White paper

Real-time Monitoring of Electric Vehicles on the Edge

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Despite the numerous benefits of EVs, their high-rated power dictates the need for real-time monitoring. The benefits for energy retailers are manifold. Firstly, real-time monitoring can help to balance the load demand in the house and optimize the energy portfolio for the intraday energy market trade. Secondly, it allows the employment of demand response strategies to mitigate potential voltage violations. Finally, it offers direct financial benefits to consumers who charge at peak times or consume their home solar-generated energy as much as possible.

With the prevalence of in-home chargers increasing, real-time EV monitoring for residential customers has become a huge benefit. For this reason, at NET2GRID, we have developed a cost-effective real-time EV monitoring system running on the edge.

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Background

EV Charging at home

The impact of Electric Vehicles (EV) loads in residential installations is closely linked to grid stability and planning use-cases. Research shows that 70% of all EV charging in Europe happens at home and it is projected to stay that high in the years to come (Figure 1). Especially with the electrification of HVAC appliances in the home, there will be a significant impact on total home energy management and therefore real-time consumption monitoring is essential.

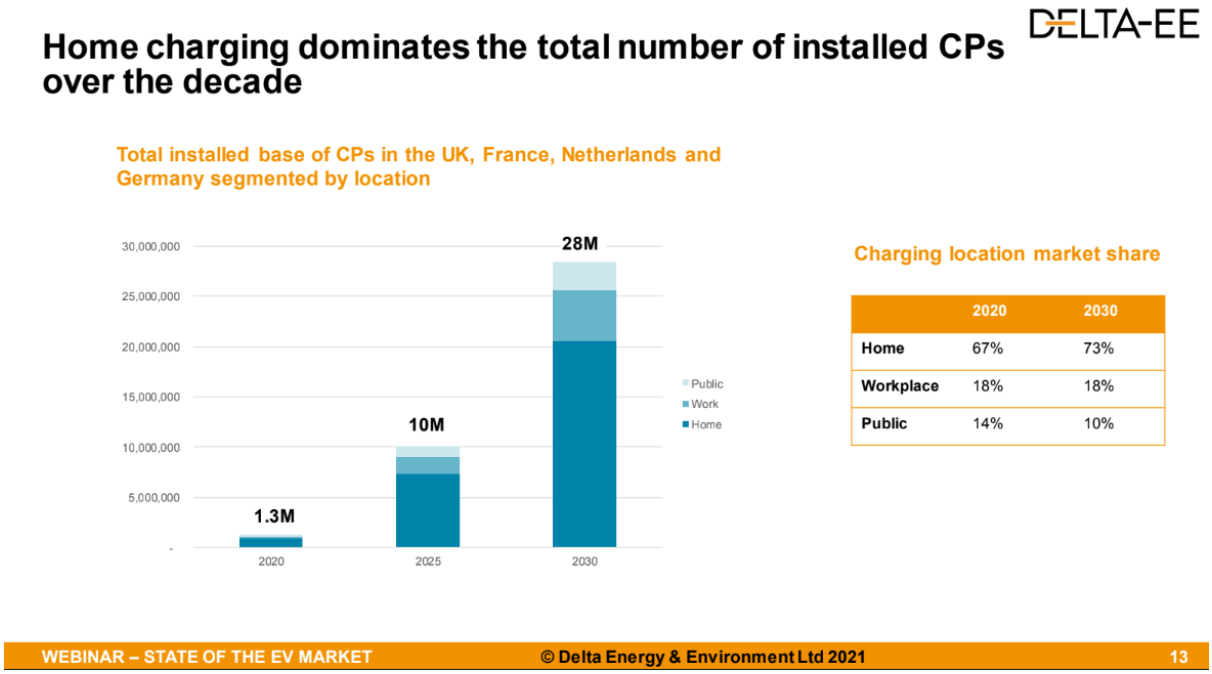

Figure 1: Source Delta-EE

In the US, charging at home has not yet taken off in sheer volume due to high upfront investments in EV equipment. US EV charging session numbers indicate that the majority of EV charging happens at home locations right now, but in the coming years will

not pick up like in Europe (Figure 3) That's also because not all street-level power infrastructure supports high loads of peak demand from L2 and L3 chargers. With the increase of residential PV panel installations, there is an even bigger peak load impact on the US local grid as solar grid feed-in is not always in sync with EV charge loads at home, resulting in an even steeper shark curve (Figure 2).

Power demand spikes are a usual occurrence at times of the day when, for example, EV owners return home from work and plug in their cars. Due to the level 2 home chargers being much less powerful than level 3 DC fast chargers, the large number of EV cars plugged in at the same time creates a problem. It also explains why demand response programs are more apparent in the US than elsewhere in the world.

Therefore, smoothing out EV charging using real-time load balancing or ToU tariff to steer the EV charging process can help reduce peak loads. At the same time, as the total amount of home charging activity grows, there will still be a significant need for EV charging optimization solutions in home situations.

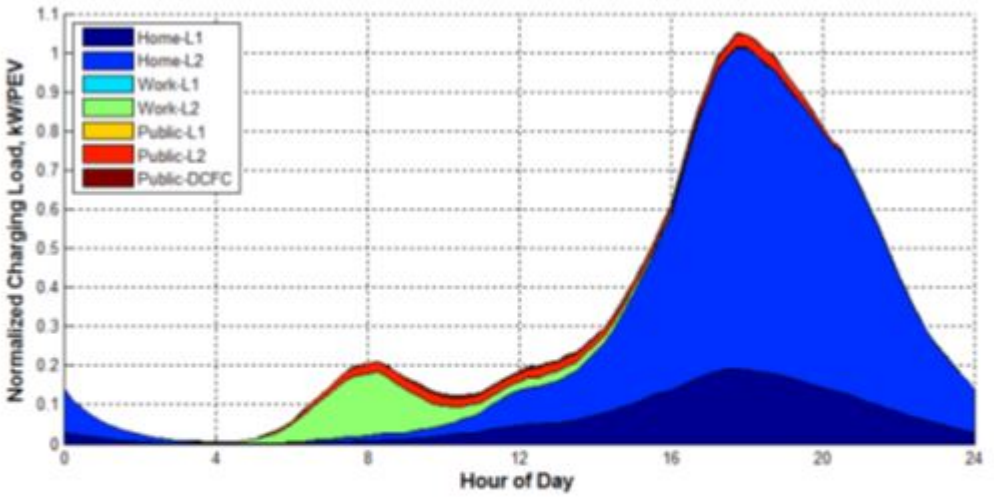

Figure 2: Shark Curve, Source: NREL National Plug-In Electric Vehicle Analysis

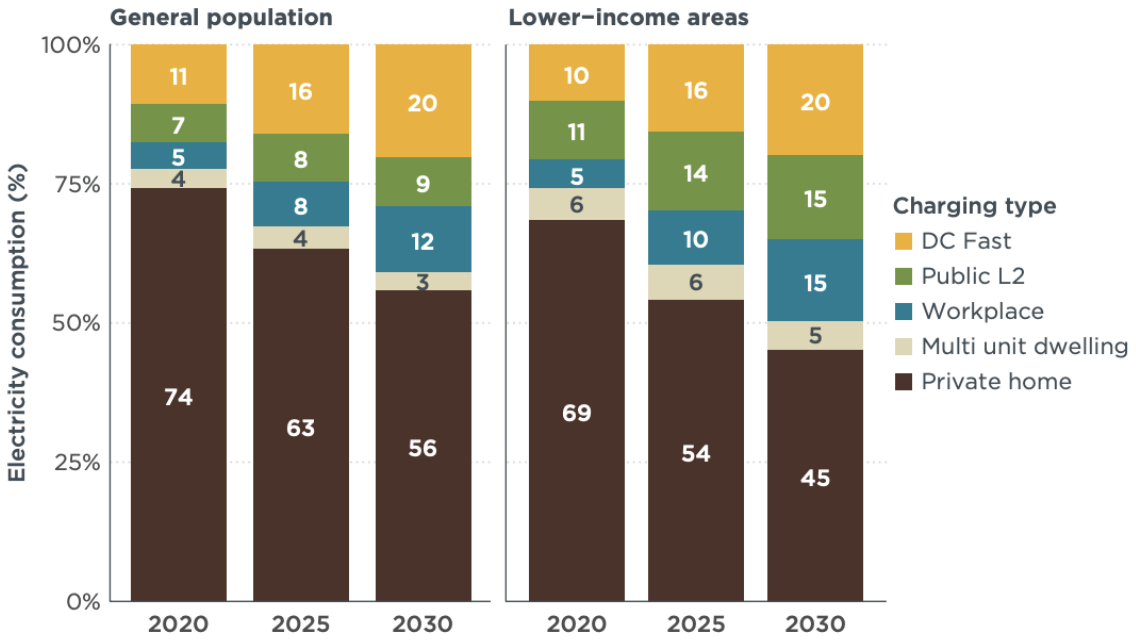

Figure 3: Charging energy consumption by charging type and year, for the general population and in lower-income communities in the US, Source: [The International Council on Clear Transportation]

The impact on the grid

Even though electrification can lead to a significant decrease in carbon emissions, the significant rated charging power of EVs can also create problems for the smooth operation of transmission and distribution networks. The high penetration of EVs causes several issues such as voltage violations, increased load, and peak demand.

Next to the growth of electricity demand, there is also a large increase in the last years in homeowners installing solar panels on their roofs. This makes the predictability and reliability of these renewable energy sources a challenge for both network operators and homeowners. Network operators need to absorb all the dynamic fluctuations in the

subnetwork and bigger electricity networks. On the other hand, homeowners like to use as much of the self-generated solar PV energy for HVAC and EV charging as possible.

As seen in Figure 4, the purchase or use of EV chargers at home drives the adoption of residential PV solar installations by almost 10% and this is expected to increase in the coming years as the costs for PV lowers. Next to investing in solar panels, once homeowners have an EV they also tend to switch to new energy contracts with better tariff plans for their EV charging moments by almost 30%. This makes apparent the need for solutions that help prosumers to optimize EV charging and PV self-consumption to make the best use of their produced solar energy or specific EV tariffs.

In that context, as the number of residential/home chargers increases, real-time EV demand monitoring for residential customers becomes essential to help stabilize the grid and make sure end-users charge their cars at the lowest electricity prices.

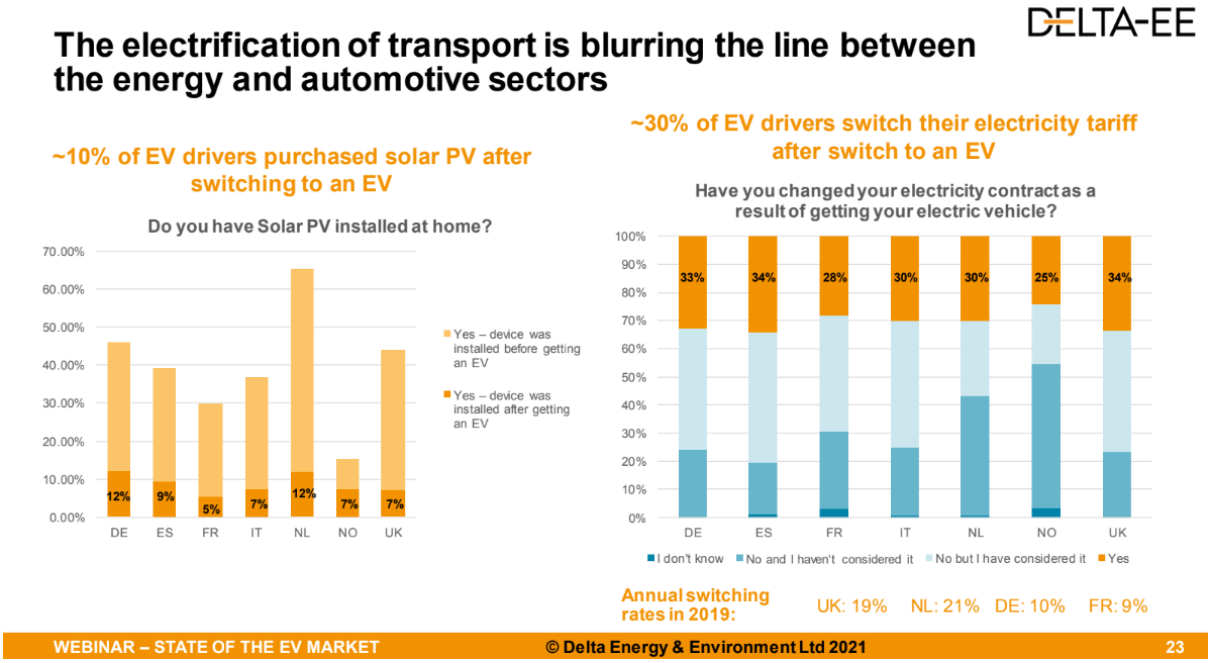

Figure 4: The electrification of transport is blurring the line between the energy and automotive sectors. Source: Delta-EE

Real-time EV monitoring approaches

There are five ways in which real-time EV monitoring can be performed:

1. **Implement a software solution on the Analytics side.** This approach dictates the creation of an intelligent service, capable of monitoring EV consumption. By using the Net Consumption Measurements available from the primary smart metering equipment, a non-intrusive approach is implemented without any additional costs on the customer side.
2. **Creating a car/charger API**. The good thing about this service is that one can have a very accurate monitoring system. On the other hand, there are too many models and types of EVs out there; each one has its own API / Mobile App, making it nearly impossible to create a unified approach to retrieve data information from all of them.
3. **Installing second special hardware.** This approach is perfectly accurate since the metering equipment retrieves consumption measurements only for EV. However, this solution is more intrusive and costly than the first approach.
4. **Integrate with multi-brand car EV charging API service providers.** Following this approach, a charge-for-subscription is required for each charging event or flat fee per connected car subscription.
5. **Integrate with an Charge Point Operator (CPO) backend system**. This approach allows reading at the charging pole infrastructure for home installations, while for public charge stations uses their EV charge card subscribers data.

NET2GRID's approach: Software & Analytics

At NET2GRID, we made the strategic decision to go with the first approach as the second and third approaches are both costly and lack scalability. A software solution provides a viable way for utilities to perform large-scale deployments that fit their business model. The fourth and fifth options are costly for just reading the real-time charging status of a car. Plus, they do not provide a full 360 home energy consumption view, as they only integrate with the car or charge pole as a silo solution.

To this end, we have implemented **a cost-efficient, intelligent, and non-intrusive monitoring system with low computational and memory requirements running embedded inside smart meters.** Our approach leverages **AI to estimate the EV consumption in real-time, based only on the aggregated active power consumption at home level at intervals of 10 sec,** without using additional metering equipment or employing any car/charger API or sensor.

Additionally, we support multiple chargers running at the same time or at independent times, meaning that we can **automatically detect numerous EVs charging** in an installation. No feedback from the end-user regarding charging level or brand is required.

The following images present some examples of aggregated house-level power consumption and the estimated EV consumption. It can be seen that all power levels are supported even for households with installed solar production. However, the delay of identification varies according to the power level; super-fast chargers are detected immediately, whereas hybrid EVs with low power consumption are detected with a delay to avoid false positives due to other appliances.

The following table (Table 1) presents the mean accuracy per charging type, along with the time to detect and verify an event. The total mean accuracy is about 90%.

Type	Power level	Mean accuracy	Time to confirm an event
Super-fast	Over 6 kW	96%	7 min
Fast	2.9 - 6 kW	88%	10 min
Normal	Under 2.9 kW	94%	2 h

Table 1

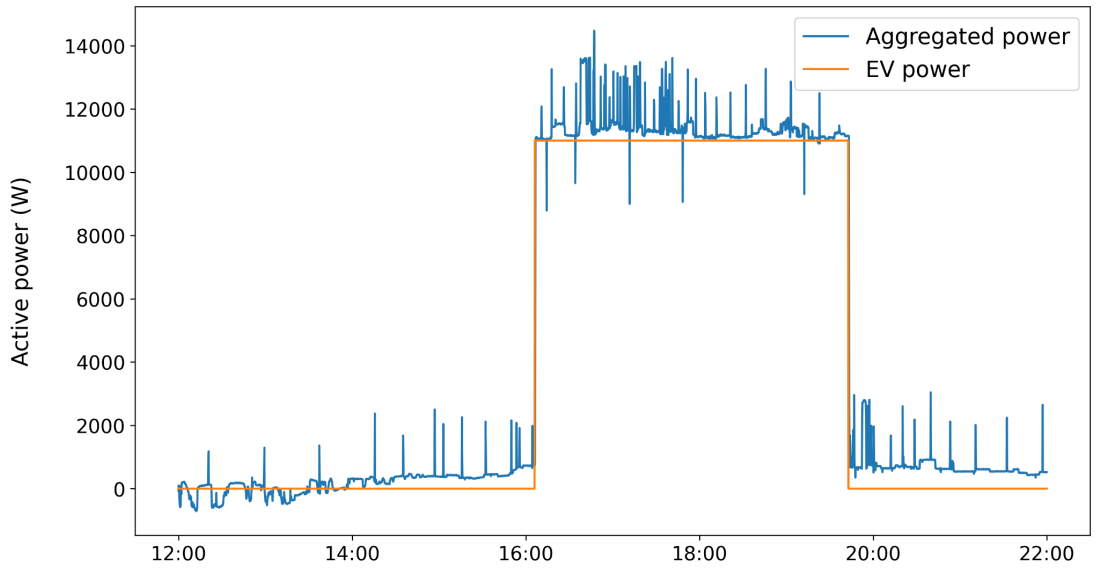

Figure 6: Super-fast charging pattern

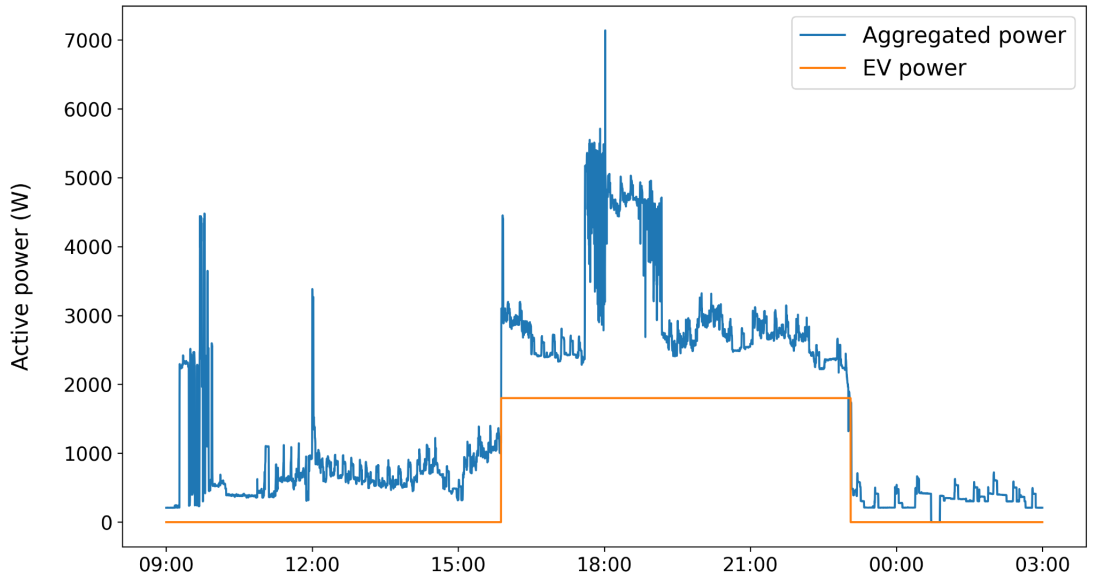

Figure 7: Normal charging

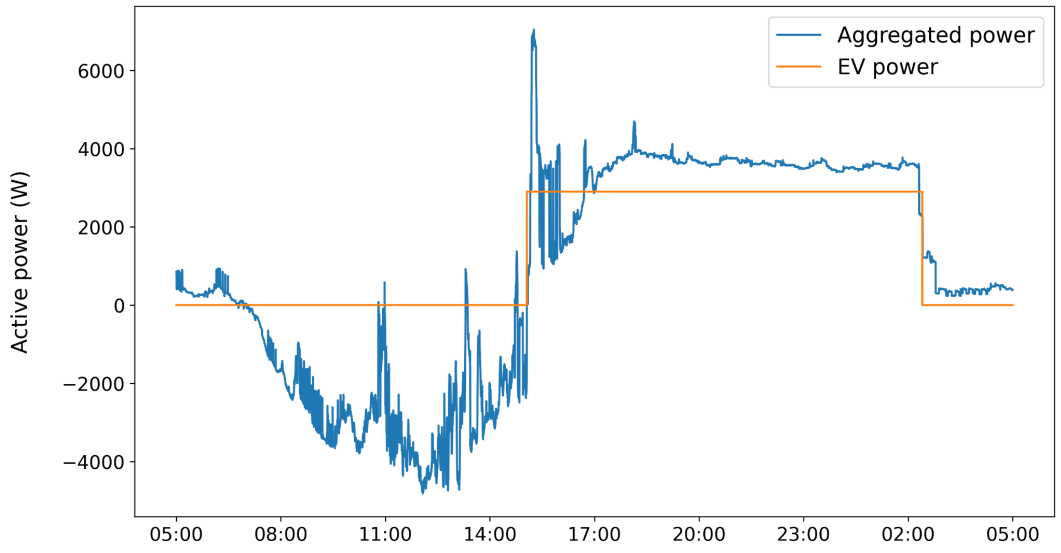

Figure 8: Fast charging during solar production

Business Benefits

NET2GRID's real-time EV monitoring service can provide diverse assets for various stakeholders, such as utility customers, EV users, energy suppliers, and DSOs/DNOs:

- **Utility Customers and EV users:** The end-customer now has in its possession an all-in-one service/app, which allows monitoring for how many hours the EV has charged and when it is fully charged. There is no need to check multiple apps at once, to integrate PV production data from inverter suppliers, or to install a piece of intrusive additional metering equipment.
- **Energy Suppliers:** From an energy retailer perspective, knowing when and where an EV is charging, and the power it consumes, can help plan the demand and efficiently procure electricity in the intraday energy market. Additionally, real-time EV monitoring has a great demand response potential. Identifying customers who are still charging during on-peak hours and offering them financial incentives to shift to off-peak hours can help ease the high demand and mitigate voltage violations.
- **DSOs / DNOs & TSOs / TNOs:** The Grid Operators can overview the actual EV penetration in the distribution network, making better forecasts and managing their assets and production needs based on their customers' requirements. Identifying nodes in the grid where EVs are present is essential since these nodes should be prioritized for maintenance and support. Additionally, knowing the aggregated power consumption of EVs in real-time creates a virtual power plant due to the flexible nature of EV charging sessions that can be shifted to off-peak hours and act as virtual generators.

Functionalities

Thanks to NET2GRID's real-time EV charging monitoring, we can provide end-users with real-time information about EV energy consumption, what time a charging session started, and when it stopped. As a next step, an overview of the daily consumption events and a monthly consumption report can be provided, helping end-users understand the EV consumption behavior impact and how its operation affects their electricity bill. This is critical since an EV constitutes a large proportion of the monthly energy consumption, up to 40 - 50% of the total energy consumed. The charging behavior of each end-user can also be beneficial for energy retailers, enabling them to expect peak demand due to multiple charging events.

Finally, based on this service, we can create additional value by providing recommendations and tips for better-charging behavior to end-users. By analyzing time-of-use and dynamic tariffs, we can recommend the optimal time intervals to charge an EV in order to reduce the billing costs. Moreover, the expected solar production is considered during our analysis to incentivize end-users to charge their EVs when a surplus of generated energy is available.

To sum up, several useful metrics can be provided to the end-users, giving helpful feedback and a broad overview of EV consumption. More specifically, such metrics include:

- **Recent charging sessions:** A list with the most recent charging sessions, including the start/stop time and the energy consumption for each one.
- **Daily/monthly energy consumption:** The value of the daily/monthly EV energy consumption in kWh or as a percentage of the overall consumption of the installation.

- **Standard charging hours:** The hours when the end-user usually charges their EV.
- **Recommended charging hours:** A list of recommended hours when charging will be cheaper, if the end-user shares their tariff policy.
- **Estimated time to full charge:** Once an EV charging session is detected, an estimation of the time when the EV will be fully charged can be provided. This estimation is based on historical data, so some charging sessions must be detected before enabling this feature.

Would you like to learn more about NET2GRID's real-time EV monitoring? Contact us at sales@net2grid.com and we would be happy to assist you.