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Smart charging in the era of electric vehicles

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Introduction

According to the provisional report 'Energy Futures 2050 | 2023-2035: the first step towards carbon neutrality' by RTE (the operator of the public high-voltage electricity transmission network), 42% of the French car fleet should be electric and rechargeable hybrid vehicles by 2035, representing around 18 million vehicles. This transition towards electrified mobility will lead to a significant increase in electricity demand, particularly during evening charging periods. Therefore, it is crucial to manage charging intelligently to maintain the balance of the electric grid, especially during peak demand times.

The widespread adoption of smart charging offers multiple advantages, including reducing consumption peaks, improving the flexibility of the electric grid, and promoting energy decarbonization through increased self-consumption.

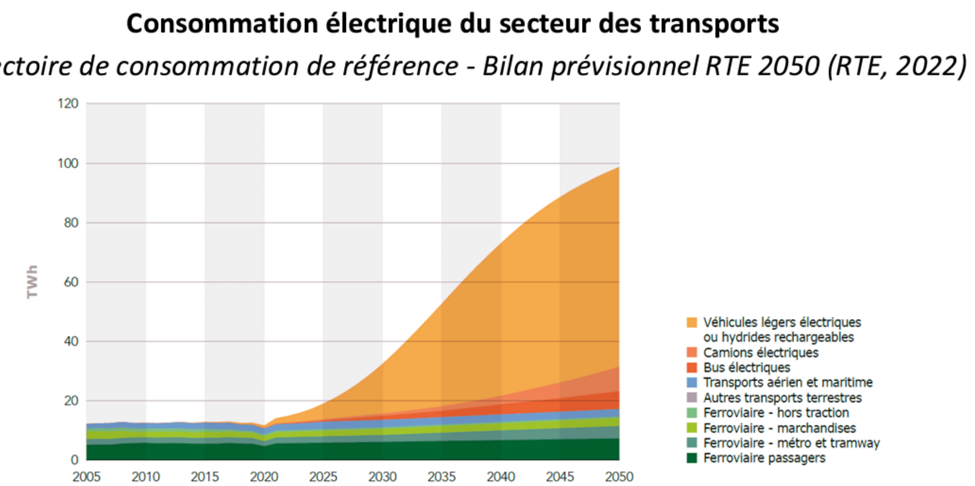
In France, the challenges for generalizing smart charging are considerable, as around 65% of electric vehicle owners and 90% of fleet managers do not yet actively manage their charging, either at the charging station level or directly via the vehicle.

The aim of this article is to explore the various challenges related to the smart charging of electric vehicles, from simple tariff-based management to bidirectional charging technologies (V2X, or Vehicle-to-Everything).

Growing needs, with significant room for progress in bidirectional charging

The rapid increase in vehicle electrification in France and Europe will lead to a significant rise in electricity consumption. According to RTE's forecasts, the French transport sector's electricity consumption will reach approximately 86 TWh in 2035, representing about 15% of total national electricity consumption (~615 TWh). This sharp increase in demand will primarily come from light vehicles, used for both personal and professional purposes.

The graph below illustrates RTE's forecasts for road transport electricity consumption until 2050.



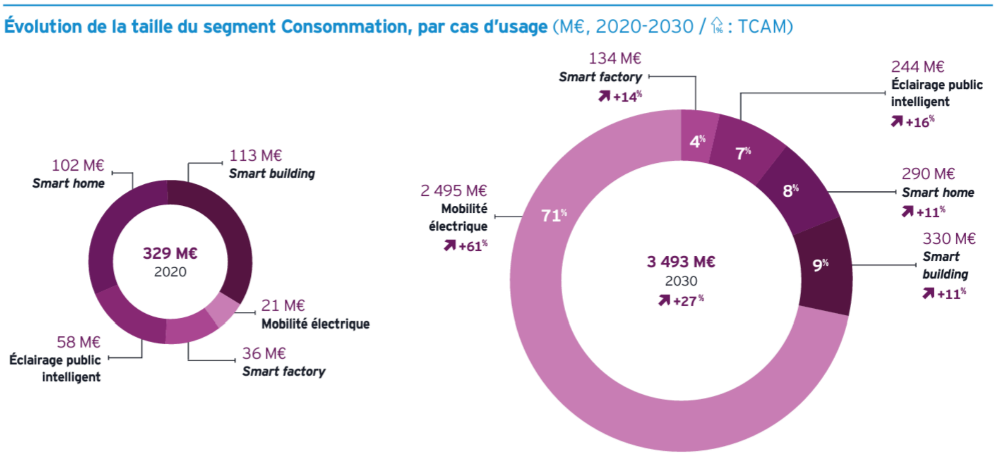
Source – Avere, 2023 | White Paper on Charging Management and Vehicle-to-Everything

Beyond the strong increase in the volume of electricity needed for road transport, another major challenge lies in the peak consumption observed in the evening when users plug in their vehicles for immediate charging. Enedis[1] estimates that the simultaneous charging of 15 million vehicles would require 10.2 GW, equivalent to nearly 10 nuclear reactors, while the potential at the European level reaches 35 GW[2].

Fortunately, charge management solutions are already available, and innovations are gradually emerging to transform the electric vehicle into a key element of the electric grid's flexibility. RTE predicts that 70 to 85% of the electricity required for charging could eventually be managed.

In the short term, electric mobility will establish itself as the main area of electrification, significantly surpassing smart buildings and intelligent public lighting.

[1] Responsible for managing and developing 95% of the electricity distribution network in France.
[2] V2X Enablers and Barriers: Assessment of the regulatory framework of bidirectional EV charging in Europe, December 2023.



Source – EY-Parthenon, 2022 | The French smart grids market in 2030

What is smart charging?

Smart charging encompasses three main approaches, based on their degree of optimization:

- **Static management:** charging is scheduled at fixed times, typically based on a tariff logic.

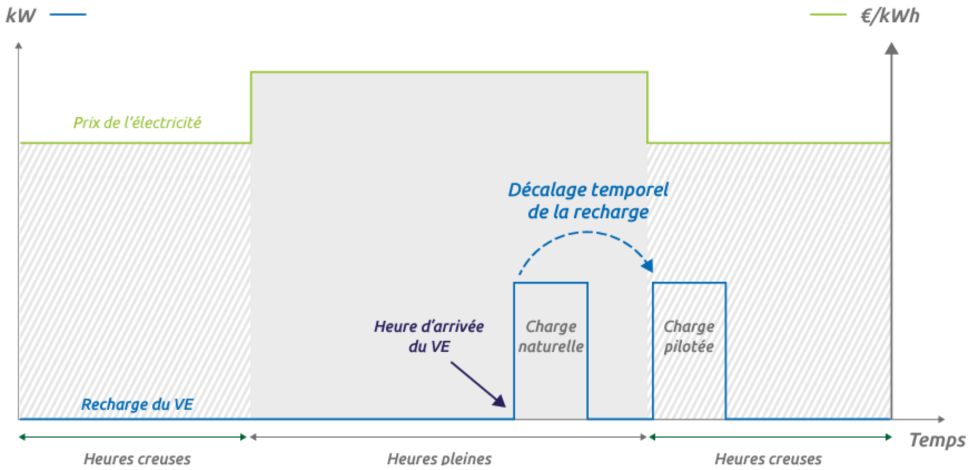
This approach shifts charging to off-peak hours, usually at night, to avoid overloading the grid. It relies on communication between the charging station and the Linky meter, directly with the vehicle via telematics from the dashboard, or through a local energy manager (Home Energy Management System).

Although easy to implement, only 35% of vehicle owners use static management, mainly due to a lack of awareness of the tariff offers proposed by energy suppliers. Yet, EDF (French public electric utility company) estimates that reinjecting kWh from the vehicle back into the grid when prices are highest could provide the owner with financial compensation equivalent to 15,000 km driven annually.

While this approach offers significant flexibility for the grid, it has several major limitations:

- Shifting the charging of millions of vehicles to off-peak hours can create a new consumption peak, this time at night.

- Electricity consumption during these off-peak hours cannot rely on renewable energy production and may require the import or use of more carbon-intensive energy.



Source – Enedis, December 2020 | Opportunity for consumers and the public electricity distribution network

- **Dynamic management (V1G):** involves adjusting charging in real-time based on electricity prices, renewable energy production, or other parameters (e.g., Ecowatt alerts for grid stress in France).

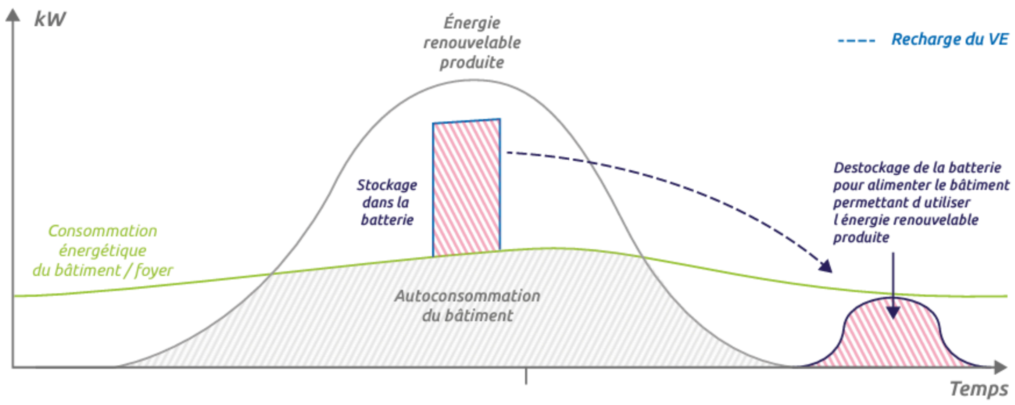
This method uses an internet connection to offer more precise management compared to static management. It is much more personalized, taking into account not only the specific needs of the driver but also those of the household, such as the morning departure time, the desired minimum charge percentage, and the capacity of the home meter.

The management can be executed either via a connected charging station with Linky (Smart Meter for electricity in France) or directly through the vehicle's telematics. Most new vehicles are now connected, and OEMs provide applications that allow control of certain vehicle functions, including charge management. This technique is ideally suited for vehicle fleets that benefit from regular use during the day, as well as employees using charging stations at fixed times at their workplace.

- **Bidirectional charging (Vehicle-to-Grid, V2G):** is the most intelligent approach as it leverages the electric vehicle as a system for energy storage and discharge, capable of reinjecting electricity back into the grid.

Using the battery for electrical storage raises a crucial question about the risk of premature battery aging due to an increased number of charge and discharge cycles. However, an English study shows that smart charging could increase the battery's State of Health (SoH) by 8 to 12%, thus extending its lifespan by about a year through optimized charging cycles.

This article focuses on the V2G aspect, although other forms of V2X (Vehicle-to-Anything) mechanisms exist, such as direct reinjection into a building (V2B) or an individual home (V2H), which are particularly useful for those utilizing solar energy self-consumption.



Source – Enedis, December 2020 | Opportunity for consumers and the public electricity distribution network

The smart grid: diverse benefits for decarbonized mobility

Smart charging offers numerous advantages, the main ones being:

- Reduction of CO2 emissions by minimizing the use of carbon-based electricity

Reducing grid demand during peak consumption times helps avoid the use of backup fossil fuel power plants, primarily gas, and the import/export of energy with neighboring European countries. Another decarbonization lever is maximizing self-consumption for users equipped with photovoltaic panels. It is wise to charge the vehicle during solar production periods, thus during the day.

- Better control of charging costs for vehicle owners

The main economic benefit of smart charging is the optimization of electricity expenses by favoring less expensive tariff hours, such as those in the peak/off-peak time slots. 63% of drivers are willing to shift their charging to relieve the grid[3], often through scheduled programming (51%, a decrease of 11 points between 2022 and 2020) or via the manufacturer's mobile application (29%, an increase of 13 points).

- A powerful tool for balancing the electric grid

While the expansion of the electric vehicle fleet increases electricity needs, electric vehicle batteries can play a crucial role in balancing energy production and consumption. The autonomy of electric vehicles does not require daily recharging, except for intensive B2B uses such as deliveries or service interventions, but rather weekly. RTE estimates that the aggregation of 16 million batteries (in an optimistic

[3] Behavioural survey of electric vehicle owners, Enedis.

scenario for 2035) could represent a capacity equivalent to ten times that of pumped-storage hydroelectricity stations, currently used to quickly balance the electric grid.

What are the barriers to V2G adoption?

As previously mentioned, V2G (Vehicle-to-Grid) is a bidirectional charging method that uses the vehicle battery's storage capacity to reconnect electricity into the grid as needed. Several obstacles, of various natures, hinder its adoption:

- Double taxation threatening V2G business models

Historically, energy storage faced double taxation during both the charging and discharging of the battery, as it is considered both a producer and a consumer of electricity. This double taxation, which would also apply to electric vehicles in principle, complicates V2G business models. The situation of double taxation varies across Europe: Spain and Sweden, for example, have removed this tax from their fiscal regimes, while it still exists in Denmark and Great Britain. Discussions are ongoing at the European level to revise the 2023 energy taxation directive, aiming to eliminate the double taxation of stored energy. However, the likelihood of a community-wide agreement remains low, making it likely that specific regulations will need to be adopted in each country.

- Varying V2G ambitions across european countries

Germany and the United Kingdom have particularly developed strategies in favor of V2X. In Germany, the master plan for charging infrastructure explicitly references bidirectional charging, and the government financially supports V2G projects through its "Bidirectional Fleet Power Plant 2025" initiative, along with additional incentives for projects integrating photovoltaic panels, storage systems, and charging stations. In the United Kingdom, the Department for Energy Security and Net Zero funds programs aimed at industrializing V2X offerings.

The diagram below illustrates the heterogeneity of the regulatory and fiscal framework for V2G across Europe.

Table 6 – Government Policy and Regulations Detailed Question Scoring

Detailed Question	BE	DK	FR	DE	GB	IT	NL	NO	PO	ES	SE
Are there specific national V2X policies in place?	orange	orange	orange	green	orange	orange	orange	orange	orange	red	orange
Are there double taxes or levies charged for V2G? *	red	red	orange	orange	red	green	orange	green	red	green	green
Do system operators consider V2G as a part of their resource adequacy assessment?	orange	orange	green	orange	orange	red	orange	orange	orange	red	orange

Source – smartEN, 2023 | V2X Enablers and Barriers: Assessment of the regulatory framework of bidirectional EV charging in Europe

- Few electric vehicle models currently support V2G

Currently, few electric vehicle models are compatible with V2G. Nissan remains the main manufacturer offering a range of V2G-capable vehicles, while some Asian manufacturers, such as Hyundai (IONIQ model), Kia, and Mitsubishi (iMiev model), have only a few compatible models. The Japanese manufacturer is even a pioneer, as its Leaf models have been V2G-compatible since 2010 with their CHAdeMO connectors and have recently launched their own V2G offer in Japan: Nissan Energy Share.

Western manufacturers have long lagged behind in V2G compatibility, partly because it required adopting the Japanese CHAdeMO standard. The CCS 2 standard, now V2G-compatible, is used by almost all European brands. In this context, Renault introduced V2X in 2024 with the launch of the electric Renault 5, developed in partnership with the German startup The Mobility House. This car stands out for its integrated V2G compatibility within its onboard charger, allowing the use of slow charging as the AC/DC conversion will occur directly on board.

- Imperfect harmonization of communication protocols

The interoperability of communication systems between charging stations, electric vehicles, and grid operators is crucial. These communications must also ensure data confidentiality and protect against cyber threats. Several international standards already exist, including IEC 61851-1, which covers communication for charging process control, and ISO 15118-20, specific to V2G communications. The latter allows dynamic control of exchanges and requires the use of the Transport Layer Security (TLS) protocol to secure data.

However, the ISO IEC 15118 standard is only applicable to vehicles equipped with CCS connectors (European standard). Models using GB/T or CHAdeMO connectors, which are widespread in China and Japan and are the main alternatives to CCS, do not support this standard.

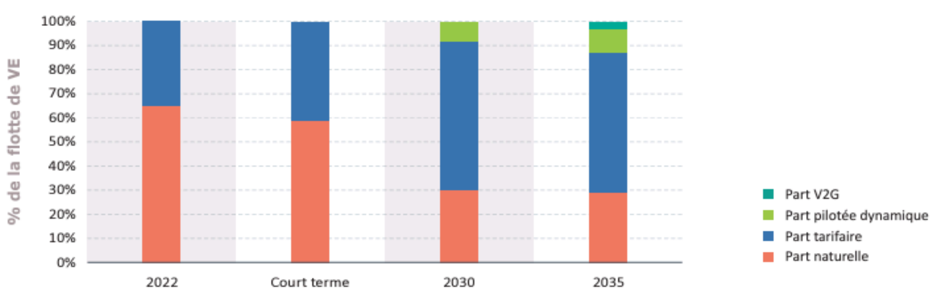
Where are we really with the smart grid?

The deployment of V2G management in Europe is still in its early stages. In 2022, RTE certified the use of a corporate fleet to contribute to the real-time balancing of the electric grid for the first time, a breakthrough made possible by technology developed by Dreev, a joint venture between NUVVE and EDF.

Several notable projects are currently being experimented with in Europe. Hyundai is collaborating with the city of Utrecht and the operator We Drive Solar to utilize a fleet of IONIQ 5 vehicles. The EVVE project, led by EDF with BNP Paribas Mobility, Enedis, Stellantis and Volkswagen Group France, aims to install 800 V2G stations in Europe by the end of 2024. Enedis worked with a consortium of 13 industrial companies, including Renault and Stellantis, on the aVEnir project.

At the same time, RTE has drawn up several charging control scenarios for 2035 (see diagram below). Its forward-looking report 'Energy futures 2050 | 2023-2035: the first step towards carbon neutrality' reveals that tariff control will remain the main use case in the medium term, while V2G would account for only 3% of loads in the most optimistic scenario.

Figure 2.52 Évolution des parts des modes de pilotage des véhicules électriques légers (trajectoire de flexibilité médiane)



Our convictions: software for monetizing managed charging

Several business models for charge management, whether static, V1G, or even V2G, seem particularly relevant in the coming years. Among the essential features to offer, we identify the following:

- The ability to define a driver persona

Startup example: The Swedish startup Theter, a 2023 Techstars alumni, analyzes driver habits to offer personalized charge management. It explicitly models monetary gains, environmental benefits, and battery lifespan extension.

- API integration into third-party mobile applications

Startup example: The Norwegian company Enode develops APIs that facilitate the integration of V2G management directly into the mobile application of the vehicle manufacturer or the charging station used by the driver. Enode's APIs leverage relevant external data, such as European electricity market spot prices or the vehicle's state of charge. Enode is notably used as a white-label solution by the Estonian charging station provider Vool. Another key player in smart charging APIs is the British company ev.energy, which serves both individual users and fleet managers.

- A comprehensive energy management dashboard to optimize self-consumption

Startup example: The German company Lade offers a comprehensive energy management platform named LadeGreen, which coordinates photovoltaic production with vehicle charging needs via its proprietary artificial intelligence. The French startup Youree goes further by integrating a carbon compatibility module, allowing precise tracking of each vehicle's carbon footprint.

Conclusion: V2G is not the ultimate solution for managed charging

Managed charging of electric vehicles will become essential due to the massive electrification of usage and its potential key role in increasing the flexibility of the energy grid. According to RTE scenarios, managed charging will play a predominant role by 2050, with 45 to 70% of drivers using unidirectional management and up to 20% adopting bidirectional V2G solutions.

While V2G indeed presents significant potential for improving grid flexibility, its widespread adoption is not guaranteed. Achieving this goal would require the creation of a new energy ecosystem integrating energy providers, public regulators, car manufacturers, and charging station suppliers. This involves major challenges in harmonizing standards and protocols to ensure the interoperability and remote control of all relevant equipment.

It is likely that dynamic management will become the predominant use case as it is simpler to deploy and offers considerable benefits without the regulatory and technical complexities inherent in V2G. Dynamic management, due to its ease of implementation and direct impact on reducing electricity consumption peaks, could become the preferred method for managing the energy demand of electric vehicles in a more sustainable and efficient manner.

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