EVS30 Symposium
Stuttgart, Germany, October 9 - 11, 2017

The Dutch revolution in smart charging electric vehicles

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Abstract

More and more energy is generated using sustainable sources, such as the sun and the wind. In the nearby future, it therefore might be the case that there is more supply than demand of energy at certain times. In order to use this abundance of sustainable energy efficiently, electricity will have either to be stored and used at the most optimal time or user patterns will have to shift. One way to achieve this, is to integrate the electric car as part of the energy system. This integration is made possible by the novel concept of smart charging. With modern and smart technologies, electric vehicles can be charged at the right time, i.e. at night when a lot of wind power is generated and demand is little. Whereas this might sound like a future vision, the Netherlands is already taking important steps to realize this connection in the near future. In March 2016 the Living Lab Smart Charging has been founded to carry out research on smart charging. This paper will go into detail on smart charging and the role of the Living Lab Smart Charging, including the projects of Jedlix, deferred charging in the province of Noord-Brabant, FlexPower, and LomboXnet, that are part of the nationwide Dutch living lab. Also, an outlook on future projects will be given with which the Living Lab Smart Charging and its partners are shaping the defined action plan, to eventually create an international and open standard for smart charging.

Keywords: smart charging, electric vehicle, renewable, solar energy, standardization

1 Introduction

A recent newspaper article reported that ‘climate leader’ China is still throwing away a lot of green electricity [1]. Last year, more than 17 percent of total wind energy capacity was not used, which summed up to 49.7 TW. This amount of energy would be enough to power the entire city of Beijing for six months. This illustrates that there are difficulties with balancing supply and demand, and that some countries already face a surplus of renewable energy that is used inefficiently. China is looking for technical solutions, such as static batteries, to cope with this surplus. Currently, however, they are investing heavily in expensive high-voltage

cables that are able to transport the renewable energy a few thousand kilometers east where there is demand for energy.

Zooming in on the Netherlands, this growing trend in the supply of renewable energy can also be seen (see Fig. 1). The graph illustrates that the capacity of solar PV and wind energy has grown respectively by 791 MW and 510 MW within a year. This renewable energy, originating from natural resources such as the sun, comes in peaks and dips. Often the generation of this type of energy does not coincide with its demand, meaning that either demand should be shifted or the generated energy should be stored in order to use it as efficiently as possible.

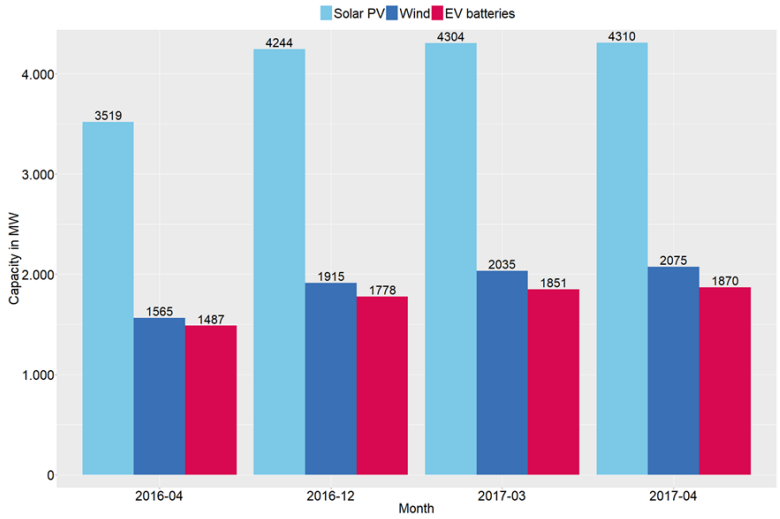

Figure 1: Capacity (MW) of respectively solar PV, wind and EV batteries in the Netherlands [2]

Besides the growth in renewable energy, there is also an increase in the number of electric vehicles. Since the introduction of electric vehicles (EVs) in the Netherlands in 2011, both the number of EVs as well as its related charging infrastructure has experienced a significant growth [3]. Within five years, the number of EVs has grown to more than 117,000 in total, of which approximately 13% are battery electric vehicles (BEVs) and 84% are plug-in hybrid electric vehicles (PHEVs). Charging points, consisting of (semi-)public, private and fast charging points, have increased in number as well. On top of more than 25,000 public and semi-public charging points, fast charging points can nowadays be found at somewhat more than 650 locations in a nationwide network across the Netherlands. As can be seen in Fig. 2, it is expected that the number of BEVs will already increase significantly over the coming months. One of the reasons for this increase is the beneficial financial climate in the Netherlands that exempts BEVs from certain road and purchase taxes [4]. Additionally, given the aims that the government has set – leading up to all transportation being zero emission in 2035 – it can be expected that this number will increase even more.

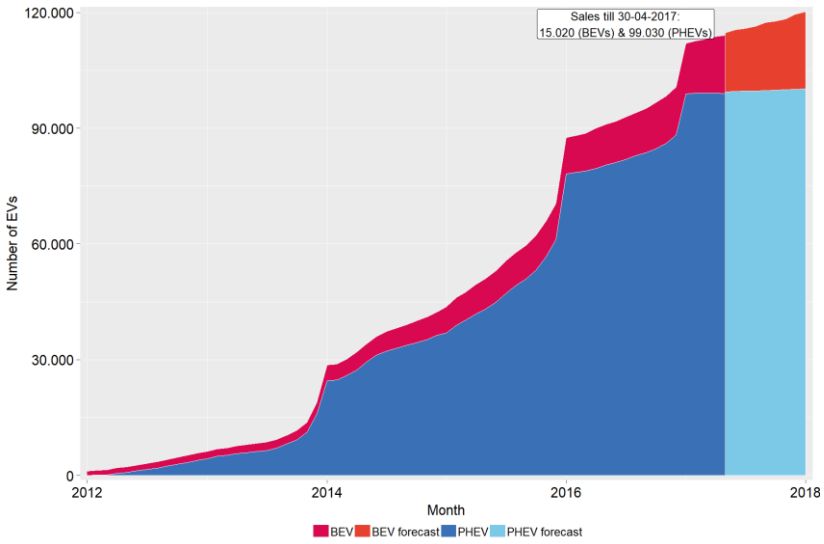

Figure 2: Forecast of BEVs and PHEVs in the Netherlands [2]

In a recent study by Ecofys, this growth has been linked to the necessary charging infrastructure [5]. The conclusion of the report is that – even in the base scenario – up to 2020 an increase of 170% to a total of 45,500 public and semi-public charging points is needed compared to 2016 in order to anticipate the growing demand for BEVs. The report also ascribes an important role to work chargers, which they expect to rise to 50,900 – a 300% increase compared to 2016. This growing number of EVs and charging points will have an impact on the electricity grid and power quality if these cars are charged during periods of peak demand.

The abovementioned example of China – where wind energy capacity was underused – and the example of the Netherlands – where a significant growth of EVs is expected – both illustrate ongoing trends. Despite the fact that renewable energy as well as electric vehicles can contribute to combatting climate change, their scale-up presents a number of challenges. By linking the two in a smart way, the two 'challenges' can strengthen and reinforce each other. This paper will go into this 'smart' solution called smart charging. Besides providing some general information on the technology, the paper will elaborate on the Living Lab Smart Charging. This platform makes the roll-out of this novel concept possible in a nationwide Dutch living lab. Besides outlining the action plan that the Living Lab Smart Charging has drawn up, three projects are described that help to eventually achieve an international open standard regarding smart charging.

2 About smart charging

Whereas EVs are often seen as a means to 'green' mobility, they can also act as an integral and crucial part in the future energy system. As can also be seen in Fig. 1, these 115,000 vehicles currently have already enough battery capacity to store and use a part of the generated renewable energy. Therefore, they can act as buffers during peak times and support grid management, and their flexibility will also optimize the use of renewable energy during times of low demand. In 2020, the number of sold electric vehicles should be 10% of the total number of cars sold, which comes down to approximately 40,000 EVs sold per year. The aim for 2025 is for 50% of all new cars sold to have an electric powertrain, which would be an annual sale of 200,000 EVs. Given these goals and the expected growth, within a decade the number of EVs on Dutch roads will have the capacity to store all renewable energy that is generated. This link between the generation of sustainable energy and charging electric cars is better known as smart charging.

Because of the complexity of the process, smart charging involves a wide range of different stakeholders. First of all, it includes the EV-driver who has certain wishes and preferences, and the connected electric car which should be able to communicate with the charging point. Furthermore, the charge point operator (CPO) is involved to roll-out and maintain the smart charging infrastructure. Via a clearing house – which facilitates charging transactions – the CPO is linked to the electric mobility service provider (eMSP) who distributes charging cards. The transmission system operator (TSO) and distribution system operator (DSO) also play an important role, as they have to communicate the forecast of the available capacity of the electricity grid.

In order to allow smart charging, the mentioned stakeholders communicate via a variety of open protocols (see Fig. 3).

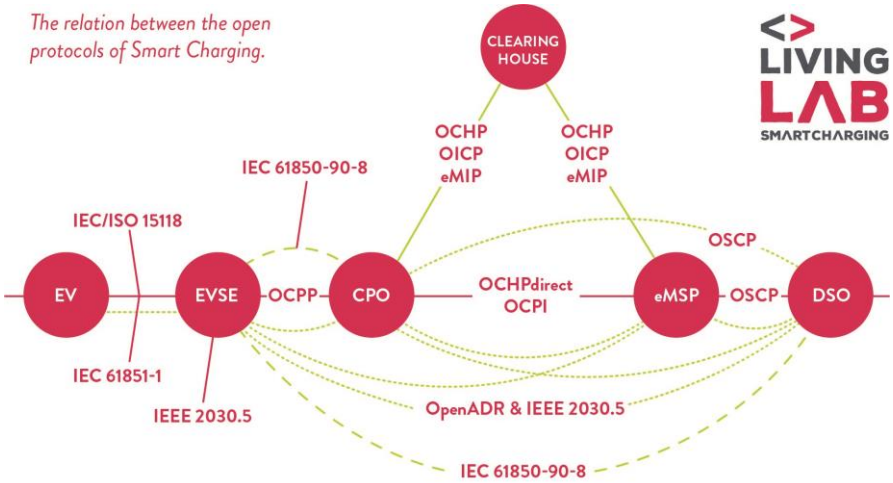

Figure 3: Communication protocols between involved stakeholders in the process of smart charging [6]

Since smart charging combines several aspects, including available grid capacity and renewable energy, it offers direct advantages to the majority of the stakeholders involved. By shifting their charging pattern, e-drivers can for example be rewarded for lowering peak load which results in the avoidance of costly grid reinforcements by the DSO. To investigate the possibilities of smart charging to eventually benefit from the potential of this technology, the Living Lab Smart Charging has been created.

3 Living Lab Smart Charging

In the Netherlands, the government has emphasized the importance of electric transport and smart charging. Therefore, a Green Deal Electric Transport 2016-2020 was drawn up and signed last year [7]. In this public-private agreement, various stakeholders have collectively committed themselves to speeding up the transition of sustainable mobility. One of the actions that has been drawn up in the agreement, was to actively get involved with living labs in order to set up pilot projects. Emphasis was put particularly on the creation of a Living Lab Smart Charging, which was founded in March last year by ElaadNL - a knowledge and innovation center on behalf of the majority of the Dutch grid operators. The Living Lab Smart Charging is an open platform where companies, universities and local and regional governments and grid operators cooperate and perform research on how smart charging can be realized. Already 325 municipalities, including the cities of Amsterdam, Rotterdam, Utrecht and The Hague, have joined the Dutch Living Lab Smart Charging, representing more than 80% of all charging stations in the Netherlands. The Living Lab Smart Charging has formulated an ambitious program, consisting of three main points:

(i) make existing and future charging infrastructure Smart Charging Ready;
(ii) carry out research and tests on smart charging; and
(iii) develop an international standard.

3.1 Smart Charging Ready infrastructure

Smart charging starts with charging infrastructure that should be able to handle a smart transaction, taking into account the several aspects mentioned earlier. In order to prepare as many charging stations for smart charging as possible, since March last year the Living Lab Smart Charging has been working on implementing software (OCPP 1.6) in existing charging points. This open and standardized protocol allows to steer a charging transaction, shifting or postponing the charging session to the most optimal moment. Already 78% of almost 7000 public charging stations in the Netherlands has been made Smart Charging Ready (SCR) and can handle a smart charging transaction (see Fig. 4).

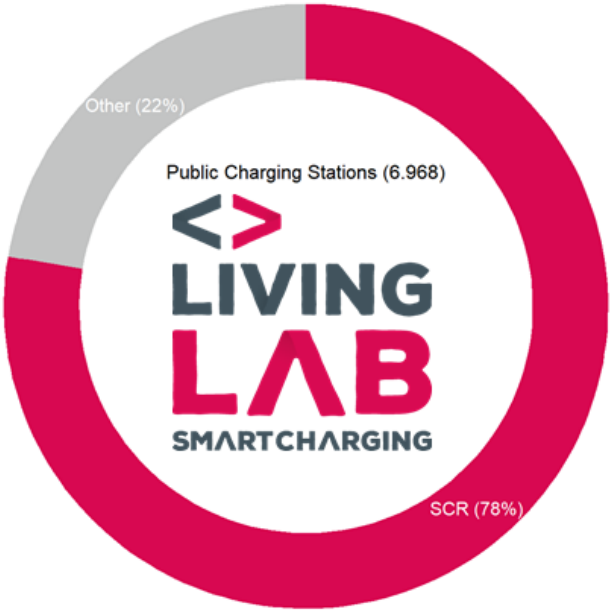

Figure 4: Total number of Smart Charging Ready public charging points in the Netherlands [2]

This significant number of charging infrastructure has been achieved by making Dutch municipalities a partner of the Living Lab Smart Charging. These municipalities play an important role regarding charging infrastructure in the Netherlands, as they are responsible for the requirements of these charging stations. Already 325 municipalities, representing more than 83% of all Dutch municipalities, are part of this living lab and have agreed on making their existing charging infrastructure Smart Charging Ready. Besides focusing on making *existing* charging points Smart Charging Ready, effort has been put into including smart charging as a requirement in new tenders. These requirements include what SCR is, and how this functions between the different parties involved (see Fig. 3). Furthermore, it explains what a charging point should be able to do, which includes postponing a charging session, charging slower or faster, and being able to communicate with a back office. These requirements, and others, have been integrated in the open communication protocol OCPP 1.6.

3.2 Research of Smart Charging

As mentioned previously, smart charging includes a variety of stakeholders and processes. In order to develop an international smart charging standard, these different individual pieces of the puzzle have to be put together. Therefore, the Living Lab Smart Charging has drawn up a research agenda with different research themes: batteries, communication protocols, cyber security, dynamic pricing, electric vehicle, energy, behavior, interfaces, internationalization, interoperability, charging algorithms, grid management, and Vehicle-to-X (V2X). The Living Lab Smart Charging is researching, among other aspects, what preferences people have regarding smart charging, how communication protocols should be developed to be able to communicate between the car and the charging point, how the charging infrastructure can be upgraded from a technical point of view, how electricity can flow from wind farms to electric vehicles, and what opportunities there are for the electricity grid.

Furthermore, data research is an important focus. This type of research includes i.e. analyses on the use of the current charging infrastructure in the Netherlands and what the potential of smart charging could be. However, not only technical and social aspects are being considered. Last year a report was published – commissioned by ElaadNL – on the fiscal barriers of smart charging in the Netherlands [8]. Currently certain tax structures withhold the incentive for charging in a smart way. By commissioning this type of research on legislation, besides technical and social research, the Living Lab Smart Charging tries to pave the way for smart charging with an integral approach.

The various research themes are developed in close cooperation with the partners of the Living Lab Smart Charging, as every partner brings in unique knowledge that is necessary to develop an international standard. Projects that are part of the Living Lab consist of, among others, a mobile phone application which allows e-drivers to charge their car cheaply when wind energy is generated but there is little demand, and a project concerning Vehicle-to-Grid (V2G) in which an EV is charged using solar panels and used as storage to restore grid balance. Section 4 of this paper highlights some projects and elaborates on them in more detail.

3.3 International and open standards

Besides making charging infrastructure Smart Charging Ready and carrying out tests and research on various themes, the third aim of the Living Lab Smart Charging is to enable an international standard on smart charging. In order to facilitate smart charging in the most optimal way possible, it is important to create international and open standards so that smart charging is not only available in the Netherlands, but worldwide. As illustrated in section 2, there are already some interoperable communication protocols that are shared and can be used on a global scale. In order to share Dutch experiences, the Living Lab Smart Charging has – together with its partners – also translated Dutch lessons learned into a book called 'Smart Charging & Electromobility: Driving on solar and wind power!' [6]. However, cooperation and collaboration across borders is necessary to innovate existing protocols and advance the functionalities of smart charging. The Living Lab tries to accomplish this foreign cooperation by e.g. trade missions to countries including Norway, the United States of America and Germany. Additionally the Living Lab Smart Charging would like to invite foreign businesses and organizations to share their innovative ideas on (smart) charging, in order to jointly work together towards an open smart charging standard that benefits all parties involved.

4. Driving on the sun and living off the wind

In 2016, already more than 50 projects have united themselves under the flag of the Living Lab Smart Charging. Four of them – Jedlix, deferred charging, FlexPower, and LomboXnet – are highlighted in the following paragraphs.

4.1 Jedlix

Jedlix, a Dutch start-up, has developed a mobile phone application – #ichargesmart – that charges an electric vehicle based on the balance between demand and supply of renewable energy. The application aligns the supply of renewable energy from the sun and the wind with the demand for electricity of e-drivers. The user of the application can set his or her preferred time of departure and the application will make sure that the car is fully charged at that moment with as much renewable energy as possible. Because the car does not have to be charged immediately – the car will often be parked for a couple of hours – flexibility is generated. This makes it possible to shift the demand for energy in time, e.g. at night when there is an abundant supply of wind energy and demand is low. Shifting the charging pattern provides benefits for the consumer as well as the energy supplier and grid operator. Because the application aligns demand and supply in the most optimal way, this will unburden the electricity grid, avoiding costly grid reinforcements. Furthermore, the supply of renewable energy is used in a more efficient way, which makes the financial return on this renewable energy higher. Jedlix receives a financial bonus for creating this flexibility, part of which flows back to the e-driver.

4.2 Deferred charging

In the southern Dutch province of Noord-Brabant, a network of smart charging infrastructure has been realized. This not only facilitates electric driving, but it is also part of the national testing area of the Living Lab Smart Charging. Using this charging infrastructure, a pilot project on shifting charging patterns has been initiated by the province Noord-Brabant in cooperation with Enexis – a local DSO. The main question in this research was how e-drivers could be motivated to charge their electric car outside the timeframe from 16:00 to 19:00, which constitutes the evening peak in the Netherlands. Participants of the pilot project, 30 e-drivers in total, were asked to charge their electric car at night when electricity prices are relatively low. They were ensured that their car would be fully charged the next day. In case of an emergency, e-drivers could use a special mobile phone application to charge their car immediately after plugging it in, instead of shifting their

charging pattern to nighttime. This deferred charging resulted in lower evening peaks, benefiting the DSO, and consumers were rewarded by paying a lower electricity price. The pilot has been a big success; 65% of the charging sessions between 16:00 and 19:00 were shifted to the late evening and nighttime. Half of the participants experienced no limitation with regards to mobility, partly because the mobile phone application enabled direct charging. Only 25% of the participants actually used this application to charge their car directly. Participants reported that especially the lower charging tariff was seen as a benefit: they were given €0,02 discount per kWh. Environmental reasons were argued to play a minor role in shifting charging patterns.

4.3 FlexPower

Currently, cars are being charged in an inflexible way. This means that when the electric car is plugged in, it immediately will start to charge at full power. The consequence of this is that demand increases at times that are already stringent for the electricity grid. Furthermore, this results in an inefficient way of using renewable energy. The aim of the pilot FlexPower was therefore to gain insight and experience in flexible charging using the public charging infrastructure of EVnetNL. For the duration of a year, electric cars, both BEVs and PHEVs, of 71 participants were charged at half the normal charging speed during the evening peak (17:00-19:00). This charging at reduced speed was compensated by enabling the participants to charge 25% faster during off-peak times. PHEVs which were not able to charge at a higher speed were rewarded by receiving 70 Euros or took a share in solar panels. There was also an option for all participants to overrule the slow charging speed, which enabled the regular charging speed during peak times.

The results of the pilot show that – on average – the demand for electricity was lowered by 46% during the evening peak. Via a survey, the majority of the participants indicated that charging at a slower speed was no problem. The majority of the participants also did not experience any difficulty in scheduling their charging session, but they would like to be in control of the charging session. Therefore, they valued the ‘overrule’ option to charge at regular charging speed during the evening peak. In practice, however, this option was barely used by the participants. In contrast to the pilot with deferred charging, participants were primarily motivated by the idea that they contributed to the development of smart charging, instead of the financial reward.

4.4 LomboXnet

In 2015 the area of Lombok in Utrecht was the world’s first place to install Vehicle-to-Grid (V2G) charging points, connected to solar panels on roofs in the neighborhood. These charging points make it possible to charge locally generated renewable energy, and also store this energy in the batteries of electric vehicles for later use. This results in a higher efficiency of the solar power, it reduces grid peaks, and it stimulates electric driving.

The project has been initiated with the idea to become the first European region with a ‘new’ and futureproof energy system. The project gives a good image of how smart charging can be used in combination with delivering energy back to the grid. By experimenting with smart technologies, the pilot shows how the area of Lombok can connect solar energy to charging electric vehicles. Where it has started out as a project on smart charging – linking solar panels on local roofs to charging points – the project has expanded and nowadays also includes a fleet of shared cars and in the nearby future a battery will be installed at the conference center in the neighborhood which will function as energy buffer. This battery will be one of the largest energy storages in the Benelux area [9].

4.5 Future projects

The coming years, more pilot projects will be set up to get acquainted with smart charging. Currently, the Living Lab Smart Charging is working on shaping a National Benchmark Smart Charging in cooperation with the G4 – the cities of Amsterdam, Rotterdam, The Hague and Utrecht – the Metropolitan Region Amsterdam and the provinces of Noord-Brabant and Gelderland. This research will provide insight in what the possibilities of smart charging are regarding *public* charging infrastructure. On the one hand the current use of the public charging infrastructure will be monitored, and on the other hand an analysis will be carried out on how these charging patterns could be linked to available renewable energy. Another project in the

pipeline is the organization of a Smart Charging Challenge. The target of this hackathon will be to develop a flex service which puts all the obtained results of the Living Lab Smart Charging into practice, and will be made available on all charging infrastructure that is exploited and maintained by the partners of the Living Lab.

These and other projects should provide insight in how to apply smart charging in the most optimal way. How sensitive are different groups of EV-drivers to financial incentives, or do they simply prefer comfort, and which role does sustainability play? What techniques work best? The answers to these questions will eventually lead to fitting products and services in the field of smart charging, which will hopefully be adopted by market parties.

4 Conclusion

What this paper has shown, is that there is a significant increase in both the number of electric vehicles as well as the generation of renewable energy, including solar and wind power, in the Netherlands. On the one hand these electric vehicles have an impact on the electricity grid, and on the other hand this renewable energy is currently used in an inefficient way. By coupling the two – charging at times when there is an abundance of renewable energy – benefits are generated that flow to a number of stakeholders. Research that has been done in the Netherlands shows that people can actually be motivated to shift their charging pattern, meaning that smart charging is a promising alternative. The experience of the Netherlands in the field of smart charging can be brought down to four lessons learned.

First of all, renewable energy should be used as efficiently and optimal as possible. In our current era, renewable energy from free sources – such as the sun and the wind - is abundantly available and we have mastered the technologies to capture and harvest this energy. By making smart connections, e.g. by linking renewable energy to charging electric vehicles, the energy transition can be accelerated.

Secondly, open standards and protocols are crucial in order to accelerate innovation. By developing standards in isolation, only a small public will adopt it and no complete market will come into existence. When working together on these open standards and incorporating country-specific knowledge and experiences, cross-border innovation is stimulated which will open up competitive markets.

Thirdly, it is important to continuously invest in development on a national and international level. More important, however, is to share this knowledge on an international scale. By sharing lessons learned, products and services can be improved to a great extent. By accumulating and sharing the knowledge and experience gained from Dutch pilot projects, the Living Lab Smart Charging, for example, not only tries to support the Netherlands in the energy transition, but it also wants to spread this knowledge on an international level. Cross-border collaborations constitute an important part in developing smart charging.

Above all, however, it is a matter of trying to take risks and not being afraid to fail. Innovation is about successes, but also about failure – not everything that is set out in a pilot project works. But by taking small steps and jointly researching individual parts of smart charging, innovation – in the form of an open standard for smart charging – will come along. Therefore, take up this glove together with the Netherlands and the Living Lab Smart Charging, and share your experiences to speed up the energy transition by smart charging.

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