Charge management of electric vehicles

An opportunity for the prosumer
and the electricity distribution network

December 2020 report

Executive summary

Reduction of air pollution, decarbonisation of transport, ecological transition… these are social issues that the public authorities have largely taken up, in particular by promoting alternative mobility. Under this impetus, the development of electric mobility, according to all forecasts, will be particularly supported by 2035 everywhere in the territory. Mechanically, this increase in the number of electric vehicles (EVs) within the fleet will induce an increase in power demand due to new charging needs. The electrical system must therefore adapt!

Enedis, in charge of managing the electricity distribution network across 95% of the French territory, anticipated these new needs, facilitating the integration of the electric vehicle into the electricity distribution network (EDN) and into the electrical system.

The latest studies carried out and published by Enedis and the Réseau de Transport d'Electricité (RTE) in 2019 show that the integration of electric mobility into the French electricity system does not present any particular difficulties for the network at the local level, nor at the national level. The development of electric vehicles and charging infrastructure can therefore continue smoothly, while preserving a good price-performance ratio for the electricity distribution network.

Good news: charge management of electric vehicles can generate value now for the end user, as well as for the electricity ecosystem and its stakeholders in the longer term.

Charge management of electric vehicles: savings for the end user

The absence of integration difficulties, however, does not exclude the need to implement significant optimization efforts. Indeed, in the medium term, the management of electric vehicle charging should make it possible to reduce the impact on the electrical system, and to reduce the cost of upgrading the electrical networks, the investments of which are ultimately financed by the consumer. Another advantage of managed charging: savings for the end user.

Let us take the example of an individual user of an electric vehicle. Simply programming off-peak charging can save the user up to 90 euros per year per vehicle for a Zoé-type city car compared to so-called "natural" unmanned charging. By adding up the potential gain obtained by not increasing the subscribed power and, where applicable, by individual self-consumption, the expected gain can be up to €300/year/EV depending on the user profile and that of the car.

3 ways to optimize charge management

Charge management is based on three means of optimization: the shift in charging time (charge time management) to benefit from advantageous tariff offers issued by the suppliers, the adjustment of the charging power (management of charging power) to reduce the vehicle's power demand, and management to maximize self-consumption (which corresponds, for owners of photovoltaic roofs, to charging their electric vehicle with the surplus solar production during the day rather than charging in the evening).

In addition, the principles of Vehicle-to-Home (V2H), Vehicle-to-Building (V2B), and Vehicle-to-Grid (V2G) consist of reinjecting the electricity contained in the battery into, respectively, the electrical network of a household, building, or the electricity distribution network. These technologies make it possible to increase all of these values by exploiting the storage capacity of the battery. The principle is simple: when necessary, the vehicles themselves become sources of energy thanks to the electricity stored in their battery. This electricity is ready to be sent back to a home, a building, or the network!

The majority of users could thus manage the charging of their electric vehicle in order to limit their expenses. To achieve this, they could rely on existing price signals (for example, differential day/night tariffs for electricity or the cost of the subscription linked to the required supply capacity).

Benefits for all energy market players

In addition to the benefits linked to existing tariff offers and the possibilities of flexibility offered on national markets such as RTE in order to balance supply and demand and manage the transmission network, the management of electric vehicle charging can offer local flexibility for players in the electricity market, distribution system operators (DSO) or even players in "energy communities". For example, the charging of electric vehicles in a given area could thus be interrupted at the request of the network operator, if the power level called for exceeds the capacity of the network and risks causing an outage. For the distribution system operator, these additional flexibilities will constitute a resource that can be mobilized during the operation phase (during incidents or work), during the planning of investments in the electricity distribution network (postponement of reinforcement or limitation of connection costs), or to facilitate the development of renewable energies (for example by optimizing self-consumption).

Ultimately, new local flexibilities

The value created by these types of flexibilities (charging demand response), a value to be distributed between market players, operators and network users, can range between a few tens of euros per electric vehicle per year and €200 per electric vehicle occasionally during network incident. The realization of this value is conditional. For flexibility to be exploitable, it is necessary that a minimum threshold of electric vehicles is reached, or that these are aggregated with other types of flexibilities.According to the use cases studies, the number of electric vehicles alone should become sufficient locally from 2025 in the most favorable cases. The use of these flexibilities may be particularly valuable in areas where the network would be subject to availability constraints, as there are currently only a few of these areas.

Finally, these local flexibilities concerning the charging of electric vehicles will have to be competitive in the face of alternative solutions, such as mobile batteries or even generators.

Enedis, facilitator in the operational implementation of charge management

In this context, Enedis is a major player in the ecosystem for the management of EV charging and flexibility, thanks in particular to the services it implements via the Linky smart meter; the latter indeed offers opportunities in terms of managing the charging of electric vehicles or even through the "measurement and verification method" of demand response.

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Introduction

The electric vehicle saw sustained growth in the first half of 2020, with nearly 70,000 units sold[1] in France, i.e. twice as many as over the same period in 2019, despite the health crisis. This strong growth is accompanied by a densification of the network of charging points across the territory. There are now nearly 30,000 charging points open to the public[2], directly or indirectly connected to the electricity distribution network (EDN).

As the operator of the electricity distribution network (EDN) for 95% of the French territory, Enedis plays a key role in the deployment of charging infrastructures by ensuring their connection and their continuous supply, as well as metering the distributed energy. Enedis is also a player in electric mobility as a user: with more than 3,000 electric vehicles, the company has the 2nd largest fleet of electric vehicles in France. Finally, the company supports innovation in electric mobility, as evidenced by projects in the field, and studies already carried out by Enedis and its partners on the impact of electric vehicles on the network and on the evolution of behavior[3].

Studies by Enedis and RTE (Réseau de Transport d'Electricité) show that the integration of the electric vehicle into the French electricity system does not present any difficulty, both at local and national level. The possibility of controlling vehicle charging[4] is good news and will facilitate the integration of electric vehicles in the medium term, with the following benefits: for the community, charge management will limit the cumulative power demanded from the network by electric vehicles, and, consequently could make it possible to spread out and optimize the investment needs in network infrastructure; users will be able to charge their electric vehicle when electricity is cheapest and moderate the supply capacity as well as the connection power; charge management will also make it possible to promote local and/or green supply (for non-economic reasons), in particular by synchronizing the charging of electric vehicle batteries with the production of renewable energy.

Managing the charging of a significant number of electric vehicles can also allow "local flexibility[5]". This management aims to reduce congestion that may appear locally on the distribution network, by modifying the charge demand or even by reinjecting the electricity stored in the batteries into the network. For several years, Enedis has been developing methods and conducting experiments in order to exploit these local flexibilities, whether they come from charge management of electric vehicles or from other technologies deployed on the network, such as demand response. In 2019, Enedis set up a framework conducive to their development[6], which resulted in the launch of several local calls for tenders in 2020.

In line with the work undertaken by Enedis for several years, this report aims to enlighten the reader on the contributions of managing the charging of electric vehicles, in terms of solutions, values and coordination of stakeholders, and it is part of Enedis's desire to support the development of electric mobility.

1 Avere-France - National Association for the Development of Electric Mobility – June 2020.
2 Avere-France - National Association for the Development of Electric Mobility – July 2020.
3 Enedis report, Partner of electric mobility.
4 As opposed to so-called "natural" charging, in which charging the vehicle begins as soon as it is plugged in and ends when the battery is full.
5 **Electric flexibility** allows the network to adapt to the lack of production, to excess consumption.
6 Enedis's vision on flexibilities.

Chapter 1

Simple forms of charge management allow for significant savings for the prosumer

If the vehicle is charged during off-peak hours rather than during peak hours of the French regulated electricity sale tariff, the user of the electric vehicle will be able to save around €90/year. These savings may amount to a little over €300 depending on the situations encountered, as indicated in the chapter below.

1.1 The four charging use cases utilized for this report

Electric vehicle users express different expectations regarding charging:

- #1 Having a vehicle that is as easy to use as a traditional combustion vehicle, that is to say available and with the necessary autonomy when the user needs it;
- #2 Minimize the costs associated with charging and, more generally, their personal electric bill;
- #3 Allow for monitoring of charge management, in particular by:
  - an individual invoice in the case of charging in collective housing,
  - monitoring, capacity management, and a good understanding of the operating costs of electric vehicles (in the case of companies);
- #4 Where applicable, benefit from a supply of "local" (produced on site or at the district or even regional level) or green (renewable) electricity.

Charging management solutions meet these expectations. Charging is said to be "natural" when the car charges to full capacity as soon as it is connected to the network. **Charge Management** makes it possible to modify this "natural" behavior and to minimize the cost of the user's electricity bill while meeting their personal constraints in terms of availability and autonomy of the electric vehicle (expectation #1: the vehicle must be charged when it needs it). This management makes it easier to match consumption with local or green supply.

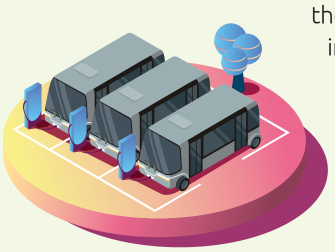
Four practical cases were studied to illustrate the constraints exerted on the management of charging as well as the savings (costs and benefits) induced by charge management for different types of users.

Practical cases of electric vehicle charge management

In order to assess the value of charge management in different contexts, four practical cases, or "charging profiles", have been identified:

A. **Charging points within the company, for employees:** these charging points mainly concern vehicles of employees that commute; they are intended to charge vehicles during the day, during working hours. They are generally of "normal" power (less than or equal to 22 kW[7]) and positioned in the company's parking lot. The company is responsible for their operation and therefore for charge management.

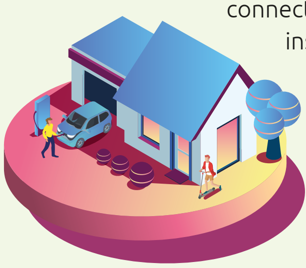
B. **Charging points in depots**: they reload the fleets of utility vehicles (delivery men, postmen, repairmen, bus drivers, etc.) providing their service during the day and parked at the company depot at night. These fleets are mainly charged at the depot at night in order to meet load level constraints in the morning. **Utility fleet charging points are sized to charge the entire fleet's battery overnight,** and may require an increase in the electrical power supplying the depot. In addition, these players often need increased reliability of charging to ensure that utility vehicles are operational the next day.



C. **Residential charging points for night charging** – these are "normal" charging points (3 to 22 kW) mainly used by individuals to charge at the end of the day when they return home.
They can be located:

a. in a house, in a subdivision, in a hamlet or isolated (stand-alone), with individual charging points
b. in collective housing,
c. on the road, in the absence of private parking.

The vehicles are generally not connected to the charging point during the day. These charging points can be connected to the indoor electrical installations of homes or in a dedicated manner, directly to the electricity distribution network.



D. **"Normal" and "opportunistic" charging points,** which concern charging points open to the public and used without any particular need for charging for the user. These charging points are generally low or medium power, installed on public roads or in the car parks of shops or shopping centers, and are used on an ad hoc and "opportunistic" basis by passing electric vehicles.

The times when users charge their vehicle vary, such as the leeway to optimize charging; charge management, therefore, does not make it possible to identify the same levels of value for each of these profiles.

7 In order to simplify understanding, the powers will be described in kW in the report, whether they relate to apparent (kVA) or real (kW) power.

	Hypotheses of the study for practical cases			
	Charging profile characteristics			Cost assumptions
	Charging power	Charging period	Constraints and sizes fleet averages	Costs[1] of charge management
Charging profile A Business charging points (CPs)	7 kVA	8h - 19h	Fleet of 20 vehicles. No obligation to charge	**Charge management:** ~0 to €4/month/terminal
Charging profile B Utility vehicle CPs	11 kVA[2]	20h - 4h	Fleet of ~20 utility vehicles. Obligation to be 100% charged the next day	
Charging profile C Residential CPs	3 kVA - 7 kVA	20h - 8h	The car needs to be charged the next day. For public terminals, no V2H/V2B value	
Charging profile D Public CPs	7 kVA	9h - 19h	Unpredictable connection, of short duration (a few hours)	

(1) Charge management and aggregation cost
(2) There are no utilities with an 11 kVA charge to date, but the report is placed in the context of the development of this range of electric vehicles.

Case of fast charging stations

The charging profiles above concern exclusively normal charging stations. The case of fast charging stations (50 kW or more) is specific: the constraints of using these stations are greater and therefore the room for maneuver for the management of charging is more limited.

Above all, users of these stations want to charge their vehicles quickly and reliably during opportunistic charging or during long journeys. On the other hand, the charging price is higher (5 to €20 charge for 100 km of range) due to more expensive installations.

Consequently, the managers of these charging points - which represent 6% of the available charging points in France (quarterly barometer of Avere-France Q2 2020) - cannot shift the charge over time or achieve significant flexibility for the local network. However, they can pool the power of their charging points to limit connection and subscription costs with the EDN, in order to reduce their costs, depending on the deployment strategy they wish to implement.

1.2 To save money, the prosumer can shift charging times, reduce the charging power or even favour the consumption of their local production if possible

Managing charging changes the "natural" charging profile by shifting the time of charging, by modifying the charging power, or by reinjecting the electricity stored in the battery into a home or building. The latter action is referred to as Vehicle-to-Home (V2H) or Vehicle-to-Building (V2B), mainly associated with on-site production and self-consumption configurations.

Each of these actions is implemented by "price signals", that is to say by a specific electricity tariff for the customer, which reflects the costs of supplying and delivering electricity for the electrical system.

1. **Charge time management** consists of choosing the most opportune times for charging, when **the variable price of the electricity consumed** – expressed in €/kWh – **is the lowest.** The regulated tariff for the sale of electricity, like most market offers, has variable prices depending on the hours of consumption and the days. For example, the difference between off-peak hour (OPH)/peak-hour (PH) tariffs amounts to an average of €4.5c/kWh for regulated residential sales tariff in 2020[8] i.e. a difference of nearly 25%.

   These price variations are explained by the fact that during periods of high or medium consumption (PH), the requested means of production are activated according to the merit-order principle (from the cheapest first to the most expensive): the more consumption, the more expensive the electricity. To reflect this variation, the supplier offers pricing options (eg OPH/PH).

Distribution networks, sized for periods of highest consumption (peak hours) in order to guarantee electricity to everyone even during the coldest winter periods, therefore also bear a higher cost. The part linked to the network, the Tariff for the Use of Public Electricity Networks (Tarif d'Utilisation des Réseaux Publics d'Electricité or TURPE), corresponds to ~30% of the prices mentioned above for residential customers.

These tariffs encourage users to charge during off-peak hours to limit their bills, with a direct effect on costs for the community. The Distribution System Operator (DSO) is responsible for determining the PH and OPH time slots for the network tariff and for broadcasting the time signal to the meters. With the Linky[9], communicating meter, charge management can be refined, because 11 time slots and up to 13 typical days can be defined, in particular by the suppliers (eg: off-peak, or "super-off", or WE), to differentiate prices more significantly.

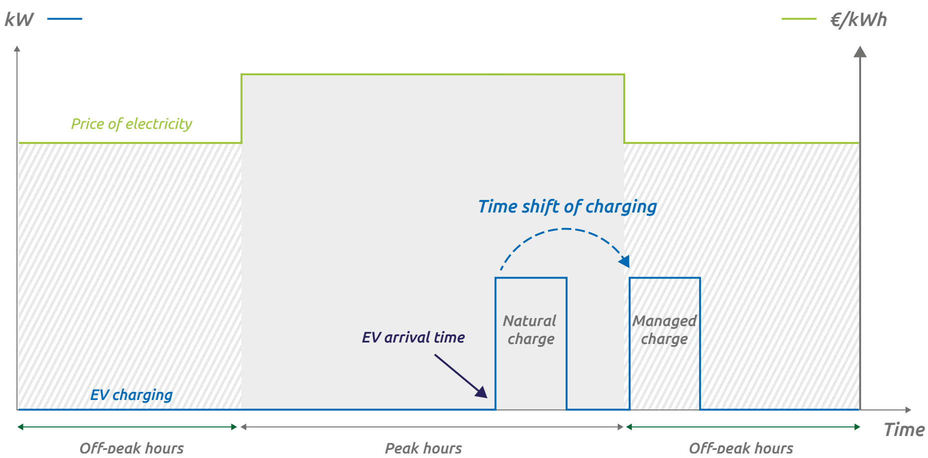


Figure 1: Charge time management in the case of an off-peak/peak hour tariff

8 Regulated Electricity Tariffs - Blue Tariffs for the 1st half of 2020.
9 For simplicity, only Linky will be cited in the rest of the report, but the elements also apply to the SME-SMI smart meter.

2. **Management of charging power,** consists of controlling the charging power demand (in kW). When charging is carried out within the private electrical network of a site, such as a house, building, or business, the control of the charging power must be carried out in coordination with the total power demanded by the site. The objective of this control is not to exceed the supply capacacity[10] subscribed to with the supplier or the connection power[11] .

This management can make it possible to avoid two expenses:

- **The increase in the annual subscription,** in €/year: it depends on the supplied capacity of the site, and is therefore, in theory, an indicator of the cost incurred for the network, which must always be able to deliver this power[12]. A private customer who increases his subscription by 3 kW to accommodate a charging point equivalent to this power will pay a supplement of around €30/year. A business customer can pay up to €120/year for the same power increase[13].
- **Strengthening the electrical connection :** in some cases, setting up an electric power supply for electric vehicles may lead the DSO to make investments to provide the necessary power. In practice, this reinforcement is rarely necessary for individuals: 87% of electric vehicle users do not increase the power demanded from their site (BVA/ Enedis survey). The costs of the works are generally less than €100/kW of investment.

Power management can also take place during the connection process, to avoid reinforcements. The customer then chooses not to subscribe to the reference connection offer and chooses a Smart Connection Offer (SCO); the latter consists - at the request of a customer connected (or wishing to be) connected to the MV network[14] – to offer the customer, when possible, a faster and/or less expensive connection method in return for their commitment to flexibility. It differs from the Reference Connection Offer in this way. Consumption or production can then be limited occasionally when congestion appears on the structures to which the site is connected. The valuation is described in § 2.2 and following.

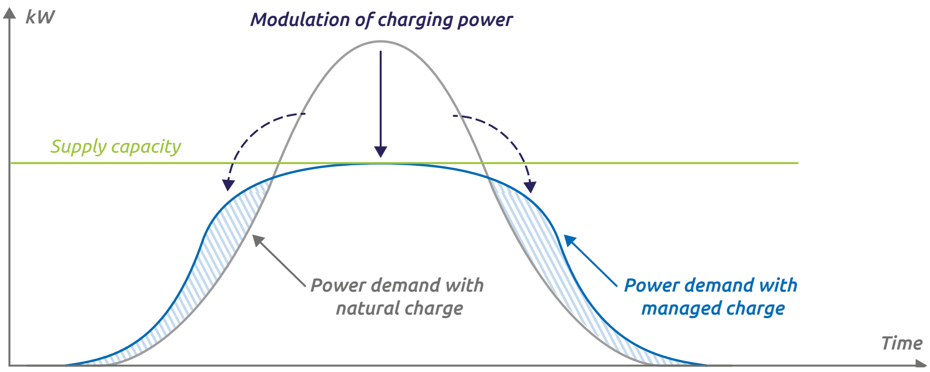


Figure 2: Management of charging power

10 The supply capacity is the power that the customer wishes to have at the connection point, according to his consumption needs. Its value is fixed by the customer for 12 months within the limit of the capacity of the works.
11 For withdrawal, the connection power is the maximum power under normal operating conditions that the customer plans to demand at his delivery point. For injection, this refers to the maximum injection power taken into account to size the connection structures.
12 In practice, this indicator is only partially representative of the costs incurred on the network.
13 The cost of the increase in power-related subscription amounts to 8 to €10/kVA/year for private customers, and can represent up to €40/kVA/year for businesses.
14 The industrialization of SCOs for producers is subject to changes in regulations. For consumers, the generalization of SCOs also requires educating different technical and regulatory subjects. Finally, industrialization and generalization will be effective first in MV, then in Low Voltage.

3. **Management to maximize self-consumption**[15] corresponds to the value that consumers can capture by maximizing their self-consumption rate, that is to say by charging their electric vehicle with excess solar generation during the day rather than by charging in the evening.

With this storage, electric vehicle users save the cost of charging in the evening[16] and lose the benefit of surplus production during the day.[17]. The difference between the two allows for a gain of 1.75 to €4 for charging a battery[18] by self-consumption for private customers and between 0 and €1.75 for charging in a business.

Vehicle-to-Home or Vehicle-to-Building consists of reinjecting the electricity contained in the battery into the electrical network of the home or building. This method **makes it possible to increase all of these values, by exploiting the storage capacity of the battery.** V2H or V2B can also ensure the continuity of supply for certain uses (freezer for example) following a power cut.

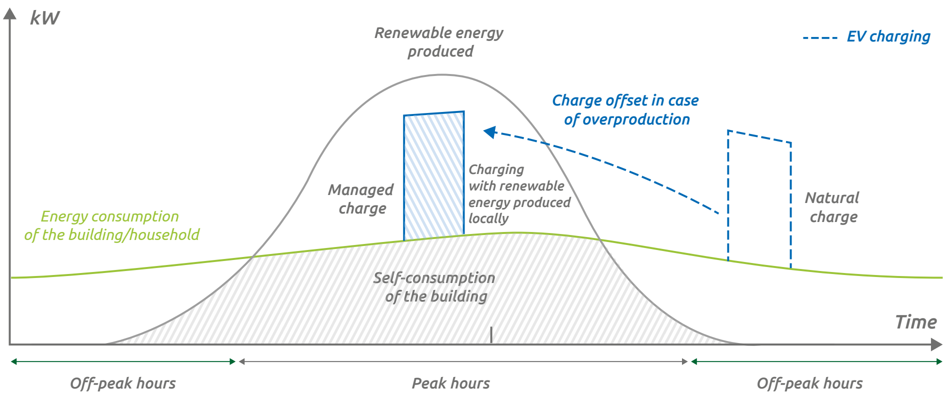


Figure 3: Management to maximize the rate of self-consumption

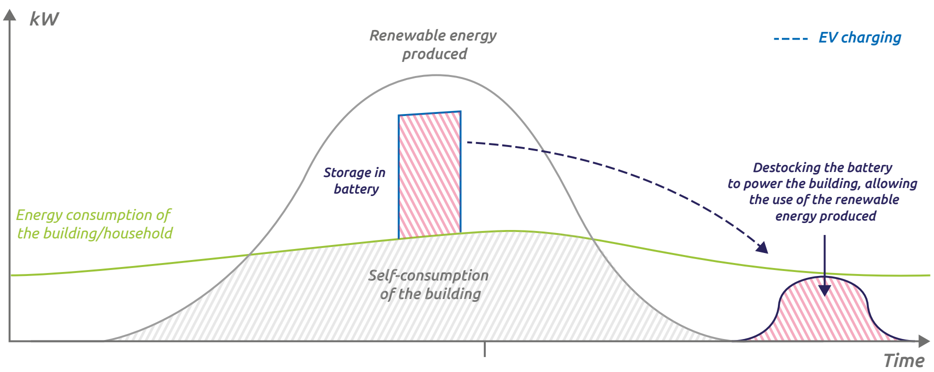


Figure 4: Example of V2H/V2B charge management to optimize the self-consumption value

15 Self-consumption is a new and growing use that consists of consuming all or part of the energy that we produce. It mainly involves photovoltaic production.
16 Charging costs between 13.5 and €18c/kWh for private customers, and between ~6 and €10c/kWh for businesses, depending on the charging times and their supply offers.
17 Valued ~€6c/kWh for businesses and ~€10c/kWh for private customers.
18 50 kWh, Zoé-type.

Battery wear in V2H/V2G: presentation of state of the art studies

V2G[19] , V2B, and V2H cause battery duty cycles that are not used for moving the vehicle. The economic viability of V2G/V2H/V2B therefore depends in part on the impact of additional charge and discharge cycles on battery degradation. This is the subject of modeling and academic publications, which show that, as a whole, the way electric vehicle batteries are used will have a significant influence on the efficiency of batteries over time.

Knowledge of the aging mechanisms of Li-ion batteries is developing: the impact of discharge cycles linked to V2G or V2H-V2B on the battery capacity will be very dependent on their depth and other factors being studied today; the management of the conditions of use of the battery for these uses under the supervision of the manufacturer or the owner of the battery (in case of leasing) will be necessary to industrialize this application.

- According to a study from the University of Hawaii published in 2017, the implementation of a V2G solution aimed only at maximizing the owner's profit leads to an acceleration of the aging of the battery: the loss of capacity can reach approximately - 20% after 5 to 6 years in the case of daily use of V2G, against only -10% in the case of less degradation (that is to say two charge cycles per day for mobility).

- A study published by the University of Warwick shows that if the V2G is optimized - thanks in particular to an intelligent management of the state of charge at rest of the vehicle, the depth of the discharges, and the various factors of aging of the battery - it could extend the life of electric vehicle batteries.

The deployment of intelligent systems and an improvement in knowledge of battery aging according to operating parameters (depth of discharge, capacity, temperature, usage, etc.) will help support the development of V2G.

19 **Vehicle-to-Grid (V2G),** that is, the reinjection of the energy contained in the battery into the grid in order to temporarily act as a generator of electricity.

1.3 An individual living in a single-family home can hope to save from €90 to €320 (tax included) per year while waiting for off-peak hours to charge and maintaining his initial subscription power

The gain obtained thanks to charge management by existing tariff offers varies greatly depending on the type of user:

- Electric vehicles charging at home (charging profile C) can expect to capture a maximum value (thanks to charge management) of €318/EV/year (tax included), in the case of intensive use of a sedan (15,000 km/year at 23 kWh/100 km) and for a consumer who would consider increasing his contract power, this value is €90/EV/year (tax included) in the context of a city vehicle for lighter use (12,000 km/year at 16 kWh/100 km) for a user who does not wish to increase the supply capacity of his accommodation.
- Utility vehicles (charging profile B) are those that can benefit from the most significant gain (energy consumption and high power), with a maximum of €430/EV/year under the most favorable conditions: they can shift charging to the middle of the night and spread it out over the nighttime period.
- Electric vehicles charging during the day (charging profiles A and D) have a reduced charging management value. Indeed, these users cannot shift to charging overnight, and the time when charging is necessary generally corresponds to the time of maximum consumption of the local site (during the day). Thus, the management of the charging of employees' vehicles provides a maximum value of around €130/EV/year, while the value of the management of daytime opportunistic charging in the street is limited to ~€65/EV /year.
- For these cases, the value may also be non-existent, when the site is in an area where the connection power can be increased without cost (either at the site or at the local network level). For example, the charging of employee vehicles on an industrial site where the supply capacity is very high in relation to consumption, thus leaving capacity already available for charging.

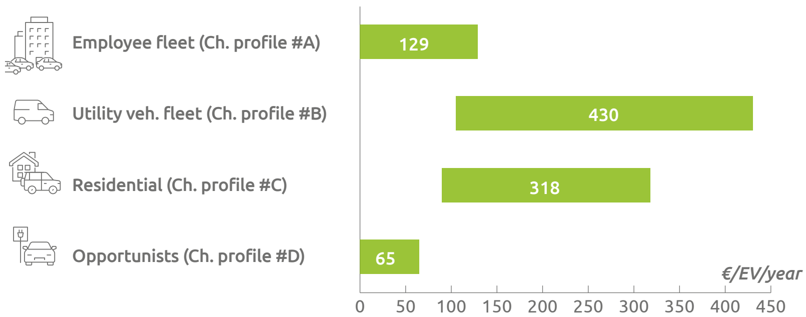


Figure 5: Interval of charge management value based on existing signals compared to natural charge (excluding V2H/V2B/V2G)

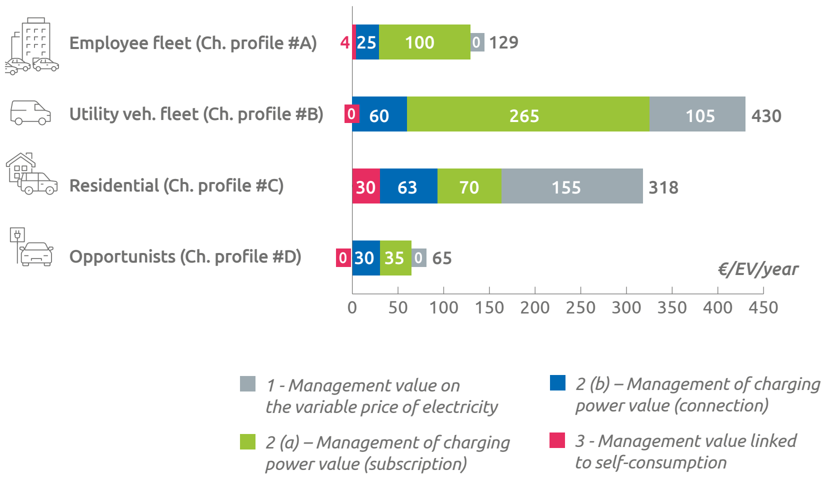


Figure 6: Breakdown of the value according to the price signal, in the case of maximum value (excluding V2H/V2G)

Mangement to reduce the cost of the user's electricity bill - the variable portion and the fixed monthly fee - is responsible for most of the value (from 55 to 100%). The more powerful the charging points, the more the fixed fee (related to the capacity) share can become significant in this total, as shown by the comparison of charging profiles B (11 kW charging points) and C (3/7 kW charging points).

The value linked to the reduction in the cost of connection can represent 25 to €63/EV/year, but is not systematic, because many sites do not generate additional connection costs in the event of an increase in power. Furthermore, this value is only captured once, when setting up the charging point[20].

Finally, the value linked to self-consumption is relatively low, of the order of a few tens of euros per vehicle per year. In fact, for this value to exist, the vehicle must be connected during the day to a site equipped with photovoltaic (PV) panels. This is not the case with our assumptions for utility fleets that circulate during the day (B charging profiles), nor for charging in the street where there is no PV installation (D charging profiles). In the residential case (charging profile C), the assumptions used all assume almost daily use (during the week) of the vehicle, during the day. In the case of company car parks, for employees' electric vehicles (charging profile A), although the vehicles are connected during the day, the value is limited by a lower unit value of the self-consumed energy.

V2H/V2B /V2G can improve these results marginally, from ~10 to € 70/EV/year. However, this practice is very limited, since, to date, most vehicle models do not allow V2H/V2B/V2G.

By encouraging charge management, tariff offers allow the user to reduce their costs, but also to reduce their impact on the network (lower power withdrawn, lower consumption at peak hours, less reinjection of locally produced electricity). Indeed, these aim to reflect the costs for the players of the electricity system. Charge management is therefore also virtuous for the electrical system and therefore for the community.

20 It is assumed here that this single gain is amortized over 10 years, to represent the value in €/EV/year.

Chapter 2

Charge management of electric vehicles can also offer flexibility to the electricity distribution network, in addition to that offered to national mechanisms

In addition to the flexibility linked to electric vehicles for national mechanisms (Adjustment Mechanism, NEBEF, or Ancillary Services), charge management can also offer flexibility to the EDN; the value of this flexibility evaluated below can occasionally reach € 200 per electric vehicle in the event of a network incident, to be shared between the players, and for vehicles located in areas with constraints (<1% of the electric vehicle fleet).

2.1 The flexibility offered by electric vehicles can be useful the players present at the national level and at the local level

Charge management can respond to orders from market players, national network operators (RTE) or even local players (distribution system operators, energy communities, etc.) in order to provide "flexibility" to the electrical system. It is then a question of modulating the charging power[21], at the request of an operator and in return for remuneration, in order to optimize production costs, help the network to absorb temporary peaks in production or consumption, or consume locally. For example, industrial sites are now a source of flexibility by practicing demand response for the national balance of the network. The operator seeks this "flexibility" in a competitive scheme, that is to say if it is less expensive than the other options available to him to meet his needs, whether they are generation options (start-up of additional means of generation, for example) or other technical options (reinforcement of the network, for example).

Charge management can produce flexibility through three types of action:

1. **Demand response,** that is, the reduction or temporary interruption of charging to relieve the grid.

2. **The increase in consumption by accelerating/shifting charging,** especially when there is a surplus of local production.

3. **The injection of electricity stored in batteries during periods of high consumption thanks to Vehicle-to-Grid (V2G),** thus temporarily acting as a generator of electricity. The number of vehicle models capable of re-injecting into the networks is still relatively low (less than 5 models). Experiments have started in a few countries in Europe and around the world (eg Norway, the Netherlands, Great Britain, Belgium, Portugal ...); in France, the first tests will take place in the first half of 2021.

21 This can be "upward" (reduction in consumption or reinjection of electricity), or "downward" (increase in consumption or stopping reinjection).

Flexibilities, whether at local or national level, are characterized by several elements such as:

1. **The period,** over which a flexibility is committed to be available and to be able to respond to an activation order;

2. **The power**, which must be activated to meet the need during the period of use;

3. **The direction of the offer,** which indicates whether flexibility should be upward (in the event of a lack of electricity on the grid) or downward (in the event of excess electricity);

4. **The mobilization time,** which is the time between sending an order to request flexibility and its effective activation at guaranteed power;

5. **Minimum activation times,** which meet the need for flexibility;

6. **The maximum frequency of activation of flexibility[22],** which depends on the frequency of occurrence of the need, and which is often a sizing constraint for flexibility solutions (for example, an industrialist who practices demand response will not be able to repeatedly stop the production line several times a day);

7. **The location,** flexibility must be available and "activatable" in the area where it has been demanded.

The RTE transmission system operator uses flexibilities to ensure that the supply/demand balance is maintained on the network at all times, and to allow peak consumption to pass regardless of the contingencies (e.g. power failure at a production plant). Thus, RTE ensures an aggregate of around 4 to 5 GW of flexibility in France to maintain the supply/ demand balance via "reserves", including more than 50% demand response. Other flexibilities exist and are active in different markets (energy, mechanism capacity, etc.). Electric vehicles can participate in these mechanisms; RTE estimated that these demand responses could be remunerated in the order of a few tens to a few hundred euros per vehicle per year[23].

What about the distribution network?

Under the effect of the massive arrival of renewable electricity production, the development of self-consumption and the emergence of new uses of electricity such as electric vehicles, the distribution network can benefit from the effects of local coordination between production and consumption. It is in this context that, for several years, Enedis has been carrying out research and development (R&D) work and experiments on local flexibilities.

The arrival of new technologies (sensors on the network, smart meters, 5G telecommunications, etc.) will also make it possible to better understand the status and demand of the network in real time, thus facilitating the implementation of local flexibilities.

Thus, Enedis has initiated a major work program to integrate local flexibilities into its industrial model. The report published in October 2019[24] describes the use cases envisaged and the relevance of local flexibilities on its network, as well as the methods to be implemented. Five calls for tenders were launched in the first half of 2020 to buy local flexibilities in the departments of Nord, Morbihan, Paris, Gard and Côte d´Azur.

Compared to the transmission network, the implementation of flexibilities on the EDN grid has specificities: the value of local flexibility is closely dependent on its location on the network (where the congestion is precisely located) and its reliability (it is not possible to count on an abundance of flexibility resources to overcome their possible failure). The need for flexibility can also be more volatile: changes in consumption or production can trigger an investment that negates the need for local flexibility.

22 Defined by the neutralization delay between two activations.
23 Amount not taken into account in this report, see the RTE/Avere report on the challenges of developing electromobility for the electricity system.
24 Enedis's vision on flexibilities.

2.2 For the distribution network, the flexibility of electric vehicles could be used in the event of incidents or works to defer investments or reduce the cost of connection to the network

The flexibility generated by the charge management of electric vehicles can present five opportunities, as long as it is competitive compared to current alternatives:

1. **In the event of an unplanned operating incident,** following a technical failure, the flexibility will allow the local network to replenish the maximum number of consumers with the remaining distribution capacity;

2. **To reduce the impact of the work on the EDN,** by avoiding the power outages associated with the latter, or by reducing costs (for example by avoiding the relocation of an emergency generator);

3. **To avoid or postpone investments in the network** strengthening or extending the network, temporarily responding to additional constraints on the network through flexibility;

4. **To reduce the cost of connecting charging points**, when the arrival of a fleet of electric vehicles creates congestion, the user of the fleet may be offered to manage his charging to avoid these congestions and reduce the cost of connection. This flexibility can be part of a "Smart Connection Offer" (SCO);

5. **To absorb the local renewable energy surpluses, during one of the 3 previous cases (incidents, works, investment deferral),** and thus avoid the loss of this energy which cannot be distributed by the network.

The value of local flexibility described corresponds to the maximum value for the community: this collective value must be distributed among the different market players - network users, distributor, flexibility operators, user of the electric vehicle, etc. The assessment is based either on normative and unit cost values for the community of energy not distributed to consumers, or on the gains linked to the deferral of an investment, described in Figure 7 and published by Enedis[25] in 2019.

25 Enedis's vision on flexibilities

		Collective value for the MV network	Remuneration	Capacity of EVs to respond
1	**Incidents**	Value from 0 to €20/kWh	On activation (€/MWh)	↑ ✔ **Activation delay:** charge management can be sufficiently responsive **Activation time :** the demand response produced by charging can take several hours ↓
2	**Works**	Value from 0 to €10/kW/works	↑ Capacity reservation (€/MW) + On activation (€/MWh) ↓	
3	**Investment deferral**	Value from 0 to €24/kW/year		
4	**Smart Connection Offer**	Up to €90/kW *(increased injection value)*	Reduced cost of connection	
5	**Local surpluses of renewable energy**	~€50/kWh of cutback avoided	To be determined	

For comparison, a private electric vehicle consumes ~16 to 23 kWh/100 km, and uses a charging point from 3 to 7 kW

Figure 7: The different applications of local flexibility and their characteristics

For each of these applications[26], the RPD will formulate, within a call for tenders, an expression of the need for flexibility (in terms of power, frequency, schedules) which will be very dependent on each specific local situation.

We illustrate in Figure 8 the need for flexibility in 5 real situations, allowing for the examination of different local flexibility applications and their characteristics.

		Examples of the need for local flexibilities			
		Context	Period of need	Max power requirement (MW)	Volume and frequency in expectation (MWh/year)
Incidents	**1A**	Rural	Night	2 MW	4 MWh/year (<1/year)
	1B	Urban	Day	1 MW	8 MWh/year (<1/year)
Investment deferral	**3A**	Rural	Day	3 MW	45 MWh (<1/year)
	3B	Semi-urban	24H	Up to 45 MW	90 MWh (3/year)
SCO Illustration SCO LV, not industrial to date	**4**	No impact	When there is charging	For a fleet of 20 vehicles: 50 to 150 kW	Depends on the local situation

Figure 8: Assumptions for illustrations of situations of need (maximum volume) of local flexibilities

Reading aid for Figure 8

- Situation 1A corresponds to a rural area, where when incidents weaken the network, it may lack capacity at night, leading to consumer cut-offs. To respond to this problem, the DSO needs 2 MW of flexibility. This has less of a chance to happen per year, and the flexibility is expected[27] to be activated to the tune of 4 MWh per year, without guarantee.
- Situation 3A corresponds to a rural area, where Enedis could avoid an investment in the network if 3 MW of local flexibility could be contracted year-round, with an estimate of an activation volume - only during the day - of up to 45 MWh/year.

26 Excluding the smart connection offer which is contractualized by a B-to-B contract between the requester and the DSO.
27 Expectation is the value that one would expect to find on average if one observes the need for flexibility over a large number of years. However, the need may be zero in some years and much greater in other years.

If this flexibility were to be provided by charge management of electric vehicles, a sufficient number of electric vehicles should participate in the service. Among the electric vehicles registered for the service, only those connected to a charging point when flexibility is required will be able to contribute to providing flexibility. For example, if flexibility is expected during the day to relieve a withdrawal constraint (too much power demand compared to the local capacity of the EDN), private electric vehicles mainly used for the daily commute to work and which charge overnight at home (charging profile C) will have a limited or no contribution to offer the desired flexibility.

From 2025, the number of electric vehicles could allow for a volume of local flexibilities that can be exploited by Enedis. Local flexibility needs are limited to areas where the network is under stress, in a specific geographic space.

By way of illustration, the calls for tenders recently initiated by Enedis concern areas with a population of between 500 and 100,000 inhabitants. For each of the situations presented in Figure 8, the number of electric vehicles that must participate in the service to provide the local flexibility sought is estimated between 500 and 6,500, cf. Figure 9. This number depends on the flexibility power required- which depends on the local situation - and the ability of electric vehicles to provide flexibility - which depends on the charging profile.

			Charging profile *Business CPs*	Charging profile B *Utility veh. CPs*	Charging profile C *Residential CPs*	Charging profile D *Public CPs*
Average flexibility power available per EV[28]			1.2 kW/EV	~3-4 kW/EV	~0.4-0.8 kW/EV	~0.5 kW/EV
Incidents	1A	Night 2 MW	✗ *No charging at night*	✔ ~600 EVs required	✔ ~2,500-4,600 EVs required	✗ *No charging at night*
	1B	Day 1 MW	✔ ~800 EVs required	← ✗ *No charging during the day* →		✔ ~2,000 EVs required
Investment deferral	3A	Day 3 MW	✔ ~2,500 EVs required	← ✗ *No charging during the day* →		✔ ~ 6,500 EVs required
	3B	24h -1 to 45 MW	← ~ EVs are not sufficient in terms of volume and times available: they can only be complements to other solutions →			
SCO	4		← ✔ EVs are the source of the need for flexibility They can therefore fully meet it through management →			

Figure 9: Analysis of the capacity of each charging profile to participate in local flexibility and the minimum number of EVs necessary to respond to it - excluding V2G

Reading aid for Figure 9

- In situation 1A, since flexibility is needed at night, only electric vehicles with a utility or residential-type charging profile charging at night could provide flexibility. To achieve 2 MW of flexibility, it would be necessary to have ~600 utility vehicles (each representing 3.5 kW of average usable power, by assumption) or 2,500 to 4,600 residential vehicles to fully meet the need.
- In situation 3A, the need for flexibility being the day, it is the charging profiles of the company fleet or opportunistic charging on public roads that can meet it, and respectively either 2,500 vehicles (company fleet) or 6,500 public points (assuming there are two 20-minute charges per day) would be needed to meet the need.

28 Average power voluntarily conservative in relation to the real power of the charging points installed on the one hand, and to the desire not to provide the full potential of the battery by occurrence (the electric vehicle must indeed be able to keep a running capacity) .

For all the local cases studied, it will be necessary to wait until at least 2025 for the density of electric vehicles alone to provide sufficient potential[29] for flexibility: before this date, even if all the vehicles present locally participate in flexibility, the capacity obtained will be less than 500 kW (minimum size of current local flexibility calls for tenders).

After 2025, some urban and semi-urban areas will have a sufficient fleet of electric vehicles, provided that a majority fraction of these electric vehicles actively participate in the flexibility service (i.e. electric vehicles are registered with a flexibility operator and have the necessary technical equipment).

Conversely, in sparsely populated areas, in the two cases studied, the local electricity supply should not make it possible to offer a significant local flexibility capacity, even in 2030. Whether one is in a dense or slightly dense zone, the flexibility provided by the electric vehicle can already be added to other flexibilities, and can therefore render the service “in part and up to the volume provided”.

Low Voltage (LV) network and MV/LV substations

MV/LV substations and the LV network represent a challenge for flexibility, because many means of flexibility, in particular electric vehicle recharging infrastructures (EVRI), will be connected to them and will be able to participate in both national and local flexibility services.
However, it is more difficult to take advantage of the local flexibility on this equipment for the needs of the low voltage network than for the national market and than for the needs of the higher voltage levels:

- These LV equipments cover a small geographic area and a number of less than 300 sites. As the sample in which to find flexibility is reduced, there is a greater risk in the ability to find sources of flexibility and ensure that they will be available within these areas.
- Low voltage equipment is of low power (<250 kVA), and avoiding or postponing its reinforcement only allows for a limited gain for each local situation: postponing the renewal of a MV/LV transformer for one year makes it possible to save around €1,000 to €2,000 per year for the community.

These characteristics currently do not allow for local flexibility to have an economic interest in optimizing the management of low voltage in the short term: in the absence of standardized solutions (technical, commercial, contractual and finally technological) and at lower cost, the costs of implementing these flexibilities outweigh the gains.

This is why studies and tests between stakeholders should be continued to identify the conditions for development and, if possible, fulfill them. This is the meaning of Enedis's work on the aVEnir project: when the local flexibility market is developed with diffuse flexibilities (such as electric vehicles), and when management solutions have been deployed on these flexibilities in order to oversee/run them, for multiple reasons (reducing the costs of charging, for national flexibility, for the needs of the high voltage network or even to consume locally), local flexibility for low voltage could then be a significant product of income, in addition to income drawn from national flexibility markets.

29 The potential for flexibility is the flexibility capacity available if the set of electric vehicles available over the necessary period offer their flexibility. This assumes that 100% of electric vehicles with the correct charging profile offer their flexibility.

2.3 The value of local flexibility to be shared between market players is a few tens of euros/EV/year and can occasionally reach €200/EV in the event of a network incident

The value created for the community from flexibility resulting from charge management varies greatly depending on local situations and charging profiles. In the most favorable case among those studied, a fleet of 800 employee electric vehicles (charging profile A) could be made flexible to allow the DSO to avoid power cuts in the event of an incident on the network in an urban situation (situation 1B). If each vehicle provides flexibility of ~10 kWh/year (equivalent to a daily charge), this could create a maximum value of €200/EV per incident for all stakeholders. This value does not correspond to the amount obtained by the user of the electric vehicle, because it must be distributed between the user, the flexibility provider (in particular to cover the costs of running and managing the flexibility), the users of the network - those who would have been cut off and the others - as well as the DSO.

Conversely, the absorption of local renewable energy surpluses does not generate significant value for the community. This is the consequence of a different socio-economic valuation: *non-distributed energy*[30] is supposed to have a cost of 9 to €20/kWh for the community ; on the other hand, *non-injected energy*[31], is valued at the level of its market value, ie ~€0.040-0.060/kWh. There is therefore less value in absorbing excess energy than in resolving a lack of energy.

In other cases, the value is of the order of a few dozen euros per vehicle per year.

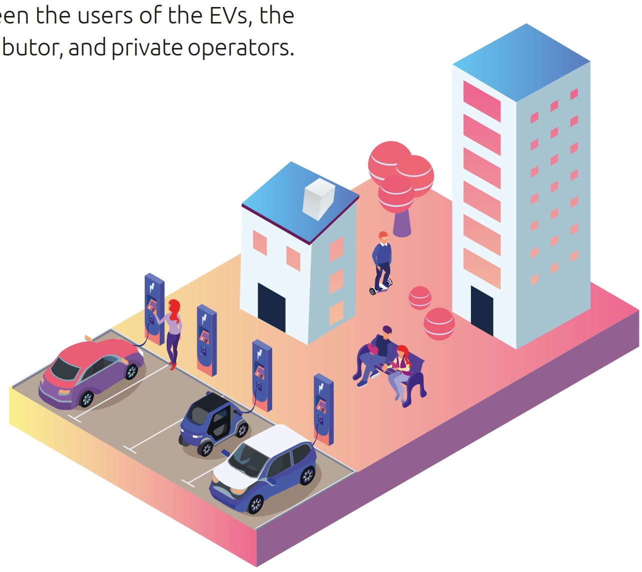
30 Energy that the network has not been able to distribute to the consumer in need, notably because of unforeseen outages linked to a failure on the network.
31 Energy produced that the grid could not absorb.

<table>
<tr><th></th><th></th><th></th><th>Charging profile A
Business CPs</th><th>Charging profile B
Utility veh. CPs</th><th>Charging profile C
Residential CPs</th><th>Charging profile D
Public CPs</th></tr>
<tr><td rowspan="2">Incidents</td><td>1A</td><td>Night
2 MW</td><td></td><td>✔ Maximum collective value:
€140/EV/incident</td><td>✔ Maximum collective value: ~20-
€35/EV/incident</td><td></td></tr>
<tr><td>1B</td><td>Day
1 MW</td><td>✔ Maximum collective value:
€200/EV/ incident</td><td></td><td></td><td>✔ Maximum collective value: ~€75/CPs/
incident</td></tr>
<tr><td>Works</td><td></td><td></td><td colspan="4">← ✔ Maximum of €40/EV/worksites →</td></tr>
<tr><td rowspan="2">Investment deferral</td><td>3A</td><td>Day
1 MW</td><td>✔ Maximum collective value:
€28/EV/year</td><td></td><td></td><td>✔ Maximum collective value:
~€10/CPs/year</td></tr>
<tr><td>3B</td><td>24h
-1 to 45 MW</td><td colspan="4">← ✔ Collective value
less than €100/EV/year →</td></tr>
<tr><td>SCO</td><td>4</td><td></td><td colspan="2">← Value for the site from
~50 to €70/EV/year for 10 years →</td><td></td><td></td></tr>
<tr><td>Local surpluses of RE</td><td></td><td></td><td colspan="4">← ✔ Collective value less than €5/EV/year on average →</td></tr>
</table>

Figure10: Value created for the community by local flexibility by application and charging profile.

Reading aid for Figure 10

- In situation 1A, the participation of utility vehicles (charging profile B) in local flexibility could make it possible to create a value of €140/EV/incident for the community, which would have to be distributed between the users of the EVs, the other network users, the distributor, and private operators.
- In situation 3A, the value for the community created by the company fleets would not exceed ~€28/EV/year.



Without prejudging the future, the value of the management required to produce local flexibility is now twice lower than that resulting from the management of existing price offers (see § 1.3). This last value is revealed at each occurrence (see § 2.2) and is a new opportunity for remuneration.

It is also estimated that less than 1% of the electric vehicle fleet will be located in constrained areas (on the basis of current constrained areas) and therefore likely to participate in a mechanism offering local flexibility and, therefore, to be paid for it.

Possible synergies between charging an electric vehicle and solar PV generation (PV)

The distribution network adapts simultaneously to the development of distributed generation facilities, photovoltaic and wind power, and to the development of new uses, charging stations. If consumption and production are concomitant, there may be synergies at different scales:

- **At the site level,** when production and consumption are in the same place, the consumer/producer can maximize his own consumption and capture the associated value described in part 1. This could also make it possible to reduce his impact on the network, by limiting the injected power and withdrawn power thanks to this optimization, subject to the concomitance of this management over time with the needs of the network.
- **At the national level,** the flexibilities provided by electric vehicles, in addition to other flexibility solutions, could facilitate the integration of photovoltaics by allowing the market and RTE to balance the electricity system more easily. They can also help to remove constraints on the HV network.
- **At the local grid level,** Enedis has implemented flexible solutions to facilitate the insertion of renewables into the grid, with Smart Connection Offers (SCO) for producers and the ReFlex S3REnR program aimed at increasing the capacity of S3REnR programs. Like the other flexibilities, electric vehicles will be able to participate in market calls.

Chapter 3

The implementation of a flexibility service for the Electricity Distribution Network is a collective action, requiring numerous players to work together

Many stakeholders need to coordinate in order to enable EV users to offer their local flexibility services to the EDN. On one hand, the players in electric mobility:

- **The consumer,**
- **The charging point operator,** who manages the charging stations (maintenance, access control, management, invoicing, etc.),
- **Car manufacturers,** who are committed to battery life, range and charging speed,
- **The energy supplier,** who provide the electricity, constructs the tariff offer, and notably sets the tariff periods (week/WE, day/night) and the prices of electricity,
- **Local authorities,** providing incentives in terms of the deployment of charging stations and local and green supply,
- **The mobility services operator,** intermediary between the charging point operators and the consumer to whom he gives access to the various charging points.
- **The managers of eco-districts and energy communities,** who wish to develop local consumption.

And on the other hand, the players specific to the flexibility of electric vehicles:

- **The flexibility aggregator,** takes charge of managing the load of several consumers or producers and aggregates the flexibility offer intended for the DSO or TSO.
- **The transmission system operator (TSO),** which balances electricity supply / demand at the national level and must take into account the effect of flexibilities on the national network,
- **The distribution system operator (DSO),** which connects the charging infrastructure for electric vehicles and facilitates their integration into the network.

Consumer	• Have a functional and charged vehicle at the desired time • Have the desired type of energy supply (green, local, etc.) • Reduce costs associated with the use of EVs
Flexibility aggregator	Maximize the volumes and value of flexibility provided to grid operators and electricity markets
Supplier	• Provide electricity and associated services at the best price for the customer • Be a key interlocutor for the client
The charging point operator	• Offer charging points and associated services (managing, invoicing, maintenance) that meet customer needs and maximize the value derived from these services • Be a key interlocutor for the client
Mobility services operator	• Maximize the size of its network of charging points and of its customer portfolio • Be a key interlocutor for the client
Auto manufacturer	• Offer a vehicle (at the best value for money) that meets customer needs over time (including range, performance, reliability, durability) • Allow value to be generated by charge management without impacting the main use
Local authority	Achieve the objectives set in terms of deployment of charging stations, EV registration, energy transition, local and green procurement, and facilitation of local exchanges within local energy communities
DSO	•Distribute energy to consumers with an excellent level of quality (number of outages, voltage withstand) and reliability • Make the deployment of electric vehicles and exchanges between energy players as easy as possible (e.g. on flexibility) • Reduce the cost of electricity distribution for the community, and therefore the cost of integrating EVs
TSO	• Balancing supply/demand for electricity in France • Reduce the costs associated with transport and balancing for the community, by allowing for the development of flexibilities

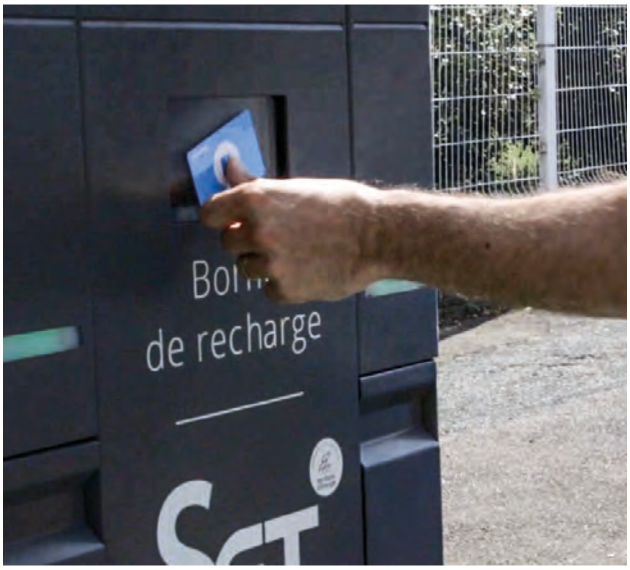
Figure 11: Interests of the different market players

A local flexibility solution requires combining the objectives of each contributor.

For each of the many interfaces between these market players, an appropriate technical and commercial framework must be available.

Among these interactions, some are regulated or already have a defined framework (such as supplier compensation for DR, etc.), while others are virtually devoid of any reflection; for these, a framework must be defined, either within a bilateral commercial framework, or within the framework of regulated processes or specifications defined in consultation with all the players concerned. Examples:

Between the DSO and the TSO on the use of a common source of flexibility: until now, only the TSO has activated flexibilities; in the future, the DSOs will also have to request local flexibility resources. Faced with a common pool of flexibilities, network managers are currently working on the methods (process, data exchange, etc.) to be implemented to allow shared use of this pool with the aim of (i) the operating safety of the network and (ii) the possibility for market players to maximize opportunities to enhance their flexibility.



Charging stations at SAP in Mougins

Between the car manufacturer, the consumer and charge managers on the responsibility for battery wear: certain forms of charge control (V2G / V2B / V2H) could accelerate battery wear and thus call into question the customer's promise or the vehicle manufacturer's warranty regarding battery life. The latter could therefore define upstream the conditions of use covered by the warranty (average number of complete charging cycles to be carried out, maximum % of cycles to be carried out to neutralize the effect of additional cycles, preferred charging power, etc.) Charge managers could make a commitment to the end consumer to carry out load control under the recommended conditions to limit battery wear. However, conditions of use or technical requirements that are too strict by the manufacturer could limit the battery recovery capacity or slow down its development.

Between the supplier, the charging point operator, and the flexibility aggregator who are all intermediaries between the consumer and the DSO to ensure charge management: these players can all carry out charge management and thus claim flexibility. In certain cases, several players can have an impact on the management of a single vehicle: the supplier for the management linked to the hourly seasonal tariffs, the local flexibility aggregator, the national flexibility aggregator. There will, therefore, be a traceability issue to identify each person's charge management actions and assign responsibility for them, according to common rules (anteriority, charging period, etc.)

The large number of market players involved in the implementation of local flexibility is not only a reflection of the many stages of the technical process; it also reflects the variety of technical architectures used to manage charging, which are all ways of distributing the roles of each player.


enedis

Chapter 4

4. As DSO, Enedis plays an essential facilitator role for the operational implementation of charge management

4.1 Several architectures offering different functionalities make it possible to manage charging

Depending on his needs, the consumer can choose a technical charge management solution[32] adapted to his charging solution; they nevertheless have consequences on the expected functionalities and the accessible values.

The main features expected in a technical charging solution are:

1. **Metering of the electric vehicle's electricity consumption and/or injection**, to allow for monitoring and provide many services associated with charging (generation of invoicing, expense reports, management of fixed prices, association with a green electricity offer, etc.);
2. **Charge management**, that is to say the activation on command or programming of the charge/discharge, and the adjustment of its power according to that of the home/building;
3. **Measurement and verification,** that is to say the measurement and verification of the flexibility provided, in particular by comparing the actual electricity consumption of the site with its theoretical value if the local flexibility had not been activated.

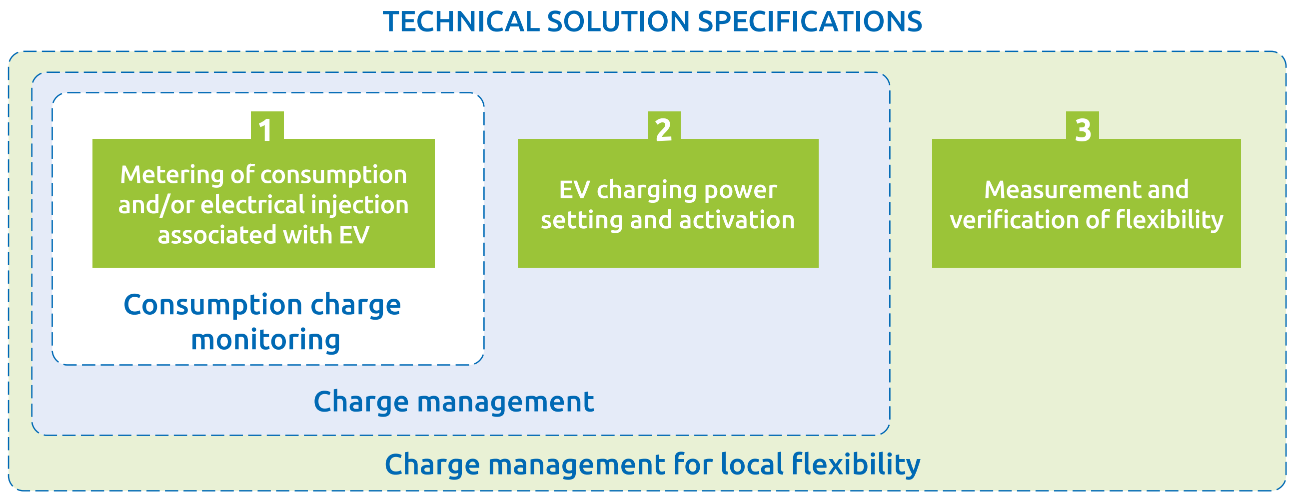
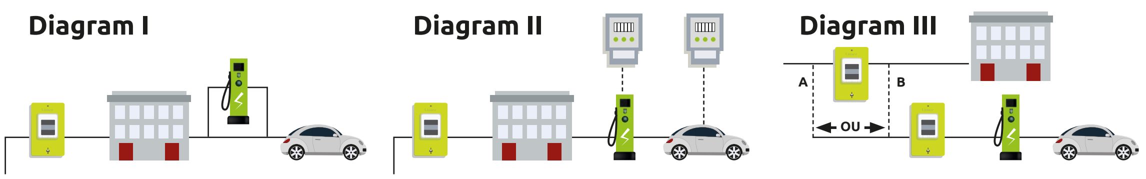


Figure 12: Main functions of the technical solution expected by the consumer

32 This document is not intended to list the various existing means of management (telephone and mobile apps, charging points, metering, vehicles).

The user's choice of technical solution will depend on the type of site, the layout of the premises, and the desired functionalities. There is a wide variety of architectures, but there are 3 main cases shown schematically in Figure 13 in the case of an individual charge. These 3 cases are distinguished according to the ability to isolate, in terms of electricity metering, the vehicle from the site where it is being charged (for example, diagram I does not allow this, while diagram III amounts to completely isolating the vehicle), and the ability to provide a measure opposable to the various players on these two perimeters (for example diagram II makes it possible to isolate the vehicle, but does not allow a separate supply contract).



<table>
<tr><th></th><th>Diagram I</th><th>Diagram II</th><th>Diagram III</th></tr>
<tr><td>Description</td><td>The vehicle is connected directly to the site or via a charging point downstream from the meter without a sub-meter integrated into the charging point.</td><td>The vehicle is connected to a charging point downstream from the meter with an additional private metering infrastructure in the charging point, or within the car.</td><td>The vehicle is connected via a charging point to its own dedicated Linky meter. The charging point can thus be directly connected to the EDN.</td></tr>
<tr><td rowspan="2">1 Metering, supply & associated services</td><td>Only a common electricity supply offer for the site and to the vehicle is possible.</td><td>Only a common electricity supply offer for the site and to the vehicle is possible.</td><td>Two electricity offers are possible: one for the household, and one for the vehicle.</td></tr>
<tr><td>• The specific consumption of the vehicle can be known thanks to an on-board meter.
• Additional services such as billing for expense reports are possible thanks to on-board meters.</td><td>• The specific consumption of the vehicle is known but can only be opposed between private players (re-invoicing, etc.).
• Certain additional services such as billing by third parties are possible through private metering.</td><td>• Consumption specific to the vehicle is known and can be used against all players.
• All additional services are possible (re-invoicing, etc.)</td></tr>
<tr><td>Accessible management values</td><td colspan="2">• The accessible charge management values are:
-the temporal management of charging,
-power modulation,
-Vehicle-to-Home (V2H) and Vehicle-to-Building (V2B).
• As the charging point is not directly connected to the EDN, charge management must take into account the site's consumption to be optimized: to use Vehicle-to-Grid (V2G), the car must reinject more energy than household consumption.</td><td>• The accessible values are:
- the temporal management of charging,
- power modulation (of charging),
- V2G.
• As the charging station is not directly connected to the site, it is impossible to do V2H/V2B.</td></tr>
<tr><td rowspan="2">2 Management activation and adjustment</td><td colspan="3">The activation of charge management on price signals can be done:
• REMOTELY,
> Via Linky, which can trigger charging according to one of the daily time slots predefined by the supplier
> Via a third-party control system
- Example: the third party (car manufacturer, supplier, charging stations operator, flexibility aggregator) installs a control system in the charging point or the vehicle. This system triggers charging or discharging according to the time slots set by the third party, the customer, or on a one-off order.
• MANUALLY, BY THE CONSUMER
- Example: The consumer who manages his charging based on tariff signals plugs in his vehicle himself and manually manages his charge according to his needs.</td></tr>
<tr><td>Activation of charge management for flexibility is possible, but takes into account the consumption of the site.</td><td colspan="2">The activation of charge management for flexibility is possible via third-party control system, or manually, in response to a request from the flexibility aggregator.</td></tr>
<tr><td colspan="4">It's the measurement of the Linky meter that makes it possible to measure and validate the impact of charge management (all diagrams).</td></tr>
<tr><td>3 Measurement and verification of local flexibility</td><td colspan="3">• In the context of local flexibility, the measurement and verification of the provided flexibility requires a "customer baseline load" tested and validated by Enedis (see Measurement and verification of flexibility on the next page). The customer baseline load must be adapted to the site concerned (residential, tertiary, industrial, etc.), its size, and the type of charge management carried out (demand response, V2G, etc)
• If Linky is not dedicated to the vehicle, the measurement of flexibility is carried out by taking into account the site as a whole.</td></tr>
</table>

Figure 13: Description of 3 common technical architectures and accessible values

In terms of uses:

- Diagram I enables simple charge management based on tariff offers. Automatic activation of charging is carried out thanks to the Linky meter. The applications of electric vehicles also allow for easy management of charging, but the latter are not “activated” by a price offer. Billing services can be provided by third parties, in particular using on-board meters in the vehicle.
- Diagram II is suitable for tertiary, industrial or collective housing installations, because it allows for under-metering and therefore a distribution of charging costs. However, the flexibility offered by managing charging, measured at the site's charging points, can be "hidden" by the consumption of this site - for example, if the site's consumption increases when charging demand response is initiated.
- Diagram III makes it possible, on one hand, to measure the flexibility linked to charging without being hidden by the site's consumption/production, and on the other hand to choose an ad hoc supply contract for charging, separate from that of the site. Note that diagram III does not allow energy consumption and power consumption to be pooled between the site and the vehicle, which limits the value of controlling charging for the benefit of the user.

Measurement and verification of flexibility

The measurement and verification process is the method for evaluating the flexibility provided by vehicles, comparing the actual consumption of flexibilized electricity to the reference consumption if local flexibility had not been activated. Several "customer baseline methods" are proposed by Enedis to determine the reference consumption.

For diffuse sites, particularly residential sites, for which the supply capacity is less than or equal to 36 kW:

- **The "panels" method,** which compares, at a certain level of aggregation, the consumption of sites that achieve flexibility with that of a panel of non-flexible mirror sites. To be suitable for charge management, the constitution of the mirror panel must naturally include sites with electric vehicles.
- **The "default" method, of the "simple rectangle",** considers the consumption before the activation of flexibility as a reference. It only applies to activations lasting less than or equal to 2 consecutive hours. It is not very suitable for modeling consumption that varies over time - for example, a simultaneous activation of flexibility when starting a hot water tank.

For collective housing sites and businesses, whose supply capacity is greater than 36 kW:

- **Comparison methods, which are based off of historical use** ("consumption history", "k most comparable historical cases") which are only valid for sites with regular consumption.
- **“Consumption forecast” methods,** proposed for MV and LV sites >36 kW, previously approved.

4.2 The Linky smart meter, a hardware and software solution that can meet consumer expectations

The Linky smart meter, the deployment of which is underway by Enedis across the country, offers a simple charge management solution. Beyond its metering function, the Linky communicating meter is a solution for activating and controlling the performance of charge management thanks to its technical capabilities. In technical diagram I, Linky is sufficient to mobilize and enhance the value of charge management, excluding local flexibility. In addition, Linky is also a base for additional services, by producing the data allowing them to be carried out. 28 million households are already equipped with Linky, and the deployment will be completed by the end of 2021.

Linky has many functionalities allowing it to perform the services associated with charging, in particular:

Metering and monitoring of charging:

- Linky can measure consumption and injection (separately) at appropriate time steps upon user request (from a few hours to 10 minutes);
- Linky displays consumption in real time on its screen and can communicate with a visualization tool inside the site.

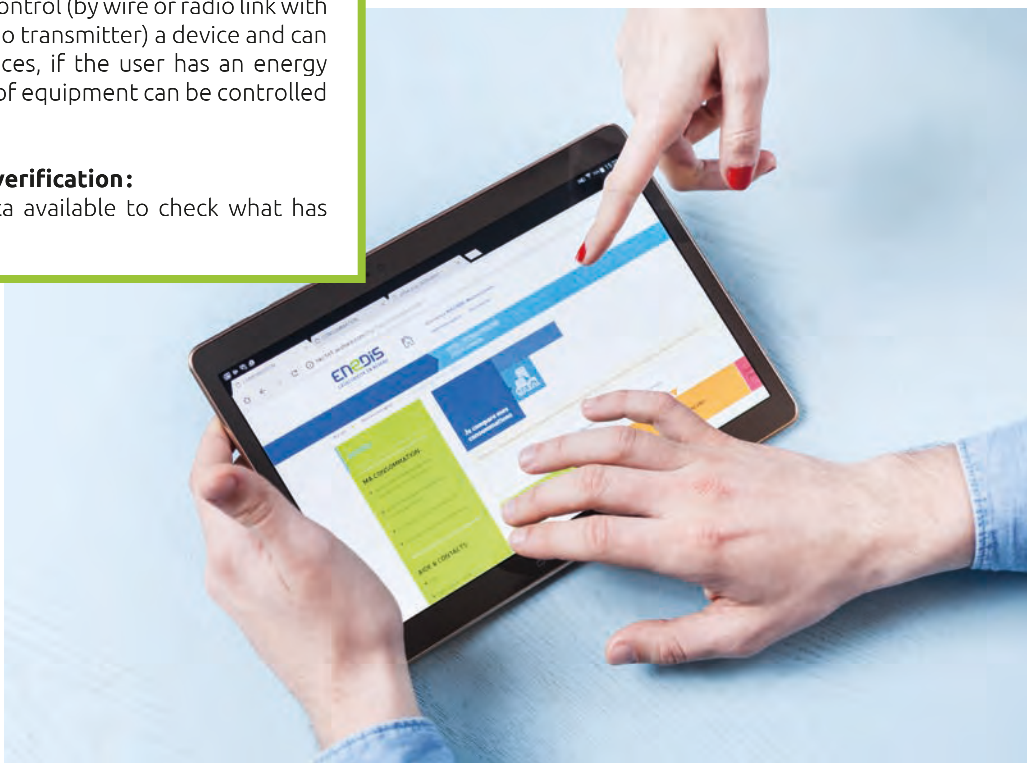
Activation of charge management:
Linky can activate and deactivate equipment based on time and tariffs, which allows equipment to be controlled with a feedback loop. The Linky meter allows you to easily control (by wire or radio link with the addition of a radio transmitter) a device and can control up to 8 devices, if the user has an energy manager. Each item of equipment can be controlled by the tariff offers.

Measurement and verification:
Linky makes the data available to check what has been done.

Enedis develops energy monitoring solutions promoting the implementation of local energy communities.[33]. These solutions are operational for collective self-consumption projects, in order to allocate locally produced energy to different consumers. They are deployed on more than 35 projects. In addition, Enedis is continuing its work, in order to offer solutions for:

1. Certifying the origin of the charging energy (green, local, and produced simultaneously with consumption).
2. Managing and allocating the energy produced and consumed locally between network users, in order to allow them to exchange energy locally according to their needs, and to facilitate contractualization between them.

This work aims to facilitate the projects of the various stakeholders - users of electric vehicles, private market players, local authorities - to enable them to obtain and guarantee a local and green source of electricity for their uses.



33 Energy communities are defined in two separate directives of the "Clean Energy Package". The Renewable Energy Directive (EU) 2018/2001 establishes the framework for "renewable energy communities" covering renewable energies. The revised Internal Electricity Market (EU) Directive 2019/944 introduces new roles and responsibilities for "citizen energy communities" in the energy system covering all types of electricity.

4.3 Enedis, a player in the development of charge management and local flexibilities

The users of the distribution network are the main beneficiaries of charge management. The more charging is managed, the better the integration of the electric vehicle into the network. The benefit, for the electricity system and the community, cycles back to all network users.

As Distribution System Operator, Enedis participates in identifying the needs and the value of charge management:
- For charge management which benefits the consumer, Enedis participates in the establishment of tariff signals such as TURPE, by defining the time slots of these tariff signals by geographical areas and by propagating the time signal to the meter of the house.
- To manage charging for local flexibility, Enedis identifies the areas of flexibility service opportunities and organizes calls for tenders to source local flexibilities. During the operation phase, Enedis validates the activation order to flexibility service providers.

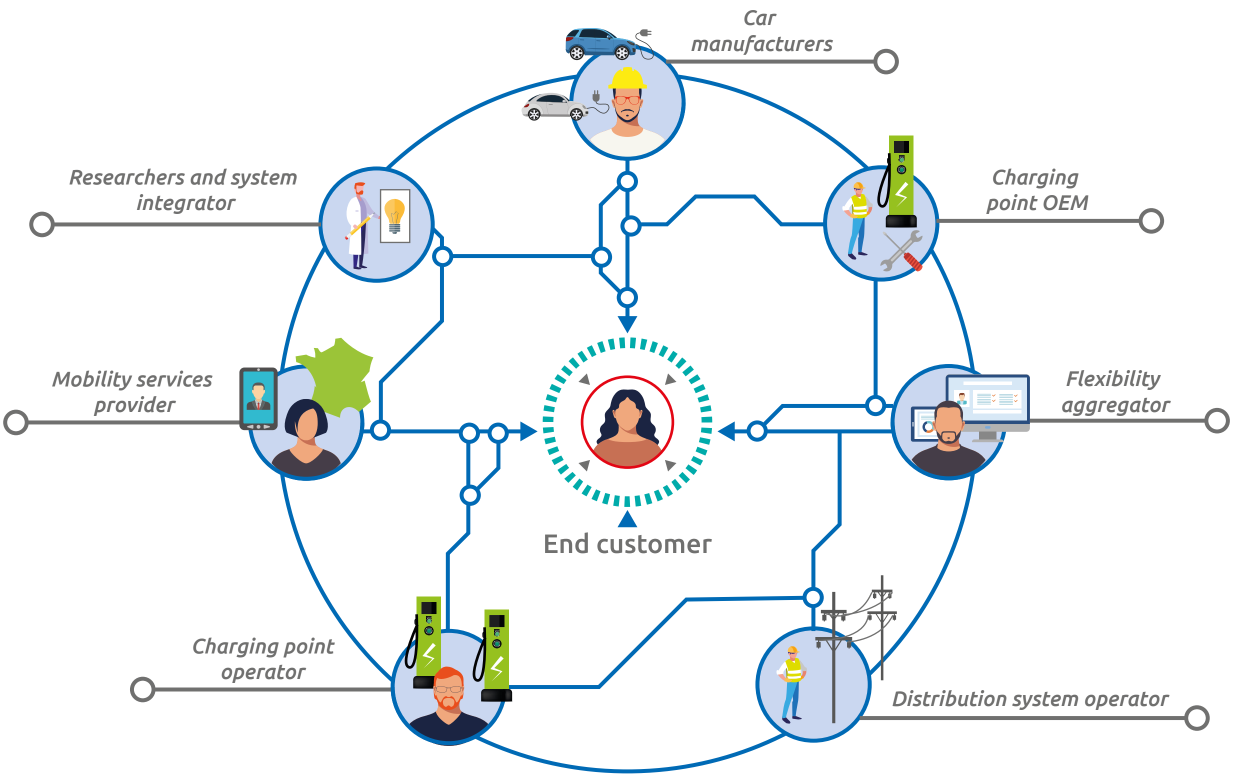
The implementation of flexibility requires financial exchanges between many players in the electricity market. Enedis is therefore not only a user of local flexibility, but also the trusted third party for all stakeholders - consumers, market players, public authorities -. For this, Enedis:
- certifies aggregation entities and initiates flexibility tests to validate their compliance;
- takes care of the measurement of consumption or energy injection in the face of the market, and carries out the measurement and verification of the level of flexibility provided;
- determines (in a manner identical to what exists on national markets) the flows and exchanges between the various private and public players following the achievement of flexibility;
- communicates this information to the players concerned.

The electric mobility market is evolving rapidly, driven in particular by falling costs and growing environmental awareness. In order to support the development of the sector, and to facilitate its continuous integration into the electric system, Enedis initiates or is involved in various R&D projects, demonstrators and the development of organizational and regulatory frameworks (standards, protocols, etc.). In addition, Enedis is carrying out, in a new laboratory inaugurated in 2020, charge management tests for its own internal fleet and contributes to the development of intelligent charging management solutions, as, for example, within the framework of the various ongoing demonstrators.

4.4. Innovation and outlook - "aVEnir" - of charge management

To continue developing charge management, Enedis is involved in several demonstrators in France and Europe on electric vehicles and/or flexibility, which make it possible to experience the benefits of charge management in concrete situations. Recently, Enedis launched the aVEnir project, in which 11 partners are participating in the metropolitan area of Lyon and the Sud Provence Alpes Côte d´Azur region between 2019 and 2022. The objectives of this project are:

- To experiment in real conditions, different management situations of electric vehicle charging points and their interfaces with the Electricity Distribution Network,
- To test smart charging solutions to facilitate the integration of electric vehicles into the network (in particular thanks to Vehicle to Grid - V2G - and synchronization techniques between charging and solar production),
- To evaluate the opportunities provided by electric vehicles for the management of local flexibilities on the electricity network to support the development of large-scale electric mobility thanks to the flexibilities approach.



Each partner puts its expertise at the service of this experimentation right up to the end customer.

In addition, Enedis follows developments in other European countries, in order to coordinate international work and learn lessons for France. Enedis, member of eDSO, the European association of distribution system operators, contributes to European work on coordination between TSOs and DSOs.

Studies and projects relating to the management of charging for local flexibility will therefore be continued by Enedis. Several essential topics have already been identified:

- Measuring the impact of flexibility on battery wear with car manufacturers;
- The ability of the electric vehicle to provide flexibility in low voltage;
- The evolution of user behavior and their adaptation to electric mobility;
- Niche situations that may be of potential interest, such as station or airport parking managers (long-term parking) which could enhance the batteries of parked cars.

On operational matters, Enedis works alongside RTE to simplify the coordination of market players for the operation and promotion of management, by making it possible to carry it out for the benefit of the national network, the local network, and the user. In addition, Enedis is developing operational solutions (eg: energy monitoring in the context of collective self-consumption, "indirect" connection, etc.) to enable players to offer services associated with the charging of electric vehicles, such as offers of "green" and local supplies, consumption monitoring solutions, etc.

Methodological appendix

1.1 Method for evaluating the value of charge management against existing price offers

The assessment of the value of charge management against existing tariff offers is based on **the difference between the cost of managed charging and "natural" charging**. The management is optimized to minimize the cost of charging, as a function of the different price signals, which are the different elements of the invoice for charging the vehicle.

The behavior of natural charging used in the study follows the following rules: as soon as the vehicle is plugged into the charging point or a simple electric outlet, charging begins until full charge, up to the maximum power of the terminal[34]. In the context of managed charging, the behavior of charging is modified to minimize bill items, that is to say: (1) shifted to the hours when electricity is cheapest and (2) modulated all throughout the potential time slot for charging to reduce demanded power as much as possible, (3) optimized according to site consumption, (4) synchronized according to local production, **while respecting the constraints of the charging profile.**

Charging profiles are therefore input assumptions that define the time slots when vehicles plug in, can charge, and the maximum power demanded corresponding to the power of the charging stations. For each price signal, a low value and a high value are defined.

Charge optimization against the variable price of electricity

This optimization makes it possible to consume the electricity required by the vehicle when the price is the cheapest and not necessarily juste after the vehicle is plugged in. It therefore depends mainly on:

- The vehicle's electricity consumption, in MWh/year or in kWh/d;
- The supply of electricity used by the user of the electric vehicle, which determines the off-peak hours - the cheapest - peak hours - the most expensive - and the price levels associated with each of these time slots.

Example for a residential vehicle: a residential vehicle consuming 3.4 MWh/year - i.e. 15,000 km with a consumption of 23 kWh/100 km - can shift its OPH charge while the natural charge was in PH, and assuming a rate €4.5c/kWh incl. tax, cheaper in OPH than in PH, can save €155/year incl.tax thanks to charge management **(maximum value retained).**

34 This is a simplifying assumption, because the power demand generally decreases with the progress of the load, especially when the vehicle is already loaded to more than 80%.

Vehicle type	Annual distance traveled (km)	Consumption (kWh/km)	Battery size (kWh)	Associated charging profile
Private vehicle A, Zoé-type compact	12,000	16 kWh/100 km	50 kWh	Profile C
Private vehicle B, Tesla-type sedan	15,000	23 kWh/100 km	80 kWh	Profile C
Commercial vehicle, Tesla-type sedan	15,000	23 kWh/100 km	80 kWh	Profile A
Utility vehicle	20,000	27 kWh/100 km	80 kWh	Profile B

Table 1: assumptions of the characteristics of vehicles selected and their uses

To assess the vehicle's electricity consumption, several types of vehicles and uses are associated with different charging profiles.

The electricity offers used as assumptions are the French “blue” OPH/PH Regulated Electricity Tariffs - with off-peak hours at night from 11 p.m. to 7 a.m. - for the residential profile (charging profile C) and the historical structure of old French “yellow” Regulated Electricity Tariffs for companies (charging profiles A and B). The "opportunistic" charge (charging profile D), in the street, assumes that it is not possible to shift the charge, and therefore there is no associated value.

Charge optimization against the price of the fixed fee for the electricity subscription

This optimization consists of modifying the power of the charge, depending on that of the site, in order to minimize the total power subscribed to in the fixed fee of the electricity subscription. Natural charging could involve increasing the power of the subscription up to the power of the charging station. The optimization aims to minimize this additional power demand, while ensuring sufficient charging power for the vehicle's needs.

This assessment depends on:

- The power consumption behavior of charging sites, to which the vehicle's consumption will be added;
- The power of the charging points, defined in the charging profile assumptions; for companies, the vehicle fleet size assumption (20 EVs per site) makes it possible to compare the impact of an electric vehicle fleet against the rest of the site's consumption;
- The tariff structure adopted.

Example for a residential vehicle: if the home consumption peaks at 7 p.m., and the electric vehicle is connected at the end of the day with a 3 kW charging point, natural charging could encourage the user to increase their subscription up to 3 kW. By shifting the charging to nighttime, when the home consumes little, management of charging can avoid increasing the subscription, allowing them to gain 3 kW of subscription, or €30/year for their vehicle. In the case of a 7 kW charging point, this gain can reach €70/year (maximum value retained).

Conversely, if the consumption peak is during the day, or the site has some margin on subscription power for other reasons, the gain from this optimization may be zero.

For all charging profiles, the low value retained is zero for this optimization. The average consumption behavior of the sites used corresponds to:

- That of a residential site consuming ~12 MWh/year (housing with heating) and with a peak consumption in the 7 p.m.-8 p.m. slot is used for charging profile C;
- That of a company site consuming 300 MWh / year, mainly during the day, for charging profiles A and B.

The same tariff structures (blue Regulated Electricity Tariffs OPH/PH and yellow Regulated Electricity Tariffs) as for the optimization of the variable cost were used; they make it possible to value the additional average cost of one kW of subscription power to the tune of ~€10/kW/year for residential, and €30 to €40/kW/year for businesses.

Example for a fleet of 20 utility vehicles charging on 11kW charging points (charging profile B): if the site has no available power, natural charging would require 176 kW of additional supply capacity[35]. Thanks to charge management, by spreading it over time and over the different vehicles, only 3.5 kW per EV are needed to ensure charging, or 70 kW for the fleet of 20 vehicles. Moreover, as the site's consumption is lower at night than at 8 p.m. at 28 kW (assumption of the company's consumption behavior), only an additional 42 kW must be subscribed, i.e. a gain made possible by the charge management of 134 kW of supply capacity, i.e. €265/ EV/year maximum (at €40/kW/year), **maximum value retained.**

Charge optimization against the cost of connection

In situations favorable to the electric vehicle, there is no connection cost, because the initial connection exists and is sufficient to absorb the increase in power associated with the connection of electric vehicles. There is then no optimization to perform, and **the low value is zero.**

In less favorable situations, the assumption of the investment cost of the connection/unit reinforcement used for the study is €90/kW; These are, on one hand, an upper bound, and on the other hand, only on MV networks. An extrapolation is made for a LV network for the purposes of this study. It is assumed that the consumer spreads this cost over 10 years, ie €9/kW/year.

Example for a fleet of 20 utility vehicles: by taking the gain of 134 kW of power thanks to the management of the charging of the fleet of 20 utility vehicles, this corresponds to a gain of ~€60/year/EV.

For the residential case, the maximum value is €63/year/EV. It is rarely existing, since a minority of cases will require upstream reinforcement of the network, which can also be integrated into the TURPE (tariff for the use of the public electricity network) for overall needs.

Self-consumption value

The self-consumption value requires a photovoltaic installation on the electric vehicle charging site. **The low value is therefore zero,** corresponding to a situation where there would be no photovoltaic.

If PV panels are present, the value depends on:
- Installed photovoltaic power - we use an assumption of 6 kWp for residential profiles and 100 kWp for business profiles;
- The consumption behavior of the site. Those used - the same as for the other price signals - correspond to an initial self-consumption rate of ~35% for individuals and 92% for companies with the consumption curves used;
- The availability of electric vehicles to be charged when it is sunny - this is not the case for commercial vehicles which are circulating during the day (charging profile B). Even for very regular charging profiles, this availability varies throughout the year, as the sun is present in the evening and in the morning in summer.
- The value associated with maximizing self-consumption, which can be from 0 to €35/MWh for businesses and from 35 to €80/MWh for individuals[36].

The calculation determines the share of solar production in the case of natural charging, then maximizes this share by shifting consumption from the night, generally to the morning.

Example for a residential vehicle on a home with photovoltaic power: the vehicle can be charged in summer at the end of the afternoon with the remaining sun production, and on weekends during the day. The analyses show that with a 7 kW charging point, it is possible to use up to 600 kWh of solar energy (mainly from April to September) to charge the vehicle in the charging profile C. By optimizing management, it is possible to consume 1250 kWh of solar energy. In this case, the management gain is ~650 kWh/year additional self-consumption, i.e. a value of 20 to €30/MWh for a consumer under the OPH/PH tariff for a value of ~€35/additional MWh self-consumption.

35 That is 80% x 20 x 11 - assuming that a load aggregation coefficient, initially used, already made it possible to reduce the total power, up to 80% of the sum of the powers. This coefficient is assumed to be 50% for employee fleets (charging profile #A), the operational requirements for charging being lower.
36 This value corresponds to the difference between the cost of charging when electricity is consumed from the network -13.5 and €18c/kWh for private customers, and between ~6 and €10c/ kWh for businesses - and the cost of PV production which would otherwise have been reinjected, valued at ~€6c/kWh for businesses and ~€10c/kWh for private customers.

Charging profile D, consisting of charging on the road, does not benefit from this value.

The sum of the values linked to the price signals gives a total upper bound value linked to charge management depending on existing price signals, excluding V2H/V2B. For the residential case, the maximum value studied, the calculation of each elementary part of which was described above, is therefore €318/EV/year[37].

Additional value linked to V2H / V2B

The additional value related to V2H / V2B is determined incrementally, allowing the electric vehicle to discharge as long as it meets the constraints of use. It was assessed using the same assumptions as those for each of the relevant value blocks; certain additional assumptions are retained:

- ~81% charge/discharge cycle efficiency (90% charge, 90% discharge);
- Minimum state of charge of vehicle batteries set at 35% so as not to accelerate battery wear;
- No wear costs are built in.

The value of V2H / V2B is not evaluated to reduce the supply capacity or connection power, because these powers are already dimensioned and optimized to reduce the impact of the electric vehicle by charging at low power over the entire possible range, and that in in the cases studied, the vehicle does not reduce the power of the site to which it is connected.

The V2H / V2B therefore optimizes energy-related values at the margin, for example by de-stocking a little energy in the evening and in the early morning, when it is peak hours. For residential charging profiles, the value of V2G can reach €20/EV/year.

For example, for the residential case, the value of V2H is estimated at €20-30/MWh.

2.2 Method for evaluating the benefit of charge management for local flexibility

Estimation of the collective value of charge management for local flexibility

The value of the estimated local flexibility corresponds to the maximum value for society: this value must be distributed between the different players - network users, distributor, flexibility operators, user of the electric vehicle, etc. The assessment is based either on normative and unit cost values for the energy collectivity not distributed to consumers, or on the gains linked to the deferment of an investment, described in Figure 7 and published by Enedis[38] in 2019.

The estimation of the value of charge management for local flexibility is based on real situations, the needs for flexibility have been studied in detail by Enedis. These analyses make it possible to know, in different illustrative contexts:

- The **necessary power for flexibility** in each situation (1, 2, 3MW…);
- The **time slot** of the need for flexibility (eg night/day);
- **The expectation of the annual need for flexibility** – i.e. the average annual volume of use of the flexibility that can be expected by flexibility providers, if they provide flexibility over several years - defined in MWh of flexibility provided and which assess the value to the local flexibility community.

Furthermore, for each charging profile, the average flexibility that can be offered by an electric vehicle (in kW/EV) was defined as being equal to the average vehicle charging power, depending on its use (in kWh/d) and the charging range defined by the profile (in h/d of charging).

Example for a flexibility brought by residential electric vehicles:

- needing 12 kWh of charge over a period from 8:00 p.m. to 8:00 a.m. has an average power of 1 kW, which it can supply to the grid, even if it means charging later.
- a fleet of 500 vehicles of this type can then provide flexibility of 500 kW over the time slot from 8:00 p.m. to 8:00 a.m.: assuming that each of the 500 vehicles charges 1 kW on average over the period, they can curtail themselves and each provide 1 kW of flexibility, or 500 kW of the 500 vehicles.

In a theoretical area needing **500 kW of flexibility power** over this period, this vehicle fleet would therefore be sufficient to meet the need. If **the expected annual need for flexibility** is 3,000 kWh/year, this corresponds to a total expected value of €60,000/year (at €20/kWh, the maximum value), i.e. a maximum value for the community of €120/EV/year.

37 Or 155 + 70 + 63 + €30/EV/year.
38 Enedis's vision on flexibilities.

Estimation of the capacity of electric vehicles to be significant to provide local flexibility

The assessment of the ability of electric vehicles to provide sufficient flexibility locally in relation to the need is carried out from:

- An **estimate of the development of the electric vehicle in each of the constrained zones** from the prospective scenarios of Enedis concerning electric vehicles and charging points, which are established at the municipal level and by type (residential, business, public, etc.) (in number of electric vehicles),
- The **average flexibility that can be offered by an electric vehicle** in each charging profile, determined previously (kW/EV),
- The **power needed for flexibility** in every situation (1, 2, 3 MW).

Thus, if a constraint area requires 2 MW of local flexibility, 2,000 electric vehicles that can provide an average flexibility of 1kW/EV are needed.

Enedis, partner of electric mobility everywhere and for all

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Definitions and abbreviations

The main abbreviations used in the report are:

LV Low Voltage
RE Renewable Energy
DSO Distribution System Operator
TSO Transmission System Operator
OPH Off-Peak Hours
PH Peak Hours
MV Medium/Average Voltage (20 kV)
HV High Voltage, from the electric transmission network
SCO Smart Connection Offer
PV Photovoltaic
EDN Electricity Distribution Network
EV Electric Vehicle
V2B Vehicle-to-Building
V2G Vehicle-to-Grid
V2H Vehicle-to-Home
CP Charging Point

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