure legislation review. See Sustainable Transport Forum, 2019.

[24] These methods would need to reflect factors such as the increasing range of EVs and decreasing range anxiety, anticipated use patterns of EVs in other vehicle segments and geographical characteristics, as suggested by Thiel et al., 2019, but also the energy that charge points can provide to EVs and their availability. See Transport & Environment, 2020a.

Define an essential charging network

Revised Alternative Fuels Infrastructure legislation should require Member States to develop an essential charging network. The idea is to provide minimum charging infrastructure that encourages more EVs while avoiding both overbuilding the network and creating barriers to a functioning commercial market for charging services. It would improve the existing public infrastructure legislation by requiring governments to commit to, and focus on, realistic infrastructure targets, anchored from the outset into an integrated planning approach to cost-efficient grid integration.[25]

The essential network would allow Member States to:

- Provide sufficient public charging infrastructure to support significant expansion in the use of electric vehicles, including cross-border travel.
- Make public charging infrastructure accessible to all consumer groups to provide reliable charging and boost consumer confidence.
- Integrate EV charging optimally with the electric transmission and distribution systems.
- Address the risk of rural communities as well as low-income and disadvantaged communities being left behind as charging infrastructure is built. The risk is higher in areas where there are fewer alternative transport options available, such as rural areas.[26] Governments can choose to include a minimum number of these communities in the essential network.

Including in revised legislation the requirement to create an essential network will provide overall certainty to Member States for investing in e-mobility infrastructure expansion, while allowing governments to focus their investments where needed, thus avoiding stranded assets.

The essential network approach values Member States' past efforts made in response to legislation, the current AFI Directive. Including the requirement to create an essential network in the revised legislation will provide overall certainty to Member States for investing in e-mobility infrastructure expansion, while allowing governments to focus their investments where needed in view of the market situation and anticipated demand, thus avoiding stranded assets. It allows public policymakers to meet the goal of ensuring minimum density and reliability, while helping alleviate burdens from any financial support needed to jump-start the market.

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[25] This represents best practices in planning for electrification of transport. More guidance to policymakers to approach planning for transport electrification along with grid integration is in Farnsworth, D., Shipley, J., Sliger, J., LeBel, M., & O'Reilly, M. (2020). *Taking first steps: Insights for states preparing for electric transportation*. Regulatory Assistance Project. https://www.raponline.org/knowledge-center/taking-first-steps-insights-for-state-utility-commissions-preparing-for-electric-transportation/. See also Hall, D., & Lutsey, N. (2020). *Electric vehicle charging guide for cities.* International Council on Clean Transportation. https://theicct.org/sites/default/files/publications/EV_charging_guide_03162020.pdf

[26] "There is a serious lack of conventional transport and of various shared mobility options that are being deployed in many urban areas. The reality for many rural areas is few buses, even fewer train stations and an almost total dependence on cars." European Network for Rural Development. (2019). *Smart villages and rural mobility.* https://enrd.ec.europa.eu/publications/smart-villages-rural-mobility_en

The concept of an essential network is being implemented in the U.S. states of New Jersey[27] and Florida.[28] The state legislatures recognised the importance of stakeholder engagement and instructed either a work group or a state agency to convene a stakeholder engagement process to determine an appropriate essential charging network. The aim of both states is to provide security for EV drivers and electricity consumers while setting the foundation for a market for EV charging services to develop.

Next we discuss which planning tools can help Member States determine the optimal locations for charging infrastructure and effectively allocate the necessary financial support for the essential network.

Start with public tenders

Public tenders are run by public sector entities to award contracts for services, supplies or civil engineering works, choosing among competing offers based on price and quality.[29] Thoughtfully designed public tenders have proven to be effective in ensuring minimum charging infrastructure is built and in properly allocating public funding to phase in the EV charging market. In locations where charging infrastructure is not yet being pulled or driven by demand from the growing number of EVs, policymakers may initially need to push infrastructure development. Identifying an essential charging network can help planners decide where to allocate subsidies if needed. It is important, however, to involve commercial parties from the start that could take over operation in a more mature market.

Best practices from the Netherlands and from Norway suggest that well-designed public tenders are a successful tool to phase in charging infrastructure operation by providing a minimum density of chargers based on demand, thus avoiding oversupply.[30] In Amsterdam, EV drivers can request that the municipality install a charging point at a location convenient for users. The public procurer appointed by the city checks whether the user's request can be granted based on criteria such as distance to existing or planned charging points and their occupancy rate, and whether previous requests exist for the same spot. For the installation of a new charging point, the grid operator and city district are consulted, and if appropriate, a grid connection is granted and built as required.[31] Norway's public innovation agency Enova has developed a targeted

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[27] New Jersey General Assembly, A.B. 4634, introduced 22 October 2018. https://www.njleg.state.nj.us/2018/Bills/A5000/4634_I1.HTM. The New Jersey legislation is discussed in Kadoch, C. (2020, February). *Roadmap for electric transportation: Model legislation*, pp. 21-23. Regulatory Assistance Project. https://www.raponline.org/knowledge-center/roadmap-electric-transportation-model-legislation

[28] Florida Legislature, C.S./S.B. 7018, Essential State Infrastructure, 26 May 2020. http://www.flsenate.gov/Session/Bill/2020/7018/BillText/er/PDF and https://www.flsenate.gov/Session/Bill/2020/7018#:~:text=Essential%20State%20Infrastructure%3B%20Authorizing%20the,requiring%20the%20department%20to%20coordinate%2C

[29] European Union. (n.d.). *Public tendering rules*. https://europa.eu/youreurope/business/selling-in-eu/public-contracts/public-tendering-rules/index_en.htm

[30] Hildermeier et al., 2019.

[31] Another best practice example for optimising the location of charging infrastructure is the price-based instrument used in Norway to site charging points based on grid capacity. The entity building the charging infrastructure pays a connection charge that varies based on location. The charge is lower for sites with available grid capacity. This pricing structure also ensures that the network companies can cover their costs. The charge provides a price-based mechanism to determine the best locations for charging infrastructure and provides revenue for grid companies that ensures the costs to connect charging infrastructure will not be passed on to all electricity consumers. For more information, see Norwegian Energy Regulatory Authority. (2020, 31 March). *Anleggsbidrag* [Plant contributions]. https://www.nve.no/reguleringsmyndigheten/nettjenester/nettilknytning/anleggsbidrag/

funding scheme to address citizens' public charging needs with gradually narrower financing criteria to phase in a commercial EV charging market.[32] Data show that the number of fast charging stations being installed without public support has been increasing, especially in and around cities as well as along major highways.[33] This suggests that in these areas e-mobility service suppliers have a commercial interest to enter the market, and less publicly supported charging will be needed.

There are many advantages to using public tenders to phase in a commercial EV charging market. They can help decision-makers assess the financial support needs for building charging infrastructure in different locations.[34] At the same time, their design can also support smart EV grid integration. Options for municipalities to achieve both include the following:

- Encourage higher utilisation of the charging infrastructure; for example, by basing financial support on capacity factors or other utilisation-based indicators.
- Identify and prioritise charging infrastructure at locations that promote a modal shift towards alternatives to private passenger vehicles, such as transport hubs, in line with cities' and regions' overall sustainable transport and social equity goals.[35]
- Require that all charging infrastructure supports time-varying pricing, encouraging customers to charge when prices are lower.[36]

Equipping remote areas remains the largest challenge for governments in building charging infrastructure. Evidence from Norway, Europe's most developed EV market, shows that despite pursuing good practices in planning to encourage a charging market, a few locations remain in which no commercial bidders for public tenders could be found to equip more remote areas with charging points. Even with 100% financial support for installation costs, no companies have bid on Enova's fourth tender round to build charging stations in the far north of the country. Governments are grappling with the question of how and to what extent to finance charging infrastructure in locations where service providers cannot build a business case. In these cases, several approaches can be considered:

- First, public authorities can issue a joint tender for rural charging locations combined with

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[32] Early tenders in 2015 and 2016 supported 230 fast charging stations along the country's main highways, covering up to 100% of installation costs. Since 2017, only new installations in municipalities with fewer than two installed fast chargers can get investment support, which covers 40% of installation costs. Enova. (2017, June). *Enova vil hurtiglade distriktene* [Enova will quickly charge the districts]. http://presse.enova.no/pressreleases/enova-vil-hurtiglade-distriktene-2036526

[33] Lorentzen, E., Haugneland, P., Bu, C., & Hauge, E. (2017, 9-11 October). *Charging infrastructure experiences in Norway: The worlds most advanced EV market.* 30th International Electric Vehicle Symposium and Exhibition. https://elbil.no/wp-content/uploads/2016/08/EVS30-Charging-infrastrucure-experiences-in-Norway-paper.pdf. Additional measures supporting electric vehicle use and supply in Norway also helped establish a successful EV charging market.

[34] It is important that DSOs not be allowed to compete, as they could disadvantage competitors, mostly with regard to the costs of connecting to the DSO network. The clarifications needed for the role of DSOs are further explained in the next section.

[35] An example is supporting infrastructure for the electrification of bus fleets. In general, these planning priorities require governments to strengthen municipal decision-making and multistakeholder planning efforts at the city level and should be based on the revised sustainable urban mobility planning guidelines for cities issued in mid-2019. Guidelines for including electrification into sustainable urban mobility plans can be found here: European Platform on Sustainable Urban Mobility Plans. (2019, June). *Electrification in sustainable urban mobility planning: Planning for electric road mobility solutions in urban areas in a SUMP context.* https://www.eltis.org/sites/default/files/electrification_in_sustainable_urban_mobility_planning.pdf

[36] Hildermeier et al., 2019, Chapter 4; and smartEn. (2019). *Making electric vehicles integral parts of the power system*. https://www.smarten.eu/wp-content/uploads/2019/07/FINAL-smartEn-White-Paper-E-Mobility.pdf

more densely populated areas as part of the essential network defined by Member States. This can help identify bidders who can support operation of charging points by using profitable locations to cross-finance unprofitable ones with the benefit of providing charging points across the entire territory.

- Second, auctions could be used to reveal the value of charging point locations and any subsequent need for public support. Similar to auctions for renewable energy generation sites, governments could design the auctions to determine whether support is needed to build the charging market in specific locations. Companies could bid for either the lowest price to own and operate charging points or the lowest subsidy needed to develop them.
- Third, as a last resort if no commercial party is interested in participating despite funding, grid operators could be considered. Recent electricity market legislation allows policymakers to involve grid operators in supplying minimum infrastructure if it is in the public interest.[37] The next section of this paper outlines why this last-resort solution needs close monitoring and should only apply under certain conditions.

Preceding sections outlined considerations to plan EV charging infrastructure effectively, starting from the need for a holistic approach, or vision, for a competitive market for smart EV charging services in Europe. The review of the Alternative Fuels Infrastructure legislation opens the door for this opportunity.

But targets and tools for the infrastructure build-out are only the first step towards establishing a robust market for EV charging. In the next section, we look at the additional policy changes needed to set up a competitive market for smart EV charging to ensure consumers can gain the benefits EVs provide for the clean energy transition.

Policy options for effective infrastructure planning

We recommend that policymakers revising the Alternative Fuels Infrastructure Directive:

- Develop a common vision for an EV charging infrastructure in Europe.
- Require Member States to define an essential charging network with the objective of providing a minimum coverage of charging points, also in areas with lower population density. A stakeholder group from both the mobility and energy sectors could be given the task of defining locations to represent all interests.[38]
- Establish public tenders as the default procedure to ensure cost-effective infrastructure build-out, based on current best practices and criteria for well-designed tenders.
- Consider alternative tools, such as auctioning charging point locations to reveal the economic value of each charging point.

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[37] European Parliament and Council of the European Union. (2019a, 14 June). Directive (EU) 2019/944 of 5 June 2019 on common rules for the internal market for electricity and amending Directive 2012/27 (recast), Art. 33. *Official Journal of the European Union.* https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32019L0944&from=EN

[38] As practiced in U.S. states implementing an essential network. See the section above on defining an essential charging network, starting on Page 8. Similar approaches exist in Europe on the local and national level; examples are London's EV Infrastructure Taskforce and the Netherlands' Sustainable Fuels Vision, which included municipalities' and regions' input. See Mayor of London & London Assembly. (n.d.) *Electric vehicle infrastructure*. https://www.london.gov.uk/what-we-do/environment/pollution-and-air-quality/electric-vehicle-infrastructure; and Ministry of Infrastructure and the Environment of the Netherlands. (n.d.). *Summary of the Netherlands Sustainable Fuels Vision.* https://dutchmobilityinnovations.com/attachment?file=YbkhZETd%2FiLStzUSTxJKFg%3D%3D

Eliminating barriers to a competitive electric vehicle charging market

We need solutions to enable a functioning EV charging market in which EV drivers everywhere in Europe would have ready access to sufficient, accessible and smart charging infrastructure providing a range of charging services to fit their needs, with competition driving the innovation needed to provide those services at attractive prices. To realise this vision, Member States need to address several barriers to establishing cost-effective and beneficial EV charging. Member States can start developing solutions to these barriers by implementing provisions of the recent electricity market reforms. Implemented ambitiously enough, these reforms will build the necessary backbone for an electricity market capable of optimally integrating increasing numbers of small and larger EVs.

First, regulated grid operators have played a pivotal role in helping some countries build early charging infrastructure. In transitioning to a commercially viable market for EV charging, Member States need to clarify how and whether regulated entities are allowed to be involved.

Second, high and non-time-varying network charges — the prices for electricity delivery — make it difficult for e-mobility service providers to build and operate charging points. Time-varying network tariffs aimed at shifting network use away from peak hours to reduce the need for grid reinforcement, or temporary reductions in tariffs in the early stages of market development, can help to address this problem.

Third, consumers often face confusing information about pricing at public charging points. Basing the cost of charging services mainly on the cost for electricity consumed could reduce drivers' uncertainty and encourage usage by keeping prices reasonable.

Clarify ownership and operation rules

One challenge facing policymakers when developing a market for EV charging is finding the right balance between creating a competitive market that will ultimately ensure sufficient and convenient EV charging and guaranteeing a minimum density of charging points to allow all users to take advantage of e-mobility, as defined, for example, in an essential network. In general, where infrastructure is not defined as a monopoly service, the competitive market can provide it. Two related questions emerge for regulators and policymakers: first, whether regulated entities need to be involved in developing the charging infrastructure market and how their role can be defined with regard to private competitors; second, what role they can play if the market is unlikely to be developed in the near future.

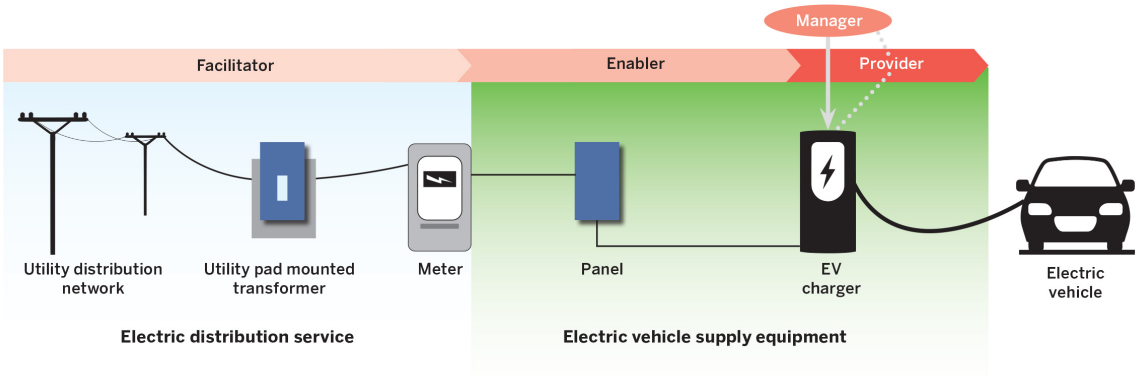
In the United States, the involvement of regulated utilities in deploying electric vehicle supply equipment has generated a robust debate.[39] Proponents argue that involving regulated entities helps provide more certainty for planning purposes, fosters identification of optimal siting for charging infrastructure and ensures greater expertise for system integration. Opponents of

[39] Kadoch, 2020, p. 23. About half of the U.S. electricity markets are vertically integrated markets in which utilities cover both energy supply and distribution functions with regulated prices. In addition, U.S. regulators generally require more transparency and monitoring from regulated companies than do their EU counterparts, which means a higher degree of control is likely for any utility involvement. In the EU, the unbundling requirement stipulates that grid operators only must remain regulated, and this process has been completed to varying degrees. Smaller DSOs with fewer than 100,000 customers, the threshold for unbundling, remain vertically integrated.

regulated entity involvement in providing charging infrastructure cite a concern that these entities have an unfair competitive advantage as they are commonly known monopoly service providers that could chill the evolution of a charging market by lesser-known providers. Another concern is that, depending on the regulatory framework in which they operate, they can have a bias towards inefficiently high levels of capital investment from which they recover costs and potentially less incentive to control the costs of charging infrastructure.[40]

As a result, many states currently find themselves balancing the desire to promote an EV market and the delivery of electric transportation services against the need to make sure that utility investments neither carry too high a price tag nor eliminate opportunities for competition among market entrants who could provide charging services and benefit the overall power system. States have taken varied approaches to utility involvement in charging infrastructure. These range from neutral facilitator treating EV charging as any other load to active manager of charging points, with a middle ground of an enabling role deploying make-ready infrastructure capacity in key areas to enable project development. Figure 2 illustrates the areas of responsibility for four potential utility roles in providing public charging.[41]

Figure 2. Potential roles for utilities in EV charging infrastructure



Sources: Base illustration based on California Public Utilities Commission, Application 15-02-009, Proposed Decision of ALJ Farrar, mailed 14 November 2016. Roles drawn from Nelder, C., Newcomb, J., and Fitzgerald, G. (2016). *Electric vehicles as distributed energy resources*; and Advanced Energy Economy. (2018). *EVs 101: A regulatory plan for America's electric transportation future*

[40] To counter this effect, regulatory frameworks can provide incentives to regulated companies to control costs by setting revenue caps or other performance-based incentives. See Pató, Z., Baker, P., & Rosenow, J. (2019). *Performance-based regulation: Aligning incentives with clean energy outcomes*. Regulatory Assistance Project. https://www.raponline.org/knowledge-center/performance-based-regulation-aligning-incentives-clean-energy-outcomes/; and Lazar, J. (2014). *Performance-based regulation for EU distribution system operators*. Regulatory Assistance Project. https://www.raponline.org/knowledge-center/performance-based-regulation-for-eu-distribution-system-operators/

[41] Base illustration based on California Public Utilities Commission, Application 15-02-009, Proposed Decision of ALJ Farrar, mailed 14 November 2016, p. 8. http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M171/K213/171213824.PDF. Roles drawn from Nelder, C., Newcomb, J., & Fitzgerald, G. (2016). *Electric vehicles as distributed energy resources.* Rocky Mountain Institute. http://www.rmi.org/pdf_evs_as_DERs; and Advanced Energy Economy. (2018). *EVs 101: A regulatory plan for America's electric transportation future.* https://info.aee.net/advanced-energy-policy-brief-ev-101

In the EU, most governments have been seeking to phase in a commercially driven market for charging services as indicated by existing legislation.[42] Echoing this understanding, the Council of European Energy Regulators specifies that the sale of EV charging can be considered the sale of a service, not the sale of electricity — implying that charging infrastructure and EV charging services should be supplied by parties in a commercial market.[43] This approach is consistent with the European Electricity Market Directive stipulating that "distribution system operators shall not own, develop, manage or operate recharging points for electric vehicles."[44] (A recent contrary legal opinion may need further discussion.[45]) In other words, grid operators are being assigned the role of facilitators.

One challenge facing policymakers is finding the right balance between creating a competitive market that will ultimately ensure sufficient and convenient EV charging and guaranteeing a minimum density of charging points to allow all users to take advantage of e-mobility.

While building the early EV market, several EU Member States had to rely, however, on DSOs as regulated entities to serve as enablers, and temporarily also as managers, of charging infrastructure to encourage infrastructure build-out. This was mostly due to a lack of commercial providers in the early market phase. In some states this has temporarily meant that the situation in practice has not followed legislative guidance on phasing in commercial charging infrastructure development and operation.

[42] The current AFI Directive includes as a goal: "The establishment and operation of recharging points for electric vehicles should be developed as a competitive market with open access to all parties interested in rolling-out or operating recharging infrastructures." See European Parliament and Council of the European Union, 2014, Art. 30, p. L 307/5.

[43] The Council of Energy Regulators specifies further, "This implies that the CPO [charging point operator] has an ordinary contractual relationship with the electricity retail supplier and the DSO considers the whole station as a single point of delivery. Therefore, EV users do not require any contract with the supplier to the CPO; EV drivers can either enter into a transaction with the CPO or with a 'mobility service provider' (MSP), which may act as an aggregator for charging services." Council of European Energy Regulators. (2019). *New services and DSO involvement: A CEER conclusions paper*. https://www.ceer.eu/documents/104400/-/-/ef4d6e46-e0a5-f4a4-7b74-a6d43e74dde8. In some Member States, such as France, this is already enshrined in national law.

[44] European Parliament and Council of the European Union, 2019a, Art. 33 (2), p. L 158/160.

[45] In this opinion, the EU's VAT Committee "unanimously agrees that the transaction carried out by the CPO shall be considered to be a supply of goods in accordance with Articles 14(1) and 15(1) of the VAT Directive." VAT Committee. (n.d.) *Guidelines resulting from meetings of the VAT Committee up until 8 April 2020*, p. 251. https://ec.europa.eu/taxation_customs/sites/taxation/files/guidelines-vat-committee-meetings_en.pdf

DSO involvement in charging infrastructure build-out: EU examples

- In Spain, DSOs have deployed most of the charging infrastructure, leaving commercial operation to retailers.[46] But infrastructure deployment has remained low. The government passed a decree in October 2018 to allow DSOs to own and operate charging points as a last-resort option under certain conditions, such as lack of private interest after a competitive tender.[47]
- In Luxembourg, the regulator tasked DSOs with building the country's public EV charging infrastructure network in 2015.[48] The country's five DSOs built, operated and maintained the EV charging infrastructure until 2016. In that year, the regulator outsourced commercial operation to energy supplier Engie Cofely Luxembourg, and the procurement and operation platform was awarded to an e-mobility service provider. To this day, the distribution companies have retained ownership of the network of charging points.[49]
- In the Netherlands, charging infrastructure development has been driven by DSOs since the early days. The government has, however, sought to phase in commercial operation where possible in cooperation with municipalities.[50] EVnetNL, an initiative of five network operators, set up around 3,000 charging points between 2009 and 2014 jointly with innovation platform ELaad. EVnetNL was the primary owner of this public charging infrastructure until 2016. It gave municipalities the option to take over operation and management, and some outsourced this to commercial parties once again. EVnetNL is still responsible, however, for the operation and maintenance of around 800 charge points in 200 municipalities and remains the largest manager of public charging points in the country, albeit representing only a minor fraction of the total public charging points network.[51]
- In Germany, DSOs may manage EV charging under certain circumstances through a specific tariff. National legislation defines EVs as a "controllable end use" that allows distribution system operators and suppliers to offer discounted network charges for EV charging (see the section on network tariffs on Page 17).[52] In return, consumers grant the DSOs the right to adjust their demand from controllable loads during predetermined on-peak hours if the distribution network is stressed. In effect, these tariffs permit DSOs to interrupt EV charging during peak hours if it is necessary to safeguard the power supply.

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[46] Wargers, A., Kula, J., Ortiz De Obregon, F., & Rubio, D. (2018). *Smart charging: Integrating a large widespread of electric cars in electricity distribution grids*, p. 9. European Distribution System Operators for Smart Grids. https://www.edsoforsmartgrids.eu/wp-content/uploads/EDSO-paper-on-electro-mobility-2.pdf

[47] Boletín Oficial del Estado [Official State Gazette, Spain]. (2018, 6 October). N242: Real Decreto-ley 15/2018, de 5 de octubre, de medidas urgentes para la transición energética y la protección de los consumidores [Nr. 242: Royal Decree-Law 15/2018, of 5 October, on urgent measures for the energy transition and consumer protection]. https://www.boe.es/boe/dias/2018/10/06/pdfs/BOE-A-2018-13593.pdf

[48] Már Baldursson, F., Lazarczyk Carlson, E., & von der Fehr, N. H. (2019). *Electric vehicles rollout in Europe: Towards an improved regulatory regime*. Centre on Regulation in Europe. https://www.cerre.eu/sites/cerre/files/cerre_2019_electricvehicles_energyregulation.pdf

[49] Már Baldursson et al., 2019, p. 43.

[50] Ministry of Economic Affairs. (2017). *Vision on the charging infrastructure for electric transport,* p. 5. https://www.rvo.nl/sites/default/files/2017/05/Vision%20on%20the%20charging%20infrastructure%20for%20electric%20transport.pdf

[51] EVnetNL. (n.d.). *Beheer laadpalennetwerk* [Charge point network management]. https://www.evnet.nl/organisatie/. There are 38,000 public charging points in the Netherlands. Már Baldursson et al., 2019.

[52] Bundesministerium für Justiz und Verbraucherschutz [Federal Ministry of Justice and Consumer Protection]. (2005). Gesetz über die Elektrizitäts- und Gasversorgung (Energiewirtschaftsgesetz – EnWG) [Law on electricity and gas supply (Energy Industry Act – EnWG)], Para. 14a. https://www.gesetze-im-internet.de/enwg_2005/BJNR197010005.html. For a detailed discussion on adjustments needed to this approach, see Jahn, A., Maier, U., Langenheld, A., & Lenck, T. (2020, February). *Kommentierung: Spitzenlastglättung nach § 14 a EnWG; Digitalisierung der Energiewende — Thema 2: Regulierung, Flexibilisierung und Sektorenkopplung* [Explanation: Reducing peak load according to § 14 a EnWg; Digitization of the energy transition — topic 2: regulation, flexibility and sector coupling]. Agora Energiewende. https://www.agora-energiewende.de/veroeffentlichungen/kommentierung-spitzenlastglaettung-nach-14-a-enwg/

As they transition to a market for EV charging services, Member States will have to clarify the role DSOs can and should play to pave the way for a competitive EV charging market, lowering costs for consumers and the costs of grid integration. This will need to be based on transparent criteria and will require close monitoring. Member States will also need to address the future responsibilities of grid operators in a transforming energy market more broadly.[53]

Given the need to develop charging infrastructure in underserved areas when no commercial party expresses interest, DSOs could be involved based on a minimum service approach to charging infrastructure build-out and help governments build parts of the essential charging network. Grid operators have justified this type of involvement, arguing that "the DSO ownership model is relevant in nascent markets, or where commercial parties are reluctant to install a sufficient number of charging stations (i.e., low-density/wide geographical areas, or those with underdeveloped public transport)."[54]

Legislation that Member States are implementing reflects this. The Electricity Market Directive provisions in Article 33 do account for the possibility that distribution system operators may need to own and operate charging infrastructure in case of market failure. The directive requires that an open, transparent and nondiscriminatory tendering procedure must have determined that competitive offers are lacking and the market has failed.[55] But the question remains how to define, verify and monitor lack of competition.[56] In particular, the market situation can show improvement after only a short period. This implies that regulators need to have a means of frequent monitoring and control, including requiring that DSOs forfeit the ownership and operation to let market parties take over.

A mechanism for deciding DSO involvement could be the level of charging point utilisation. Governments could define a threshold for market development, above which DSOs must hand over ownership and operation to market parties. The threshold would need to be locally specific and should reflect the turning point when DSO involvement is no longer necessary because charging point utilisation has increased in a maturing market.[57] When deciding the extent of DSO involvement in managing charging infrastructure, additional principles of beneficial EV grid integration should apply:

- Avoid overspending for investments related to charging infrastructure and seek to maximise net benefits for customers.

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[53] This new definition is also part of a larger change in the role of DSOs as a consequence of electrifying sectors such as transport. See Baker, P. (2020, 8 June). *Challenges facing distribution system operators in a decarbonised power system.* Regulatory Assistance Project. https://www.raponline.org/knowledge-center/challenges-facing-distribution-system-operators-in-decarbonised-power-system/

[54] Wargers et al., 2018, p. 9.

[55] The Electricity Market Directive requires that this was proven by an "open, transparent and non-discriminatory tendering procedure that is subject to review and approval by the regulatory authority, [that the bidding entities] have not been awarded a right to own, develop, manage or operate recharging points for electric vehicles, or could not deliver those services at a reasonable cost and in a timely manner." European Parliament and Council of the European Union, 2019a, Art. 33 (3), p. L 158/160.

[56] This could be designed similarly to provisions to accelerate the market for storage. The monitoring intervals, however, need to be frequent enough to reflect a rapidly changing market; for example, annually. European Parliament and Council of the European Union, 2019a. See also European Parliament and Council of the European Union. (2019b, 14 June). Regulation (EU) 2019/943 of the European Parliament and of the Council of 5 June 2019 on the internal market for electricity (recast). *Official Journal of the European Union.* https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32019R0943&from=EN

[57] An alternative approach could allow any commercial entity to offer to take over DSO-owned assets at a depreciated value set through regulation.

- Require grid operators connecting EV charging points to choose the more cost-efficient option when deciding whether to invest in network development or in demand-side programmes that can defer investment.
- Ensure best use of the existing networks. Use price signals, for example, to communicate power system costs.

In summary, several policy options exist for Member States to clarify DSO involvement in building out charging infrastructure. These need to be in line with the electricity market reforms, in particular the Electricity Market Directive; that is, regulated entities should only be involved as a last-resort option to ensure minimum charging service. If DSO involvement is allowed, regulators should consider the following requirements:

- Utilisation and market conditions are closely monitored to quickly phase in any third parties who wish to take over commercial operation of charging points. A market penetration threshold adapted to local conditions is set, at which point grid operators would have to exit the market.
- Grid operators make data on grid usage available to all involved market parties and planners to further the objective of making the best use of existing networks.
- Sufficient transparency about how grid operators use the revenues from charging infrastructure is established. Regulators should also ensure that companies do not overspend and that they seek to maximise net benefits for customers.

Next we illustrate why, in many EU countries, building a market for EV charging that does not rely on involving regulated entities needs to go hand in hand with cost-reflective and transparent pricing, starting with a reform of network pricing structures.

Introduce cost-reflective network tariffs

Another important barrier to building a self-sustaining market for EV charging is the lack of cost-reflective and transparent pricing, both for the production and delivery of electricity that the service provider buys from the energy supplier and, by extension, in the end price the final customer pays for the charging services. This part of the paper explains the need for cost-reflective network tariffs — that is, the way grid operators recover costs that come from operating their network. The next discusses implications for the end customer.

By influencing how and when drivers charge their vehicles, time-varying pricing can help manage the impact that EV charging will have on the grid and can be an effective tool to facilitate EV grid integration.[58] This is also true for the charges consumers pay to network companies for using the network, referred to as network tariffs, which keep growing and currently represent about a third of the average electricity bill in Europe.[59] Evidence shows that designing network tariffs in a way to reduce peak load periods can help shift all consumption,

[58] Hildermeier et al., 2019.

[59] Pinto-Bello, A. (2019). *The smartEn map: Network tariffs and taxes,* p. 17. smartEn.. https://www.smarten.eu/wp-content/uploads/2019/12/the_smarten_map_2019.pdf

not just EV charging, away from peak hours into hours with more grid capacity.[60] There are many markets for charging services depending on whether charging happens at home in single- or multifamily buildings, at office or commercial sites or in public, at parking areas or transport hubs or at fast charging stations along highways. Depending on the use case, cost-reflective network tariffs, such as critical peak pricing, or targeted tariff designs temporarily reducing network costs for fast chargers can support cost-efficient EV grid integration.[61] To illustrate these points, this section discusses network cost implications for public fast charging.

The way network charges are currently designed in many European countries represents a particular barrier to building the market of fast charging services, a key component of the European charging network, especially along highways or at transport hubs.

Fast and ultrafast charging points needed for this type of electric transport seek to provide a lot of power in short amounts of time and typically offer capacity from 50 to 150 kilowatts (kWs). Public chargers with similar and higher capacity will also become crucial to complement the growing charging demand from the logistics sector.[62] Depending on the Member State, network charges often combine several elements: a fixed charge that doesn't vary with consumption, a capacity-based (kW) charge that depends on the size of a consumer's connection to the network or the consumer's peak demand across a predetermined period, or a volumetric (kilowatt-hour, or kWh) component based on the user's consumption.[63] The share of capacity-based charges tends to be high for commercial and small industrial consumers, the class that typically includes fast and ultrafast charging points.[64] This implies high fixed costs for operators of fast charging points that are mostly based on peak demand and do not sufficiently reflect the number of EVs charging. In a developing fast charging market with initially low utilisation rates, this can slow down or even entirely prevent the development of a market for public fast charging.[65]

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[60] Kolokathis, C., Hogan, M., & Jahn, A. (2018). *Cleaner, smarter, cheaper: Network tariff design for a smart future.* Regulatory Assistance Project. https://www.raponline.org/knowledge-center/cleaner-smarter-cheaper-network-tariff-design-for-a-smart-future/; and Lu, L., & Waddams Price, C. (2019). *Designing distribution network tariffs that are fair for different consumer groups.* Centre for Competition Policy. https://www.beuc.eu/publications/beuc-x-2018-099_designing_distribution_network_tariffs_that_are_fair_for_different_consumer_groups.pdf

[61] Hildermeier, J., & Shipley, J. (2020, 14-17 June). *EV tariff design can optimize grid resources and save drivers money: Selected examples and lessons learned from the U.S. and Europe* [Paper presentation]. 33rd World Electric Vehicle Symposium and Exposition, Portland, Oregon (conference cancelled).

[62] Groen et al., 2019.

[63] Pinto-Bello, 2019.

[64] Kolokathis et al., 2018.

[65] The same consequences have also been observed in the U.S. electric vehicle market, where public policy discussions on grid integration of EVs revealed network tariffs as a key barrier. Fitzgerald, G., & Nelder, C. (2017). *EVgo fleet and tariff analysis: Phase 1: California.* Rocky Mountain Institute. https://rmi.org/wp-content/uploads/2017/04/eLab_EVgo_Fleet_and_Tariff_Analysis_2017.pdf

Network tariffs as a brake on market development: EU examples

- In Slovakia, high and invariable network tariffs impede the business case for charging point operators. The charge point operator Greenway provides fast charging services in Slovakia and Poland. In Slovakia, for instance, for a 50-kW fast charger the company faces a total expenditure for one year of slightly over 1,000 euros for a low-voltage grid connection and about 5,800 euros for a mid-voltage-level connection (typically required for fast chargers). Costs rise to between 2,400 and 11,600 euros respectively for a 100-kW connection.[66] The example implies that operators of fast chargers face high fixed costs independent of the actual utilisation rate of the charging points.

Network tariffs can also become a barrier to commercially operating fast charging infrastructure where their level varies strongly between service areas of DSOs within a country. This is illustrated by the example below from Germany, where network tariffs are based on annual peak demand and vary strongly by grid area and, as in many regions, tend to be higher in less densely populated areas where the electricity grid is less developed. As a result, operators of fast charging in less populated areas are at a disadvantage and face significantly higher network costs. They are thus discouraged from building where fast charging infrastructure is needed; for example, along highways between cities.

- In Germany, highly varying network tariffs across grid areas could distort the fast charging market.[67] Example calculations in Table 1 show that, depending on the geographical characteristics of the grid operation area (i.e., urban, dense or rural), the network costs that the charging service providers would pay to grid operators for operating a fast charging point with low usage will vary considerably. Assuming 100 EVs charge per year — a usage below, but within reach of, the 2018-2019 average — they range from nearly 4 euros per EV per year in Berlin to nearly 23 euros in rural northeast Germany.[68] The estimates reflect total network costs, based on tariff information from network operators in the related areas, assuming a 50-kW fast charger connected to the low-voltage grid with EVs charging 20 kWhs on average.[69]

Table 1. Network tariffs per EV per year at 50-kW fast charger connected to low-voltage grid

	10 EVs	100 EVs	1,000 EVs	10,000 EVs
Urban (Berlin)	€29.91	€3.90	€1.30	€0.85
Dense (Westnetz)	€63.20	€7.13	€1.53	€0.85
Rural (Edis)	€219.20	€22.78	€3.14	€0.51

Data sources: Stromnetz Berlin. (2019). *Preisblatt der Stromnetz Berlin GmbH. Voraussichtliche Entgelte für den Netzzugang gültig ab 01.01.2020*; Westnetz (n.d.). *Entgelte für Netznutzung*; and Edis. (2019). *Preisblätter Netzentgelte Strom der E.DIS Netz GmbH*

[66] Amounts are rounded. Costs are estimated for 2017, including costs for connection and fixed cost for network usage. They do not include the variable part of network tariffs as well as energy tariffs. Based on information provided by Greenway with permission to publish.

[67] In Germany, network tariffs for fast chargers are based on the peak demand measured during the period billed, which is usually one year. Similar to the situation in Slovakia, this can become an obstacle for operators who are trying to create a business case. Many fast chargers have low overall consumption in kilowatt-hours, compared with the peak demand in kilowatts, because vehicles typically charge in a short amount of time. Network tariffs can represent a very high share of the charge point operator's total electricity bill, particularly during the early market phase when a lower number of EVs can be expected.

[68] The average utilisation rate of fast DC chargers from 43 to 100 kWs was 0.5 EVs charged per day, as measured across Germany at all publicly accessible fast charging points from the second half of 2018 and first half of 2019. Bundesministerium für Vehrkehr und digitale Infrastruktur [Federal Ministry of Transport and Digital Infrastructure]. (n.d.). *Erster Bericht über die Umsetzung des nationalen Strategierahmens in Deutschland (AFID-Bericht)* [Initial report on implementation of the national strategic framework in Germany (Alternative Fuels Infrastructure Directive)], p. 51. https://www.bmvi.de/SharedDocs/DE/Anlage/G/MKS/afid-erster-bericht.pdf?__blob=publicationFile

[69] Author's calculations based on grid operators' network tariff information. See Stromnetz Berlin. (2019). *Preisblatt der Stromnetz Berlin GmbH. Voraussichtliche Entgelte für den Netzzugang gültig ab 01.01.2020* [Price sheet from Stromnetz Berlin GmbH. Estimated fees for

As examples suggest, addressing network costs is crucial, especially in the early phase of building a fast charging market. This is true for several reasons. First, a market for EV charging services will struggle to develop unless utilisation rates are high enough to reduce network costs. The recent debate on prices for ultrafast charging at highways revealed that customers are sensitive to pricing in particular if prices exceed those for gasoline.[70]

Second, differences in cost between rural and urban settings are being reinforced, which makes it even harder for e-mobility service providers to justify their business in less densely populated areas. This emphasises the need for a well-designed essential network.

Solutions are needed to ensure network charges become more dynamic or are phased in gradually as EV adoption and charger utilisation increase. The European electricity market reforms give only limited guidance on this question.[71] The Electricity Market Regulation merely recommends "that Member States shall consider introducing time varying prices" to reflect more closely the actual cost of delivering electricity, without giving further clarity.[72]

Some promising practices can be gleaned from the U.S. experience, where high network costs also impeded development of an EV charging market. Regulations in California established additional solutions to high network tariffs to encourage the early development of an EV charging market, such as reduced network tariffs (or a temporary exemption from these) for operators of fast charging stations until the utilisation rates for their charging locations improved.[73] Following earlier pilots, the utility Southern California Edison approved EV tariffs employing a volumetric time-of-use tariff, with a five-year exemption from all demand charges (comparable to European network costs), assuming that utilisation rates will increase with the

network access valid from 01.01.2020]. https://www.stromnetz.berlin/globalassets/dokumente/entgelte/zugang/entgelte-01.01.2020/voraussichtliche-nne-b-2020.pdf; Westnetz. (n.d.). *Entgelte für Netznutzung* [Network charges for electricity]. https://iam.westnetz.de/ueber-westnetz/unser-netz/netzentgelte-strom; and Edis. (2019). *Preisblätter Netzentgelte Strom der E.DIS Netz GmbH* [Price sheets for network charges for electricity from E.DIS Netz GmbH]. https://www.e-dis-netz.de/content/dam/revu-global/e-dis-netz/dokumente/Preisblaetter_Netzentgelte_Strom_20200101.pdf. Estimated costs are based on a fixed charge for a 50-kW connection, divided by the number of assumed charging events (10, 100, 1,000 or 10,000). In Germany, in addition to the fixed fee, the total network costs a charging operator pays also include a volumetric component. To calculate this, we assumed 20 kWhs consumed per EV. According to the Federal Ministry of Transport and Digital Infrastructure (n.d., p. 51), the average amount of energy charged at 50-kW DC was slightly lower at 13.8 kWhs in 2018-2019. It can be assumed, however, that the amount of energy charged per occurrence will grow with faster charging times and increasing battery capacity.

[70] This will likely prove especially challenging to the EV charging market given low oil prices in the wake of the COVID-19 crisis. See Manning, J. (n.d.) *IONITY network dramatically increases EV fast charging costs.* Fleet Europe. https://www.fleeteurope.com/en/new-energies/smart-mobility/europe/analysis/ionity-network-dramatically-increases-ev-fast-charging-costs?a=JMA06&t%5B0%5D=Ionity&t%5B1%5D=charging%20infrastructure&t%5B2%5D=Mercedes-Benz&t%5B3%5D=BMW&t%5B4%5D=Volkswagen&t%5B

[71] Hanson, C. (2019). *Distribution network tariff design under the Clean Energy Package: Legal requirements and policy impacts.* ClientEarth. https://www.documents.clientearth.org/wp-content/uploads/library/2019-12-04-distribution-network-tariff-design-under-the-clean-energy-package-legal-requirements-and-policy-impacts-ce-en.pdf

[72] European Parliament and Council of the European Union, 2019b, Art. 18, p. L 158/127.

[73] California Public Utilities Commission, Rulemaking 18-12-006, Order on 13 December 2018 instituting rulemaking to continue the development of rates and infrastructure for vehicle electrification and closing rulemaking 13-11-007. http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M252/K025/252025566.PDF

growing EV market. Starting with the sixth year, the demand charges will be introduced back into the EV tariff.[74]

These solutions, however, need to be designed carefully. Total exemption from network costs, for example, may increase the network cost for general electricity customers, as grid operators would have to compensate for this from general network fees. Also, it is important to note that reduced network costs are not a subsidy, and the cost can be recovered through the energy component at peak times. This is important for allowing developers to see the real costs of using networks and encouraging them to optimise consumption — for example, by adding more flexibility, such as storage, or choosing more grid-optimal locations. The latter, however, needs to be weighed carefully against requirements for minimum coverage of charging points and access, such as for rural EV users.

These findings suggest that as part of implementing the electricity market reforms, national regulators need to be more ambitious about introducing time-varying network tariffs. Time-varying pricing sends critical price signals to consumers about the cost of delivering electricity and accelerates the expansion of smart charging. Regulatory options include:

- Encouraging grid operators and municipalities to adopt critical peak pricing for network charging. Locally, this can be done through pilots to gather experience on how this model helps smart charging.
- Requiring that all charge point operators have dynamic price contracts with energy suppliers, including time-varying network fees.
- Offering reduced rates or temporarily exempting operators of public fast chargers from network charges in the first years of operation.
- Consulting grid operators in local infrastructure planning as part of integrated planning practices. This process could include municipal charging infrastructure planning procedures, with information on grid capacity and reinforcement needs, with costs being made available to all actors. This could also include studying which types of charging best enable smart charging and optimal grid use. Non-fast charging up to 22 kWs is often sufficient to cover charging needs and opens up more possibilities for smart charging than fast charging at 50 kWs or more, making it overall more cost-effective.

This part of the paper identified the need for network tariff reform, which would address another barrier to building a competitive charging infrastructure market in Europe.
A competitive market, however, also requires that end consumers, the EV drivers, have transparent and comparable information about the cost of EV charging. Transparent pricing that allows consumers to see the share of additional, non-electricity-related cost layers can encourage smarter consumption and eventually help them reap the benefits of more cost-reflective energy and network tariffs.

[74] Harper, C., McAndrews, G., & Sass Byrnet, D. (2019). *Electric vehicles: Key trends, issues, and considerations for state regulators*. National Association of Regulatory Utility Commissioners. https://pubs.naruc.org/pub/32857459-0005-B8C5-95C6-1920829CABFE

Make charging prices transparent and easy to compare

The third barrier to building a competitive EV charging market is the lack of transparent and easy-to-compare pricing for EV charging at public stations. Consumers have identified this as one of the main barriers to EV use.[75] Experience from residential and workplace charging has shown that cost-reflective pricing, coupled with intelligent technology, can ensure that EV charging is steered towards the most beneficial hours for the grid, with benefits for consumers and the environment.[76] The challenge for public policymakers is how to provide incentives to charging service providers to pass on these benefits to EV drivers while protecting competition among e-mobility service providers.

To foster transparent pricing, regulators can set guidelines for establishing a basis for comparing EV charging prices. In accordance with the vision for developing a successful EV charging market, drivers should be able to:

- Charge at any publicly accessible charger, regardless of whether the user has a contract with that charging point operator (also called ad hoc charging).
- Pay prices mainly based on actual consumption, calculated in kWhs.[77]
- Participate in a smart charging programme that reflects the true cost of the services.

The review of the legislative framework for EV charging offers a starting point for guaranteeing that pricing guidelines are refined and properly enforced. The current legislation already requires that prices charged by e-mobility service providers are "reasonable, easily and clearly comparable, transparent and nondiscriminatory."[78] But the majority of offers do not meet these standards. Across the EU, prices for EV charging are currently based on different metrics:

- Session fees: If high, fees per charging session can present a disadvantage to all users who do not require a full charge but rather a lower amount of power for topping up.
- Time-based fees: Prices based on time will disadvantage consumers whose cars charge more slowly. Also, the charging speed varies depending on how many EVs are being charged at once at all outlets. For example, if an operator offers 22 kWs at two charging points and two EVs charge at the same time, each will pay the same time-based fee for 11-kW service. Because of this situation, California recently banned per-minute billing at public charging points.[79]

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[75] Bureau Européen des Unions de Consommateurs [BEUC, The European Consumer Organisation]. (2019). *Making electric cars convenient*. https://www.beuc.eu/publications/beuc-x-2019-032_making_electric_cars_convenient.pdf

[76] Hildermeier et al., 2019.

[77] This is feasible as long as the energy tariff is dynamic; however, prices at charging stations would also include an element covering the use of networks paid by the charging point operators. This could, for example, include a time-varying energy element to reflect the investment implications of consuming energy over network peak (again, time related) but will also need a small fixed element that represents a fair contribution to the residual costs of using the existing network.

[78] European Parliament and Council of the European Union, 2014, Art. 4 (10).

[79] Benoit, C. (2019, 24 December). *California bans per minute billing; Tesla superchargers will need displays.* Elektrek. https://electrek.co/2019/12/24/california-bans-per-minute-billing-tesla-superchargers-will-need-displays/

- kWh-based pricing: With this model, consumers pay for the kWhs charged, and the electricity consumed is the main component of the service provider's charges. In Germany, for instance, national legislation obliges e-mobility service providers to offer EV charging based on kWhs charged.[80]

Consumption-based pricing, per kWh, is the preferable solution for the following reasons:

- It offers a basis for comparison across all offers to customers. This would also address the strong variation in prices for public charging observed in many EU countries.[81]
- It reflects actual consumption and allows end customers to see the advantage, depending on the price of electricity, of the lower total cost of ownership for EVs compared with gasoline-powered vehicles.[82] For its similarity to petrol pricing, consumption-based pricing is also easier to understand for new EV users and can help make switching to EVs more attractive.
- It enables further savings for EV charging, should the charge point operator decide to pass through the signals from time-varying tariffs.[83]

Although prices for charging should remain mainly consumption-based, it can make sense in some cases to add additional price elements to the total price of EV charging. In dense urban areas where parking spaces are very expensive, municipalities seek to encourage EV drivers to vacate parking spaces once charging is completed. This is also necessary to allow sufficient utilisation of charging points as well as a reasonable estimation of the charging point density needed in relation to the number of cars. Some municipalities with EV charging schemes face space constraints and have needed to add a time-based element to EV charging to alleviate congestion by encouraging more efficient utilisation of charging points. Paris, for example, used time-based pricing as a tool while the city temporarily owned and operated EV parking and charging places as part of its former EV car sharing scheme in 2019. The pricing Paris designed allowed users to park and charge in public EV parking spaces at a reduced rate of 1 euro. After one hour — deemed sufficient for topping up enough to cover the average urban distance

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[80] Bundesministerium für Wirtschaft und Energie [Federal Ministry of Economic Affairs and Energy]. (2018). *Preisangabe für und Abrechnung von Ladestrom für Elektromobile (Rechtsgutachten)* [Pricing for and billing of electricity for charging electric vehicles (legal opinion)]. https://www.bmwi.de/Redaktion/DE/Downloads/P-R/preisangabe-fuer-und-abrechnung-von-ladestrom-fuer-elektromobile-rechtsgutachten.html; and Hildermeier, J., Shipley, J., & Jahn, A. (2019). *Elektrofahrzeuge, Ladeinfrastruktur und das Stromsystem in Kalifornien* [Electric vehicles, charging infrastructure and California's power system]. Regulatory Assistance Project. https://www.raponline.org/knowledge-center/elektrofahrzeuge-ladeinfrastruktur-kalifornisches-stromsystem/

[81] Bureau Européen des Unions de Consommateurs [BEUC, The European Consumer Organisation], 2019. In Austria, a 2018 study comparing 20 different tariffs at public charging stations found considerable price differences across but also within different tariff models. The average difference between rates for 100 kilometres is 5.41 euros, which adds up to 55 euros per month based on monthly average mileage. For more details, see Soder, M. (2018). *E-Mobilität: Eine Markt- und Preisanalyse für das Laden an öffentlichen Ladestationen* [E-mobility: A market and price analysis for charging at public charging stations]. Arbeiterkammer Wien [Vienna Chamber of Labour]. https://www.arbeiterkammer.at/interessenvertretung/wirtschaft/energiepolitik/AK_Studie_E-Mobilitaet_August_2018.pdf

[82] Soder, 2018. For lower total cost of ownership see Stewart, A., & Dodson, T. (2018). *Availability and affordability of EVs: Final report for BEUC and ECF.* Element Energy. https://www.beuc.eu/publications/beuc-x-2018-079_availability_and_affordability_of_zevs.pdf

[83] There are arguments, however, against a mandatory requirement to pass time-of-use costs through to EV drivers. For example, a charging station provider can operate storage in conjunction with the station. This would mean that electricity would not necessarily be drawn from the grid at the time when drivers are charging.

travelled — the session fee jumped to 16 euros to discourage parking while not charging.[84]

European guidelines for transparent and comparable pricing should also support an open charging market for all customers, regardless of whether they have a contract for EV charging with a specific service provider. Although it is at cross-purposes with this objective, an e-roaming network has emerged in which operators either offer joined services through bilateral contracts, or centralised service platforms connect customers to different EV charging networks within or across different countries.[85] Both developments add layers of complexity and cost to the charging services, creating lock-in risks for customers and hindering the spread of EVs. The current situation is analogous to the roaming solutions offered for mobile phone services in different countries in Europe, which were finally abolished: Customers typically pay more to use a "foreign" service than they would for their own home network.

Instead, guidelines aligned to a common vision for a European EV charging market should promote an open charging network analogous to the existing network of petrol stations, or today's European mobile network, offering unrestricted access to charging across Europe while allowing optional additional paid services to encourage competition. To further this development, ad hoc payment solutions at all publicly accessible charging points are also needed to provide minimum interoperability standards in line with a vision for a competitive EV charging market.

The implementation of both the electricity market reforms and the revised Alternative Fuels Infrastructure legislation should contain, where appropriate, guidelines for transparent and comparable pricing for EV charging services across the single market. Pricing for EV charging services needs to reconcile and reflect the two objectives discussed in this paper. First, it is important to realise a minimum essential infrastructure. Second, the market for EV charging services needs to be competitive to give consumers access to a range of charging services to fit their needs. As a consequence, policymakers should consider issuing guidelines on the following pricing aspects:

- Base the price consumers pay for charging service primarily on consumption (kWhs) to protect consumers from distorted prices and hidden costs.
- Make roaming prices transparent and ensure they are kept reasonable. It will be important to monitor the share of additional, non-electricity-related cost layers.
- Make ad hoc charging and payment, as well as information about ad hoc charging prices, available at all publicly accessible charging points and through navigation software.

[84] Users also had the option of an annual subscription of 120 euros. Compagnon, S. (2019, 10 June). À Paris, vous pouvez recharger votre voiture électrique … sur un lampadaire [In Paris, you can charge your electric car … at a lamp post]. *LeParisien*. http://www.leparisien.fr/info-paris-ile-de-france-oise/transports/a-paris-vous-pouvez-recharger-votre-voiture-electrique-sur-un-lampadaire-10-06-2019-8090112.php

[85] Sümmermann, D., & Morris, J. (2019). *The time to decentralise electric vehicle e-roaming is now.* Euractiv. https://www.euractiv.com/section/electric-cars/opinion/the-time-to-decentralise-electric-vehicle-e-roaming-is-now/

Conclusions

Developing charging infrastructure to fit EV drivers' needs is paramount to expand the European EV market as part of the transport and energy transition. Policymakers and national regulators have the opportunity to develop a common vision for a self-sustaining and competitive EV charging market. In this vision, EV drivers everywhere would have ready access to sufficient, accessible and smart charging infrastructure providing a range of charging services to fit their needs, with competition driving the innovation needed to provide those services at attractive prices.

The good news is that there are numerous policy options to realise this vision. The revised Alternative Fuels Infrastructure legislation should require, by way of a binding target in a directive or as a regulation, that Member States define an essential network of charging points to provide minimum coverage for public charging. Public tenders or auctions for charging point locations can serve as tools to ensure public subsidies are optimally allocated when phasing in a commercially viable market for EV charging.

Policies for building a successful European EV charging market need to look beyond sufficient coverage for charging points; they also need to ensure that the infrastructure is planned and used most beneficially for consumers, the environment and the grid.

When implementing the European electricity market reforms, the Electricity Market Regulation and Directive, national governments need to clarify the role of regulated entities in building, owning and operating charging infrastructure. Part of these decisions is mapping out the transition from DSO-driven infrastructure supply to a commercially viable market.

Tariff design also plays a pivotal role. By designing more time-varying network tariffs and offering reduced network charges for fast charging services in particular, regulators can support economics for e-mobility service providers and charging point operators, a key condition for establishing a functioning market. Consumers need more transparent and easy-to-compare pricing for charging services, with the pricing mainly based on electricity consumption. Member States can help by issuing guidelines to operators for designing prices accordingly.

The policy solutions developed in this paper specifically address decision-makers' need to strike a balance between providing sufficient coverage and developing a competitive charging market, both with a view to ensuring smart EV grid integration. Implementing these policy solutions will contribute to building Europe's EV charging market, which can assist with a faster, smoother and more equitable transition to zero-emissions transport. It will at the same time advance the energy transition through smart grid integration of electric transport, with wider benefits for consumers and the environment.

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