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The power of moving loads: Cost analysis of megawatt charging in Europe

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Executive summary

To accelerate the uptake of electric trucks and advance the electrification of long-haul freight across Europe, it will be crucial to build and operate facilities to provide the necessary high-capacity charging along highways, also known as 'megawatt charging,' at reasonable cost. The Alternative Fuels Infrastructure Regulation requires Member States to build out megawatt charging sites along core EU highways starting in 2025. With this process in mind, it will be helpful for policymakers, planners and operators of charging infrastructure to have a better understanding of the costs and likely market effects of megawatt charging along core freight corridors. Recognising that current discussions on freight electrification and charging infrastructure build-out fail to consider this angle, RAP seeks to provide critical input to the debate with this new analysis.[1]

We found steep price differences for megawatt charging between charging sites, often between sites located in neighbouring EU Member States. It is important that truck fleet operators can choose where to charge their trucks; this choice, however, can expose the weaknesses in national grid regulation and taxation policies. It can also cause negative impacts on power grids if charging is heavily concentrated in certain regions, straining the system, while remaining light in other areas. If the various actors involved in integrating electric trucks into the grid fail to coordinate, it will hamper the build-out of a high-capacity charging network and slow down the overall electrification of freight.

[1] The authors would like to acknowledge and express their appreciation to the following people who provided helpful insights into early drafts of this briefing: Fabian Sperka, Transport & Environment (T&E); Dr. Till Kreft, Milence; and Dr Hussein Basma, The International Council on Clean Transportation; as well as Jaap Burger, Zsuzsanna Pató, Louise Sunderland and David Farnsworth at RAP. Deborah Bynum provided editorial assistance.

Our analysis identified an incentive to develop 'charging tourism' between EU Member States, encouraging fleets to only charge where prices are lowest. In contrast to the cross-border 'petrol tourism' known from diesel trucks, charging tourism will likely lead to inefficient grid use, with high system costs that all consumers must bear. This incentive will be particularly strong in the maturing truck charging market. It is reasonable to assume the truck charging sites will initially have low utilisation rates, which can incur high costs for use of the power networks.

The main cost component charging site operators face for megawatt charging, besides electricity costs, is the network cost, or the price charged for use of the grid. Due to varying network costs across — and also within — EU Member States, operators will be able to offer cheaper charging prices at certain locations, which will attract more trucks. At the border between Poland and Germany, for example, the grid fees in Poland are one-third cheaper than in Germany. As a result, fully charging a 500-kilowatt-hour electric truck on the Polish side costs approximately EUR 13 less than it would in Germany.[2]

Supporting the build-out of megawatt charging in Europe while avoiding the negative impacts of charging tourism requires coordinated policies across sectors and across Member States. We recommend that policymakers:

- **Ensure network prices closely reflect the actual costs incurred,** over the medium to long term, through setting volumetric time-of-use network pricing. Recent European energy market reforms reinforce this principle and guide national energy regulators when setting network tariffs.
- **Coordinate taxes and levies for truck charging between Member States where large price differences are likely to emerge**, in the near term.

Combining these two policy approaches will help ensure a balanced build-out of the truck charging network across European freight corridors — and prevent European consumers from having to pay for lack of foresight.

Supporting the build-out of megawatt charging in Europe while avoiding the negative impacts of 'charging tourism' requires coordinated policies across sectors and across Member States.

[2] This price does not include taxes and levies.

Truck charging costs influence freight electrification

Electrifying heavy-duty trucks[3] to accelerate decarbonisation of the hard-to-abate road freight sector is imperative to reach the EU's climate goals. Two main factors will determine the speed of the transition in the very competitive, low-margin business of long-haul trucking:

- The cost and availability of megawatt charging.
- The cost to buy and operate electric trucks.

With upfront costs for e-trucks expected to fall significantly in the coming years,[4] operational costs will become a more important factor in whether fleets can stay competitive.

A large portion of fleets' operational costs will stem from megawatt charging[5] along motorways. However, charging prices — and their effects on the emerging market for these services — are as yet hard to estimate, because Member States are only now beginning to build the necessary infrastructure. With this in mind, in this paper we analyse the different cost components for megawatt charging, and discuss how emerging cost differences could impact the build-out of a truck charging network across Europe and the wider power system.

The more costs for charging differ between locations in relatively close proximity, the more incentives fleet operators will have to charge where it is cheaper. For example, an electric long-haul truck travelling the 730 km from Berlin, Germany, to Antwerp, Belgium, will likely need to charge at a public megawatt charging site along the highway once or twice during the trip.[6] Operators are therefore dependent on third-party providers and their prices for charging services.[7] Within operational constraints,[8] truck fleet operators should be able to optimise their costs by choosing to charge at a specific site, with a specific charge point operator, or on a specific side of a border. Although the current Alternative Fuels Infrastructure Regulation

[3] Heavy-duty vehicles, defined as all vehicles above 3.5 tonnes, represent approximately a quarter of climate emissions from Europe's road transport. They are the second largest contributor to the EU's transport emissions after passenger cars. European Environmental Agency. (2023). *Reducing greenhouse gas emissions from heavy-duty vehicles in Europe.* https://www.eea.europa.eu/publications/co2-emissions-of-new-heavy/reducing-greenhouse-gas-emissions-from

[4] Retail prices for electric tractor-trailers, which make up about 70% of all long-haul trucks on EU roads, are expected to more than halve by the end of this decade. According to pledges by manufacturers, the availability of e-trucks will increase, also driven by CO_2 reduction targets for heavy-duty vehicles. Basma, H., Saboori, A., & Rodríguez, R. (2021). *Total cost of ownership for tractor-trailers in Europe: battery electric versus diesel*. International Council on Clean Transportation (ICCT), p. 11. https://theicct.org/publication/total-cost-of-ownership-for-tractor-trailers-in-europe-battery-electric-versus-diesel

[5] We define 'megawatt' charging as high-capacity opportunity charging needed to serve trucks on highways. For this type of recharging, for example within the mandatory 45-minute break for truck drivers on highways, capacities of 350 kW or more are needed. For the sake of simplicity, we keep using the term 'megawatt charging' to designate high-capacity opportunity charging of trucks even at lower than 1 MW capacity. We assume that mid-term, with maturing battery technology and increasing charging needs, high-capacity opportunity charging for trucks will be in the megawatt range. The Alternative Fuels Infrastructure Regulation requires Member States to build publicly accessible recharging pools for heavy-duty vehicles with a power output of at least 1,400 kW, with at least one charging station with an individual power output of at least 350 kW, from 2025 onwards for the EU's core highways. These truck charging pools are required for each direction of travel every 60 km, and coverage will gradually be scaled up in the following years. European Parliament and Council of the European Union. (2023). Regulation of the European Parliament and of the Council on the deployment of alternative fuels infrastructure, and repealing Directive 2014/94/EU, p.73. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52021PC0559

[6] The number of times that a driver will need highway charging depends on operational schedules, mileage, payload, battery size and other vehicle- and transport-related factors. These aspects are not factored into our analysis, which takes the perspective of a charging point operator.

[7] Charging prices for e-trucks along highways will differ from those at the depot or a third-party destination such as freight centres, which are out of scope for this analysis. As evidence from the electric passenger car sector suggests, charging prices for public high-capacity charging can be expected to be higher. Morrison, K. & Wappelhorst, S. (2023). *Are battery electric vehicles cost competitive? An income-based analysis of the costs of new vehicle purchase and leasing for the German market*. ICCT, p.13, figure 4. https://theicct.org/publication/cost-ownership-battery-electric-gasoline-car-germany-oct23

[8] Operational constraints such as regulated driving and resting times, as well as limited space at rest stops, will limit fleet operators' ability to choose a charging point. Overall, however, truck fleet operators will seek to optimise operational costs. We expect that price competition for charging will emerge in a growing market, within border regions in particular.

intends for truck charging to develop as a competitive market, 'charging tourism' driven by large price differences could lead to overburdening local grids and increasing system costs. Operators of megawatt charging sites will of course legitimately seek to offer competitive prices by siting their charging stations in cheaper network areas, as we explain below.

Take the case of a truck charging at the Polish-German border. Our analysis shows that the respective network costs will be 2.6 euro cents per kilowatt-hour (kWh) lower in Poland (see case study on page 10). For an electric truck with 500 kWh of usable battery capacity, this translates into a difference of EUR 13 per charge. If we assume charge point operators pay industrial power prices and the taxes and levies for electricity — all of which differ between European countries — the price difference between Poland and Germany increases. Poland is cheaper by more than 8 euro cents/kWh, which adds up to a difference of more than EUR 40 per charge.[9] For fleet operators with vehicles crossing the same border and charging several times a week, this can result in considerable additional operational costs.

'Charging tourism' concentrates electricity demand in some network areas while leaving grid capacity in others underutilised. This inefficient use of the grid results in unnecessary system costs in both areas, adding to all consumers' electricity bills.

Unlike 'petrol tourism,' the effects of charging tourism will impact an area's electricity network. If trucks charge mainly on the Polish side of the border, this concentrated high-capacity electricity demand could overload the local grid. On the German side of the border, by contrast, the capacity would either not be built in the first place, or would remain underutilised, meaning existing network costs must be borne by fewer users. As a result, unnecessary system costs would be incurred in both areas due to inefficient use of the grid. These costs would then be passed on to all electricity consumers via network fees.[10] It is therefore in the common European interest to coordinate the build-out of dense truck charging infrastructure and prevent the spread of charging tourism. This will require Member States to cooperate closely, beyond the implementation of the Alternative Fuels Infrastructure Regulation, in the areas of network and charging infrastructure planning, and to monitor the developing market for charging services.

Developing a competitive market for truck charging and planning power networks accordingly requires coordination between different sectors and approaches. For fleet operators, being flexible about where their trucks charge and choosing the lowest prices is no different than it

[9] Some of the Member States discussed have greenhouse gas quota schemes, which could help to level out some of the identified charging cost differences. We did not consider this mechanism in our analysis, as it does not feature in all of the Member States reviewed.

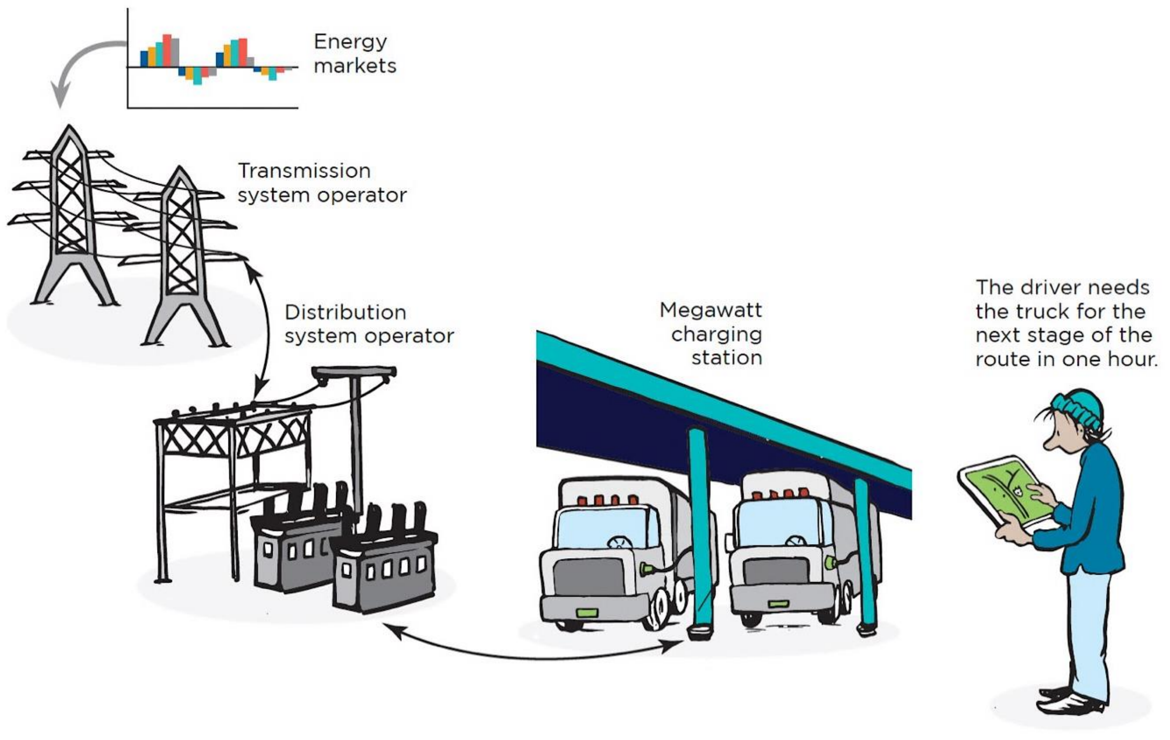
[10] Explained in more detail in Hogan, M., Kolokathis, C., & Jahn, A. (2018). *Treasure hiding in plain sight: Launching electric transport with the grid we already have.* Regulatory Assistance Project. https://www.raponline.org/knowledge-center/treasure-hiding-in-plain-sight-launching-electric-transport-with-the-grid-we-already-have

is when operating diesel trucks. For power network planners, however, having to plan for the charging demands of 'mobile' consumers is a new challenge, particularly as their other customers — such as building managers and industrial facilities — are typically bound to the stationary location where they consume electricity.

In this report, we focus on raising awareness of the new policy and planning approaches needed for the effective build-out of megawatt charging infrastructure. Recommended policy solutions include short-term coordination of financial incentives for megawatt charging between neighbouring countries, and fundamental reform to establish more cost-reflective network pricing across all EU Member States in the medium to long term (see page 15). Before we present our analysis of cost differences for megawatt charging in selected EU border areas (see page 9), we will discuss the various cost components in the next section.

Our analysis is grounded in the perspective of the companies operating the infrastructure — the charge point operators, or CPOs — who must reconcile transport users' needs with the needs of the transmission system and of the distribution system operators.[11] Figure 1 below illustrates the elements of megawatt charging, showing how they interact.

Figure 1. Elements of megawatt charging



[11] We refer to CPOs as the entity that bears the costs of operating a charging site. In cases where the CPO is not responsible for these costs, the service provider passes on the costs to customers.

The cost of megawatt charging will vary by country

This report focuses on the operational costs of megawatt charging, rather than the investment costs for the charging infrastructure. Operating costs for a charging site can be broadly divided into costs for electricity (including network costs for transmission and distribution, as well as potential levies on that electricity), land use,[12] maintenance, insurance and taxes. All of these vary by country, and can make a difference for decisions over where to locate a charger and where to charge in border regions.[13]

Wholesale energy prices are also based on competitive markets across the EU. Power prices will increasingly vary depending on the time of day as the shares of variable wind and solar generation in the power mix increase. Similarly, as EV use increases, the amount of charging taking place will have an impact on electricity prices during certain periods, such as in the evenings and at times of peak electricity demand. In this regard, megawatt charging can also be 'opportunity charging' as a way to make use of excess renewable energy.

With the exception of maintenance, land use and insurance, all other operational cost components for truck charging site operators are regulated, which means that they will vary depending on the regulations in place in the EU Member State where the site is located. How high these expenses run for CPOs depends on the country's approach to network cost allocation. Network fees and their structure — for example, euros per kilowatt-hour, euros per kilowatt for peak demand, or a fixed annual rate — vary by country, as do the levies and charges imposed on electricity.[14,15] As a result, the different ways in which these network charges are designed and regulated are the main cause of cost differences between sites. The following section explains why in more detail.

Cost of truck charging at intra-European borders

The prevailing design of network fees across EU Member States means that the utilisation rate of charging points is the key cost factor for CPOs — that is, the total hours of charging at maximum capacity for a given charging point per year. Many Member States recover costs for grid usage primarily through demand fees based on the annual peak demand capacity in kilowatts (kW), rather than through a price based on the amount of electricity actually

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[12] Costs for land-use are potentially significant but are uncertain, depending on the market and on use. Ecomento.de. (2022, 5 March). *Zu wenige Flächen für E-Auto-Ladestationen könnten Netzausbau verzögern* [Not enough room for electric vehicle charging stations could delay grid expansion]. https://ecomento.de/2022/05/03/zu-wenige-flaechen-fuer-e-auto-ladestationen-koennten-netzausbau-verzoegern

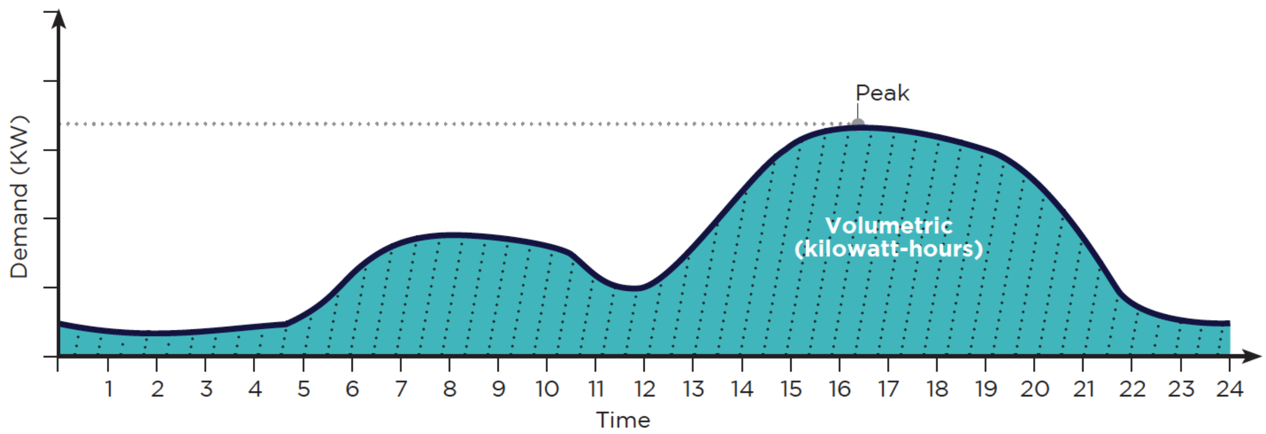
[13] Our analysis focuses on the operational cost components that the operator cannot influence. It therefore excludes costs that CPOs will seek to drive down in a competitive market, such as hardware and any part of the maintenance costs that the investor can influence. We also do not investigate specific one-off costs for establishing the grid connection or the costs for the land.

[14] For residential demand, the portion of network costs in a total electricity bill varies across Europe from 13% to 45%. European Commission Agency for the Cooperation of Energy Regulators (ACER) & Council of European Energy Regulators (CEER). (2022, October). ACER/CEER *Annual report on the results of monitoring the internal electricity and natural gas markets in 2021, energy retail and consumer protection volume*, p. 58, figure 39. https://www.acer.europa.eu/Publications/MMR_2021_Energy_Retail_Consumer_Protection_Volume.pdf

[15] The share of network costs for industrial consumers varies and can be higher, for instance close to 70% for a logistics depot in Germany. See Hildermeier, J., Jahn, A., & Rodríguez, F. (2020). *Electrifying EU city logistics: An analysis of energy demand and charging cost*. Regulatory Assistance Project and ICCT. https://www.raponline.org/knowledge-center/electrifying-eu-city-logistics-analysis-energy-demand-charging-cost

used (kWh), also known as a volumetric fee.[16] The peak demand fee means that a one-off charging process at the maximum charging capacity can cause significant network costs for the user, in this case the CPO, regardless of the number of vehicles charging over a specific period of time. Conversely, volumetric network fees would only be incurred for actual charging processes by customers, which ultimately reduces costs for CPOs with higher utilisation rates. Figure 2 illustrates the logic of these two different types of charges.

Figure 2. Two principal ways of designing network charges (illustrative values over 24 hours)



As a result, the current design of network tariffs in most countries makes it particularly costly for CPOs to serve a pattern featuring fewer hours of full utilisation and more peaks in demand.[17] This profile is to be expected from freight electrification because heavy goods traffic is concentrated on weekdays during daytime hours.[18] We assume that around two-thirds of truck charging is done via high-capacity opportunity charging — during the mandatory 45-minute break for example — for which we assumed charging at 800 kW. The remaining one-third of charging happens over rest stops longer than eight hours — typically during the longer overnight break for truck drivers — for which lower capacities at around 50-150 kW would be sufficient.[19] This would allow the CPO to charge trucks at lower power levels and lower costs. Looking at this highway charging pattern for trucks from the angle of grid cost, we assume that the grid connection serving the charging site is only fully utilised for

[16] By and large, network charges can be divided into two main components, the volumetric price for the electricity used (euro cents/kWh) and the fixed price (EUR/year). The latter consists of a standing charge (EUR/year) and a price for the maximum peak electricity demand for that connection (EUR/kW) in the billing year. High demand charges based on capacity can present a barrier to integrating distributed, flexible demand from, for example, electric vehicle charging. For more information, see Regulatory Assistance Project. (n.d.) Power System Blueprint/Smart Network Tariffs. https://blueprint.raponline.org/smart-network-tariffs

[17] The assumptions defining low and high utilisation rates for charging sites can be found in the Annex. Note that this analysis looks at the structure of costs to operate the charging point from a CPO perspective. Therefore, we do not consider variations from individual charging sessions linked to battery capacity or model, type or range of electric trucks. The variation in these factors leads to a higher or lower number of charging processes but has no influence on the absolute cost for offering charging capacity at the site.

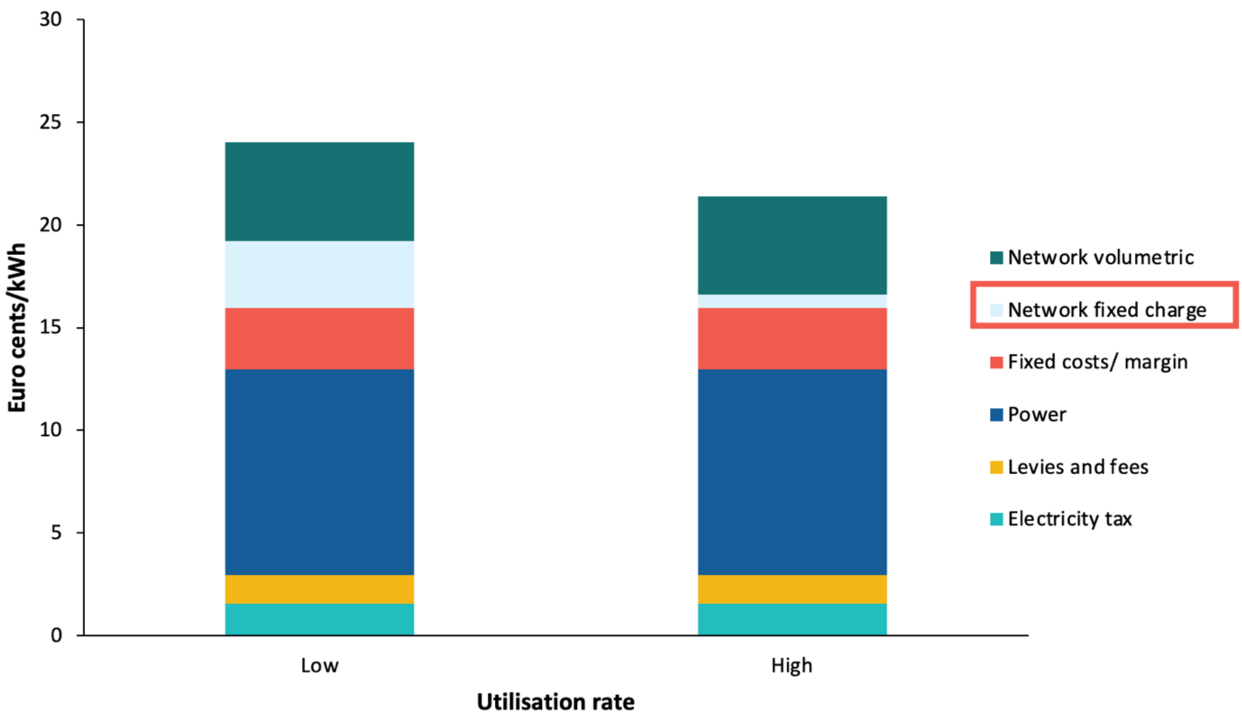
[18] With regard to the cost effects of megawatt charging, and thus the price of long-distance heavy goods traffic, other regulatory measures also have an influence. This includes the fact that truck traffic is prohibited on Sundays and public holidays in most EU countries. On Saturday, too, heavy goods traffic is already reduced or partially restricted. This results in lower utilisation of the charging points, for example, compared to charging points for passenger cars.

[19] Transport and Environment. (2023). *Fully charged for 2030*. https://www.transportenvironment.org/discover/fully-charged-for-2030

around two hours a day throughout the year. From the grid perspective, utilisation rates will determine charging points' profitability.

To illustrate this point in another way, in Figure 3 we compare costs for operating a megawatt charging station with different utilisation rates[20] in a large distribution grid area in Germany.[21,22] This shows that the cost for CPOs to provide the same capacity at the same charging point can vary by EUR 15 per 500 kWh of charging, depending on a high or low utilisation rate over a given timeframe.

Figure 3. Comparison of 2023 charging costs by site utilisation



Sources: BDEW, Avacon price lists. For full source information, please see footnote 21.

The section above shows why grid costs recovered through demand charges pose a risk for charge point operators trying to operate their charging points profitably. That risk is exacerbated by the low utilisation rates that typically occur in the early phases of market development. Given that CPOs are facing steep price differences caused by network tariff design that includes demand charges, we assume that they will eventually be forced to pass on the cost differences to their customers, the truck fleet operators. This will encourage charging tourism, as we explain in the next section.

[20] We assume 450 annual full-utilisation hours for low utilisation and 2,250 hours for high usage/utilisation to reflect the range from an early market phase to a maturing market.

[21] The prices for 2023 for the high-voltage network are based on German costs by BDEW – Bundesverband der Energie- und Wasserwirtschaft e.V [Federal Association of the Energy and Water Industry]. (2023). *BDEW-Strompreisanalyse Juli 2023* [BDEW analysis of electricity prices, July 2023]. https://www.bdew.de/service/daten-und-grafiken/bdew-strompreisanalyse; the regional network prices are based on Avacon. (2022). *Preisblatt – Netzentgelte Strom* [Price list for electricity network tariffs]. https://www.avacon-netz.de/content/dam/revu-global/avacon-netz/documents/netzentgelte-strom/2023/Preisblätter_AVANG_Strom_01.01.2023_(19.12.2022).pdf

[22] We excluded VAT in all cost calculations in this paper.

Price differences for charging can encourage charging tourism

For charge point operators, the cost of operating megawatt charging sites will generally vary between countries, and to some extent even within countries. The case study section below provides examples of both scenarios. Variations within a country occur if there are several grid areas in which network operators[23] charge different tariffs to use their power networks. Over the long term, in a functioning competitive market, CPOs will have to pass on their costs to customers at some point. As a consequence, the energy costs, taxes, and levies — and at least to some extent the power network costs — that are incurred will determine end-user prices.

To avoid stranded assets,[24] it is very likely that CPOs will attempt to level out price differences and seek to offer the same price across a wider region[25] to the degree that competition allows. As soon as competing CPOs are significantly cheaper in a low-cost grid area, however, other CPOs that are within reasonable proximity for the fleet operators will need to lower their cross-regional offers to remain in business. In light of this, we can expect CPOs who offer megawatt charging to adopt a pricing strategy similar to traditional fuel providers: the closer the alternative chargers, the lower the price. Assuming CPOs will enter into competition, below we examine the cost differences in operating truck charging sites in selected European border regions that may encourage charging tourism.

Case studies: truck charging costs at selected EU borders

In this section, we present examples of the differences in the 2023 network charges for megawatt charging on both sides of selected intra-European borders.[26] We chose four border crossings, marked with circled dots in Figure 4, along European core transport corridors — the so-called TEN-T network.[27,28]

[23] In Europe, there are more than 3,500 network operators that run network areas ranging from very small to large, in a very heterogeneous landscape. The number of network operators in EU Member States ranges from 880 in Germany to effectively one in France. GEODE – The voice of local energy distributors across Europe. Geode News, the EU DSO entity. https://www.geode-eu.org/the-eu-dso-entity

[24] Many charging locations are distributed via calls for tender and concessions to CPOs to run charging infrastructure. The way these tenders are designed will also help in levelling out price differences, as these permits tend to include rights to operate in areas where more and less profitable sites are expected.

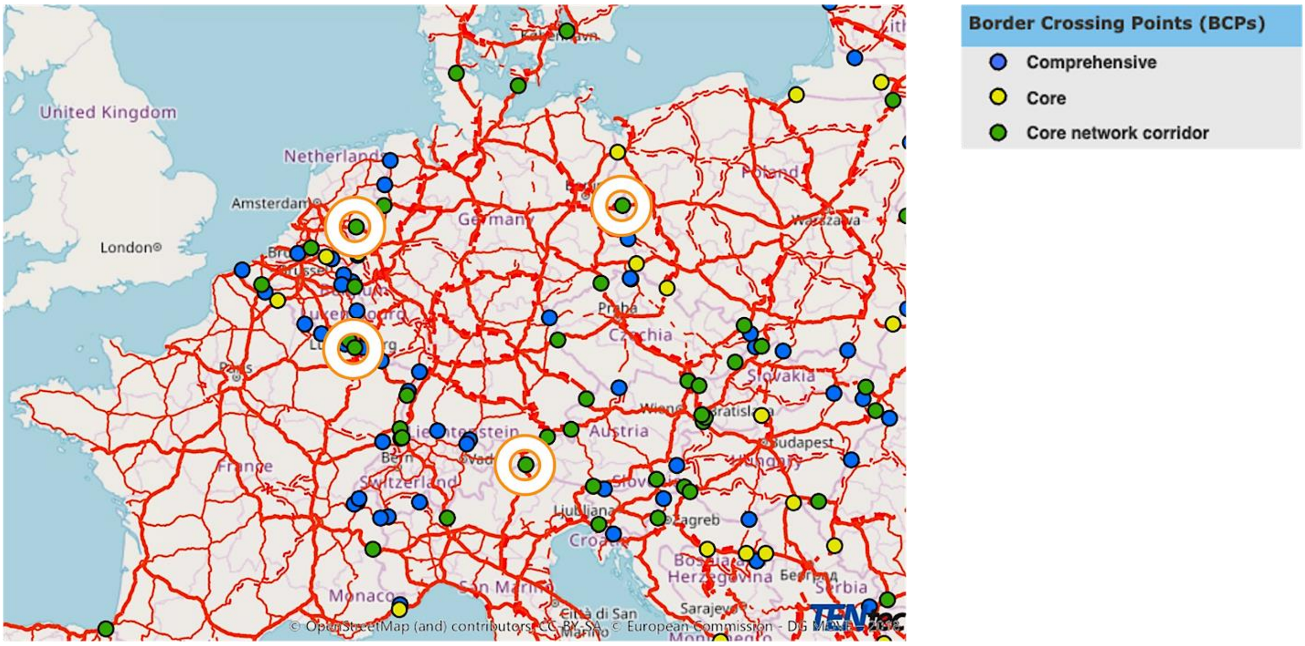
[25] This assertion is based on information from exchanges with truck charging service providers.

[26] The distribution network operators considered in these examples and those that follow are listed in the Annex, including the sources and calculations.

[27] European Commission. (n.d.). *Mobility and transport: TENtec interactive map viewer*. https://ec.europa.eu/transport/infrastructure/tentec/tentec-portal/map/maps.html

[28] The green dots represent border crossings on Europe's core highways as defined in the TEN-T network, connecting major cities and nodes.

Figure 4. The TEN-T road network of central Europe and main border crossings



Source: European Commission. (n.d.). *Mobility and transport: TENtec interactive map viewer*

Germany – Poland

The main highway border crossing between Germany and Poland is between Frankfurt (Oder) and Słubice. Charges for use of the high-voltage distribution networks located on either side of the border differ in structure and amount, resulting in variations in cost. Charge point operators utilising the Polish high-voltage grid pay only around 30% of what it costs to use the German grid.[29] The cost difference works out to about 2.6 euro cents/kWh, which adds up to EUR 13 for a 500-kWh battery load. As a result, the lower network charges will tend to increase the expected price difference for megawatt charging between the two countries, leading to higher demand on the Polish charging infrastructure. Given the characteristics of the two grid areas along the border, increased usage on one side can exacerbate existing problems. On the German side, the grids are well developed, with high levels of renewable energy sources — so high that these are periodically curtailed[30] — but

[29] Table 1 in the Annex summarises the sources for all of the figures used in the case studies.

[30] Bons, M., Knapp, J., Steinbacher, K., Greve, M., Grigoleit, K.J., Kippelt, S., & Burges, K. (2020). Verwirklichung des Potenzials der erneuerbaren Energien durch Höherauslastung des Bestandsnetzes und zügigen Stromnetzausbau auf Verteilnetzebene [Realising the potential of renewable energy by increasing capacity utilisation of existing grid and rapidly expanding the distribution network]. *Climate Change (51)*2020. Umweltbundesamt [German Federal Environment Agency. https://www.umweltbundesamt.de/sites/default/files/medien/5750/publikationen/2020_12_14_cc_51-2020_zuegiger_ausbau.pdf

with limited cross-border grid capacities. The Polish grid operators are already reporting internal grid congestion and have identified an urgent need for grid expansion.[31]

> Based solely on today's network fees, megawatt charging is significantly cheaper in Poland than in Germany. This is likely to concentrate truck charging on the Polish side of the border.

Austria – Italy

One of the main routes for long-distance heavy-duty traffic across the Alps runs via the Brenner, the border crossing between Austria and Italy. Similar to many crossings, there are truck parking spaces on both sides of the border. If these or nearby rest areas are equipped with megawatt charging stations, network price differences will arise. The prices for use of the power network are some 30% to 80% higher in Austria than in Italy. The network price differences range from 1 to 2.5 euro cents/kWh, although these would drop in the case of higher utilisation rates for the charging stations.

> If network fee differences result in different charging costs, it is likely that fleet operators will charge their trucks more on the Italian side of the border. It will be challenging to achieve higher utilisation on the Austrian side.

The Netherlands – Germany

A heavily travelled motorway border crossing runs between the Netherlands and Germany. When looking at the power network in the Dutch region of Venlo, network costs for operating charging stations with low utilisation rates are extremely high, at more than 14 euro cents/kWh. Use of the power network in the neighbouring Germany's lower Rhine area is significantly cheaper, at only 6 euro cents/kWh. This significant difference results from the fact that the Dutch network costs are recovered exclusively through demand charges. The only determinant of the network price, therefore, is the charging capacity or the contracted capacity, not the kilowatt-hours charged by the vehicles. At a high utilisation rate, however – which we consider to be 2,250 out of 8,870 hours – the German network will be 1 euro cent/kWh more expensive.

[31] Skrzypczyk, A. (2023, 6 April). How to modernize Poland's outdated electric grid. *Energy Transition. The Global Energiewende*. https://energytransition.org/2023/04/how-to-modernize-polands-outdated-electric-grid

This example illustrates that cost differences for operating megawatt charging infrastructure change significantly if utilisation rates increase on both sides.

The structure of network costs is decisive for ramping up megawatt charging. Network tariffs based on kilowatt-hours spent charging, as opposed to demand charges, can boost utilisation rates for the charge points and networks, and lead to more balanced and cost-efficient grid-use.

Belgium – Luxembourg

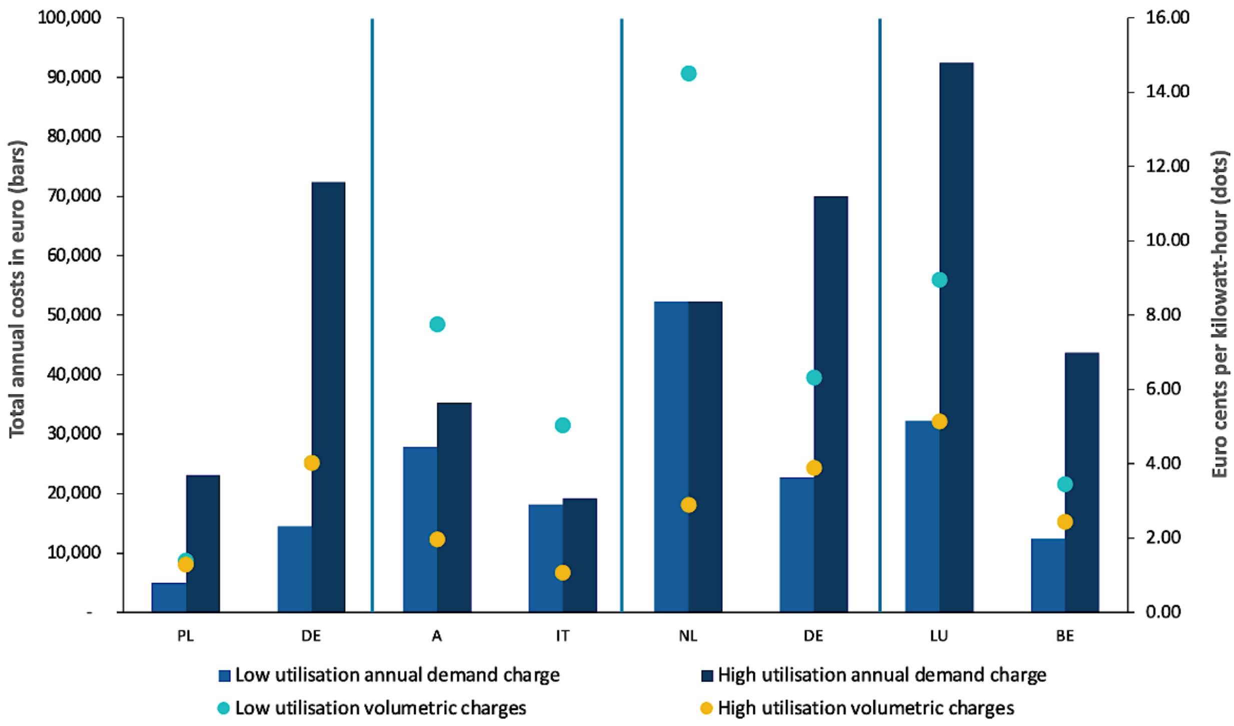
Traditionally, taxes on petrol and diesel are low in Luxembourg,[32] which has generally led to an increase in border traffic and a corresponding increase in domestic petrol consumption. In response, Belgium has introduced a diesel tax rebate for heavy-duty vehicles, which reduces the marginal effects of the price differences with the aim of attracting more truck drivers to fuel up in Belgium. The network costs, however, can have the opposite effect for megawatt charging. Using Belgian power networks at the border is cheaper than using the networks in Luxembourg by a factor of two to three. The absolute differences in grid costs are about 5.5 to 2.7 euro cents/kWh, for low and high utilisation rates, respectively. Without interventions, these differences will likely drive up charging site utilisation locally on the Belgian side of the border.

Governments can implement tax-based countermeasures to balance network cost, regardless of network requirements.

We summarise the charging costs described in these case studies in Figure 5 below.

[32] Locher, T. (2021, 12 August). *Gas taxes in Europe 2022*. Tax Foundation. https://taxfoundation.org/data/all/eu/gas-taxes-in-europe

Figure 5. Summary of charging costs at border crossings, low and high utilisation rates



Sources: For full data sources, please refer to Annex.

Case studies: truck charging costs within national borders

Germany

Network cost differences can also arise within the borders of Member States. This is the case in Germany, for example, where around 880 grid operators serve small and large areas. The sheer number of network operators will create challenges for the build-out and pricing of national truck charging networks, even across smaller distances, particularly if they are connecting a less costly grid area with an expensive one.

Northern Germany is an illustrative case. The dense urban power network for Kiel is surrounded by rural areas in the federal state of Schleswig-Holstein, where significant renewable energy penetration would make it highly beneficial to locate megawatt charging. However, the current network tariff regime could discourage CPOs from locating truck charging in the rural network. If space is available, network pricing could encourage them to choose the urban network, where high-voltage network fees are approximately ten times cheaper than in the surrounding area for a similar utilisation rate. This results in a network price difference of more than 10 euro cents/kWh.[33] The fact that the costs for these highly varied networks must be borne by local residents tends to create misleading incentives and consumer choices: prices shift additional demand to where most electricity consumption takes place, resulting in lower grid use in rural areas, where costs are driven up even further.

Even within a country, cost differences for using the grids can lead to price differences for megawatt charging and to misleading incentives for grid users.

The analysis and case studies show that network costs, in addition to the structure of taxes and levies, will likely determine the competitiveness of truck charging points across Europe. More specifically, the way network charges are designed will determine how well charge point operators can optimise electricity consumption at truck charging sites and reduce their costs. It is important that fleet operators have the choice of where to charge their trucks. This ability to choose their point of consumption, however, will expose the weaknesses of current network tariff regulation in the medium term.

The resulting policy challenge for decision-makers is to mitigate the effects of charging tourism while advancing the build-out of a competitive market for truck charging services. The last section of this paper discusses policy areas through which they can address this challenge.

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[33] Based on German energy costs, taxes and levies according to BDEW (2023) for the high-voltage network, and Schleswig-Holstein Netz (2023) for the City of Kiel and surrounding regional network. See Annex for full sources.

Policies to support cost-efficient truck charging and the energy transition

To date, the rollout of megawatt charging has been driven by practical and administrative factors rather than being based on mobility and system needs. Grid operators are currently overburdened with connection requests from charge point operators, private and commercial consumers, as well as solar photovoltaic and wind projects, at a time when their lead times for system upgrades are very long.[34] As a consequence, megawatt charging developers build the sites for which they obtain permission to build first or fast, or where additional network capacity can be added in a certain timeframe.

This problem will increase as national governments strive to meet the deadlines imposed by the EU Alternative Fuels Infrastructure Regulation for building out the truck charging infrastructure. High price differences in charging costs pose a risk to the build-out of a sufficiently dense and balanced truck charging network.[35] They also risk slowing down freight electrification and could cause local grid constraints. The consequences may be increased network congestion and costs, in particular in more sparsely populated border areas if truck drivers prefer to charge for less money on one side of the border. The solutions to address this problem, described below, require coordination between national governments and European policymakers.

More cost-reflective pricing of electricity networks

Across and within EU Member States, the way network fees are regulated varies, which contributes substantially to cost differences and their potential impact on megawatt charging prices. Differences in network pricing are rooted in the different geographical characteristics of network areas and historic patterns of regulation. To support the development of cost-efficient megawatt charging — while also supporting the economic electrification of other end uses — network pricing needs to more accurately reflect the actual costs for when and how much customers use the grid.[36] According to the EU Electricity Market Regulation,[37] network charges for use of the electricity grid should be based on the principle of cost causation, also known as cost-reflectivity. This means well-implemented network tariff regulation must consider the siting and the geographical flexibility of new demand across borders.

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[34] Schlandt, J. (2023, 8 September). „Ansturm" aufs Stromnetz ['Rush' on the electricity grid]. *Tagesspiegel Background*. https://background.tagesspiegel.de/energie-klima/ansturm-aufs-stromnetz

[35] Hildermeier, J. (2020). *EV charging infrastructure in Europe: A clear path for a competitive market*. Regulatory Assistance Project. https://www.raponline.org/blog/ev-charging-infrastructure-europe-clear-path-for-competitive-market

[36] In some EU regions such as Denmark, network operators have introduced network tariffs that are designed in a way to shift consumption away from hours with more demand, or congestion, on the power network. They have introduced, for example, a 'peak charge' in the early evening peak hours for industrial and residential consumers: Radius Elnet (Danish Network Operator). *Tariffs and network subscription*. https://radiuselnet.dk/elnetkunder/tariffer-og-netabonnement

[37] European Parliament and Council of the European Union. (2019). Regulation (EU) 2019/943 of the European Parliament and of the Council of 5 June 2019 on the internal market for electricity (recast). https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32019R0943

Moving towards more cost-reflective network pricing depends on national regulatory frameworks and geographies, and is not easily achieved. But an important improvement towards which power network regulators can strive is to base network pricing more consistently on the volume of electricity consumed at a given time (time-of-use charges), rather than on demand charges based on the peak capacity needed, independent of the total energy actually used (see Figure 2). This switch would make many megawatt charging sites cheaper to operate, in particular those with low utilisation rates, and would therefore be a particular support during the early phases of the build-out of truck charging infrastructure. These observations are echoed in the European Commission Agency for the Cooperation of Energy Regulators' (ACER's) recommendations to implement cost-reflective pricing, such as through mandatory time-varying network tariffs.[38] Introducing time-of-use volumetric network pricing also offers larger benefits for the energy transition, in that it would allow regions with very different characteristics to use existing power networks most cost-effectively.

Financial incentives

The current taxes and levies on charging services differ by country, and could be adjusted to balance existing cost differences. Belgium and Luxembourg have already done this for fuel taxes (see case studies starting on page 9). Governments can use taxes and levies on specific electricity uses — in this case for high-capacity charging — as a means of regulation to phase in a competitive charging market based on real costs. This requires a high level of coordination between neighbouring countries, which will increase in importance as the infrastructure build-out gains momentum. The need for collaboration will be further heightened as the policy framework around EV charging develops. As Member States transpose the Renewable Energy Directive,[39] for example, they will be required to design national crediting schemes for renewable electricity used at public charging points.[40]

Adjusting taxes and levies to phase in cost-efficient truck charging can be a temporary measure to counteract the grid impacts of charging tourism, and raise awareness among policymakers of the need to find a coordinated solution.[41] It does not, however, replace the necessity of developing more cost-reflective network pricing — the lack of which is causing these high price differences — over the medium term.

[38] European Union Agency for the Cooperation of Energy Regulators (ACER). (2023, January). *Report on Electricity Transmission and Distribution Tariff Methodologies in Europe*. https://www.acer.europa.eu/Publications/ACER_electricity_network_tariff_report.pdf

[39] Directive (EU) 2023/2413 of the European Parliament and of the Council of 18 October 2023 amending Directive (EU) 2018/2001, Regulation (EU) 2018/1999 and Directive 98/70/EC as regards the promotion of energy from renewable sources, and repealing Council Directive (EU) 2015/652. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32023L2413&qid=1699364355105

[40] Other national incentives that influence electricity prices, such as the greenhouse gas quota, require similar coordination. See Umweltbundesamt [German Environment Agency]. *Anrechnung von Strom für Elektrofahrzeuge* [Offsetting electricity for electric vehicles]. https://www.umweltbundesamt.de/themen/verkehr/kraftstoffe-antriebe/vollzug-38-bimschv-anrechnung-von-strom-fuer

[41] This could include ending tax subsidies for diesel fuel, which would make operating diesel trucks more expensive. Comparatively high taxes on gasoline and the ability to offer cheap electricity for charging were among the early success factors to boost EV uptake in Norway, Europe's largest EV market.

Conclusions

Building a megawatt charging network for trucks along European highways, at optimal cost for consumers and for the grid, is a common European policy challenge.

A coordinated approach is essential to support rapid infrastructure development along core freight corridors and to ensure that high differences in operating costs do not lead to charging tourism. These variances have negative consequences for the grid and can even slow the electrification of long-haul freight.

Most high costs for operating megawatt charging are currently caused by network tariff design that is not fit for purpose. Energy regulators can address this issue by implementing more cost-reflective network pricing across Europe. A first step towards this objective would be to introduce more volumetric network charges — and to vary the price by the time of use, based on the available network capacity. Demand charges, by contrast, make the peaks in demand caused by electric truck charging unnecessarily expensive. An additional short-term measure governments can take during the early electrification of freight is to adjust electricity taxation for high-capacity charging along highways, reducing cost differences between locations. Without these measures in place, megawatt charging that promotes inefficient use of power networks will add costs that all consumers must bear.

It is crucial that all stakeholders in truck electrification collaborate in this early phase of building out truck charging infrastructure. Having choices for where to charge offers fleet operators an opportunity to drive this process across Europe. They can use this leverage to urge national and European policymakers to build out truck charging in a cost-efficient and coordinated way, to keep prices for charging affordable and to avoid charging tourism, with its negative impacts on charging prices, truck electrification and power grids.

Annex – Overview of network cost calculations

Definition of low and high utilisation rates for charging points:

- **Low utilisation**: Two charging operations per working day (2 x 45 minutes at 800 kW) or one megawatt charge and one slow charge (1 x 45 min at 800 kW, plus eight hours at 100 kW).
- **High utilisation**: Ten charging operations per working day (10 x 45 min, meaning the charge point is occupied for 7 hours, 30 minutes), or nine megawatt charging operations, plus one slow charging session over eight hours (the charge point is occupied for 14 hours, 45 minutes).

Table 1. Network fees for charging at different sites in Europe in 2023 (based on definitions above and links in Table 2)

Utilisation rate		European borders in case studies								Case studies within Germany	
Low utilisation: 450 hrs /year 800 kW peak demand 360,000 kWh/year		PL	DE	A	IT	NL	DE	LUX	BE	SW Kiel	SH Netz
	EUR/year	4,958	14,475	27,859	18,147	52,200	22,752	32,208	12,412	4,120	43,172
	EUR Ct/kWh	1.38	4.02	7.74	5.04	14.50	6.32	8.95	3.45	1.14	11.99
High utilisation: 2,250 hrs/year 800 kW peak demand 1,800,000 kWh/year											
	EUR/year	23,142	72,363	35,232	19,270	52,200	69,984	92,400	43,703	13,912	139,796
	EUR Ct/kWh	1.29	4.02	1.96	1.07	2.90	3.89	5.13	2.43	0.77	7.77

Table 2. Sources for case studies, by country and high-voltage power network

Country	Utility	Year	Website
Poland	Enea	2023	Enea price lists
Germany	E.DIS Netz	2023	E.DIS price lists
Austria	E-control	2023	E-control network fees for Tyrol
Italy	Arera	2023	Arera electricity customers
Netherlands	Enexis	2023	Enexis tariff lists
Germany, Lower Rhein	Netzgesellschaft Niederrhein	2023	Netzgesellschaft Niederrhein network tariffs for electricity customers
Luxembourg	Electris	2023	Electris network tariffs
Belgium	ORES	2023	ORES price lists
Germany, Kiel (urban)	Stadtwerke Kiel	2023	Stadtwerke Kiel network tariffs for electricity customers
Germany, Schleswig-Holstein (rural)	Schleswig-Holstein Netz	2023	Schleswig-Holstein Netz network tariffs for electricity customers

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