Network development plan

ENEDIS

2023 PRELIMINARY DOCUMENT

Editorial

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The "preliminary" network development plan is the result of an unprecendented work. It aims to meet the high expectations of stakeholders in the French electricity distribution network, an infrastructure vital on a national and local scale. **Its purpose is to show Enedis' commitment by explaining the main challenges for the network and by giving reference values for planned investments in the near future.**

The network managed by Enedis covers 95% of France, and its reliability rate is excellent: over 99.9% everywhere and close to 99.99% on average. Thus, it contributes significantly to the attractiveness of the regions. This performance is made possible by a robust heritage, substantial investments (€4 billion annually), an optimised maintenance, and an efficient operation.

Customer service performance is also enhanced through innovative strategies, including the establishment of a digital network, a digital twin of the physical network: 35 million Linky smart meters are in service on the low-voltage network, thousands of connected devices monitor the medium-voltage network, data analysis and artificial intelligence are employed for the optimisation of investments, maintenance, and network management. All these assets are particularly valuable to meet the unprecedented challenge of climate change by adapting the electrical network. With 80,000 new renewable energy installations connected in 2022, **the energy transition is already a reality for Enedis.**

The objective of the present document is to offer a rich and enlightening content on investments and their methods, in order to **collect comments over time** on this preliminary work and thus contribute to shaping the content of Enedis' network development plan, which will be produced in compliance with regulatory texts on the subject.
These broad exchanges on our investments, launched in early 2023 with our stakeholders, fit in with an ideal schedule to **inform the collective dialogue on the renewal of the multi-annual energy plan (the PPE in French: French national energy and climate plan).**

Enjoy the reading!

Hervé Champenois,
Technical Director, Member of the Executive Board

Summary

The Network Development Plan (NDP) is a new regulatory requirement that applies to electricity distribution network operators. It requires they **outline investments for the next five to ten years** that fall within their remit. This document is intended to be collaborative with all stakeholders and is to be updated every two years.

Enedis has opted to seize this opportunity by providing, in the preparation of this very first exercise, **a preliminary document with a resolutely didactic purpose,** referred to as the "NDP" for simplicity throughout the text. In this document, we affirm the **five following convictions:**

1. The public electricity network holds a significant collective value

By interconnecting users at the European, national, and local levels, the network efficiently pools the generated electricity, including local excess generation, and ensures a reliable power supply to consumers with an excellent back-up coverage in case of unplanned events.

Therefore, the French public electricity network represents a **major collective asset** fostering solidarity between territories in support of energy transition and both national and local public policies.

2. Enedis develops and operates this network within a framework of dialogue and consultation both at the national and local levels

Nationwide, Enedis shapes its medium-term vision through **dialogue with all stakeholders of the electrical system, and defines a framework for optimisation and investment accessible only to a national operator (purchases, equipment ranges, information systems, expertise capacity, innovation, etc.).**

At a local level, the investment decisions made within the concession framework, either by Enedis or by the licensing authority, are closely coordinated.

This dual-level operation, as outlined in the network development plan, is the **model for electricity distribution in France.** It ensures the necessary balance between national issues -such as ecological transition, energy independence, and territorial solidarity- and local expectations regarding the development and attractiveness of each territory.

3. One of Enedis' key expertise lies in its ability to optimise and sequence investment in a complex, uncertain environment with multiple challenges

Enedis' investment decisions go further than investigating the risk of exceeding the maximum transit capacity or the age of its assets; they consider multiple factors:

- **The known present and various possible futures, particularly in terms of load evolution and connection requests.**

- **The measured incident rate, and its projected value based on climatic events or specific risks.**

- **The optimisation of the implementation schedule, costs, and environmental impact, in relation to the benefits in terms of quality of service and resilience.** This involves considering various possible solutions: traditional investments, innovative equipment, and flexibility tenders.

- **The ability to address multiple network challenges simultaneously.**

- **The long-term operability of the network.**

- **The technical framework and its complexity,** including voltage management and protection plans, among other things.

To find this multi-criteria optimum, Enedis operates powerful technical tools, makes the most of its data collected through a digital infrastructure in expansion, and relies on the expertise of its staff.

4. Investment methods must be stable over time to maintain a consistent course in the long run...

The network consists of long-lived assets. As a result, the network operator inherits past decisions, and constrains the future with its present choices.

Therefore, **investment methods** must allow the network aperator to **have a medium- to long-term perspective, by aiming for:**

- **A phased and priority-based approach to long-term renewal and resilience programs.**
- **An evolution of rules that is rigorous, avoiding uncontrolled complexity, and based on experienced feedback regarding predictable or observed impacts on network operation and management.**

Within a collaborative and regulated framework, Enedis remains sole decision-making authority over its investment methods, as it bears daily responsibility for them and their consequences.

The network development plan paves the way for a shared understanding of Enedis' decision process via a didactic approach. It is a valuable tool to discuss current methods with stakeholders, as well as their future evolutions when it applies.

5. ... but they must adapt to a fastening pace due to the energy transition

The sizing rules for electricity networks have always been adaptative, but are now subject to **a noticeable acceleration in their evolution. The energy transition brings a significant volume of connections due to renewable energies and electric vehicle charging infrastructures, thus accelerating the pace of the evolution of the network.** This raises strong expectations among stakeholders and sparks research on innovative solutions that make the best new prospects, particularly in the realm of data.

Enedis is firmly committed to developing new levers, whether technical or methodological. The company experiments and deploys them when feedback from past testing demonstrates a collective benefit.

Specifically, **network flexibilities are an innovative and promising lever** to use the full potential of the network. Their potential must be regularly assessed. To date, only one flexibility prospect (the REFLEX project, see 6.1.1.2) has shown gains sufficient to be considered in the quantified trajectories of the network development plan.

Biennial updates to this document will provide the opportunity to regularly share insights on the reassessment of this lever.

Challenges and quantified outcomes at 5 and 10 years

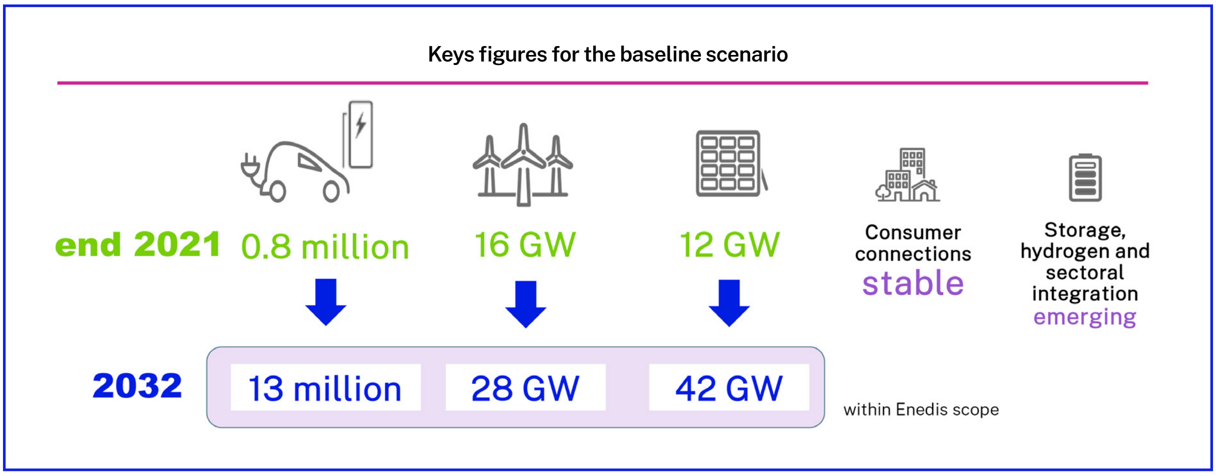
A baseline scenario for the network development plan in line with the objectives set by the multi-annual energy plan (PPE in French, French NECP)

<u>This scenario is based on three fundamentals:</u>

Stability in consumer connections: this is a result of various factors, including a slowdown in demographic growth and a decrease in the average number of inhabitants per dwelling projected by INSEE, leading to an **annual evolution of the number of housing units comparable to current trends.**

Significant development of Electric Vehicle Charging Infrastructure (EVCI): there is a strong correlation at this horizon between the number of vehicles and the number of EVCI.

Robust development of renewable energy installations: the trajectory begins at the level of current achievements and keeps rising.



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Increased investments to address these challenges and maintain network performance

These developments, coupled with **Enedis' investment policies aimed at ensuring network performance,** will result in growing expenditures over the next ten years, excluding investments decided and managed directly by licensing authorities (municipalities, owners of the distribution network signing concession contracts with the DSO for the electricity distribution activity).

These expenses **will increase from €4 billion in 2022 to over €5 billion in 2032. Connection requests addressing the challenges of energy transition (renewable energy sources and EVCI) are the main driver** of additional annual investments.

The scenario regarding renewable energy volumes is based on the multi-annual energy plan (PPE) for 2019-2028 and provides a preliminary estimate in euros. However, recent developments in energy policy, such as the European Commission's Repower EU plan and the French President's declaration on energy policy in Belfort on 10th February 2022, indicate a collective ambition for an accelerated development of renewable energy. This includes a significantly increased ambition for photovoltaics (100 GW by 2050), alongside a downward revision of the previously stated ambition for onshore wind.

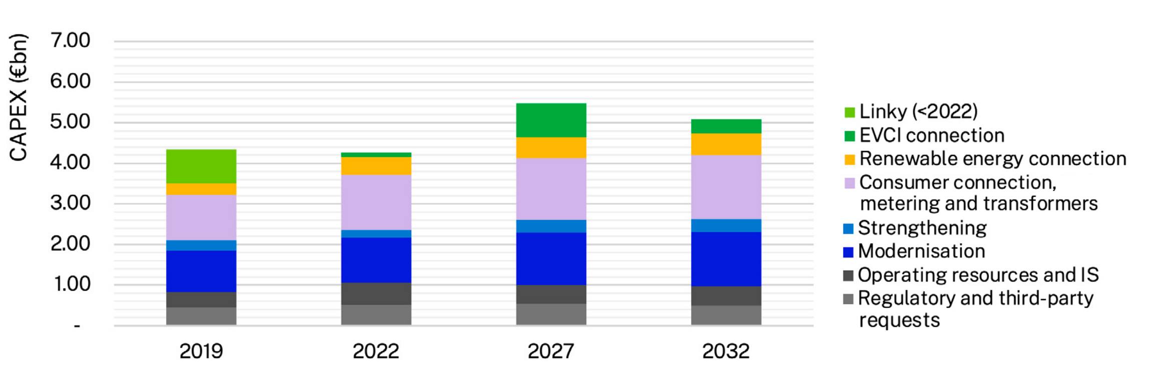
The accelerated trajectory for photovoltaic connection is already noticeable, with the "S21" decree significantly increasing connection requests received by Enedis since the last quarter of 2021. These new elements have not been assessed in this document. Collective discussions around the French energy and climate strategy (SFEC), the new PPE, and the final content of the renewable energies acceleration act will help establish new national reference trajectories for renewable energy. **Enedis will then update the measured trajectory considered in this document** and inherited from the previous PPE.

The EVCI scenario aligns with the objectives of the French national low carbon strategy (SNBC in French) regarding the assumption of the number of light electric vehicles. It has not assessed the potential impact of the electrification of heavy mobility and assumes an average penetration of 50% of Enedis' solution to equip EVCI in collective residential parking areas over the period, with a gradual ramp-up of this solution, currently in the starting phase.

Regarding other categories of Enedis' investments: **reinforcements** (adapting network capacities to load changes) **increase with connections but are kept under control.** Network changes due to regulations and third-party requests (including asset relocations) remain stable. **Investments related to the modernisation and renewal of the network** (ensuring its resilience and performance over time) are programmed over the long-term **following Enedis' established guidelines**. The end of the Linky project, as well as operating resources and information systems not directly linked to network development, are presented here for completeness to provide a comprehensive overview of Enedis' Capital Expenditures (CAPEX).

The figures below, detailed in various chapters of the Network Development Plan (NDP), are presented in non-inflated 2021 euros. **The displayed amounts are neither a commitment by Enedis to invest these sums, nor a maximum limit of investments that may be made.** They provide the current assessment of the amounts that will be required, an assessment that will evolve, particularly according to the actual pace of networks user requests. It is important to emphasize that these figures are estimated within the scope of the remit entrusted to Enedis and **do not include amounts associated within the remit of licensing authorities.**

Summary of annual investment amounts within the Enedis perimeter, by main purpose



Contents

3. Enedis invests to guarantee the long-term performance of the network

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Context and introduction to the network development plan

A deep transformation of the electrical system is underway: integration of distributed generation facilities, end-uses electrification, within a context of new technological opportunities allowing to instrument the network and to take advantage of user flexibilities.

Collective sharing on network development related to these changes is a central issue, and is now a regulatory obligation that applies to Enedis.

The Network Development Plan (NDP), which will address this regulatory obligation and of which the present document is a preliminary version, aims to be more than a projection of investments in the network. It also provides a comprehensive didactic content enabling sharing and exchange with all stakeholders on the distribution context, on the main categories of Enedis investments, on the investment methods, and on the scenario chosen for the NDP, outlining the expected connections over five and ten years, derived from national guidelines.

1.1. The Network Development Plan (NDP), a new regulatory obligation for electricity distributors, is the opportunity for an unprecedented level of communication from Enedis about network investments

A new regulatory obligation for distributors to describe their investments for the next five to ten years in a collaborative way

Article 32 of the European Directive 2019/944 on the internal electricity market, part of the "Clean Energy Package", was transposed into French law by the ordinance of March 3, 2021, creating a new Article L322-11 in the Energy Code.

This article outlines the new obligation for distribution system operators (DSOs) serving more than 100,000 customers to publish a network development plan at least every two years, concerted with stakeholders, indicating investments planned for the next five to ten years and "focusing among other things on the key distribution infrastructure required to connect new generation capacities and new loads, including electric vehicle charging points". The document must also provide "transparency regarding medium and long-term flexibility services that are needed", including the use of alternative resources to network expansion, such as "load management, energy efficiency, and energy storage facilities."

The article specifies that the DSO must consult "all relevant network users, the public electricity distribution licensing authorities […], as well as the relevant transmission network operators regarding the system development plan."

The results of the consultation process and the plan itself are then published and submitted to the French energy regulatory commission (CRE) and the public electricity distribution system committee (CSDPE). It is noted that "the energy regulatory commission may request modifications to the plan".

Enedis seizes this opportunity to broaden the subject and publish an unprecedented didactic document on the challenges and investment methods on the network, targeting professionals but also a broader audience

The legislative requirement for DSOs to publicly and collaboratively communicate prospective investment amounts comes at the right time. As emphasized by recent Intergovernmental Panel on Climate Change (IPCC) reports, the climate emergency leads to a transformation of the energy sector, with an increased electricity consumption due to end-use electrification on one hand, and a need to increase renewable energy production on the other. The public distribution network[1] is therefore facing a significant evolution in the demands of network users, both producers and consumers. The DSO must meet this challenge with controlled investments and a deep dialogue with the stakeholders, including: licensing authorities (owners of the public distribution network, signing concession contracts with the DSO for the electricity distribution activity), network users and project managers for network works. This exchange should be as extensive as possible, and not restricted to the sole ecological transition.

Climate emergency is not the only challenge for Enedis' investments, which must constantly find the technical and economic optimum for the national community, aiming for an achievable network renewal, and for a quality of service and a resilience that meets societal expectations. Enedis relies on existing proven methods, as well as others evolving due to the arrival of 'smart' objects and digital systems.

It is on this entire methodological framework that Enedis has chosen to communicate transparently in this NDP, and in a way that is more accessible to a wide audience than the elements already available in Enedis' public reference technical documentation (DTR), which describes to an informed audience the entire reference framework of current technical prescriptions[2] (*Enedis, Documentation Technique d'Enedis-État des publications au 1er septembre 2021*).

In terms of quantified trajectories, Enedis has chosen to offer an overall view of investments on the public distribution network, relying on a single forecast scenario, described in 1.6.3. Some trends and non-quantifiable developments to date (storage, sector coupling, etc.) are also addressed and will be candidates for evaluation in subsequent NDPs.

The consultations and discussions on the NDP provide an additional opportunity for Enedis to interact with its stakeholders, both on the methodological part (targeting methods requiring in-depth analysis) and on contributing to the national debate on prospective trajectories. The NDP does not present an investment target imposed and curbed by Enedis but rather reveals a prospective trajectory, inherently evolving, which will largely result from the impetus provided by the stakeholders. Updating the NDP every two years will be an opportunity to adapt this trajectory as events unfold.

A "preliminary" status NDP document published by Enedis at the start of the public dialogue in early 2023

Without waiting for the expected content of an NDP, to be defined by decree, Enedis has chosen to produce this document on a national scale and submit it to stakeholders with a "preliminary" status from early 2023.

The objective of the present document is to offer a rich and enlightening content on investments and their methods, to collect everyone's comments over time on this preliminary work and thus contribute to shaping the content of Enedis' network development plan, which will be produced and in compliance with regulatory texts on the subject.

This broad exchange launched early in 2023 with stakeholders on our investments fits into the ideal schedule to enlighten collective reflection on the renewal of the multi-annual energy programming plan (PPEin French, French national energy and climate plan).

Note: In the following text, and for simplicity of reading, it will not be reiterated that the document is in a preliminary status, and it will be referred to as "NDP" or "Network Development Plan."

1. Except for primary substations: according to Article L322-4 of the Energy Code, "However, the company managing the public distribution network, resulting from the legal separation imposed on *Electricité de France* by Article L. 111-57, owns the part of the high or very high voltage to medium voltage current transformation substations that it operates"
2. The DTR sets out the regulatory requirements and technical rules that Enedis applies to all users, including calculation methods, commonly used electrical diagrams, practices resulting from Enedis' industrial choices, models of contractual documents, and information to be exchanged between Enedis and network users.

1.2. The community-dedicated public distribution network, a brief description of a large-scale electrical structure facing new challenges

The network enables access to electricity with the objective of collective optimisation

Electricity is an essential commodity in daily life, and the connection of each user to the public electricity network provides several services: metering, free market choice (choice of electricity supplier for the consumer, choice of customer for the producer), transmission of electricity, an electrical signal meeting quality standards in voltage and frequency, access to a guaranteed power supply 24/7, 365 days a year, with a reliability rate close to 99.99%,[3] permanent troubleshooting service and pooling of needs allowing economies of scale. These are the main missions of the public network, allowing consumers to be constantly supplied with a sufficient quantity of electricity and producers to always valorise their production.

However, one should not aim for an infrastructure that is robust to any event at any cost, which would lead to an unreasonable expense. The interconnected structure of the electrical network is thus a technical and economic optimum in metropolitan France due to its significant advantages compared to a set of isolated systems. For example, to ensure a quality of power supply equivalent to that of the public network, an isolated microgrid would need to install larger storage and production capacities, especially to cover a potential failure. Furthermore, if its production is intermittent, the isolated microgrid can results in a national loss of part of the production as soon as the storages are full and consumption is lower than production.

By enabling the optimisation of power supply security investments, the sharing of production facilities, and the coincidence of consumption, the network is a major driver of comfort and prosperity for the national community.

A large-scale industrial tool composed of different voltage levels.

Within the French electricity network, the public transmission transport network is used at voltages known as “HV” (high voltage) equal to or greater than 50 kV, while the public distribution network is dedicated to voltages below 50 kV, called “MV” (medium voltage, typically 20 kV) and low voltage (“LV” 400V).[4]

In the historical operation of the network, electrical energy is transmitted by the transmission network over long distances from centralised production sites (such as nuclear power plants or hydropower dams) to the distribution network. The primary substations form the boundary between the transmission and distribution networks. At the primary substation, the electricity voltage is changed from HV to MV by a high-power transformer.

At the transformer’s output, electricity is distributed to MV feeders, which are the cables and assets that extend from the primary substation and radiate out over the surrounding geographical area. Depending on the primary substation, the number of MV feeders can vary from less than 10 to more than 50.

An MV feeder, which travels over several kilometers, supplies, along its route, the substations of customers connected in MV and the MV/LV (Medium/Low Voltage) substations, known as "public distribution" substations, which serve low-voltage customers.

This historical operation of the distribution network in a downward mode from the transmission network to low voltage is shifting toward a model that is both upward and downward: electricity is now produced not only by centralised production sites connected to the transmission network but also by increasingly significant volumes of distributed generation facilities connected to the distribution network, in both MV and LV (see figure 1).

3. In terms of outage duration, the average reliability level is close to 99.99%: meaning that out of the 8,760 hours in a year, users of the distribution network experience an unplanned electricity outage for an average of one hour.
4. Article L322-7 stipulates that “The consistency of a public electricity distribution network is defined in the third paragraph of IV of Article L. 2224-31 of the General Code of Local Authorities” For Enedis, it is established that “a public distribution network is constituted by facilities with a voltage of less than 50 kV located within the territory of the licensing authority for electricity distribution”.

Figure 1: electric system description

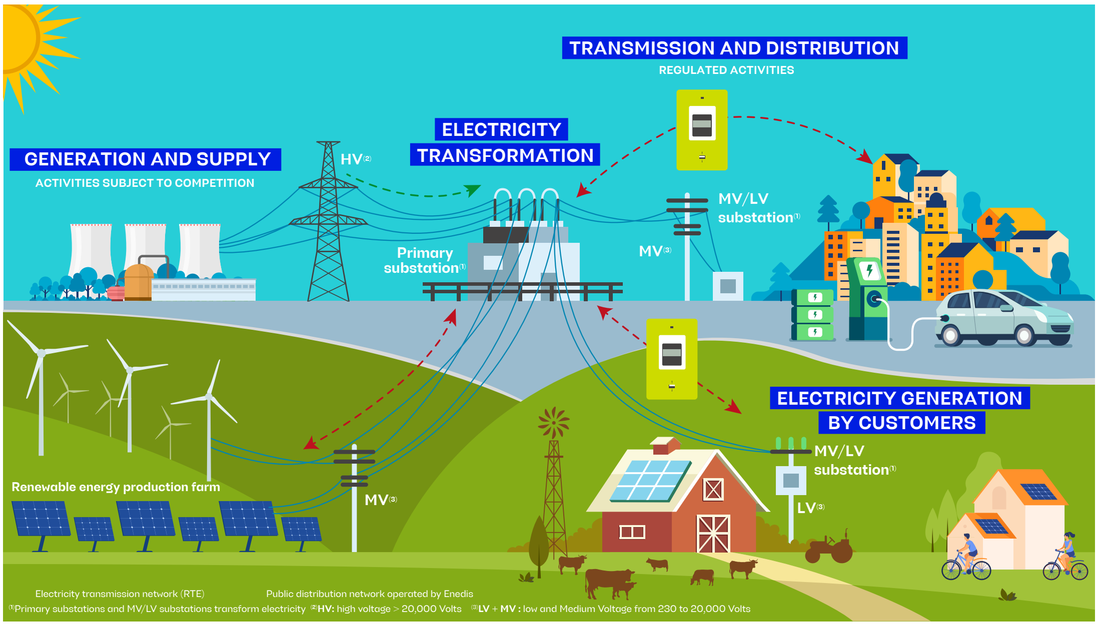

Figure 2: assets of the network managed by Enedis (as of end of 2021)

Number of primary substations	MV overhead grid (km)	MV underground grid (km)	Number of MV/LV substations	LV overhead grid (km)	LV underground grid (km)
2,300	317,500	341,300	801,400	381,000	351,900

Key figures and main infrastructures

Serving 37 million customers, the public electricity distribution network managed by Enedis is the largest distribution network in Europe, consisting of 1.4 million kilometers of electrical lines evenly distributed between buried cables (underground network) and cables suspended on poles or attached to facades (overhead network). Figure 2 presents the key figures of the mentioned infrastructures.

The primary substation – the network comprises 2,300 primary substations, with an average of 10 new primary substations created each year. A primary substation includes transformers, monitoring, protection and remote control equipment, energy metering devices, and automatic load shedding systems to contribute to the safety of the electrical system. Physically, these facilities are integrated into an enclosure of several hectares in rural or peri-urban areas (see figure 3). In urban areas, the primary substation is sometimes entirely underground or integrated as well as possible into its urban environment. Primary substations are operated jointly with RTE, which owns and is responsible for the HV (high voltage) part of the substations.

Figure 3: a primary substation [63 kV to 20 kV] in Cap Ferret

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Figure 4: overhead public distribution substation: MV network on the left, MV/LV transformer on a pole, twisted LV network on the right.

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The MV network – the network comprises more than 31,000 MV feeders:[5] 341,300 km of underground network and 317,500 km of overhead network. It serves consumers and high-power producers, as well as public distribution substations (over 800,000 substations) that interface with the LV network: see an example in figure 4. Its voltage level is mostly 20 kV, but other voltage levels (15 kV, 10 kV, etc.) still exist due to historical choices. They are gradually being phased out to facilitate the connection of primary substations for mutual assistance, maintenance, and standardisation of equipment.

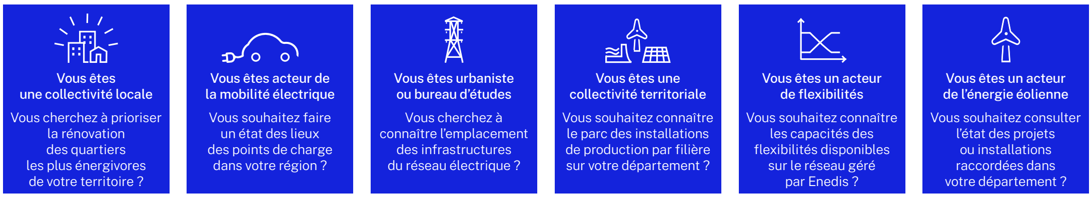
The LV network –the network comprises more than 2,200,000 LV feeders:[6] 351,900 km of underground network and 381,000 km of overhead network. It serves a vast majority of customers (residential, commercial, small industry, etc.). Its voltage level is 400 V. Its tree-like structure extends to the electricity meters at the limit of the network and the installations of each customer.

The reader interested in summaries or details at various geographical levels is invited to visit the dedicated platform that provides Enedis' open data, one of the most comprehensive among infrastructure operators in Europe (https://data.enedis.fr/, see figure 5).

Another information-rich publication is the Enedis electricity report (https://www.enedis.fr/le-bilan-electrique), which provides data on injected, withdrawn, produced, or consumed energy in the Enedis network on a monthly and annual basis, specifying extreme values and analysing trends.

5. An MV feeder is defined as all the MV assets powered from the same circuit breaker cell of a primary substation (see 5.2.2).
6. An LV feeder is defined as all the LV facilities powered from the same fuse cell of a public distribution substation.

Figure 5: Enedis' website dedicated to providing open data



A role and challenges in constant evolution

The distribution network remains more than ever the electrical backbone of the country and must adapt to three ongoing developments:

- The advent of distributed generators:

The arrival of distributed generators assigns to Enedis the new task of connecting producers. About 85% of new renewable energy installations are connected to the distribution network, either in LV or MV depending on their power. Electricity flows have become bidirectional, with consumption drawing out power and distributed generators injecting it. The growth in the number of renewable energy producers results in the backflow of electricity from the distribution network to the transmission network through certain primary substations: at certain times for some, permanently for others.

- End-use electrification and evolution:

In the context of ecological transition, the end-use electrification is a major lever for reducing CO_2 emissions, leading to a clear increase in electricity consumption levels. Societal behavior changes are also underway, such as the development of individual and collective self-consumption to promote local production or efforts to control energy demand.

The network must adapt to all these usage changes, both in volume and form.

- The emergence of 'smart' solutions:

New means of observability and control are being developed. The emergence of "smart" solutions, rooted in digital and communication technologies, allows for a more in-depth strategy for the end user to temporally shift their consumption or production to leverage this flexibility at various levels (reducing the bill by optimising the price of purchased energy, contributing to RTE system services,[7] or national supply-demand balance,[8] etc.).

These controllable loads are inherently more variable and harder to predict than traditional loads. When it comes to optimising the networks, the load coincidence on a network zone incorporating controllable loads can be more complex to calculate than if it only included traditional loads, and Enedis faces the new challenge of assessing the risk to the distribution network of loads potential resynchronisation resulting from a control that does not fall within its remit.

Moreover, the DSO must also be able to seize the opportunity of the value –when it exists– of these flexibilities for the network, by implementing them for its own use, for example to save on local investments.

7. "System services" are part of RTE's national missions in the management of the French electrical system: ensuring at all times a stable frequency at 50Hz (the frequency being monitored at the level of the interconnected European network) and regulating the voltage. An installation of production or consumption that can quickly adjust its operation can offer its contribution to these services (also called primary and secondary adjustments). They are the subject of dedicated markets organised by RTE, and Enedis is involved by enabling the participation of sites connected to its network in these markets.
8. The national supply-demand balance (electrical production/consumption) must be guaranteed at all times, with the risk, among other things, of a frequency drift that could lead to a widespread collapse of the electrical system ("blackout"). RTE deploys short, medium, and long-term forecasts to ensure this balance over time. In the case of a sudden accidental breakdown leading to an instantaneous imbalance, rebalancing takes place in real-time through system services, which involve installations that can react very quickly. In parallel, RTE uses the adjustment mechanism to issue a call for tenders to select the most efficient installation (that can be connected to the distribution network) capable of restoring the observed imbalance very quickly after its temporary restoration. This same type of tender on the adjustment mechanism is used in the case of a short-term forecast imbalance alert, which may arise from consumption deviating from initial forecasts (unexpected climatic event, for example) or from an unforeseen event that would impact the generation plan.

INFORMATION PANEL I

Investments in the distribution network involve civil engineering works

Investments in the network managed by Enedis often take the form of civil engineering works, whether it's installing new cables under the road or along the roadside, or creating transformer stations. For this purpose, Enedis relies on a rich network of local service providers.

UNDERGROUNDING NETWORK IN URBAN AREAS

The undergrounding of the network in urban areas requires opening the road surface or sidewalk. The cable is then laid in the trench before backfilling and road surface restoration.

UNDERGROUNDING NETWORK USING A TRENCHER

The use of a trencher enables efficient and rapid execution of the works: in a single operation, this machine excavates and lays the cable.

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INSTALLATION OF A NEW HV/MV TRANSFORMER IN A PRIMARY SUBSTATION

In primary substations, excavation works are carried out to create a flat and sufficiently sturdy platform to accommodate equipment, some of which will be buried. To assemble the substation, HV/MV transformers, that weigh several tons, may require the establishment of deep foundations to ensure stability over time.

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INSTALLATION OF OVERHEAD LV NETWORK TO CONNECT A PRODUCER

As illustrated in the photos below, creating a section of overhead LV network requires the installation of supports for overhead power lines. These supports can be made of wood, concrete, or metal.

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INSTALLATION OF A NEW MV/LV TRANSFORMER IN A PUBLIC DISTRIBUTION SUBSTATION

There are two categories of public distribution substations: pole-mounted substations with limited power, which are supplied by an overhead MV network (see figure 4), and prefabricated, masonry, or building-mounted substations connected via an underground MV connection (see photo opposite). The construction works for a ground-level substation include, among other things, choosing the location of the facility, grounding, installing the substation, and installing and connecting electrical equipment, including the transformer.

1.3. Enedis and its national missions as a distribution system operator

Enedis is a distributor resulting from the liberalisation of the electricity market, remunerated through the TURPE (public electricity networks utilisation tariff).

The liberalisation of the electricity market[9] separated open to competition activities from regulated activities. The unbundling modalities were strengthened with the key step of creating, on 1st January 2008, a subsidiary of the EDF group dedicated to electricity distribution (ERDF, renamed Enedis in 2016).

Enedis is remunerated through the public electricity networks utilisation tariff (TURPE), set by the French energy regulatory commission (CRE) and defined by decree. This tariff varies according to the customer segment. It is nationally equalised (each user pays a national price, which does not precisely reflect the actual local cost it incurs for the network) and is independent of the distance traveled by electricity to supply the consumer (the so-called "postage stamp" principle) (see (*Enedis, L'essentiel - TURPE 6 HTA / BT (Tarif d'Utilisation des Réseaux Publics d'Électricité)*). In the most common contractual framework (known as the "single contract"), TURPE is invoiced by Enedis to electricity suppliers, who integrate it into their offer to the final consumer. TURPE can also be invoiced directly by Enedis to customers, usually of significant size (through the distribution network access contract or CARD mechanism).

As a distribution system operator (DSO), Enedis fulfills multiple missions

According to Article L322-8 of the Energy Code, the DSO is responsible for missions in the following areas:[10]

- networks design and development;
- connection and access to the network under objective, transparent, and non-discriminatory conditions;
- providing network users with the information necessary for efficient networks access, in the framework of information protection stated by legislative or regulatory requirements. This includes assessing the impact on the network of submitted projects regarding the integration of renewable energies, deployment of charging devices for electric and plug-in hybrid vehicles, urban planning, and energy planning;
- network maintenance;
- network operation;
- and metering activities for users connected to the networks it operates.

The network development plan focuses on the DSO's missions related to investment in the networks

The network development plan is intended to shed light on how the DSO "defines and implements the investment and development policies of the distribution networks". It will thus primarily address these missions.

Investment missions shared with the licensing authorities

Enedis carries out these missions on a daily basis within the institutional framework of concessions specific to the French electricity distribution network. As detailed in 1.4, Article L. 322-6 of the Energy Code allows local authorities to manage part of the works by themselves. The missions entrusted to the DSO by Article L322-8 are thus "without prejudice to the provisions of the sixth paragraph of I of Article L2224-31 of the General Code of Local Authorities." It is important to emphasize that the scope of the DSO's activities may differ depending on the role performed: by the provisions of Article 322-6, the scope of Enedis' project management is thus less extensive than the scope of maintenance and operation, which covers all the licensed networks.

9. Directives 96/92/CE, 2003/54/CE and 2009/72/CE and their national transposition.
10. This list is not exhaustive. The reader can refer to the articles L322-8, 9 and 12 of the Energy Code for a more comprehensive view of the missions entrusted to DSOs.

These investments must enable the DSO to fulfill its network operation mission

Each investment made on the network, by Enedis or by one of the licensing authorities, is intended to be handed over to the operating teams and included in Enedis' maintenance scope.

On a daily basis, these operating teams intervene on the networks to connect new installations, carry out maintenance or upkeep work, troubleshoot in the event of an incident, and when necessary, work to restore supply or activate exceptional intervention means and coordinate them (including the rapid electricity intervention force, FIRE).

The management teams[11] will be responsible, among other things, for adapting to possible hazards in operating conditions, whether observed or forecast. This may include, for example, maneuvering elements of the network to temporarily modify its topology.

The development and operation of networks contribute together to quality of service and cannot be considered separately

There is a strong technical link between networks development and their operation:

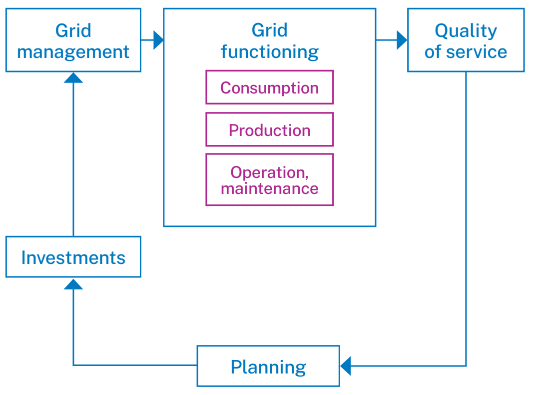
The networks operation and management functions are impacted by the investment choices of the two project managers on the network (Enedis and the licensing authorities). They operate a previously developed infrastructure under real conditions, adapting to unforeseen events using the levers made available to them.

The network development function must anticipate the use that the operation and management teams will make of the means it provides. Over a long period of several decades, it assesses the situations that management teams will have to cover and includes the way they will use the provided means.

This dialogue must ultimately ensure that the network can be maintained, managed, and operated in compliance with the established requirements.

Therefore, the distributor's various functions should not be seen as independent elements in a one-way timeline, but as building blocks of a loop in perpetual adaptation (see figure 6):

Figure 6: links between the distributors' technical functions



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Thus, contrary to popular beliefs, the purpose of the network development function is not to develop the networks (!). It should enable the DSO to find the best balance for the community by choosing the best options across these different "functions".[12]

While network operation and management are not the main theme of the NDP, they are not absent due to their connection with network development. They will be discussed throughout the document, particularly in section 3.1.1.

An illustration of this intimate relationship between network development and operation will be demonstrated by the DSO's view on flexibilities: flexibilities can be a technical and economic alternative to network development if, in operation, they achieve the initially expected service level. It is necessary for the use of flexibility services to be reliably available when needed, in order to ensure an efficient risk transfer between long-term planning and short-term challenges.

11. This concept aligns with the provisions outlined in the Energy Code, Article L322-9: "Each public electricity distribution network operator ensures, at all times, the balance of electricity flows, the efficiency, safety, and security of the network it operates, taking into account the technical constraints on the latter".
12. This link can also be illustrated by Article L322-12 of the Energy Code, which relates to electricity quality: the law states that "the managers of public electricity distribution networks design and operate these networks in such a way as to ensure a regular, defined, and compatible quality of electricity supply with the usual uses of electrical energy". The expected result comes from both the development and operation of the networks.

1.4. Enedis, licensed operator covering 95% of the metropolitan French territory: network development joint management with licensing authorities within a framework set by regulations and the concession contract

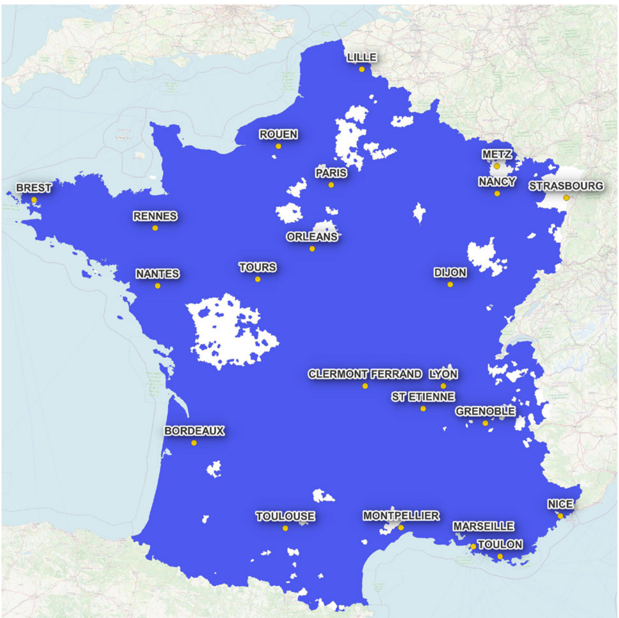
The network concession is granted to the operators who ensure its management...

During the liberalisation of markets, the specificities of the French regime for electricity distribution were maintained: public electricity distribution is a local public service under the concession system. In metropolitan France, excluding Corsica, the licensed operators are Enedis or the local distribution companies (ELD) in their respective service areas (see figure 7). With the exception of the primary substations, the licensed operator does not own the network assets, which belong to the local authorities, but it has a monopoly in its exclusive service area.

... within the framework of concession contracts

Concession contracts are signed between Enedis and the licensing authority for the network part, with EDF also signing the contract for the part concerning electricity supply at regulated sales tariffs (TRV). The signing licensing authority is defined by the law of the 15th June 1906, which specifies that the concession is the responsibility of the community: either a municipality or an intermunicipal union, with possible and even recommended groupings. With Law No. 2014-58 of January 27, 2014, on the modernisation of territorial public action and the affirmation of metropolitan areas (MAPTAM), large cities, and urban communities can replace their members within electricity unions.

Figure 7: map of Enedis/ELD perimeters (INSEE 2022 municipalities)



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Electricity distribution concessions have specificities compared to the common law of concessions. The regime of these contracts derives from the right held by the DSO in its service area (Article L. 111-52 of the Energy Code): there is, therefore, no competitive bidding procedure.

A framework agreement was signed with the federations of licensing authorities (FNCCR and France Urbaine) in December 2017 for a new concession contract model. These negotiations were an opportunity to draft the outline of a new balanced relationship, improving coordination, defining investment master plans (SDI) and multi-year investment planning (PPI).

Urban or rural areas: a significant municipalities classification in the distribution world

The notion of rural area is defined through the geographical perimeter of rural electrification[13] (ER), updated by decree at the municipal level every 6 years after municipal elections. Some entire departments are classified as 100% urban by derogation.

As of 1st January 2021:

- The urban area in the sense of rural electrification represents nearly 8,600 municipalities (26% of the municipalities in Enedis' service area), 48 million inhabitants (77% of the population), and 15% of the geographical area of metropolitan France.

- The rural area represents nearly 25,200 municipalities (74% of the municipalities in Enedis' service area), 14 million inhabitants (23% of the population), and 85% of the geographical area of metropolitan France.»

The allocation of project management between the licensing authority and the licensed operator depends primarily on the rural electrification classification and is specified locally in each concession contract

The tasks assigned to the DSO -in its exclusive service area - by the Energy Code, outlined in the concession specifications, cover both project management (definition and implementation of investment and network development policies) and their operation, maintenance, and upkeep. However, Article L. 322-6 of the Energy Code allows local authorities to handle a portion of the project management of the work by themselves. The distribution of project management between Enedis and the licensing authority (or the electricity distribution concession authority, AODE) depends on the concession municipalities, on the type of work, and is specified case by case in each concession contract:

For the aesthetic improvement of existing facilities, the licensing authority is usually the project manager, unless otherwise chosen, for the integration work of assets into the environment throughout the concession territory.

The licensed operator contributes to the financing of these works through an annual contribution (generally 40% of the cost of the works), which amount and associated conditions are formalised in a convention known as "Article 8" between the AODE and Enedis. As an exception, some licensing authorities may want the project management of "Article 8" works to be handled by the licensed operator. In this case, Enedis bears 100% of the cost of the works, and the licensing authority pays a financial contribution of 60% of this amount.

For other categories of works, the main criterion for the allocation of project management between the licensing authority and Enedis is the electrification regime of the municipality:

- In municipalities under the urban regime, the licensed operator is generally the sole project manager;

- In municipalities under the rural electrification (ER) regime.

  - The licensing authority may be entrusted with the project management of works to reinforce and secure LV networks, as well as some connection works (excluding producers connection and generally excluding branch connections);

  - Moreover, the 2017 framework agreement signed with the FNCCR and France Urbaine opens the possibility for licensing authorities, if they wish, to carry out the initial connection to the LV network for mixed consumption/generation installations with a production capacity of less than 6kVA (36kVA when these mixed installations concern public buildings).

The exact distribution of the project management scope is determined in each concession contract.

13. Defined by the decree n° 2020-1561 of 10 décembre 2020 on assistance for rural electrification.

1.5. The NDP's place within the various existing processes for dialogue on methods and investments

The NDP is part of an existing rich set of dialogues on investments (see figure 8).

On the one hand, there is a broad framework that establishes a dialogue on methods and vision, relying on orders of magnitude, macroscopic trajectories, prospective scenarios, and national frameworks (see 1.5.1). On the other hand, a set of decision-making processes on investments unfolds at the local level, in coordination with stakeholders, and at different time intervals (see 1.5.2).

These two worlds engage in constant dialogue to mutually inform each other.

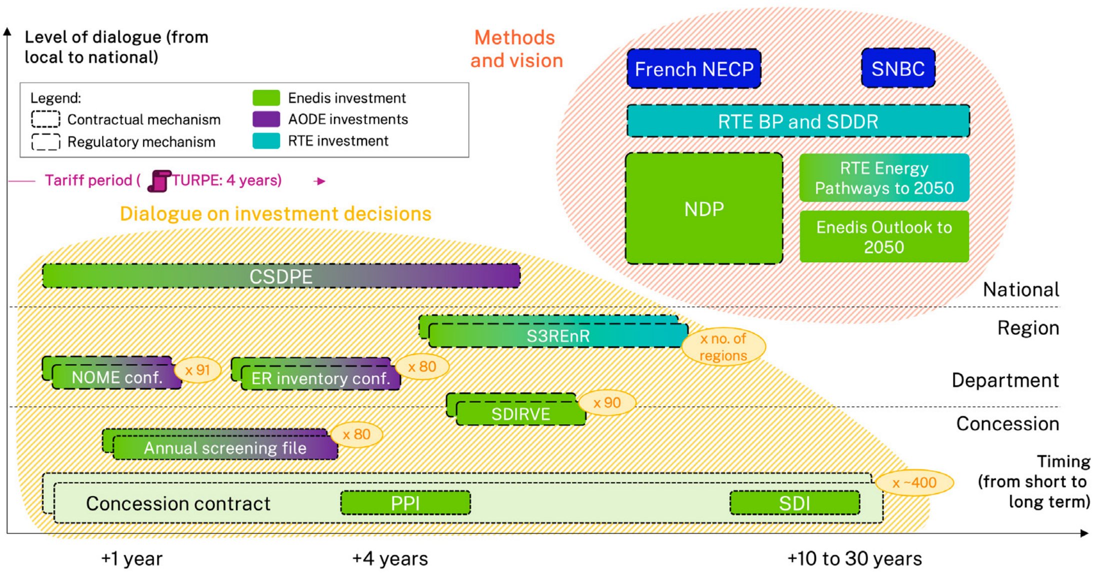
1.5.1. The dialogue on vision and methods: NDP finds its place within a highly comprehensive national framework.

There is already a range of prospective and concerted long-term documents...

France is one of the very first countries in the world to have incorporated the objective of carbon neutrality into its legislation through Article 1 of the Energy-Climate Law of the 8th November 2019. It thus plans to achieve net zero greenhouse gas emissions by 2050. In the long term, national targets are guided by public policy orientations: the multi-annual energy plan (PPE, French NECP), the national low-carbon strategy (SNBC), and, in the future, the French energy climate strategy (SFEC), which will be the national roadmap to achieve carbon neutrality by 2050, and to diversify the energy mix, ensuring supply security and competitiveness.

To consider the possible implications of these public policy objectives, and given the uncertainty associated with very distant time scales, it is essential to describe the range of possible scenarios. This is what the RTE document *Futurs énergétiques 2050* does, which, with reference to the PPE and the SNBC, describes possible visions in 2050 regarding the electrical system and the supply/demand balance (see informational panel III: *futurs énergétiques 2050*). The central issue here is to describe the broad scenarios of potential production and consumption towards which the country is heading.

Figure 8: NDP's position within the overall framework of dialogue on investments



Based on these visions, which have undergone numerous public consultations, scenarios and their consequences on the network can be developed. The publications by RTE at the France level, it's worth to mention the chapter 10 "*les réseaux*" of the *Futurs énergétiques 2050* report, the forecast balance (*Bilan prévisionel*), and the ten-year network development plan (SDDR, see informational panel IV: the ten-year network development plan (SDDR)). Enedis has also published prospective elements within its distribution scope, in the form of a long-term vision by 2050 (*Enedis, Éléments de prospective du réseau public de distribution d'électricité à l'horizon 2050*) (see informational panel II: elements of Prospective 2050).

...in which the NDP fits, using a scenario consistent with these trajectories

It is alongside these documents that Enedis' NDP finds its place.

In this first NDP exercise, Enedis has chosen a single baseline scenario, reserving scenario development for more distant deadlines. However, while this scenario, aimed at presenting and inter-comparing the issues, is unique, it is certainly not set in stone, as Enedis will adapt to connection requests from actors, regardless of their volume. The biennial update of the NDP will also allow for a regular reassessment of the trajectory presented for the five- and ten-year horizons.

The baseline scenario of this NDP, described in section 1.6.3, has been chosen to be consistent with the "Transition" scenario of the Enedis' Prospective 2050, covering the common years, as well as with the "N1" scenario of renewable energy integration presented in RTE's document *Futurs énergétiques 2050*. It is an adaptation at the scale of the public distribution network managed by Enedis.

INFORMATION PANEL II

Enedis' prospective 2050

The first Enedis prospective report on the challenges of transforming the public electricity distribution network by 2050 was published in April 2021 (*Enedis, Éléments de prospective du réseau public de distribution d'électricité à l'horizon 2050*).

By combining multiple technical and strategic data, along with analyses of production and consumption, this report enables Enedis to anticipate upcoming challenges for the public distribution network at both the local and national levels. It prepares adjustments to be made in response to the network's technical needs, societal expectations, and those of its employees.

Given the differences in each territory, local data was considered wherever possible, including demographics, housing, economic activity, meteorology, etc. This approach provides results at both the national level and targeted local scales. The detailed analysis of consumption, production, and their prospective evolution is made possible by Enedis' territorial anchorage and national dimension. Four scenarios were thus established and detailed:

- **Stagnation:** economic stagnation and slowed ecological transition;
- **Continuity:** regular economic growth and continuation of trajectories defined by the French multi-annual energy plan (PPE);
- **Transition:** regular economic growth, predominant solar production, and chosen sobriety;
- **Rupture:** strong growth in the economy, population, and distributed electricity generation, 100% renewable energy.

INFORMATION PANEL III

Futurs énergétiques 2050 (Energy pathways to 2050)

In 2019, RTE initiated a wide study on the evolution of the electrical system titled "*Futurs énergétiques 2050*" (Energy pathways to 2050). This study resulted from an unprecedented process of consultation and transparency involving interested stakeholders at all stages of scenario development, leading to the publication of main results in the fall of 2021 and their complete analysis in February 2022. Enedis contributed to this study by assessing cost evolutions related to the distribution network.

This consultation led to the stabilisation of scenarios for electricity generation and consumption that achieve carbon neutrality by 2050. These scenarios share common features: a decrease in final energy consumption, an increase in the share of electricity, and a strong growth of renewable energies in electricity generation. However, they describe contrasting developments for the nuclear sector and for the share of renewable energies in the electricity mix.

The "*Futurs énergétiques 2050*" study analyses changes in consumption and compares six scenarios for the electrical system that ensure security of supply, in a 2050 context of low-carbon electricity.

- **Scenario M0**: 100% renewable energy in 2050
- **Scenario M1**: distributed renewable energy
- **Scenario M23**: large-scale renewable energy
- **Scenario N1**: renewable energy + new nuclear program 1
- **Scenario N2**: renewable energy + new nuclear program 2
- **Scenario N03**: 50% renewable energy, 50% nuclear in 2050

1.5.2. Dialogue on local decision-making regarding Enedis' investments: the NDP provides additional information in support of local discussions

Within the framework of financial trajectories and national industrial policy, it is local needs and dialogue with licensing authorities that determine the commitments made at the level of each concession.

To ensure the proper execution of public service, the DSO and the licensing authority agree to establish, in a concerted manner, a governance system for investments in the concession's network, including the renewal of assets. This system is articulated as follows:

- An investment master plan (SDI) in the public electricity distribution network, corresponding to a long-term vision of network developments in the concession area;
- Multi-year investment programs (PPI) corresponding to a medium-term implementation of the master plan;
- An annual investment program for both the DSO and the licensing authority, based on each of the multi-year programs.

For more details, see informational panel V: investment master plan–multi-year investment program.

The implementation of these provisions takes into account national and regional guidelines defined by public authorities regarding investment, power supply and quality of service, energy efficiency, renewable energy development, and regional planning. This includes those defined by regulatory planning schemes applicable in the concession area, as well as financial resources resulting from tariff decisions.

The departmental conferences established by the NOME law,[14] known as NOME departmental conferences, fit into a recently modernised regulatory framework (decree, order of 2020) and aggregate short-term decisions at the departmental level (see informational panel VI: NOME departmental conferences).

The public electricity distribution system committee (CSDPE), created by the law 2015-992 of 17th August 2015, is responsible for reviewing the investment policy of Enedis, local electricity distribution companies[15] (ELD), and the licensing authorities for public electricity distribution. It issues opinions[16] on these matters. The CSDPE is also the recipient of the NDP and of the consultation report following the external consultation phase by the DSO. It is responsible for giving opinions on these elements produced under the responsibility of the DSO (see informational panel VII: public electricity distribution system committee (CSDPE)).

INFORMATIONAL PANEL IV

French ten-year network development plan (SDDR)

The publication of the French ten-year network development plan (SDDR) is one of the responsibilities entrusted to RTE by law. Public authorities must be able to rely on this document and use it as an operational vector for implementing the multi-annual energy program (PPE, French NECP).

In September 2019, following extensive public consultation, RTE published its SDDR, presenting the evolution of the transmission network until 2035. The key principles of this plan aim to optimise the costs associated with adapting the network to the energy transition and limit its environmental impact.

It adopts the methodological principles of the *Bilan prévisionnel*: employing a multi-scenario approach with explicit assumptions, setting out detailed financial trajectories, and incorporating numerous variants (consumption, geographic development of renewable energy, evolution of the nuclear fleet, etc.). All of this allows the document to present the evolution of all the challenges concerning the transmission network (industrial, societal, environmental, and financial).

The SDDR presents five industrial components that align with the five recommendations of the PPE regarding the need to orchestrate the first major transformation of the network since the 1980s:

- Initiate the first **renewal** of the transmission network since its creation and be in a position to significantly increase efforts by 2030 (around +30%);
- **Adapt** the network to the new energy mix: handle new flows by increasing the capacity of current lines, building new ones, or removing no longer needed lines;
- Continue to develop and adapt the **digital backbone** of the network while strengthening cybersecurity requirements and enabling new technologies to operate the current network as close as possible to its limits, and reduce the need for new infrastructure;
- Double France's **interconnection** capacity within 15 years, to make the most of differences in consumption and production in Europe and achieve a balanced and economically sustainable mix by 2035;
- Build a **network to connect marine energies.**

14. Law n° 2010-1488 of 7th december 2010 on the new organisation of the electricity market.
15. Based on investments reported during NOME departmental conferences.
16. Article L111-56-1 of the Energy Code.

INFORMATIONAL PANEL V

Investment master plan – multi-year investment program

INVESTMENT MASTER PLAN (SDI)

The investment master plan serves to articulate, within a coherent framework, the respective investment priorities of the DSO and the licensing authority, in accordance with the allocation of project management defined by the concession contract. It covers the duration of the concession contract.

Drawn up on the basis of historical data and a technical diagnosis of the network shared between the DSO and the licensing authority, the investment master plan describes the main developments projected for the territory of the concession. These developments include addressing the renewal needs of facilities, expanding the network to accommodate electricity production installations from renewable energy sources, and ensuring network security. It does not prejudge investments related to connection operations.

The investment master plan defines benchmark values for quality of power supply and facility reliability, guiding investment choices. The plan is established in coherence with the planned investments on the public distribution network in neighboring concessions served by the DSO. The plan offers a technical vision of medium-to long-term developments envisaged for the network. It is updated in a concerted manner between the parties in case of significant changes affecting the technical and economic conditions of public electricity distribution in the concession. It can also be updated, as needed, to account for the implementation of multi-year investment programs.

MULTI-YEAR INVESTMENT PROGRAMS (PPI)

Multi-year investment programs go through a 3-step cycle:

- Establishment:
    - For the implementation of the investment master plan, the DSO and the licensing authority cooperatively develop multi-year programs, detailed by purposes, for the investments of each project manager, including assets renewal, by four years periods, until the normal term of the concession.
    - A multi-year financial commitment from Enedis is associated with each PPI.
- Annual implementation and evaluation:
    - Each multi-year program is broken down into annual programs, which are included in the forecasted programs presented in the NOME departmental conferences.
    - The implementation of each multi-year program and its effectiveness are measured, respectively, by monitoring indicators and evaluation indicators, defined in consultation during the establishment of the program. An update on the progress of the multi-year program is carried out between the licensing authority and the DSO, at least at the time of NOME conferences preparation.
    - Each of these multi-year programs is updated as needed, at the initiative of the licensing authority or the DSO, after consultation between the parties.
- Review:
    - At the end of each multi-year program, the parties meet to establish the review of investments actually carried out, especially concerning the financial commitment made. On the basis of this review and the agreed technical indicators, the parties agree on the next multi-year investment program.
    - An escrow mechanism, which may lead to penalties, is provided in case of non-fulfillment of the commitment made during the establishment of the PPI.

INFORMATIONAL PANEL VI

NOME departmental conferences

The departmental conferences established by the NOME law of 7th December 2010, aim to strengthen dialogue between project managers investing in the public electricity distribution network (DSO and the licensing authority) and lead to establishing a common dynamic so that the resources implemented, respecting the prerogatives of each party, beyond sharing national guidelines, are harmonised to:

- Ensure the robustness of public electricity distribution networks.
- Direct available resources towards major national and local issues (network security and electricity distribution quality).
- Facilitate consultation between local actors – licensing authorities and distribution organisations – to optimise the synergy of investment policies.

In practice:

- The Prefect chairs the conference.
- Preparatory exchanges between Enedis and the licensing authorities are essential to share a diagnosis and investment priorities.
- The financial trajectory and the work program communicated by Enedis in the conference have an indicative value; the conference is not intended to decide on an investment program (which falls under the contract, see SDI-PPI).

The departmental synthesis includes:

- A description of the assets managed by the DSO in the department.
- A synthetic diagnosis on the quality of supply and continuity in the department.
- The DSO's investment priorities in the department and, if necessary, outside the department.
- Investments, classified by purpose, the main projects carried out in the department or contributing to the quality of supply in the department, and the investments and main projects planned over the next two to three years.
- Any other information that the DSO deems useful in presenting its investment policy in the department.

The decree of 6th January 2020, specifies the format of the expected indicators for the description of the assets and the synthetic diagnosis on the quality of supply and continuity, as well as for investments by purposes for the realised year (N-1), the planned year (N), and the forecast year (N+1).

INFORMATIONAL PANEL VII

The committee for the public electricity distribution system (CSDPE)

The committee for the public electricity distribution system (CSDPE) is responsible for examining the investment policy of Enedis, local electricity distribution companies, and the organising authorities of public electricity distribution, and for issuing opinions.

As such, the committee receives:

- Forecasts of all investments planned on the distribution network, established by departmental conferences.
- Syntheses developed by departmental conferences as well as a summary of exchanges between the DSO and licensing authorities.
- At its request, summaries and detailed reports associated with these conferences, on which it can also give an opinion.
- The network development plan and the associated consultation report.

The committee is also annually informed of the investments made by DSOs for the current year.

The committee includes representatives of:

- the State (energy, territorial communities, and economy ministries),
- territorial authorities (intermunicipalities and regions),
- organising authorities of public electricity distribution,
- local distribution companies and Enedis.

Chaired by the representative of local authorities or organising authorities for electricity distribution, the secretariat of the CSDPE is provided by Enedis. Its role is:

- to produce a national (and, where appropriate, regional) synthesis to prepare the committee's work;
- to produce reports of meetings and to draw up an annual activity report on the committee's work and the follow-up of opinions;
- to publish the committee's work on the CSDPE website. The vision of indicators and investments shared in NOME departmental conferences has been available on the Internet for CSDPE members since late 2021.

Other exercises with the licensing authorities allow for discussions on local investments, including:

- Annual reporting in the licensed operator's activity annual report (CRAC), including the annual monitoring of the PPI provided in the contract.
- The control of the licensing authority.
- Meetings within the framework of the PPI monitoring.
- Dialogue within the framework of the **"quality" decree.**[17]

Dialogue about Enedis' investments also takes place during the elaboration of the regional renewable energy connection master plan (S3REnR), the master plans for the deployment of electric vehicle charging infrastructure (SDIRVE), and through bilateral relations with RTE and the local electricity distribution companies.

The NDP does not replace these various mechanisms; it enlightens them by providing a global vision of the issues, a national baseline scenario, and a description of the methods followed for investment. Informational panel VIII: illustration of a dialogue with territories regarding urban planning and land for substations, provides an illustration of one of the local dialogue issues.

17. Decree n°2007-1826, codified at the end of 2015 within the Energy Code (D322-1 à D322-10), see informational panel XXIII: the regulatory framework for quality.

INFORMATIONAL PANEL VIII

Illustration of a dialogue with territories regarding urban planning and land use for primary substations

The growing need for electricity (described in section 2.1) leads Enedis to build not only networks but also primary substations.

Enedis is often faced, at least in dense urban areas, with the difficulty of acquiring land because local authorities prefer to reserve it for the “economic” development of their territory (residential urban planning, etc.). The required space varies depending on the substation’s technique: for an in-building primary substation, it will be around 2,500 m^2 to 3,000 m^2, while for an open substation, it will be 5,000 m^2 to 7,000 m^2 in HTB1 (90kV and 63kV, voltage levels of RTE’s “subtransmission network”) and 10,000 m^2 to 12,000 m^2 in HTB2 (225kV and 400kV, voltage levels of RTE’s “transmission network”). This area can accommodate a target structure of a substation with three HV/MV transformers, allowing the primary substation to evolve with the changing needs without acquiring new land. Enedis optimises these surfaces to be able to carry out work without impacting customers.

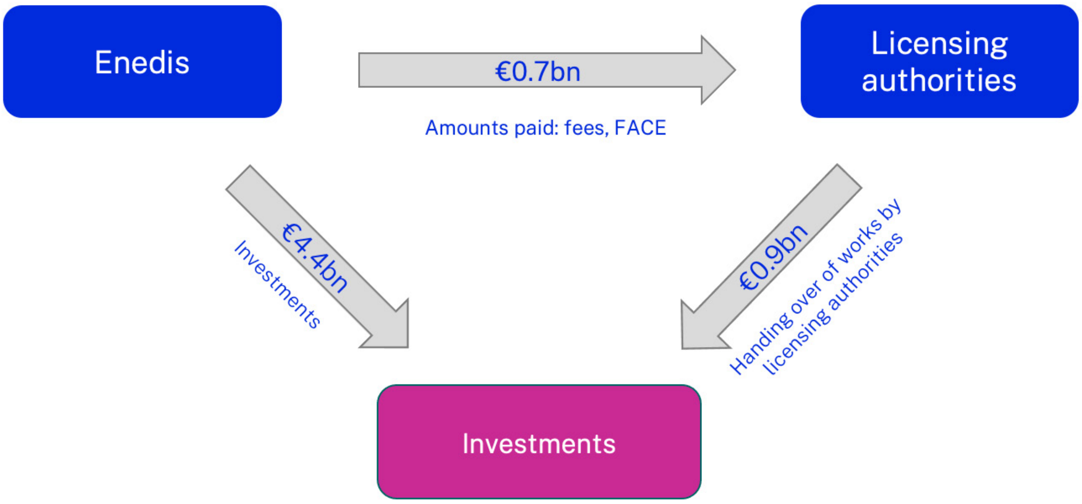
Prospective work and constructive dialogue must be established with all stakeholders as soon as the idea to develop a space emerges, and not after the decision is made, as land use for the primary substation would then be taken into account too late. This is especially the case in dense urban environments, where early research allows land to be set aside for the creation of facilities when the need arises. In a highly urbanised environment, acquiring the necessary surface may take several years, whereas the standard time frame for procedures and studies to create a new primary substation is two to four years before the work phase.

Stakeholders include Enedis, RTE, business developers (joint development zones, industrial, data centers), local elected officials, and residents in the early stages when the need is detected. During the procedure, it involves all stakeholders associated with the consultation laid down by the Fontaine circular.[18]

As a responsible industrial actor, Enedis complies with the Water Act and carries out sustainable development compensations when necessary (see chapter 7). In this regard, dialogue with stakeholders before the project is also desired to identify areas suitable for these compensations.

18. Circular from the 9th septembre 2002 on the development of public transport and distribution networks for electricity.

Figure 9: flows of investment in the distribution network made by Enedis and the licensing authorities



1.5.3. Dialogue on investment decisions by the licensing authorities: a quick overview of the financial challenges associated, outside the scope targeted for Enedis' NDP

The NDP only deals with the investment trajectories of Enedis within the scope of its distribution network project management. However, licensing authorities also have their own investment program, which is the subject of ongoing dialogue and coordination with Enedis. Various exercises facilitate discussions on this "Article 8" investment program (integration of assets into the environment across both urban and rural areas) or in rural electrification (ER) zones:

- The annual screening file (DAC), which lists LV feeders under constraint, the nature of the constraint, and the necessary technical characteristics to prioritise the treatment of these departures.

- The detailed diagnostic and recommendation file (DDDP) for LV feeders under constraint that the licensing authority commits to treating as a priority within the next twelve months.

- Dialogue to assess AODE investment needs for networks located in rural electrification zones, to determine departmental allocations for aid to local authorities for rural electrification ("ER inventory"). This takes place every two years.

The investments made by licensing authorities are outside the scope of the NDP and currently amount to €900 million per year (see figure 9), including:

- €360 million (in 2021) financed by the rural electrification aid scheme: since the 2011 reform that abolished the rural electrification cost amortisation fund (FACE), it is managed as part of a special account (CAS) of the State budget (see informational panel IX: financing aid to local authorities for rural electrification).

- €400 million financed through fees paid by the licensed operators (Enedis).

NFORMATIONAL PANEL IX

Financing aid to local authorities for rural electrification

The Amending Budget Act of 28th December 2011, established the special account “Financing of aid to local authorities for rural electrification” (CAS FACE) within the State budget, replacing the rural electrification cost amortisation fund (FACE).

FACE was created by the law of 31th December 1936, to contribute to the financing of electrification works carried out in the territories of rural municipalities by the organising authorities of electricity distribution (AODE), who were the project managers. It had been managed by EDF since 1946.

The new system, which came into effect on 1st January 2012, continued the mission of the previous fund with the primary objective of improving the quality of electricity supply in rural areas by eliminating poorly supplied connections and reducing the stock of bare wires on low-voltage networks.

Two regulatory texts[19] specify the rules for the allocation and management of aid for rural electrification, as well as the scope of operations eligible for assistance from CAS FACE. In accordance with Article 14 of the Energy and Climate Law of 8th November 2019, this regulatory framework opens the possibility of financing some AODE operations related to energy transition in rural areas.

CAS FACE is funded by annual contributions from DSOs; the revenues of CAS are exclusively allocated to support works carried out under the supervision and management of AODE through the rural electrification aid mechanism.

Like all special allocation accounts, CAS FACE is subject to control by Parliament, which votes on its annual budget, in revenues and expenditures, and oversees the rates of contributions paid by the DSOs. For the year 2022, the credits opened in the finance law for CAS FACE, representing the maximum amount of subsidised works (excluding taxes) that can be undertaken by AODE in 2022 (programming year), amount to €360 million.

19. Decree n°2020-1561 of 10th December 2020 on aid for rural electrification and the order of April 13, 2021 issued in implementation of the decree n°2020-1561.

1.6. Overview of Enedis' investments and NDP's baseline scenario

1.6.1. Types of Enedis' investments

Enedis carries out various types of investments on the network, which will be discussed in the following sections of this NDP. In terms of categories, these include connection, reinforcement, renewal, and modernisation investments:

- **The connection of new consumers and producers to the network** is carried out in low voltage (LV) or medium voltage (MV) depending on the required power level. If the customer is remote from the public distribution network, the technical solution may require extending the network. In some cases, it may be necessary to increase the network's capacity. These investments need to be made in response to connection requests, which can vary depending on economic conditions or regulations.

- **Network reinforcement** addresses the need to adapt the network to the progressively evolving existing loads. This is done to comply with contractual voltage levels at delivery points, eliminate the risk of overloading assets, and restore the necessary margins for maneuvers for network operation and management (load resumption) in case of scheduled works or unexpected incidents on the network (see 2.1.5).

- **The renewal and modernisation of the network** are decided by Enedis to ensure a good level of quality of supply and resilience of assets to the risks they face, particularly in the context of changing climate conditions. They are carried out within the framework of industrial policies based on risk analyses. These risk analyses cover all network assets (see chapter 3) and are **implemented over the long term.** Examples include renewing underground MV networks with oil-impregnated paper, which are prone to incidents, or renewing LV bare wires. Renewals are priority-based to address first those assets that present the greatest risk of failure, maximising the efficiency of each investment.

1.6.2. Investment principles of the distributor within the electric system

As detailed in section 1.5, various scenarios are considered for the potential futures of the French electrical system. To make the best technical decisions for investments involving significant financial amounts and long realisation timelines (such as the construction of a 400 kV line on the transmission nework or a production plant), it is essential to compare all possible options. In-depth scenario-building for potential changes in consumption and in the generation mix is therefore necessary to optimise the long-term economics of generation and transmission. The economics of the distribution network, on the other hand, do not generally require costly unitary investments, but follow a **logic of mass investments.** Enedis annually carries out hundreds of thousands of unitary investments, most of which are inexpensive and relatively quick to implement once the locations are known. The number of connections is therefore the main external factor affecting Enedis' investments. In addition to this logic of responding to users' connection demands, there is a logic of ensuring in the long term an efficient management of the industrial tool that is the public distribution network across France.

The predominant principles governing Enedis' investments are as follows:

- **Mastery of unitary connection:**
    - selection of an appropriate technical solution (voltage level, cable type, route, etc.);
    - limitation of environmental impact;
    - industrial management to control costs and deadlines throughout the implementation process.
- **Mastery of mass effects:**
    - process standardisation;
    - forecasting skills and equipment requirements according to current and anticipated connection requests;
    - detection of signs indicating changes in pace and discussion with RTE in the event of a need for upstream network reinforcement.
- **Mastery of technical and economic analysis** for reinforcement, renewal, and modernisation decisions, not related to connection but optimised on the basis of multiple parameters;
    - evaluation of the known present and a local assessment of various possible futures, particularly in terms of load growth;
    - measured and predictable incident analysis, based on climate hazards or specific risks;
    - optimisation of implementation schedules, costs, and environmental impact, considering the benefits for quality of service and resilience, by exploring various possible solutions: traditional investments, innovative equipment, flexibility tenders.
    - ability to address multiple network challenges simultaneously.
    - long-term operability of the network.
    - consideration of the technical framework and its complexity: voltage management scheme, protection plan, etc.

Enedis has deepened and optimised these general principles through high-performance tools implementing methods that require a balance between stability and agility:

- **Stability of methods over time** is a crucial aspect of Enedis' investments. Due to the long lifespan of facilities, the DSO inherits past decisions and constrains the future through its present choices.
- Nevertheless, the methods used remain **agile,** and a clear acceleration in their evolution is perceptible with the sustained increase in connections associated with the energy transition (renewable energy, electric vehicle charging infrastructure). This significantly alters the analyses assumptions and prompts the exploration of innovative solutions taking advantage of new possibilities, especially in the area of data and in that of accessing customer flexibility.

1.6.3. Baseline scenario of the NDP

1.6.3.1. The NDP relies on a single scenario derived from external prospective studies and applied to the distribution network

The network development plan aims to set out, over five and ten years, the operational challenges of mobilising resources (financial, human, etc.) raised by the medium-term trend. Its goal is not to explore all long-term possibilities resulting from the evolution of the electrical system, which depends on numerous external factors (generation mix, structural changes in consumption, etc.). In this first NDP, Enedis does not reopen discussions on topics that where discussed before the 2019-2028 PPE (mainly within the framework of the 2017 *Bilan prévisionnel*), or subsequent to it, including long-term projections for the future of the electrical system in general (*Futurs énergétiques 2050*).

Hence, for this first NDP, **Enedis conformed to existing prospective scenario-based studies and adapted them to the scope of the distribution network.**

The objective here is to assess the probable activity volumes and financial amounts required within Enedis' scope to address the energy transition and secure the future of the network. These assessments are non-binding for Enedis and represent a fraction of the total investments that will make the energy transition a reality. A single scenario seemed sufficient for the NDP, with the primary goal being to enlighten how Enedis will respond to a 10-year trend using explicit and robust methods. These methods will ultimately support local decisions, adapted to local demands and situations as they arise.

In terms of content, the chosen scenario aligns with the objectives of the PPE and takes as its reference, for the years they have in common, the "Transition" scenario from the Enedis' Prospective 2050 and the "N1" scenario for the integration of renewable energies as presented in RTE's document *Futurs énergétiques 2050*. Nevertheless, adaptations are necessary to combine these national objectives with Enedis' specific challenges.

Enedis has **adapted the scenario** to translate these overall national objectives into volumes relevant to the public networks operated by Enedis, with a distinction made between voltage levels (especially for PV) since the connection solutions differ according to the voltage segment.

Regarding the **sensitivity** of the chosen scenario, the distributor's investment logic is based on volume, so, as a first-order approximation, uncertainty about connection volumes determines the investment volumes uncertainty.

The sensitivity of the projected baseline trajectory will thus depend mainly on the volume of connection (number of electric vehicle charging points, volumes of distributed generation installations, etc.), as well as the modalities of these connections (proportion of parking facilities opting for an extension solution of the public distribution network for the connection of electric vehicle charging infrastructures in condominiums, relative proportions between medium voltage and low voltage for renewable energy connections).

Lastly, the industrial deployment pace of Enedis' asset management policies is a necessary input for the NDP scenario, but it is of little sensitivity: these policies are long-term programs prioritised over years.

The NDP being updated every two years, the latest published NDP will always reflect the best current view of the active policies.

1.6.3.2. Key assumptions of the chosen scenario and its costing

The baseline scenario selected in the NDP is based on the underlying factors described below:

Electric vehicle connection:

• The NDP considers a total of 13 million electric vehicles by 2032, in line with the objectives of the SNBC (national low carbon strategy) and a potential reduction in the vehicle fleet through car sharing and the development of alternative transportation modes (such as hydrogen vehicles). The forecast for the connection needs of publicly accessible Electric Vehicle Charging Infrastructure (EVCI) has been performed at the municipal level, relying on Enedis' internal models (see 2.1.2).

• The forecast for the connection of EVCI on highways (see 2.1.2.3.4), both in terms of volume and cost, is based on a joint study conducted by RTE and Enedis, publicly available, for the scope of light mobility (*Enedis et RTE, Les besoins électriques de la mobilité longue distance sur autoroute*).

• The forecast for connecting EVCI in condominiums is the most decisive point. There are two alternatives for connecting EVCI in condomniums (see 2.1.2.3.3), and the impact on Enedis' investments depends on the solution:

• **Solution 1:** connection of a private operator responsible for equipping the collective parking and managing a number of EVCI downstream of the Enedis delivery point. In this case, Enedis' investment is limited to connecting this single aggregated customer to the network.

• **Solution 2:** connection of a number of EVCI linked to an extension of the public network built by Enedis ("collective EVCI") serving parking bays. In this scenario, Enedis' investment includes, in addition to Solution 1, the collective EVCI, individual derivations connecting each EVCI to the column, and a Linky meter for each EVCI.

On a national scale, the investment required to achieve 100% electric vehicle charging is not sensitive to the proportion of choices made by collective buildings between Solution 1 and Solution 2.

However, the amount projected in Enedis' investments depends significantly on the respective proportion between these solutions. The NDP assumes an average ratio of 50% for Solution 2 over the period, with a gradual increase as this solution, currently in its initial phase, gains visibility.

Connection of renewable energy generation installations

The national volumes of wind and solar energy generation installations in the baseline scenario of the NDP are derived from scenario N1 of RTE's *Futurs énergétiques 2050*. These volumes are then reduced to Enedis' scope using the currently observed distributions between RTE, Enedis, and local distribution companies (ELDs). The resulting connection volumes are then distributed by power segments to determine the type of connection to be made (see 2.1.3.2). This breakdown by voltage levels, not available in the original scenarios, is a key point for the distribution network, as the unit connection costs are significantly higher for low voltage compared to medium voltage.

Overall, the chosen scenario adapts the initial objectives of the PPE (French NECP) by sector.

	Photovoltaic France	Photovoltaic Enedis	Wind power France	Wind power Enedis
French NCPE	• 2023: 20.1GW • 2028: 35.1-44,0GW	• 2023: 17.1GW • 2028: 29.8-37.4GW	• 2023: 24.1GW • 2028: 33.2-34.7GW	• 2023: 19.3GW • 2028: 26.6-27.8GW
NPD	• 2027: 31.2GW • 2032: 48.9GW	• 2027: 26.5GW • 2032: 41.6GW	• 2027: 28.4GW • 2032: 35.3GW	• 2027: 22.7GW • 2030: 28.2GW

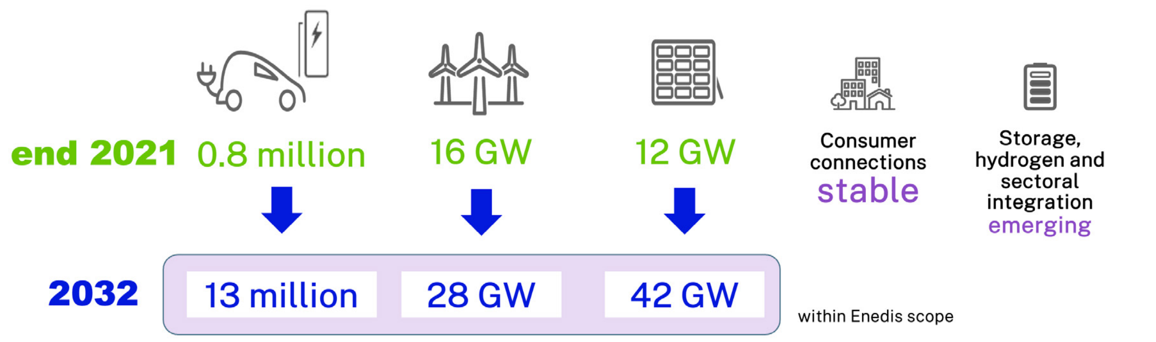
The decision to use this baseline scenario for the NDP results in an estimation that may now seem conservative in light of recent developments and shifts. On this point, it is important to emphasize that it is not Enedis that sets a trajectory for connecting renewable energies to its network. The trajectory evolves as stakeholders make decisions, encouraged and guided by the country's energy policies.

For instance, after the establishment of the mentioned baseline scenarios, Enedis has experienced a significant acceleration in low-voltage generation connections since late 2021 (S21 decree). Beyond this recent example, the ongoing changes in energy policy are extensive and clearly demonstrate the collective ambition to accelerate the development of renewable energies. Examples include the Repower EU plan by the European Commission and the French President's announcement in Belfort on February 10, 2022, outlining increased ambition for solar energy (100GW by 2050) and a simultaneous downward revision of the previously stated ambition for onshore wind energy.

The collaborative discussions surrounding the SFEC (French energy and climate strategy), followed by the new PPE (French NECP), and the final content of the renewable energy acceleration act will contribute to the emergence of new national trajectories for renewable energy. This will enable Enedis to update, in its next NDP, the measured trajectory presented here, inherited from the previous PPE.

The presented scenario is strictly national. In the assessment of future connection requests, the exact (regionalised) geographical location is not a structuring assumption, except if the transport network is saturated. The NDP has not isolated this potential saturation effect in its estimations, an issue that is addressed locally through S3REnR (see 2.1.3.3), and for which the average cost can be calculated by analysing the connections made.

Figure 10: key figures for the baseline scenario



Connection of consumer customers excluding EVs (see 2.1.4.1)

Currently, Enedis connects approximately 400,000 consumer customers a year. A combination of various effects (slowing demographic growth and a projected decrease in the average number of inhabitants per dwelling according to INSEE) leads to an **annual evolution of the number of dwellings that will remain comparable to current rates.**

Enedis, therefore, assumes an annual number of connections identical to the average observed in previous years. Storage, hydrogen, and sectoral integration have not been included in the NDP costings, as they are still emerging.

Additions to the main connection scenario

The main connection scenario presented in the NDP is complemented by investments related to Enedis' industrial decisions regarding network renewal and modernisation programs (see figure 10).

A macroscopic assessment of the network reinforcement needs is also provided. These needs will significantly increase over the period, in line with the connection of renewable energy generation installations and the intensification of electricity uses (EVCI, heat pumps), while remaining ten times lower than the investments resulting from the connections.

Capital expenditures (CAPEX) related to operational means and information systems, although beyond the scope of the NDP, are also mentioned in the summary presented in chapter 4 to provide a comprehensive view of Enedis' total CAPEX. Their evolution is closely linked to the ongoing transformations in the electrical system.

Precisions on the costed scope and displayed unit

The amounts presented are the costs of connections carried out by Enedis, not the financial amounts paid by Enedis.

For instance, if a connection performed by Enedis is billed back at 40%, it means the customer pays 60% of the amount, and Enedis covers 40%. However, the NDP displays the entire 100% of the investment, emphasizing the collective cost independently of the income that Enedis may receive from its customers.

Moreover, all presented trajectories are displayed in 2021 euros, with no allowance for inflation.

Methodology for cost estimation in euros

The investment trajectories presented in each section, and then summarised in chapter 4, are based on an internal analysis of the solutions implemented according to the different categories of operations, the various situations, and their evolution over time.

For example, connecting a distributed solar production installation > 36 kVA often requires the creation of an MV/LV substation and tends to lead to more expensive solutions than a MV connection. All else being equal, this represents a three- to four-fold increase in order of magnitude for connecting 1 MW of generation capacity.

The investment forecasts presented are neither a minimum commitment nor an upper limit

The main driver of additional annual investments required at five and ten years is related to **connection requests addressing the challenges of energy transition.** Therefore, the figures displayed do not represent a commitment by Enedis to invest these amounts, nor do they establish an upper limit on the investments that may be made. Rather, they provide the **current assessment** of the amounts that will be needed, an assessment that will evolve in line with the actual pace of energy transition and the resulting requests from network users.

The complete cost estimation produced for the NDP should be understood as a pedagogical approximation of the investment needs resulting from a baseline scenario, intended to inform the electrical system stakeholders' discussions.

1.7. Summary: the spirit of the NDP and its plan

Summary of the introduction

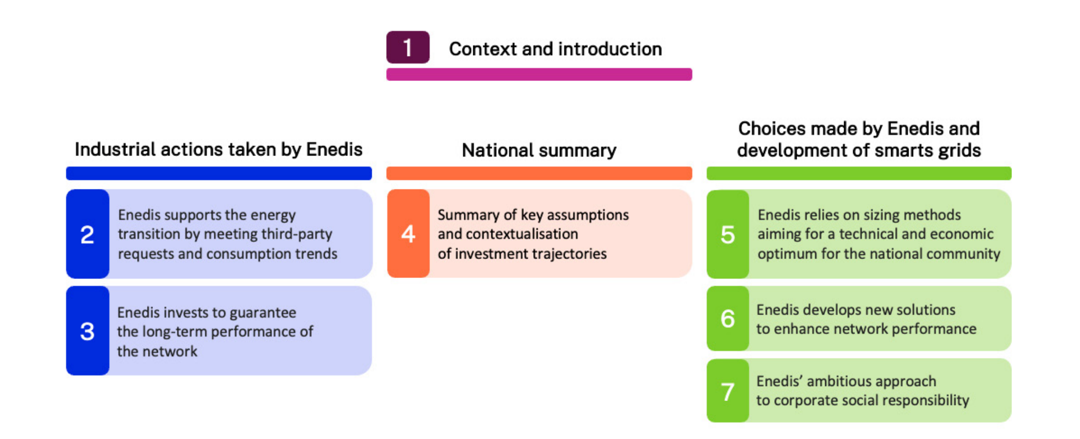
- The NDP is a document that contributes to the medium- and long-term dialogue on vision and methods.
- Each DSO with more than 100,000 customers produces an NDP. Enedis' NDP covers the concessions for which Enedis is responsible: at this level, the NDP describes Enedis' investments and not AODE investments.
- The investment trajectories presented are national forecast trajectories and are not binding. They are based on a single baseline scenario.
- Updating the NDP every two years will ensure that the latest elements are taken into acount on a regular basis.
- The NDP describes investment methods as well as alternative solutions such as flexibilities.
- The NDP aims to be technical while remaining accessible, and comprehensive while staying concise.

NDP's plan

A three-part structure has been chosen (see figure 11):

- A description of Enedis' industrial actions in response to the challenges of accommodating connection requests and improving network performance.
- A summary of the quantified trajectories resulting from these investments.
- An overview of the methods deployed by Enedis, whether conventional or flexible and smart, and Enedis' actions in terms of social and environmental responsibility.

Figure 11: NDP's plan



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2

Enedis supports the energy transition by meeting third-party requests and consumption trends

2

Enedis is utterly committed to supporting France's efforts to curb climate change. This includes connecting renewable energy and electric vehicle charging installations (EVCI) to the network as quickly and cost-effectively as possible, given the rapid growth of demands in recent years. This ambition adds up to meeting the ongoing connection requests of consumers and the reinforcements induced by changes in consumption trends (2.1). In each of these areas, Enedis is constantly looking for the best economic solution and seizes all opportunities for flexibility that can provide an alternative to investment. Moreover, Enedis is adapting its industrial tool to meet third-party requests (such as the relocation of assets) and to comply with regulatory changes (2.2).

2.1. Enedis connects new users to the public distribution network and reinforce the network while considering embedding flexibility

The present shape and sturdiness of the public distribution electricity network has been met by accompanying the socioeconomic development of the country as well as the development of electricity uses. The network development is now addressing the growing distributed generation and the electric mobility.

When a new user, whether a consumer, a producer or an electric vehicle charging installation (EVCI) manager, requests connection to the public distribution network, Enedis has a duty of providing them with a quotation that constitutes the reference connection offer (ORR), which must meet the requirements of the decree of August 28, 2007, namely:

- being necessary and sufficient to meet the electricity supply needs of customer's installations, or, for a producer, the disposal of generated power at the requested connection level;
- following a technically and administratively feasible route, in accordance with the provisions of the licensing authorities agreement;
- comply with the reference technical documentation (DTR) published by Enedis;
- minimising the full costs of connection works execution.

Adapting the upstream network capacities may be required, as part of the connection study, in order to make the connection feasible.

Upon accepting the quotation, the new user will pay a contribution which amount depends on the connection rate (approved by the CRE) and the reduction rate (set by the general directorate of energy and climate: DGEC, in French). The remaining costs are covered by the TURPE, over the lifetime of the assets.

As part of its 2020-2025 Industrial and Human Project, Enedis is committed to facilitate, hasten, and smoothen the access to electricity through a simpler, digitised, and more customer-centric experience. Enedis is thus reinventing its internal approach to connecting new customers and aims to halve the time needed to connect to the network by the end of 2022. It relies especially on better support for customers, both private individuals and businesses, throughout their administrative procedures. The connection portal made available to Enedis customers is an essential tool for achieving this ambitious goal.

Moreover, independently of connection requests, network reinforcement may be required to address transit (intensity) or voltage constraints that may arise due to the progressive evolution of loads. To ensure the long-term quality of supply, the investment is then made and fully funded by the TURPE.

In order to maintain the quality of service, Enedis conducts techno-economic studies (see 5.3) to guide its approach to connection and investments. These methods are constantly being updated to reflect changes in the economic environment (such as reference economic parameters) and technological advances. One of these updates is the use of flexibilities to meet the needs of the DSO.

2.1.1. Flexibilities: a multifaceted performance lever, studied in the NDP for the use case of investment savings (connection or reinforcement)

Flexibility typologies

The term "flexibility" encompasses a variety of configurations that should be recalled to delimit the content of the NDP.

From the perspective of the flexibility actor, activating their "flexibility" always leads to a similar situation, namely being able to adapt their generation or consumption in accordance with an adjustment request they have received: the value of their flexibility is defined by the ability to follow this request. Actually, the request to which the flexibility service provider responds can come from several major scenarios that must be clearly distinguished:

- **National flexibility:** This type of flexibility is used for balancing supply and demand on a national level, for which is RTE' s responsibility. Eligible sites can be connected to either the transmission or the distribution network.

- **Flexibility for the transmission system:** This type of flexibility is used to optimise the management of the transmission network. Similarly, eligible sites can be connected to either the transmission or distribution network.

- **Local flexibility for an immediate and short-term operational need of Enedis:** This type of flexibility is used to avoid local outages (if the current condition of the network does not allow all customers in an area to be supplied due to the fortuitous or scheduled unavailability of an asset). It may also serve to facilitate the **placement of works** (for example, to avoid the mobilisation of backup generators to ensure continuity of supply during the intervention).

- **Local flexibility, serving the connection of the flexible user themselves,** aiming for an individual benefit for this user. Regulation requires Enedis to offer an ORR, guaranteeing 100% of the available power at all times. The purpose of this type of flexibility is to allow the applicant to be connected in an area without network adaptation works, even though 100% of their requested power cannot be guaranteed at all times. This connection is then made through an alternative connection offer (ORA) with power modulation. The ORA with power modulation is less expensive for the client than the ORR due to the absence of network adaptation works. The ORA with power modulation is subject to a counterpart, namely the acceptance of the applicant to be curtailed without financial compensation, within limits set at the time of signing the ORA with power modulation. The works provided in the ORR are specifically designed to avoid these curtailment situations.

- **Local flexibility for a shared connection targeting a collective benefit:** This type of flexibility is embodied by the REFLEX project (see informational panel XII: REFLEX project), which allows to connect more production installations on the same primary substation transformer, with a collective benefit. This is made possible by authorising the use of flexibilities in specific targeted timeframe (through local flexibility tenders or, failing that, through generation curtailments),

- **Local flexibility to defer a reinforcement investment planned by Enedis** if there is a collective interest to do so. This type of flexibility allows Enedis to defer such investment. Flexibility will only be of interest if it "beats" the economic performance of the considered investment: through a tender, Enedis will seek such flexibility, which will be contracted if it meets the price and characteristics of the expected product. The investment will therefore be deferred. Since the end of 2021, Enedis has been systematically assessing every flexibility opportunity when primary substations or MV feeders reinforcement must be carried out due to constraints arising by excess generation or consumption. In any other situation (relocation of assets at the request of third parties, obsolescence, etc.), the deferral of this investment through the use of flexibility services cannot be considered.

See also the informational panel X: difference between flexibility for national services and local flexibility.

The value of flexibility

In the first case (flexibility for national needs), the geographical or electrical location of the network user is irrelevant and a location-independent market value can emerge to value the flexibility service.

In the other cases, it is essential that the user be in the right place, available at the right time, from the perspective of the electrical network, in order to offer their services. The value of flexibility will therefore be intrinsically local. It will depend on the precise electrical configurations (network topology, customer load on the network at this location), the planned investments, and the characteristics offered by the flexibility service provider. The value is ascertained on a situational basis and will fall within the range indicated in the "Economic assessment of smart grids" report (*Enedis et ADEeF, Valorisation économique des Smart Grids*)

The scope of the NDP in terms of flexibility

The NDP only examines flexibility enabling savings to be made on investments (in the instance of network connection or reinforcement), i.e. the three last cases amongst the six mentioned. In order to illustrate Enedis' general approach, section 6.1.2.3 also mentions the calls for flexibility tenders in case of operational needs and work scheduling.

Enedis' approach to flexibility

Since 2015, Enedis has been committed to seeking out the value of local flexibilities and harnessing it where it exists.

To this end, Enedis and the association of French electricity distributors (ADEeF) published the report "Economic assessment of smart grids" in 2017, which focuses on the technical and economic benefits of flexibilities. Enedis then published a document in October 2019 entitled "Flexibilities to support the energy transition and the distribution network performance" (*Enedis, Les flexibilités au service de la transition énergétique et de la performance du réseau de distribution*). This document describes the use cases of flexibilities for the distribution network, their principles, and the potential benefits. Finally, Enedis published its "roadmap for the transformation of network planning methods and the integration of flexibilities" in February 2020. The priorities and milestones of this roadmap are aligned with the potential benefits of flexibilities (*Enedis, Feuille de route pour la transformation des méthodes de dimensionnement des réseaux et l'intégration des flexibilités*).

INFORMATIONAL PANEL X

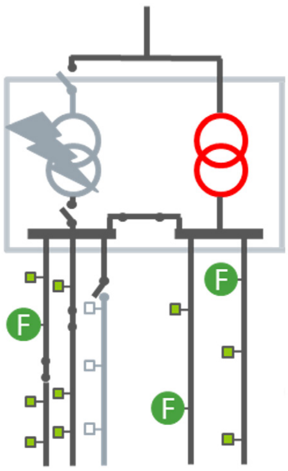
Difference between flexibility for national services and local flexibility

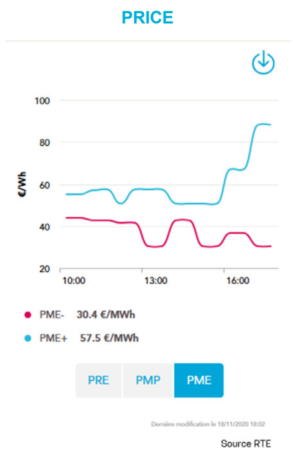
Flexibility consists of the voluntary modulation of power from one or multiple sites, upward or downward, in injection or withdrawal, at a given time for a given duration, in response to an external signal in order to provide a service.

The primary challenge of flexibility is to manage the supply-demand balance in the national markets at any given timeframe (ancillary services, balancing mechanism, etc.), which is the legal responsibility of RTE. If they are connected to the distribution network, installations that engage in these national mechanisms are called “distributed flexibilities”. Since the creation of the electric power system, flexibilities have always been used to manage the supply-demand balance. **Enedis facilitates any service provider wishing to use distributed flexibilities on one of these mechanisms. Several tens of thousands of “flexible” sites are connected to the network managed by Enedis,** with a combined power of around 2 GW, and participate in the national balancing mechanisms as well as the load shedding market.

Local flexibilities constitute an additional lever for technical and economic optimisation of network operation. Flexibility competes with "conventional" network management levers and represents an opportunity to bring new solutions with a better cost-effectiveness ratio for the community.

Local flexibility	**Flexibility for national services** = market or system flexibility
For **local congestion**	For **supply-demand balance**
Stake of network operators: Enedis, ELDs and RTE	TSO’s responsibility (see Frequency: 50 Hz)
Any site may participate, **if at the right place and available at the right time**	Any site may participate **at any time, wherever they are connected to the network**
Occurrence and value depend on local needs	Most of the value of flexibility is focused on national mechanisms





The integration of flexibilities into the network design and operation process requires a reassessment of sizing methods and parameters. It also requires changes to many processes, IT systems, and business lines, both at Enedis and at its stakeholders. In summary, to implement its flexibility roadmap, Enedis is taking the following steps:

- develops methods to quantify the value of flexibility opportunities, and to activate and control them. Enedis compares the cost-effectiveness of flexibility to other options, such as network reinforcement;

- integrates flexibilities and their value into network operation, while ensuring the safety of people and property (including adapting protection plans);

- develops a coordination model between distribution system operators (DSOs) and transmission system operators (TSOs) for the integration of flexibilities, as the flexibility resource may be shared;

- establishes a framework of rules and processes, in collaboration with stakeholders;

- develops methods and tools to integrate the lifecycle of a flexibility portfolio across its different business lines: network design and operation standards, contracting, performance tracking, investment and new customer connection processes, etc.

- leads the change and trains its employees.

The following chapters of the document describe the connection of electric vehicle charging stations (EVCI see 2.1.2), renewable energy producers (see 2.1.3), and usual consumers. They also discuss the need for network reinforcement that may be caused by increased loads (2.1.4). The flexibility resources available for each of these scenarios will be detailed and quantified in the relevant sections: load management (2.1.2.4), connection of renewable energy sources (2.1.3.4) and connection of users, reinforcements (2.1.4.2). Enedis's approach to assessing the economic value of flexibilities and implementing them will be discussed in the dedicated section of the NDP (6.1).

Enedis' overall goal is to seize and implement the performance potential associated with local flexibilities. Enedis's decision-making approach is based on a combination of technical and economic factors, and this approach is applied to flexibilities in particular.

Integration of flexibilities into the baseline trajectory of the NDP

Although Enedis has been committed to the implementation of flexibilities for a long time, the maturity of the associated levers remains heterogeneous. It depends on the types of flexibilities and the users solicited (which are discussed in section 6.1).

Flexibilities designed to reduce network withdrawal must meet strict requirements. Flexibility may be required at unpredictable times, and must be highly available due to the high cost of any supply interruption to consumers. Not all consumers will be able to meet the needed requirements to become a flexibility provider. Therefore, seizing every potential flexibilities opportunities might not be feasible when connecting consumers or strengthening the network (see 6.1.1.3). Currently, flexibility potentials appears to be at an early stage of permeation for the distribution network, hence its absence in this NDP baseline trajectory. However, this does not preclude future flexibility resources, and the regular update of the NDP will be an opportunity to re-evaluate this assessment based on the evolution of feedback from medium-voltage consumers, through either the industrial devices already deployed or the experimentation initiatives on flexibilities when connecting them.

When flexibilities are designed to moderate network injection, the appropriate time for activation is more predictable. Furthermore, in the event that the expected flexibility would not be available, the generation's curtailment remains a cost-effective fallback solution for the community. This implies the possibility of quantifying the potential of flexibilities for collective (via the REFLEX project, undergoing large-scale testing) and individual producer connections (via the ORA - alternative connection offer - with power modulation).

2.1.2. Electric mobility: with exponential growth expected, Enedis faces the challenge of network adaptation to cope with charging infrastructure

Electric vehicles (EV) are experiencing **exponential growth** in France. They are a new form of electricity consumption, a major economic development stake, and an ally of the transition to carbon neutrality by 2050. In 2021, sales of battery electric vehicle (BEV) and plug-in hybrid electric vehicles (PHEV) increased by 62% compared to 2020, which signalled the market's breakthrough. They represented 15% of new vehicle sales in France in 2021, up from 10% in 2020.

In the coming years, EV uptake is likely to continue thanks to an expanding range of vehicles with greater autonomy.

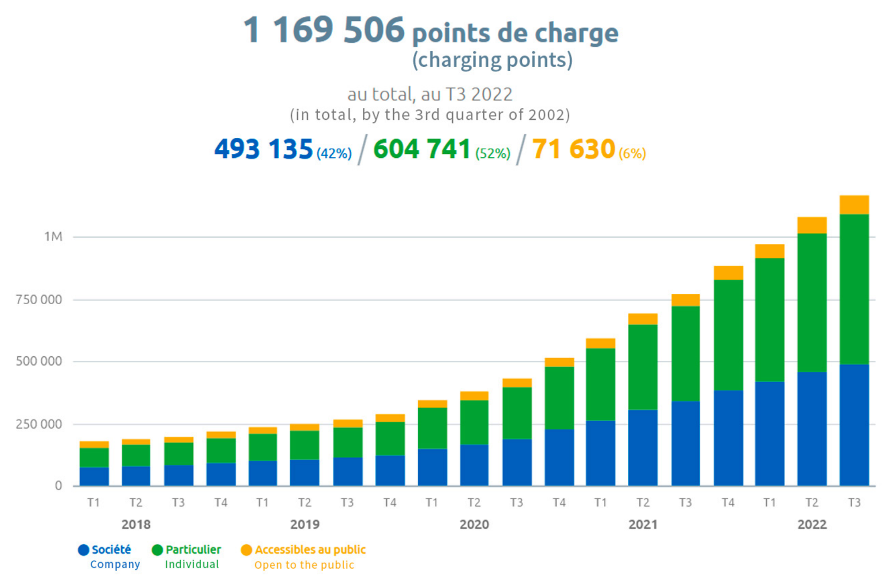
This rapid growth requires concurrent deployment of electric vehicle charging infrastructure (EVCI). As of the Q3 2022, there were more than one million charging points installed in France (Enedis estimate), including nearly 72,000 open to the public.

The forecasted needs for free-access EVCI were based on models, developed by the Enedis strategy department, that took into account the following factors:

- the projected number of EV in each municipality, based on historical data (since 2016), socio-economic factors, the competitiveness of electric vehicles, public aid...),
- the travel needs between municipalities, taking into account factors such as residential, employment, and tourism areas, travel times, and working hours,
- the behavior and charging options of electric vehicle users, such as the frequency and duration of charging sessions.

The adoption of electric mobility is induced by local commitments, made by customers or regional communities, to set emission reduction policies, namely low-emission zone. Controlling investment and coordinating charging are also important aspects of this adoption.

Figure 12: evolution of the number of electric vehicle charging infrastructure (EVCI) connected to the network operated by Enedis



Source : Enedis open data https://data.enedis.fr/

Enedis seizes the opportunity that the development of electric mobility represents to:

- demonstrate its ability to support the ecosystem towards net zero carbon,
- innovate in response to the needs of electric mobility stakeholders,
- offer its local knowledge and expertise to benefit the community.

EVCIs, which are essential for EV recharging, can be directly or indirectly connected to the public electricity network. In both cases, the power supply originates from the distribution network. Enedis is working to deploy charging infrastructure on a large scale, **in public places, private open areas, individual and collective residential areas, businesses, and along roads and motorways.** In all cases, Enedis is working with customers, partners, and local authorities to:

- design solutions with customers, partners or territories, and test them before their generalisation;
- make new connections to the distribution network, and adapt the existing network where necessary;
- plan for future investment needs by taking into account concurrent uses;
- conduct research and development to develop new technologies and solutions that are compatible with the evolving needs of users, the latest technologies, and international standards;
- continue to convert its own corporate fleet, develop its network of charging stations, and implement an associated charging management system.

Enedis is anticipating the integration of electric mobility into the distribution network in the short, medium and long term. The company is considering a range of solutions, from simple home charging points to more complex solutions that can have a greater impact on the network. Enedis is taking an optimised approach, looking for the best economic solution through innovative solutions and projects.

2.1.2.1. Enedis and all electric mobility stakeholders work together to develop solutions, both at the national and local level

The development of electric mobility is driven by a diverse range of actors: the users of electric vehicles in the first place (individuals, companies, etc.), the government, national and local elected officials, administrations and administrative authorities, industrial actors of vehicles, transport, data, electricity supply and service providers, manufacturers, installers and maintainers of terminals. Enedis, as a partner of territories in the energy transition and an operator of the public distribution network, is a key player in this evolution. To ensure that electric mobility solutions are developed and industrialised, Enedis continuously engages with electric mobility companies.

Enedis' local foothold is an opportunity for both rural and urban communities

The deployment of clean mobility is a new area of collaboration. Enedis intends to enhance its expertise on this topic and make it available to local authorities, AODEs and elected officials: to contribute to the development of tomorrow's mobility, anticipate the impact on the network and optimise the deployment of infrastructure to meet the needs of communities.

Enedis will strengthen its collaboration with the technical teams of local authorities to deploy charging infrastructure for electric vehicles. This will reflect in several ways:

- <u>Projecting into the future, working in partnership with communities:</u> based on local socio-economic dynamics and on electric vehicle market projections in their territory, Enedis conducts prospective analyses to locally stage the development of electric mobility and anticipate impacts on the network.
- <u>Supporting the development of master plans for the deployment of charging infrastructure for electric vehicles (SDIRVE),</u> in partnership with local authorities and public institutions carrying out projects. Based on regulations that strongly associate distribution system operators (DSOs) with consultation process, Enedis shares the development trajectories of electric mobility in each territory and proposes a contribution to each stage of the development of the SDIRVE:
  - diagnosis of the existing situation,
  - assessment of charging points requirements
  - assessment of the hosting capacities of the public distribution network, enabling the development of a relevant territorial deployment strategy, while optimising costs and deadlines
- Maximising the overall value of investments in electric vehicle charging infrastructure, given the potential impact of territorial changes on electricity withdrawal and injection.

As a national operator, Enedis has a national vision of the EVCI's deployment. It also contributes to the coordination of SDIRVEs at the level of mobility basins, in partnership with regions. This allows for a denser and more homogeneous deployment of charging points across all territories, taking into account the capacity of the electricity network and anticipating its development.

2.1.2.2. Some charging points can be connected to existing installations without significant methodological changes

Even though electric vehicles always draw power from the network, directly or indirectly, charging stations do not always have a major impact on it. In fact, in many cases, charging an electric vehicle simply adds to the load of an existing site and does not require any changes to the electricity delivery system. For example, we can mention the cases of:

- Home charging is the most common way to charge an electric vehicle in France, as 56% of homes are single-family homes according to INSEE. In order to avoid a raise of their electricity subscription and keep their electricity bill under control, users manage the total consumption of their household (including charging their electric vehicle).

- Charging on public lighting networks is a new use that is enabled by the reduced electricity consumption of LED bulbs. The charging installation is connected to the street lamp's low-voltage circuit, and does not require any work on the distribution network. **The only requirement is the installation of a meter in the charging station to measure separately the electricity flows dedicated to lighting and charging. This is to ensure that the operator of the charging station can freely choose its electricity supplier and comply with the regulations.** A guide is available on the French Government[20] website.

- For the charging in shopping centers, much like in individual housing, the electrical infrastructure does not always need to be reinforced. Charging stations can be connected to existing electrical networks, and users simply organise their charging in a way that does not exceed the capacity of their subscribed power.

- When installed in local authorities and businesses, charging stations are often connected to existing electrical networks. To avoid exceeding their subscribed power, site managers use control tools to manage the electric vehicles charging withdrawal. These tools can be used to schedule charging, limit the power output of charging stations, or even turn off charging stations when they are not in use.

2.1.2.3. Other charging points for daily or long-range mobility require the creation of new connections to the public distribution network

The installation of some electric vehicle charging points requires a new connection to the public distribution network. This is generally the case for charging points or clusters of charging points deployed in urban areas, on public roads, used in particular by households without private parking, or along highways. Some installations in residential parking lots might be concerned as well.

The connection can then be made by simply extending the public distribution network, or it may require adaptation of the existing network. All situations must be dealt with locally, with a specific response depending on the initial state of the network, the location of the charging point on the network, and the surrounding topology.

The applicant's goal is to have a connection that is sized to meet their needs, within the agreed costs and timeframes. They can minimise their investment costs by sizing their connection power to the "just-in-time" need, and then their operating costs by subscribing to an electricity supplier contract with the appropriate capacity.

Enedis' goal is to satisfy the end customer and minimise the collective cost. It is therefore important for all stakeholders to anticipate charging point deployment projects alongside Enedis to achieve collective investment optimisation.

This anticipation is all the more useful for large-scale projects (highway rest areas, bus depots, new urban developments, new industrial and commercial sites, etc.) and for mobility planning work in the territories.

20. "Guide to recommendations for the installation of electric vehicle charging points on public lighting systems", Ministry of the Ecological and Solidarity Transition, November 2018.

2.1.2.3.1. Enedis takes into account the natural coincidence of loads in the case of charging points clusters and continues to study the impact on the network in real condition

Enedis generally takes into account a certain degree of overlapping in its network sizing rules (see 5.3.3) to account for the fact that not all electrical loads draw their maximum power simultaneously. The evaluation of this complex statistical coincidence is constantly being improved, notably thanks to the insights provided by Linky smart meters measurements.

Similarly, but with less hindsight and less precision, Enedis uses a coincidence factor to determine the connection power for a group of charging points. This coefficient allows for the fact that vehicle charging does not start simultaneously and that the initial charge level of vehicles varies. Figure 13 shows the power drawn by three charging points delivering the same power at different times and for different durations. The coincidence factor used by the industry today is 0,4.[21] It applies to the sum of the powers of each charging point.

Based on experience gained in real-life situations, Enedis may propose to re-evaluate this coincidence factor in the future to limit the cumulated effects of connection powers on network sizing.

Finally, as electric vehicles are a "manageable" use, a local charging management solution can be associated with this kind of installation in order to further optimise the connection and/or subscribed power.

21. Coefficient recommended by Enedis and the industry through the Séquelec sheet *"Dimensionnement des infrastructures de recharge pour véhicules électriques dans les immeubles collectifs"* (IRVE).

22. A description of these experiments can be found in the Enedis document on "integrating electric mobility into the public distribution network" (*Enedis, Rapport sur l'intégration de la mobilité électrique dans le réseau public de distribution d'électricité*).

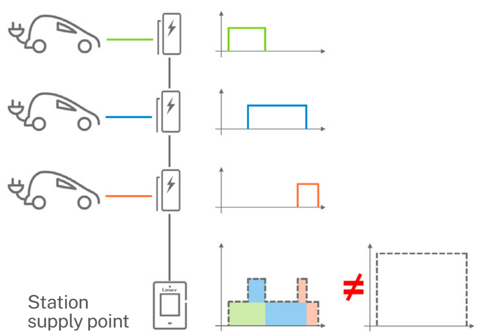
2.1.2.3.2. Enedis experiments with connection solutions adapted to various specific projects

Dedicated solutions have been established and implemented for specific projects, serving as practices that can inspire the general development of charging infrastructures.

For instance, Enedis is experimenting with the following connection solutions:

- grouped connection, which allows users to share costs in proportion to their requested powers;
- the FlexMobile project for a connection lower than requested by the customer;
- the connection of a bus depot;
- the connection of boats at dockside.

Figure 13: distribution of power demand by three load points



At this charging station, the drivers connect their EVs at different times. Thus, the power drawn from the charging station is not equal to the sum of the unit powers of the charging terminals.

2.1.2.3.3. Enedis supports the connection of electric vehicle charging stations (EVCI) in multi-unit residential buildings

The installation of charging stations in collective housing is a major lever for the development of electric mobility.

In France, 44% of the population lives in collective housing. The majority of these housing units have private parking.[23]

Installing a charging infrastructure in collective housing is more demanding than in individual housing. Generally, residents do not have the privilege of using their "right to the socket" to install an individual infrastructure. Therefore, it is preferred to opt for a collective and scalable installation. This decision necessitates a distinct decision-making procedure, which varies depending on the nature of collective housing:

- In social housing, the landlord is responsible for the decision-making process. Electric mobility can provide mobility solutions for tenants and make better use of sometimes unused parking spaces.

- In condominiums, the installation of collective recharging infrastructure requires a decision by the community of owners at annual general meetings. The co-owners must select the architectural design and agree on the corresponding budget at the meeting, based on a variety of criteria (ownership of the shared infrastructure, terms and conditions and costs of installation and usage, any contractual relationship, etc.).

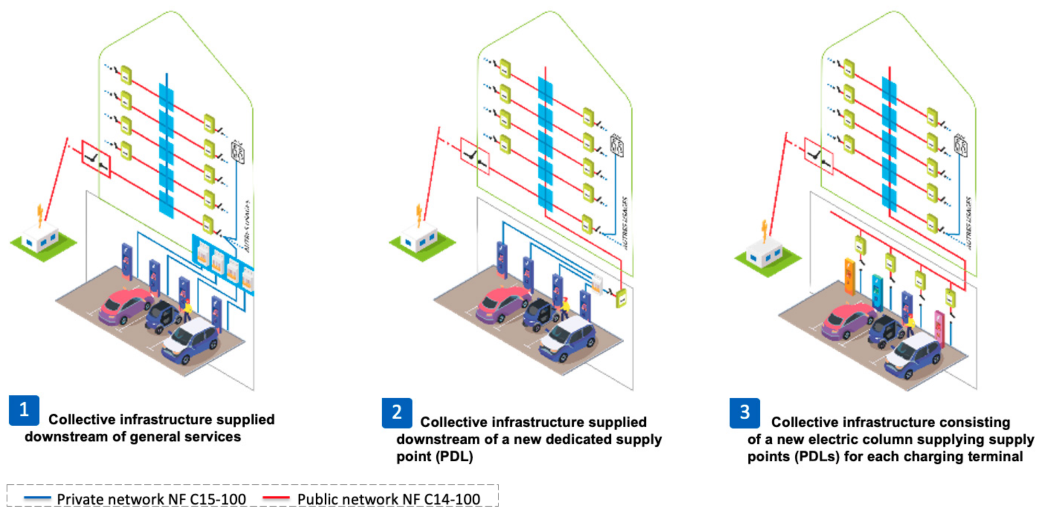
Three main technical architectures are possible to power charging stations in collective housing parking (figure 14):

- The connection of the charging infrastructure to the common area of the building, dimensioned according to the capacity of the communal area. The chosen energy supplier will therefore be that of the common areas.

- The creation of a single delivery point from the public distribution network, common to all stations ("NF C15-100 solution"). The energy supplier remains the same for all stations, even if different from that of the common areas.

- The extension of the public distribution network ("NF C14-100 solution") with individual derivation for each station: this last configuration, also known as collective EVCI, is therefore made up of a public distribution network designed, operated and maintained by Enedis. Individual metering is provided for each station, allowing users to choose their supplier.

Figure 14: the three main technical architectures for supplying power to charging stations in apartment building car parks



23. Ministry of Ecology, EVCI report, 07/2019

Enedis takes part in all of these developments and assists collective housing or their representatives (such as a charging operator), whichever they choose.

Regulations are evolving regarding the installation of EVCIs in existing condominiums, still allowing the right to an individual connection, but encouraging the emergence of collective solutions

In France, more than 180,000 condominiums with ten or more units have a parking facility, accounting for about 7 million parking spaces.

To encourage and streamline the installation of electric vehicle (EV) charging stations in condominiums, a number of regulatory incentives and obligations have been put in place, including:

- The "right to the socket" under the French mobility orientation law (LOM) grants all residents the right to install a charging point in their parking space. The co-ownership may only object if there is evidence of a study, vote or presence of a collective infrastructure within the co-ownership.

- The mobility orientation law (LOM) requires condominiums to consider the feasibility of installing charging stations in the condominium by voting on a comparative study of different collective infrastructure solutions by the 1st of January 2023. The report should determine the best options to meet the needs of residents and the condominium as a whole.

- **Pre-financing** of EVCI in condominiums under the French climate and resilience law. Enacted in August 2021 and implemented by decree in October 2022, the bill[24] offers co-ownerships solutions for the pre-financing of their collective charging infrastructure. Enedis can offer advanced financing via TURPE during the installation's lifespan, only if the infrastructure is public (solution C14-100, diagram no. 3 of figure 14). If the infrastructure is privately owned (solution C15-100, as depicted in diagram 2 of figure 14), the co-owners and the operator of the charging infrastructure may come to an agreement on pre-financing terms.

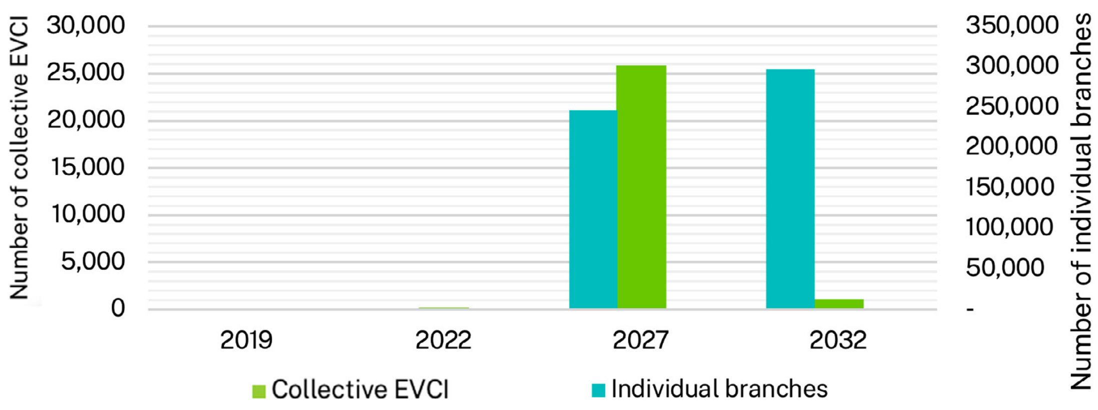
Enedis relies on its expertise to meet these new demands

As part of this activity, Enedis:

- reaches out to new types of customers:
    - charging station operators with a high volume of requests throughout the French territory.
    - condominium representatives who are not well-versed in Enedis' services seek unbiased assistance from Enedis before the general meeting to help them make a decision between public and private solutions that meets their needs solutions.
- Develops an innovative solution of collective EVCI (or "horizontal column") to serve the parking lots of condominiums with public distribution systems. This solution focuses on collective cost-effectiveness.

24. Energy Code, Art. L353-12.

Figure 15: baseline scenario - annual number of individual branches and collective EVCI created for the connection of EV charging infrastructures



• expects that the volume of activity in this area, which is already significant, will grow rapidly in the coming years (see figure 15).

• over the next few years, tens of thousands of condominiums will have to choose between the two existing solutions: private (C15-100) solution or a collective EVCI (C14-100). The outcome of the choices made between these two solutions is inherently uncertain, and Enedis, for the NDP baseline scenario, has assumed a 50% split between condominiums in favour of collective EVCI solution, on average over the time frame.

• This scenario describes the development of collective EVCI as a new type of distribution system for electric vehicle charging in condominium parking lots. The scenario predicts that the number of infrastructures will start to grow in 2023, reaching a peak of 25,000 in 2027, followed by a gradual decrease of connection requests as parking lots become saturated. By 2030, the number of individual charging stations could reach 400,000, depending on demand.

Enedis has collaborated with many stakeholders in the electric vehicle-charging sector

Enedis is a recognised partner, sought out by customers, private and public actors for its neutral and independent expertise.

Enedis has partnered with many real estate actors and stakeholders in the relevant sectors to:

• develop personalised support for all projects for the collective installation of charging points in residential buildings ;

• establish specific guides for condominiums, trustees, landlords or developers to guide them in their process and allow them to compare the different possible solutions ;

• facilitate and carry out the work concerning Enedis, in particular the extension of the distribution network in parking lots whenever this solution has been chosen ;

• work with national actors, including AVERE (the European association for electromobility) and the Automotive Platform (PFA - the French car makers' association), to work towards regulatory changes;

• and to define incentive mechanisms.

The pre-equipment of new collective residences with charging installations is spreading

The real estate industry is gradually incorporating electric mobility into its projects. The law requires developers to install cable ducts for charging stations. Some developers are going even further by offering electric car sharing or the option to install a charging station for future buyers.

2.1.2.3.4. Enedis supports the connection of very high-power charge points for long-distance journeys

The deployment of high-power charging networks on major axes has been rapidly expanding since 2020, especially in 2021 following a regulatory change that introduced a subsidy.[25] This trend is expected to continue in the coming years due to technological advances (increased vehicle range), the continuation of economic and regulatory incentives, and economies of scale (balance of thermal/electric price). As a result, EV users will increasingly undertake long-distance journeys.

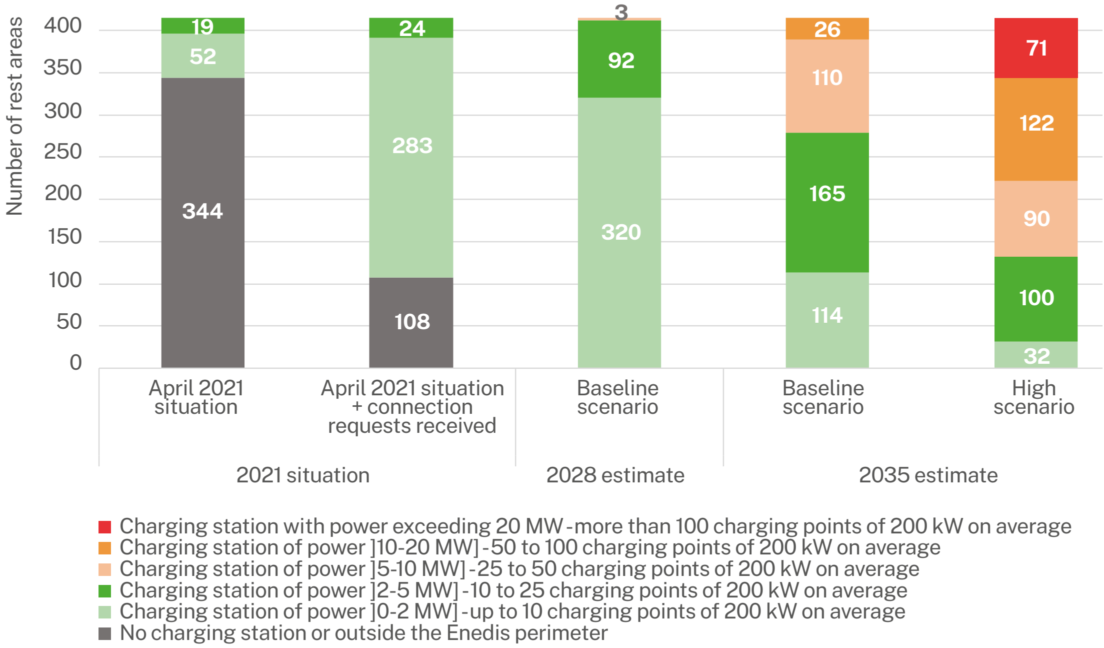
Enedis is preparing for the massive deployment of high-power charging stations on motorway service areas in the coming years. To this end, Enedis and RTE conducted a technical and economic study in 2020 to assess the expected demand for high-power charging for light vehicles at 415 motorway service areas. The study also estimated the costs of upgrading the electricity networks necessary to support this demand.

Enedis and RTE released the findings of this study to the public in a joint report published in July 2021. The report is titled "Enedis et RTE, Electric needs for long-distance mobility on motorways." (*Enedis et RTE, Les besoins électriques de la mobilité longue distance sur autoroute*). Regarding the assessment of the forecast demand for high-power charging, the study highlights the following main findings (see figure 16):

- By 2028, demand is expected to remain below 2 MW for 75% of rest areas (320), i.e. 10 hypothetical 200 kW charging points.

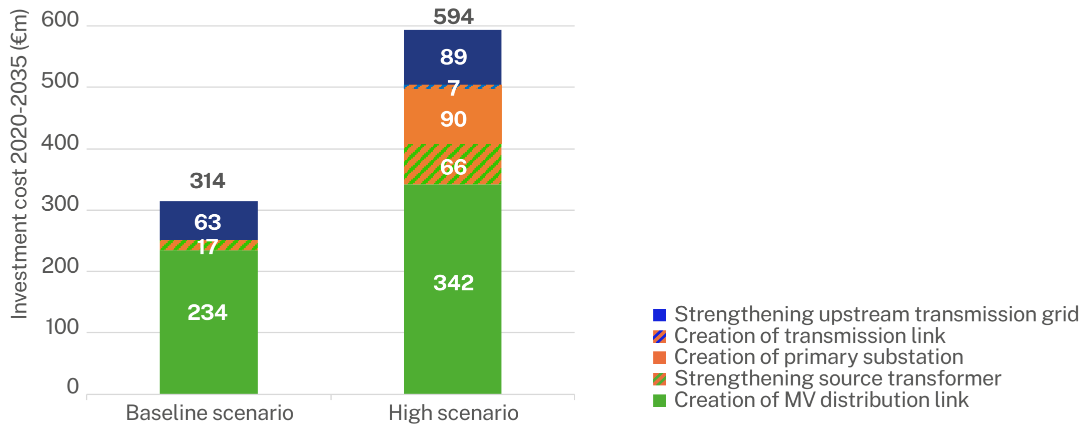
- By 2035, the total installed capacity of charging stations on motorways is estimated at between 2 GW and 5 GW, depending on the scenarios studied. This corresponds to an average capacity per area of between 4 MW[26] and 12 MW, with very significant disparities from one area to another. In the "high" scenario, which includes the stress assumptions for the network, 32 service areas (out of 415 studied) would have a capacity of less than 2 MW, and 71 service areas would have a capacity of more than 20 MW.

Figure 16: results of the joint study by Enedis and RTE – assessment of the forecast demand for high-power charging at 415 motorway rest areas



25. Decree no. 2021-153 of February 12th 2021 and Order of February 15th 2021.
26. Maximum annual hourly power reached for the 30th busiest traffic hour of the year. Currently, highway companies dimension service stations on the assumption that highway rest areas will be able to meet charging needs, without excessive waiting times for motorists, every hour of the year except for the 30 busiest hours of the year. This assumption of electrical sizing at the 30th hour is the one that has been retained in the reference scenario of the joint study by Enedis and RTE.

Figure 17: results of the joint study by Enedis and RTE - Estimated cost of upgrading electricity networks to meet demand for high-power recharging at motorway service areas



The networks will be able to adapt to motorway charging requirements, without any major impact on financial trajectories or any particular technical challenges. The cost of developing transmission and distribution networks to supply charging stations on motorways is estimated at between €300 million (reference configuration) and €600 million (high variant) between now and 2035, which represents between 0.3% and 0.6% of the investment planned by DSOs/ TSOs over the period (see figure 17).

The announced costs include the HV and MV network charges to connect the service areas (except for any medium-voltage back-up that may be additionally required), but they do not include the installation of service infrastructure (IRVE) within the service area (the cost of which varies between €2 and €3 million per area). The requirements for heavy-duty mobility charging will also need to be factored into the study.

2.1.2.4. Load management for EV charging: an opportunity for end users' savings and a potential for the network

Load management of electric vehicles can generate concrete savings for end users. In December 2020, Enedis published a report "Enedis, Load management of electric vehicles charging, an opportunity for consumers and the public electricity distribution network" (*Enedis, Pilotage de la recharge de véhicules électriques, opportunité pour le consom'acteur et le réseau public de distribution d'électricité*). That report suggests that end-users could achieve savings by reducing their peak demand, which could lower the cost of their connection, or by charging their vehicles at off-peak times, when electricity sourcing is usually cheaper.

Load management of electric vehicles can be used to reduce the peak demand for electricity, which can help to balance the supply and demand of electricity and reduce the need to upgrade the network. It can also provide flexibility opportunities to the network, such as EV charging during off-peak hours or by scheduling the charging cycle to coincide with periods of excess capacity on the network.

Finally, due to the massive deployment of distributed generation, in some cases, electric vehicles could be charged according to wind and solar power generation. Several projects are under way to assess the technical feasibility of these use cases: in conjunction with market players, Enedis is conducting real-life conditions tests to combine EV charging with renewable energies at site level (individual self-consumption) or at local level.

Enedis has also conducted several studies to describe the potential optimum for the coupling of electric vehicles and photovoltaic solar panels.

- from the user's perspective, there are several incentives to this solution, including financial savings on energy bills ;
- from the network's perspective, the situation is more mixed. A local optimum may not be optimal for the entire network. Synchronisation that reduces local transit flows could interfere with the upstream network optimisation (on the associated MV feeder) or even the nearby network (on another LV feeder).

Today, from Enedis perspective, synchronisation between electric vehicles charging and solar generation does not provide any proven benefits to the distribution network. However, Enedis intends to continue to explore this possibility while meeting society's desire to consume green and local energy.

2.1.2.5. Summary of capital expenditures for the integration of electric vehicles

The development of electric mobility has been included in the NDP forecasts, looking ahead to 2032 (see figure 18). This preliminary estimate is indicative and will have to be regularly updated according to a variety of parameters: actual development of electric mobility, installation of new charging points and their capacity, consumer habits, etc.

The planned investments for electric mobility integration initially involve completing the connection of public charging stations, a task that is already well underway. Subsequently, investments will significantly increase as the connection development advances. Charging facilities for residential buildings will employ the collective EVCI solution, assuming a 50% average adoption rate over the alternative private solution. Investment is expected to peak in 2027. The Enedis-managed network will then connect over 25,000 collective EVCI (see 2.1.2.3.3). Once apartment buildings are equipped with these collective EVCI, investments will decrease and focus primarily on deploying individual derivations upon customer request. Thus, the quantity of individual derivations to be constructed, which are currently in an emerging stage, will rise to annual 250,000 requests by 2027, peak at 400,000 in 2030 and then fall back to 300,000 by 2032.

Figure 18: trajectory of planned annual investment for network integration of electric mobility: connection of EVCIs (in billions of euros)

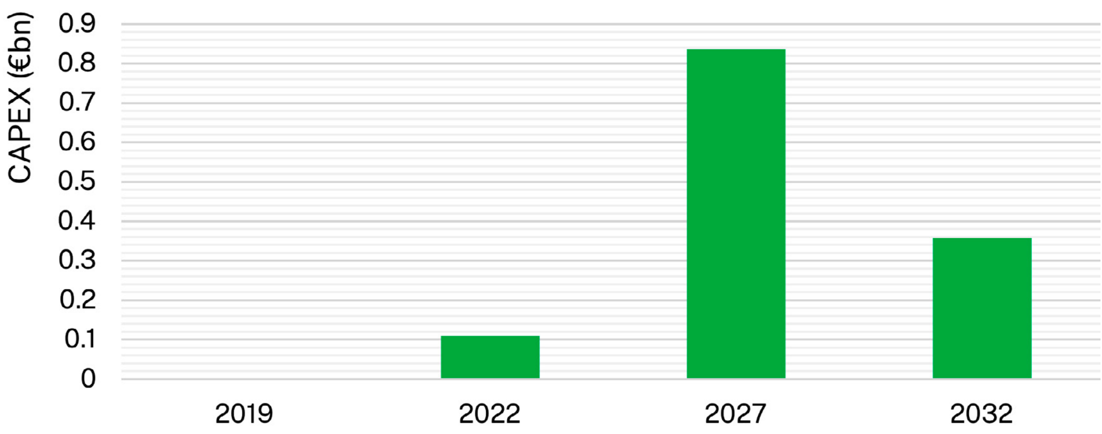
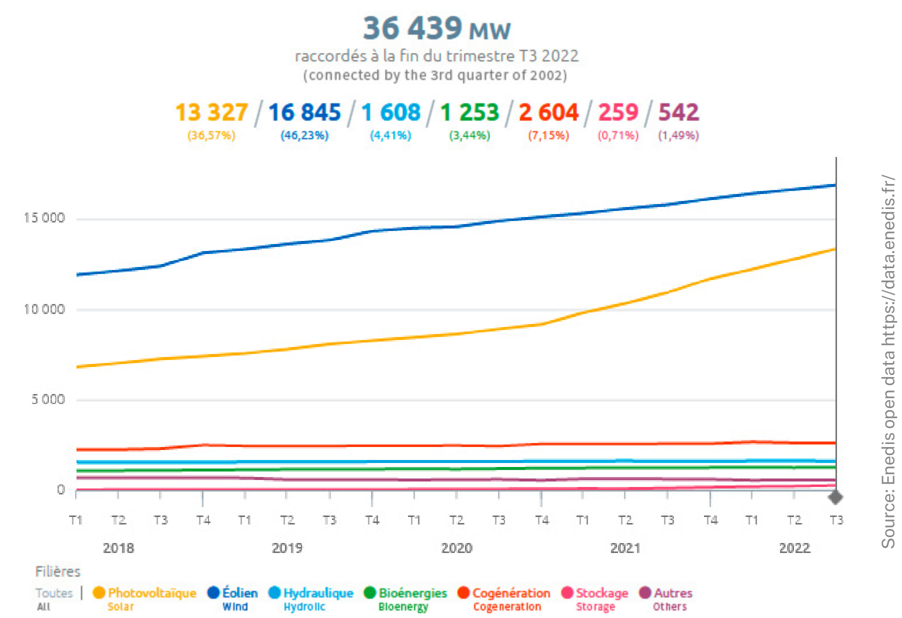


Figure 19: number of distributed power plants connected to the public distribution network by Enedis



2.1.3. Renewable energies: a significant volume already connected, with an ambitious prospect based on the French multi-annual energy plan, which requires careful consideration of the desirable mutualisations of connections and the flexibilities that can be activated

Aside from historic hydroelectricity generation, renewable energy power plants began to develop in the early 2000s at different rates depending on energy source and regulatory incentives. For instance, the installation of photovoltaic panels on residential roofs accelerated sharply from 2005, peaking at more than 100,000 connections per year, while wind power has played a greater role since 2010, with increasing installation size. Furthermore, significant solar power plants have been introduced in recent years, and photovoltaic electricity generation is poised to become the primary generation source in the near future.

This long history of connection has enabled the industrialisation of connection processes for the various renewable energy sources. This experience has led to the development of Enedis' reference connection offer (ORR), which continues to offer cost-effective connection services to meet new demands. The methods used to define the ORR are described in 5.3.1.

An inventory of connections at production sites is proposed (2.1.3.1) to provide an overview of the network issues associated with this use. Considering the significant influx of producers projected in the NDP's baseline scenario based on the PPE (2.1.3.2), the classic unitary approach of the ORR is complemented by a broader analysis of the potential for the development of distributed generation (2.1.3.3) as well as considerations on the use of flexibilities (2.1.3.4).

2.1.3.1. Renewable energy power plants connected to the distribution network: current situation and connection typology

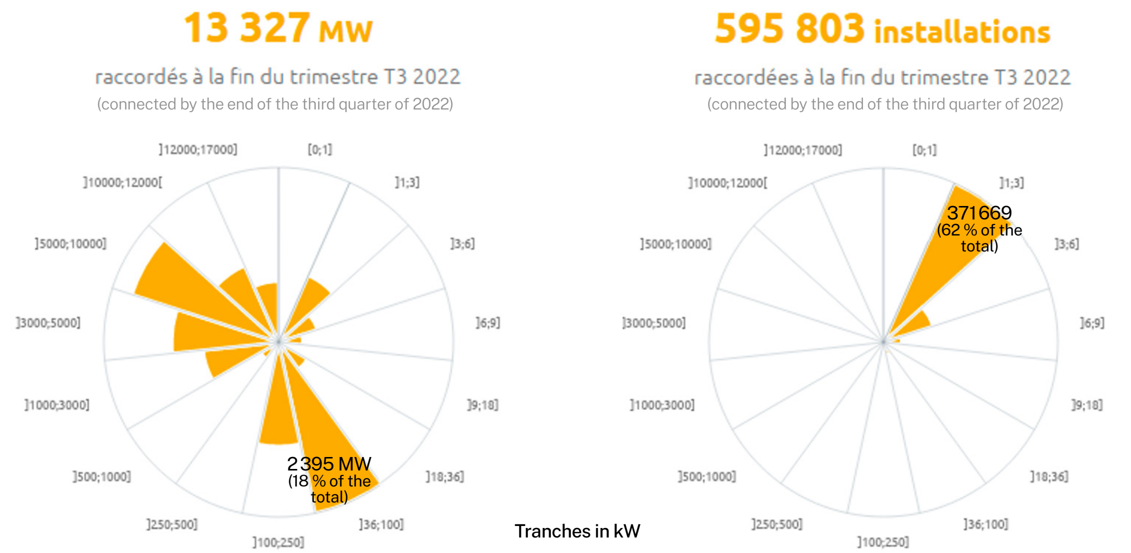
General overview of connected generation

By the end of 2021, Enedis managed a distribution network with almost 34 GW of distributed power plants capacity. Solar (12 GW) and wind (16 GW) are the primary sources of generation, as shown in figure 19.

Solar generation plants come in a wide variety of power levels:

- PV panels installed on the roofs of individual houses, typically from 1 to 6 kW. This equates to more than 400,000 installations connected to the network by Enedis (see figure 20).

Figure 20: solar generation - power and number of plants installed



Source: Enedis open data https://data.enedis.fr/

- Medium-sized solar power plants, from 36 to 250 kW, for example on top of infrastructures such as parking shades, warehouses, hangars or shops.

- Medium-voltage installations exceeding 250 kW, typically large solar power plants of several MW.

Wind power plants often possess noteworthy generating potential, owing to the individual capacity of a single wind turbine (1 to 3 MW) and the potential for numerous turbines (see figure 21).

Power plant connection typology

Depending on their installed capacity, these generators are connected to:

- low voltage (LV) networks: this essentially corresponds to the scattered connection of PV panels on residential and small business roofs, for a total connected capacity of 6 GW;

- medium-voltage (MV) networks, for installations over 250 kW: this corresponds to wind power plants and large solar power plants, for a total connected capacity of 28 GW.

The connection study determines the reference connection offer. Whether the connection is to the LV or MV network:

- Either this new producer can be connected to an existing feeder that serves consumers and/or producers, which may require reinforcing part of the feeder and/or the upstream transformer to accommodate the new power plant.

- Or it must be connected to a new feeder, which is mainly the case for producers with a high connected power compared to the power bands allowed per connection voltage level.

In both instances, the connection of a power plant to the distribution network may require an upgrade of the distribution and transmission network technical capacity. This may involve the substitution of an HV/MV transformer (i.e. the replacement of an existing transformer with a higher rated one) or the addition of a transformer at the primary substation, the creation of a completely new primary substation or even the reinforcement or creation of HV lines. The reinforcements and construction of assets are sized to meet the medium-term regional targets defined by the Prefect and set out in the regional renewable energy connection master plan (S3REnR) described in 2.1.3.3.

To meet the needs of specific geographical areas where large distributed generation groups are developed, primary substations are commonly created solely on generation capacity at the time of commissioning. For instance, the Faux-Fresnay site, unveiled in October 2021 in the Marne department, has four primary substations, combining twelve HV/MV transformers, capable of handling 400 MW of wind generation.

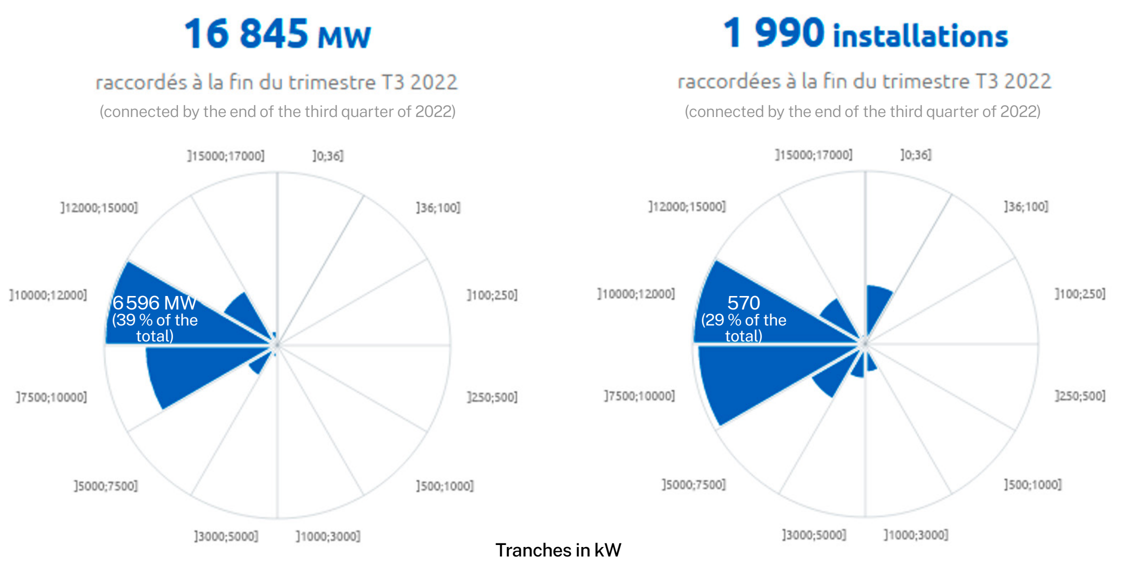
Although they were dedicated to the evacuation of generation when they were created, the above-described infrastructures are not intended to remain so indefinitely: restructuring work or the connection of new consumers in the area could subsequently benefit from these networks, even though they were initially built to accommodate massive influx of generation. There is no intention to reserve parts of the network for a specific category of users, as the public distribution network is intended as a collective optimum serving all users.

2.1.3.2. A baseline scenario based on the multi-annual energy plan (PPE): Enedis has the ability to connect renewable energies to meet these objectives

Over a ten-year period (2019-2028), the PPE aims for an increase in both solar and wind power capacity:

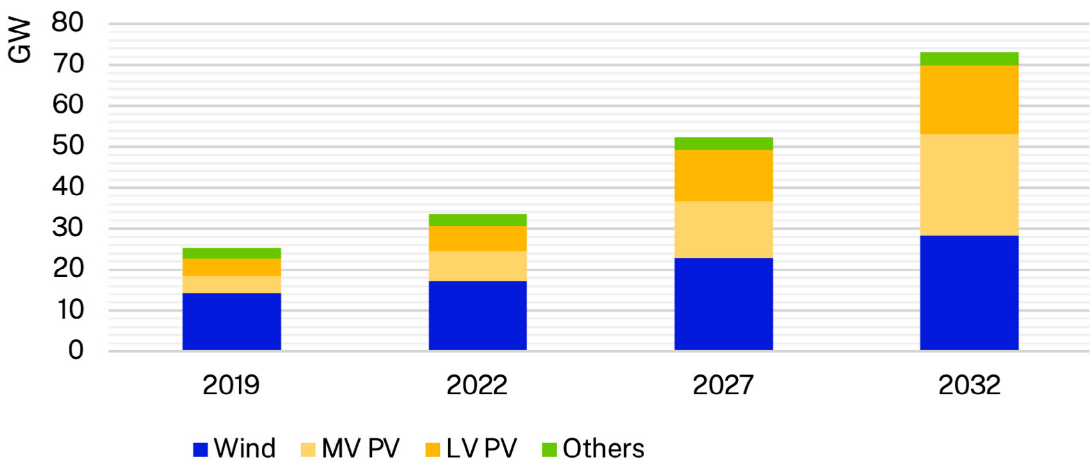
- Installed solar power capacity is set to increase from 9 GW to 44 GW in 2028 ("PPE" high target), which would multiply the amount of energy produced in proportion, from 8 TWh to 41 TWh.
- For onshore wind power, installed capacity is expected to rise from 15 GW to 35 GW, and output from 26 TWh to 60 TWh in 2028 ("PPE" high target), i.e. an additional 34 TWh injected into the network.

Figure 21: wind generation - power and number of plants installed



Source: Enedis open data https://data.enedis.fr/

Figure 22: baseline scenario - cumulative renewable power plant connection



To illustrate, in 2028 the total amount of electricity produced on the network would be over a quarter of the energy drawn by consumers.

These PPE targets refer to the total number of connections of distributed generation facilities in France: to the transmission network (RTE) and the distribution network (Enedis and ELDs). Scaling is necessary to distinguish the proportion of power generated by producers connected to the distribution network managed by Enedis from all producers connected to the transmission and distribution networks, including ELDs. It is important to note that Enedis is not involved in the connection of specific renewable energy sources: offshore wind will be connected to the transmission network.

The baseline scenario considered by Enedis for this NDP concerning the integration of renewable energy generation, which supports the investment trajectories presented in 2.1.3.7, is consistent with the ambitions of the "PPE", with a few adjustments described in 1.6.3.2.

As the connection capacity of solar producers ranges from a few kW on the LV network to several MW on the MV network, a finer graduation of the total capacity to be expected on the distribution networks is suggested, based on the segmentation of current connections and pending connection requests (see figure 22).

In this scenario, onshore wind generation grows at a steady rate of around 1 GW/year, reaching 28 GW in 2032. Meanwhile, solar generation grows apace, with capacity connected to the public distribution network increasing from 14 GW to 42 GW in 10 years, comprised of a large number of low-voltage connections in the 100 kVA to 250 kVA power range. The NDP baseline scenario is subject to two possible distortions:

- The "S21" decree of October 6th 2021 setting the conditions for electricity buy-back from solar power plants installed on buildings, hangars or shading systems, among others, has changed the tariff regulations.[27] This promotes development of solar power plants with a capacity of under 500 kW. As MV connections are more expensive for producers (who do not benefit from the rebate on their MV/LV substation and their LV line), most connection requests subsequent to the S21 decree remain in the LV range, with power ratings of less than 250 kW. As a result, the breakdown of solar power plants connectable to the LV network is shifting towards higher average capacities than previously, with installations in the 36-250 kW range. This trend needs to be monitored to ascertain whether it is a persistent phenomenon, which could significantly increase network connection costs (see 1.6.3.2).

27. Order of October 6th 2021 setting the conditions for electricity buy-back from power plants installed on buildings, hangars or shading systems, produced by solar installations using solar energy, with an installed peak power less than or equal to 500 kilowatts, as referred to in 3° of article D. 314-15 of the Energy Code and located in mainland France.

- The geopolitical context should also be factored in (e.g. the EU's REPower proposal).

The displayed scenario is merely a baseline trajectory; Enedis is prepared to adapt around the announced volumes.

The baseline scenario adopted in this NDP provides a reference trajectory, enabling the DSO to prepare its workforce, equipment, service providers and investments. As this target becomes more defined and as actual requests for connections materialise, Enedis will accommodate accordingly. 2020 and 2021 are examples of this adaptability to emerging trends, since Enedis has been able to respond to a very sharp and sudden increase in volumes of connections. Thus, in 2021, 3.7 GW of newly connected renewable power plants were added to the network managed by Enedis. This is compared to an average of 2.2 GW of annual connections over the period 2017-2020. Furthermore, Enedis was able to connect 34,000 new generation plants in 2020, despite the health-crisis, rising to 61,000 in 2021, whereas only 22,000 new plants were connected in 2017.

While the Enedis network and organisation are capable of adapting to an increased number of connection requests, new technical issues arise (e.g. related to the voltage management scheme and overvoltage, see chapter 5). Capacities of primary substations and transmission lines may reach saturation point, raising issues of shared costs and reinforcement timescales. Greater consultation between TSO, DSO and all other stakeholders is therefore essential in order to find the best collective solution.

2.1.3.3. The S3REnR: strategic planning tools to ensure the integration of renewable energies at manageable cost

The regional renewable energy master plans (S3REnR in French) provide a framework for the energy transition. These plans are subject to extensive discussion and are ratified by the regional prefect. Their purpose is to coordinate the integration of renewable energy into the electricity networks, optimising the development, use and cost of the infrastructure needed for their connection, while ensuring the safety of the system.

The main objectives of the S3REnR are:

- To plan the development of the transmission and distribution networks needed to accommodate renewable energy sources over a given period of time and in a given area.
- To share costs to encourage the development of renewable energy installations in areas where connection costs would be prohibitive for project developer.
- To provide stakeholders with medium term visibility on some of the costs and timescales for connection.

Principle of shared investment: the S3REnR allows assets costs to be shared between producers and local authorities.

Producers contribute to the development of new assets through their unit share[28] of the plan. This allows sharing of costs between all regional players (producers), both by providing medium-term visibility of the cost and by promoting parity of access to the network for part of connection costs

Thus, the S3REnRs make it possible to share some of the costs of connection to the networks, so that all renewable energy project developers (excluding exemptions) bear part of the costs associated with connecting their projects, where these costs would be prohibitive for an individual.

The S3REnR offers network planning tools drawn up by RTE in agreement with the DSOs

The purpose of the S3REnR is to specify the investments required for the structural part of the electricity networks and their financing, in order to accommodate the connections needs for renewable energy generation expected over the next ten years in each French administrative region. Accordingly, network capacities are dedicated to renewable energy generation. This plan is drawn up by RTE, the transmission system operator, in agreement with the distribution system operators, including Enedis, as required by law.

These plans aim to ensure that the network can accommodate the growth of renewable energy over the next decade, in accordance with the State's, Region's, and potential new renewable energy production facilities' guidelines, while considering environmental concerns.

Methodology for drawing up a regional plan

The S3REnR is set according to an overall connection capacity[29] set by the regional prefect, in accordance with article L. 321-7 of the French Energy Code. This capacity is defined based on the multi-annual energy plan (PPE), the regional spatial planning and sustainable development scheme (SRADDET) drawn up by the region, and the expected growth in connection requests.

28. The unit share represents the investment cost of the assets (transmission and distribution) newly created under the S3REnR, per MW created. Each renewable energy producer wishing to be connected under the plan must cover its share, which provides funding for these assets by sharing the costs between producers.
29. Cumulative power defined by the S3RENR and reserved for renewable energies connection to the electricity network in the geographical area covered.

INFORMATIONAL PANEL XI

The future of renewable energy connections in the french regions: necessary regulatory and process changes to accelerate connections progress

Since law and regulation in 2010 and 2012 respectively introduced the S3REnR principles, the regions have developed and implemented plans to connect around 10 GW of renewable generation. Regional plans, regulatory requirements and TSO/DSO's technical and operational processes have evolved continuously to improve the systems and keep pace with renewable energy development.

To meet the energy transition objectives, revisions to plans underway or carried out since 2019 have already included major increases in renewable energy capacity allocations, identifying the necessary structural changes to the networks to accommodate them.

However, as the growth of renewable energy is set to accelerate over the next few years, further improvements to the S3REnR system are now required in terms of: method used to draw up the plans; administrative and environmental procedures for drawing up and implementing works on public networks; anticipation of network's changes; methods and technical choices for network sizing; managing the collective costs of network development; etc.

All these issues are being explored by stakeholders of the electricity system, especially from early 2022, as part of the "Connection" working group led by the French directorate-general for energy and climate (DGEC). Several of the agreed measures will require legislative and regulatory amendments.

A census and analysis of the development potential of renewable energies is conducted, in collaboration with local energy stakeholders (project developers, government departments, distribution network managers, etc.), as soon as the plan is drawn up or revised. This analysis provides a spatial breakdown of the network connection capacity to be developed and reserved in order to accommodate this development. **The targeted regional network is then defined:** by projecting this power breakdown onto the existing networks, it is possible to assess the effect on these networks. A collaborative and iterative process then ensues with RTE to define the necessary investments for primary substations (existing or to be created) on Enedis' network. The process aims to find a collective technically and economic optimal solution:

- In some instances, the most appropriate technical solution for both the transmission and distribution networks can be established without ambiguity.

- Alternatively, several viable solutions with substantially different characteristics may lead to the construction of several connection scenarios.

The draft S3REnR resulting from the declared potential is then submitted for consultations in order to inform and gather opinions on the proposed solutions. In compliance with the requirements of the French Environmental Code, preliminary public consultation is undertaken. Stakeholders are then consulted in accordance with the French Energy Code.

On completion of this process, the regional prefect ratifies the unit share.

Implementation and running of the plan once approved

The S3REnR is a forward-looking plan for the development of the electricity network, based on a forecast of new production capacity. It does not commit to any specific renewable energy generation projects. Mechanisms are in place to allow for localised adjustments to network development as connection requests are received and installation projects proceed.

2.1.3.4. Flexibility to facilitate renewable energy connections

Local flexibilities are significant when considering renewable energies:

- **The REFLEX project** aims to extend the capacity of primary substations to accommodate renewable energy production by factoring in the coincidence of generated power and using selective generation limitation (also known as curtailment). This lever is described in informational panel XIII: the REFLEX project. This method would generate estimated savings of €250 million by 2035, i.e. a 30% reduction for the assets concerned.

- **Alternative connection offer (ORA) with power modulation for renewable MV producers** is an alternative to the ORR, allowing the optimisation of network adaptation work in return for occasional generation curtailments. This lever is described in informational panel XII: alternative connection offer (ORA) with power modulation for renewable MV producers. Although significant, this lever has yet to be quantified, pending a better assessment in subsequent updates of the NDP.

INFORMATIONAL PANEL XII

Alternative connection offer (ORA) with power modulation for renewable MV producers

Regulation requires Enedis to provide producers with a reference connection offer (ORR), in which Enedis guarantees the producer that it will be able to inject at maximum capacity at all times.

From now on, a renewable energy producer may request, alongside the ORR, an “alternative connection offer (ORA) with power modulation” (as defined in the Order), "for which the guaranteed injection power is lower than the requested connection power".

The ORA with power modulation allows for optimised connection costs and lead times in return for occasional curtailments of generation up to a limit of 5% annual energy generation and on a condition that at least 70% of the connection power is guaranteed at all times.

This allows the producer to be connected to the existing nearby network, rather than having to create a new feeder from the primary substation: the offer is therefore both cheaper and usually quicker. The overall collective savings (and therefore for the producer) of power-modulated ORAs for MV producers could reach €90k/MW, for a targeted 50 MW of production plants per year, as indicated in the report Economic valuation of Smart Grids (*Enedis et ADEeF, Valorisation économique des Smart Grids*).

Power modulation ORAs for renewable energy producers were authorised by decree in March 2020, within limits specified by order dated July 2021, and have been part of Enedis’ reference technical documentation since October 2021 for producers connecting to the MV network. They can be offered to any producer requesting them.

INFORMATIONAL PANEL XIII

The REFLEX project

Under current legislation[30], primary substations are sized according to the total installed capacity of producers, and transformer capacity is rarely used to its full potential.

Enedis is developing a new design in which assets are used to their maximum potential more frequently: the aim is to factor in coincidence of generated power and thus seek an economic optimum by connecting more producers to the same assets than is currently possible under current rules. This leads to occasional restrictions on their injections during rare periods when actual generation exceeds the evacuation capacities of the primary substations. Calls for tender will be the preferred means for acquiring the necessary flexibilities: these market flexibilities will compete with technically accessible, adjustable generation curtailment, at a contained and manageable cost, which is the alternative solution in the case of unsuccessful calls for tender.

This increases network hosting capacity, in addition to the optimal sizing of the public transmission network.

The "REFLEX" (REnewables and FLExibility) project, which is part of the S3REnR framework, uses targeted generation curtailments to optimise the sizing of "mutualised" assets initiated by producer groups on a region-wide scale.

ON THE CURRENT NETWORK:

- 2.5 GW of additional capacity could be made available in the short term.

BY 2035:

- Cumulative collective savings on the public distribution network could reach up to €250 million.
- The cost saving on these assets (the transformation capacity of primary substations) will amount to 30%.
- On average, curtailment will account for a maximum of 0.06% of the total energy generated by the newly connected power plants.
- In a mainly solar-powered region for instance, Enedis could economically connect 50% more producers to the same assets than it would under the current rules.

Unlike ORA with power modulation, where producers optimise the costs of their own assets, with REFLEX, a producer's curtailment will benefit everyone: therefore, unlike in the case of ORA where the producer is the main beneficiary, REFLEX curtailments will be compensated.

AS PART OF THE EXPERIMENT

Under the regulatory sandbox system validated in July 2021, REFLEX is currently undergoing testing on 10 primary substations in the Landes and Somme regions: within the scope of the experiment, producers are already benefiting from a REFLEX connection. The REFLEX experiment not only frees up more than 210 MW of capacity for renewable energy sources, but also has the potential to avoid the addition or relocation of several transformers, which could be transferred to other regional substations. This experiment is scheduled to last 4 years: assuming positive feedback and regulatory changes, REFLEX will be extended to all S3REnRs.

30. In absence of arrangements for limiting generation to optimise the sizing of shared assets on the public distribution network.

NFORMATIONAL PANEL XIV

The development of self-consumption

Today, "self-consumption" refers to two technical and contractual systems: individual and collective self-consumption.

INDIVIDUAL SELF-CONSUMPTION: WITHDRAWING RENEWABLE ENERGY FROM YOUR OWN GENERATION SOURCES

Individual self-consumption has spread rapidly under the combined effect of numerous factors:

- rising electricity prices (including the cost of networks and taxes);
- society's aspiration to "consume locally" and to "participate in the energy transition and the evolution of the generation mix";
- the technical and contractual simplifications introduced by Enedis (especially with the Linky meter, which allows connection without the need for an additional meter);
- national public subsidies (mandatory solar tariffs, calls for tenders for self-consumption, etc.) or sometimes local subsidies.

While this shift in valuation of the energy produced is likely to alter the balance in financing the networks, it has no effect on hosting capacity or sizing for the public network: the location of meters, which varies in the case of self-consumption, have no effect on the electricity flows. Rather, the behaviour of users, whether they are consumers, producers or self-consumers, can change them. Furthermore, the network sizing must take into account the diverse extreme situations that can occur, from rainy periods in a cold winter (when the network must supply maximum demand) to sunny periods during a summer slump (when the network must accommodate maximum local generation).

In order to properly size the network, it is therefore necessary to improve local forecasts of the development of all renewable energy producers (in both LV and MV networks), whether they opt for self-consumption or total injection into the public distribution network.

To date, self-consumption has thus been neutral when it comes to sizing the public networks needed to integrate renewable energy sources. Studies may be conducted in the future to ascertain possible changes in the behaviour of self-consumers.

COLLECTIVE SELF-CONSUMPTION: SEVERAL USERS SHARING LOCALLY GENERATED RENEWABLE ENERGY

Since 2018, Enedis has been offering a data-sharing service to manage collective self-consumption. More than 100 collective self-consumption initiatives had been recorded in France by the end of July 2022, which represents a 40% increase over the same timeframe in 2021, illustrating the growing societal interest in local channels.

LINKY METER, THE CORNERSTONE OF COLLECTIVE SELF-CONSUMPTION

Using load curves collected via Linky meters, it is possible to allocate the share of local production to each participant according to the modalities agreed in advance (the allocation keys are transmitted to Enedis by a representative of the operation, called the “organizing legal entity”). Enedis subsequently subtract the locally generated electricity that is consumed directly by the participant (or “self-consumed”), from the data transmitted to each participant’s electricity supplier. This subtraction is then reflected on each participant’s electricity bill. Participants retain the freedom to choose their complementary electricity supplier.

STAKEHOLDERS IN COLLECTIVE SELF-CONSUMPTION

The stakeholders in collective self-consumption are:

- electricity consumers;
- electricity suppliers;
- renewable energy producers;
- balance responsible parties;
- organising legal entities.

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Self-consumption projects vary widely depending on whether they are designed to share production between multiple buildings owned by the same individual (private individual, industrial, company, local authority) or owned by multiple owners (mixed with public buildings, social housing, social residences, etc.). However, in each project, while the players involved may differ, Enedis remains a core player, providing the smart meters essential for self-consumption as well as the associated data, such as the load curve of these customers and the calculations derived from it.

IMPACT ON THE DISTRIBUTION NETWORK

Collective self-consumption, like individual self-consumption, does not require the development of new public networks to incorporate renewable energy. If consumption and generation are synchronised, collective self-consumption reduces the amount of power that needs to flow through the network. However, the network still needs to cope with situations where there is a peak in generation and a dip in demand, or alternatively where there is a peak in demand without any generated power. Future studies may be conducted to determine whether the behaviour of consumers who benefit from self-consumption changes.

OTHER FORMS OF SELF-CONSUMPTION

Legislative and regulatory changes should accelerate the development of new forms of local energy exchange, such as renewable energy support schemes, expanded scope, opening up of collective self-consumption to medium voltage (MV), energy communities, and so on.

2.1.3.5. Technical levers to encourage the connection of renewable energy: only MV reactive regulation is covered by this NDP

Among all the technical levers promoting the integration of renewable energy sources presented in section 6.2, only MV reactive regulation of producers (tan(φ) set points or Q=f(U) law), industrialised for several years, is taken into account in the NDP trajectories. The reactive regulation of LV producers, expected to be industrialised in the first quarter of 2023, will help reduce the unit cost of LV generation insertion and increase hosting capacity (estimated at 30% additional hosting capacity). The future NDP updates will take this lever into account. As other technical levers are still at the experimental stage, their impact will be reassessed as their development unfolds.

2.1.3.6. Self-consumption, an emerging trend with no current impact on network investments

The public distribution network serves to adapt consumption to meet societal objectives. Individuals, businesses, local authorities, energy communities and eco-neighbourhoods, for instance, can adapt their consumption according to nearby renewable energy generation. Motorists can synchronise charging of their electric vehicle with solar power generation. In most cases, this involves adjusting consumption to encourage self-consumption (see informational panel XIV: the development of self-consumption). The network's collective value in serving these consumer adaptations takes three forms:

- Firstly, the network is needed in order to interconnect producers and consumers and provide them with the possibility of using local and renewable electricity.
- In addition, the network provides the data needed to adapt consumption to the power plant's generation. The principle of collective self-consumption applies here: as data manager, Enedis can certify the volume of energy injected by a given producer over a given period, as well as the volume withdrawn over the same period by the consumer.
- Finally, Enedis' smart metering infrastructure, Linky and industrial meters, can be used to set up a synchronous link between producer and consumer. For example, by using solar off-peak hours or Linky's virtual contacts.

The NDP does not discriminate the impact of investments linked to the future development of individual or collective self-consumption from that related to the development of associated generation capacity. Self-consumption is considered neutral for network development (see informational panel XIV: self-consumption development). Enedis is closely monitoring these developments and, in accordance with their deployment trajectory, will continue its work in order to improve their understanding and analyse their consequences in terms of distribution network cost allocation.[31]

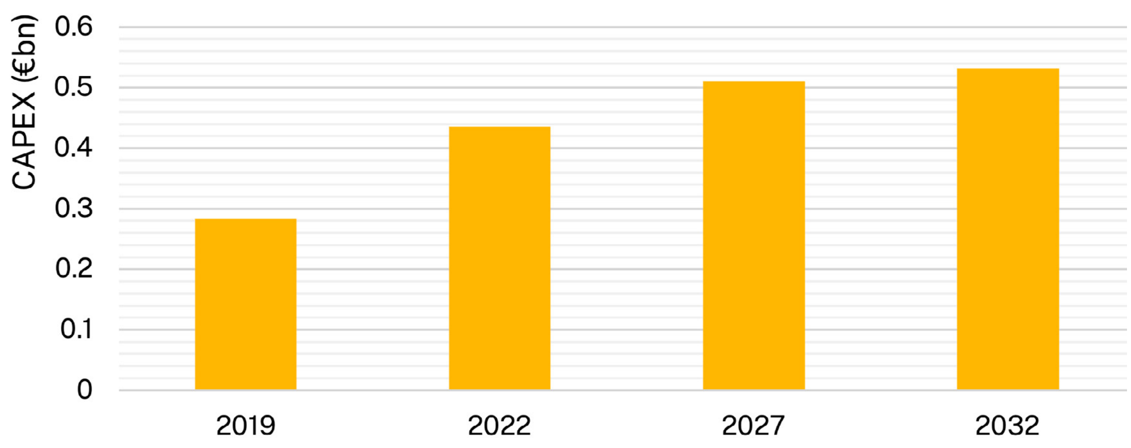
2.1.3.7. Summary of investments for the integration of renewable energies

Figure 23 gives an overview of the investment planned to roll out the S3REnRs and connect individual producers.

Capital expenditure (CAPEX) for renewable energy integration increases over the time frame, particularly in line with the number of solar power plants to be connected. Investment requirements for these connections are expected to increase by 20% over ten years, from €400 million in 2022 to €500 million in 2032. This investment trajectory is based on the costing of the NDP baseline scenario for renewable energy connections (see 2.1.3.2), which is based on the 2019 multi-annual energy plan (PPE). Recent developments in this area (publication of S21 in October 2021 and the ongoing project to accelerate renewable energy) are likely to prompt an upward revision of these scenarios. Enedis will be able to adapt to these changes and these revisions will be reflected in a future update of the NDP.

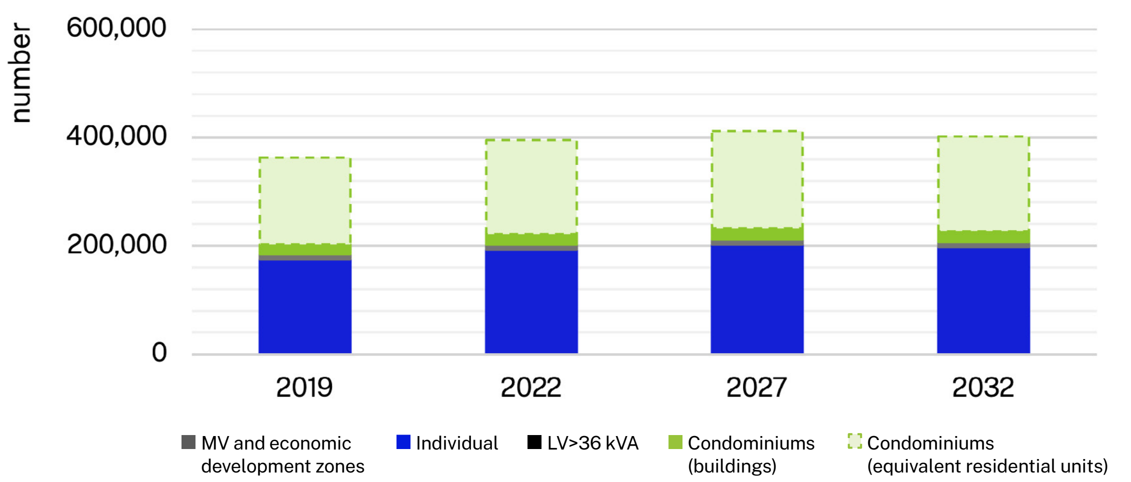
These investments will make a significant contribution to accelerating the ecological transition.

Figure 23: trajectory of planned annual investment to connect renewable energy producers



31. Initial feedback has been shared with CRE and published in its public consultation n°2020-017 of October 8th 2020 relating to the upcoming tariff for use of the public electricity distribution networks (TURPE 6 MV-LV), under heading 4.7.2.

Figure 24: baseline scenario - annual number of connected consumer customers, by category[32]



2.1.4. The challenges of consumer connections

2.1.4.1. 400,000 consumer connections per year: a major challenge in terms of performance and simplification for Enedis

While electric mobility and renewable energy developments will necessitate changes to future investment trajectories, Enedis' primary focus remains on serving all consumer customers under the best possible safety and continuity of service conditions, meeting their daily needs.

Enedis, in its role as a distribution system operator (DSO), connects all new users, whether residential or commercial, upon request. The number of new delivery points commissioned each year is close to 400,000, which is significantly higher than in neighbouring countries due to population growth and associated economic activity.

There are usually several types of connection for electricity consumption:

- individual low-voltage connections for new residential users (detached houses) or small businesses, most of which involve connecting to the existing network;
- connections to condominiums serving several units (about ten on average) as well as low-voltage commercial spaces;
- low-voltage connections for medium-sized businesses;
- MV connections for larger industrial or service companies;
- development of joint development zones (ZAC).

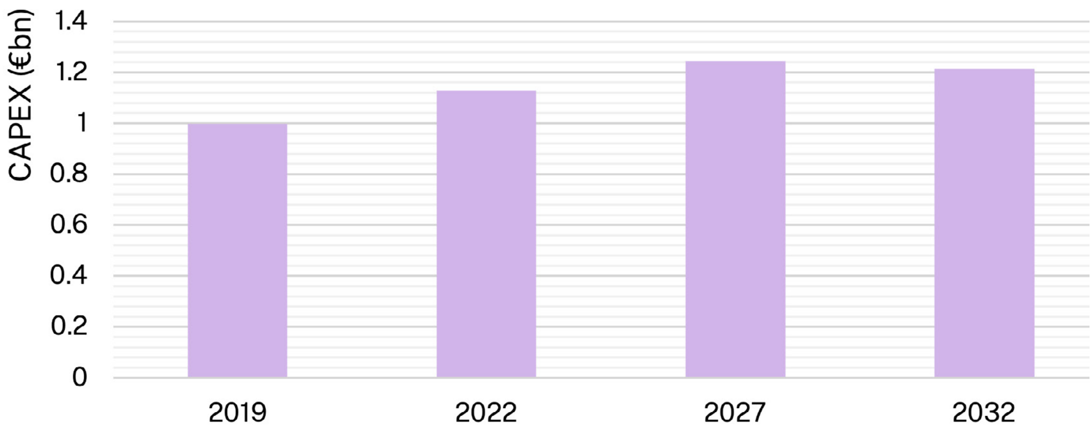
The variety of customer types necessitates different connection methods. For the most common types of customers, standardised connection methods can be used. However, individual connection studies must be carried out for customers with power requirements exceeding 36 kVA or requiring network extension. This results in significant investments by Enedis in the construction of new assets, which is Enedis's largest investment item.

The NDP baseline scenario

Enedis forecasts that, over the period covered by this network development plan, the number of dwellings (both individual dwellings and collective dwellings) will increase at an annual rate similar to the current rate. This is the result of a combination of the expected slowdown in population

32. The total annual number of connected consumers in collective (buildings) and collective (dwelling equivalent) represents an estimate of the total number of collective connected consumers.

Figure 25: planned annual investment trajectory for consumer connections, excluding electric mobility (in billions of euros)



growth, in line with INSEE forecasts, and a reduction in the average number of people per dwelling.

The NDP baseline scenario, shown in figure 24, is therefore built on a matching number of connections to the one observed on average in the previous years.

2.1.4.2. In this NDP, the flexibility levers which can be activated for consumer connections are not currently considered by Enedis

For connection requests from MV or LV consumers (excluding renewable energy and electric vehicle charging infrastructure), the alternative connection offer (ORA) with power modulation could be proposed to unitary customers as an alternative to ORRs. These flexibility options are still being tested and refined, to establish and confirm their fundamental principles, especially those related to technology and economics.

To date, Enedis considers that the potential customer base for ORA with power modulation is limited. Implementation of this new offering would require changes to existing regulations and provisions to ensure that it does not deviate from the principle of customers declaring their connection power.

2.1.4.3. Summary of investments for the connection of new consumers (excluding electric mobility)

Figure 25 shows the investment in connections for new consumers, excluding electric mobility.

Following the current period of strong connection growth, long-term growth assumptions indicate that capital expenditures (CAPEX) on consumer connections will stabilise at around €1.2 billion. The increase from 2019 to 2022 is attributed to the robust post-COVID economic recovery.

INFORMATIONAL PANEL XV

Energy performance of buildings

THE IMPACT OF ENERGY EFFICIENCY ON ELECTRICITY DISTRIBUTION NETWORKS

Energy renovation involves work carried out on an existing building to reduce its energy consumption. The government has introduced financial support to help with these renovations. In addition, the new environmental regulations (RE2020) are designed to further improve the energy performance of new buildings, following the previous thermal regulations (RT2012).

Load variations encompass both the downward effects of reducing energy consumption and the upward consequences of increasing electrification, among others. The combination of these two trends, and their respective timeframes, determines the potential investment needs on the network. Enedis' current projections suggest that the increase in electricity consumption due to the electrification of uses should eventually be stronger than the decrease induced by energy efficiency improvements.

ENEDIS ASSISTS LOCAL AND REGIONAL AUTHORITIES IN ACHIEVING FAIR AND EFFICIENT ENERGY TRANSITION

Enedis commits every day alongside local authorities to ensure that the distribution network becomes the driving force of the ecological transition by providing impartial, transparent and practical support. Enedis is also tackling precariousness in partnership with suppliers, especially with regard to the challenges of licensing authorities in France's metropolitan areas.

The involvement of Enedis in the partnership set up by the Banque des Territoires, which also includes the French government and GRDF (French gas distribution system operator), is an illustration of this commitment. Enedis provides data management support for the Prioréno AI service, which helps local authorities to identify and prioritise projects for improving energy efficiency.

2.1.5. Network reinforcement

2.1.5.1. To determine the necessary reinforcements for the evolution of consumption, it is essential to assess the growth and electrification of uses, while also taking into account energy conservation

The electricity consumption of existing customers may increase as they adopt new electrical equipment and technologies. This could be due to a variety of factors, including the growing use of home automation and connected devices. Furthermore, customer demand for electricity will gradually increase due to the electrification of uses intended to reduce greenhouse gas emissions. In particular, Decree No. 2022-8 of 5th January 2022, which specifies the minimum environmental performance requirements for the installation of equipment for heating or hot water production in buildings, is now promoting the transition to electrification. Heat pumps, which are energy-efficient electric heating devices, are becoming an increasingly popular choice amongst consumers, in accordance with global energy ambitions. Heat pump adoption has an impact on the electricity demand of electricity consumers, especially in cold weather when heat pump performance declines. Similarly, the gradual shift from combustion engine vehicles to electric vehicles is increasing electricity withdrawal from the network.

Asset adjustments, which are not caused by new connections, may sometimes be required due to this continuous evolution of loads and electrification of uses. These adjustments involve the deployment of new assets or an increase in capacity of existing ones (e.g. by replacing a saturated transformer with a higher capacity one).

These adaptations are necessary for assets whose capacities would be exceeded under the high-load diagnostic reference scenarios (see section 5.3 for a description of the reference scenarios used to size the networks). The natural increase in loads, including the impact of demand management measures (see informational panel XV: energy performance of buildings), is factored into technical and economic investment studies to design sustainable solutions.

2.1.5.2. Flexibility levers that can be activated to defer reinforcements related to consumption changes have margin value, as of today

This section analyses the various flexibilities that can be applied to postpone investments associated with consumption changes.

Two types of situations can be identified in which consumption flexibilities can intervene:

- **Constraints on primary substations and MV networks, resulting from local consumption changes.** As part of the proactive studies (see 5.3.2), the opportunity to use flexibilities is being comprehensively analysed since the end of 2021 for MV projects and associated primary substations. This analysis, seeking out situations in which flexibility could be technically and economically worthwhile in terms of investment (see informational panel XXXIV: identifying a flexibility potential), shows that the existing potential for such situations is limited. Theoretical flexibility opportunities are converted into realistic flexibility service specifications (time window, power, duration, and location), which include the associated willingness to pay. These flexibility opportunities are then tendered to market players. A collective benefit is achieved when Enedis' published flexibility opportunity is matched by a compatible offer from a market player, both in terms of specification and price. This occurs when the price of the service offered by the operator is lower than the community's willingness to pay for the service. The difference between the two is therefore equivalent to the benefit that this service delivers to the community. A brief description of this lever is provided in the informational panel XVI: what constitutes a flexibility obtained through calls fo tenders? Section 6.1.2, dedicated to methods and deployment of flexibilities, provides further details on this subject.

- **Constraints on MV/LV substations and the LV network:** As mentioned in 2.1.4.2, LV network flexibility remains a matter of research and development, underpinned by demonstrators, in order to identify the technical and economic concepts, with limited and remote potential.

INFORMATIONAL PANEL XVI

What constitutes a flexibility obtained through calls for tenders?

This is a service provided to the DSO following a call for tenders:

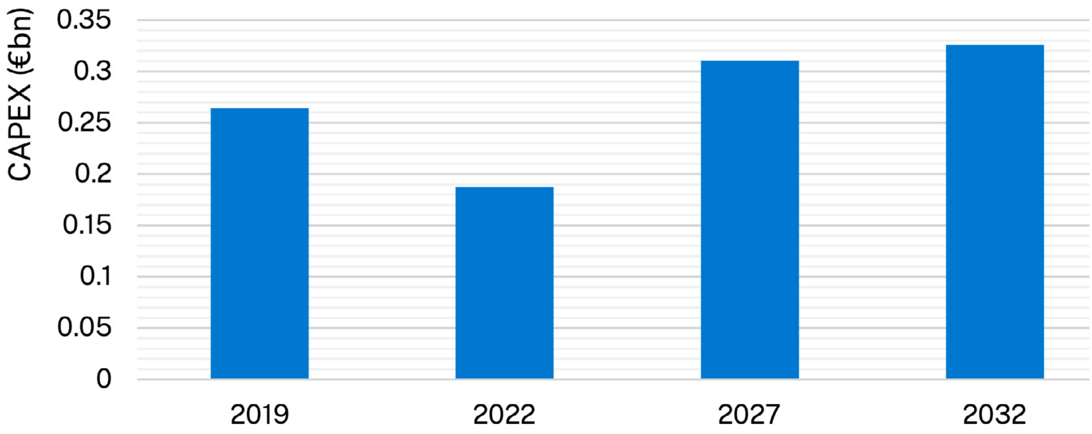
- **The DSO voices the need:** analysing network constraints and publishing flexibility services opportunities (where, when, how much flexibility).

- **Market players provide the service:** aggregators recruit and combine the flexibilities of several sites to provide the flexibility service required by the DSO. Individual sites can participate provided they are capable of delivering the service on their own.

- The DSO will contract with the market player whose offer fulfils the DSO's technical requirements and presents a better overall solution than the DSO's traditional solutions, considering both the expected value of the service and its pricing.

In real time, the operation control room activate the flexibility service as needed when a constraint occurs on the network.

Figure 26: trajectory of planned annual investments in reinforcing the network (in billions of euros)



2.1.5.3. Summary of the reinforcement investments

Network reinforcement investments in response to evolving demand are outlined in figure 26. The investments shown are entirely borne by Enedis, arising from trends in withdrawals and injections.

CAPEX for network reinforcement reached a low point in the year 2022. The decline in reinforcement in recent years is mainly due to a slowdown in consumption growth. Enedis has had to reduce its assumptions for consumption growth in the primary substation studies, resulting in fewer primary substations being constructed for reinforcement needs. In contrast, primary substations needed for connecting power plants under the S3REnR programme have increased in number. Reduced voltage drop constraints on MV feeders also led to decreased investment in MV feeder reinforcements.

Demand for network reinforcement is expected to grow by 2027, driven by the expansion of renewable energy and the electrification of uses, in particular electric vehicle charging and heat pumps. However, this growth, which is subject to some uncertainty in its assessment, will remain manageable due to intelligent management of electric vehicle charging and the coincidence factor of uses.

2.1.6. Hydrogen, sector coupling: further innovative ways of reducing the national carbon footprint, the impact of which is not quantified in the NDP

2.1.6.1. Enedis supports the development of the hydrogen industry

Enedis is contributing to the development of the local hydrogen industry by offering two types of connection. The future extent of these connections will depend on the national hydrogen roadmap, which outlines the plans for low-carbon and decarbonised hydrogen production and the development of light and heavy hydrogen-powered mobility.

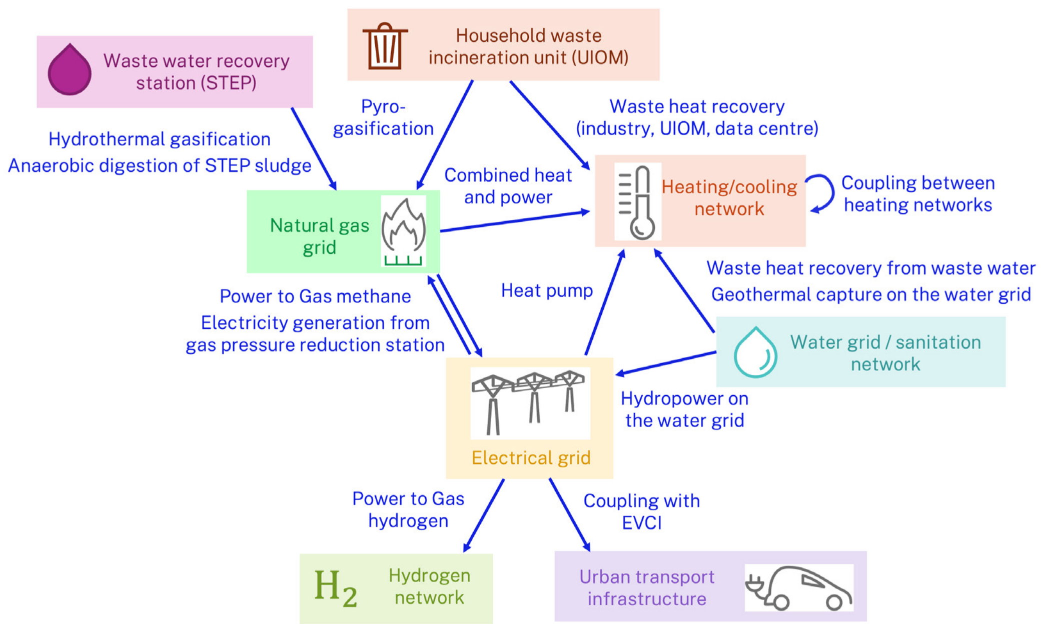
- Enedis connects the electrolysers to the public distribution network. This connection allows them to choose their energy supplier and to extract hydrogen from a low-carbon, or even decarbonised, renewable source, always available. This also allows them to participate in calls for tenders from network operators to optimise their flexibility in the energy market.
- Enedis also connects hydrogen fuel cells to the public distribution network, including heat and power cogeneration systems, providing them access to customers and enabling them to maximise their flexibility in both market and network operator tenders.

Outside the NDP (i.e. not included in the presented CAPEX trajectories), but still within the framework of the ecological transition, Enedis is working with industrial partners to develop zero-emission hydrogen fuel cell generator sets as an alternative to diesel engine generator sets to quickly restore power to customers in the event of incidents or network maintenance, excluding CAPEX and investments.

2.1.6.2. Enedis supports emerging projects of sector coupling

Sector coupling consists of combining several energy vectors to achieve synergies and optimise investment and consumption. All energy carriers, including electricity, gas, hydrogen, heat, cooling, water, sanitation, waste, and transport, can be part of sector coupling (see figure 27).

Figure 27: typologies of energy transfers by coupling between different urban networks



This sector coupling can contribute to the decarbonisation of existing infrastructures for a variety of purposes:

- adapting energy demand to optimise the consumption of different energy vectors and reduce network congestion (e.g., storing hot water for later reuse);

- reducing energy losses by using waste energy from one vector to power another (e.g., using waste heat to generate electricity);

- optimising investment costs by using local resources and networks to create a diversified energy system that combines different energy vectors.

The coupling of different energy sources can be achieved at different local levels, from within a building to a town or region. It can be implemented through local energy policies or through technologies such as hot water storage or hybrid heat pumps.

The electricity network is essential for the operation of equipment used to transport other energy fluids. It is a vector for coupling with other energy sources through the conversion of electricity to gas (power-to-gas), gas to electricity (gas-to-power), electricity to heat (power-to-heat), and electricity to cold (power-to-cold), as well as the production of hydrogen by electrolysis.

Enedis has participated in sector-coupling integration projects at a district scale. In Nice, for instance, a heat/cold network that uses geothermal energy from the Var alluvial aquifer will power the Méridia development area (24 hectares, 520,000 square meters of developable land). Solar panels coupled with batteries will complement the system. The area will have 1.6 Km of geothermal network and 5.6 Km of hot/cold water networks, so that 82% renewable or recovered energy for heat and 78% for cold will power it.

These operations could identify potential collective gains from investments, while ensuring that they comply with the national low-carbon strategy.

Enedis will therefore continue to collaborate on multi-energy projects that offer a net benefit to society in terms of both cost and greenhouse gas emissions.

Enedis is modernising the public distribution network to support the energy transition by serving the projects of local authorities and businesses, who are making their own energy choices. In some cases, sector coupling can help reduce investment costs, such as when designing or renovating a building or neighbourhood to make it more energy-efficient. By reducing the power required to connect to the electricity network, sector coupling can postpone the need for reinforcements.

However, this optimisation should be limited to local opportunities and should not significantly affect the growth trajectory of the public electricity distribution network. The NDP does not distinguish between or quantify hydrogen and sector coupling separately, but the investment volumes associated with these technologies are included in the total connection volumes.

2.1.7. Enedis innovates to increase efficiency when creating new primary substations

The construction of a primary substation, in partnership with RTE, is a major investment that will help to address the challenges of capacity constraints, future connections, and potential new operating schemes.

Approximately ten new primary substations are built each year, and this trend is set to accelerate, especially as renewable energy continues to grow.

Enedis is implementing two innovative programmes to meet this ambitious investment plan:

- **The "Express" primary substation,** an industrial innovation, enables both generators and consumers to get connected faster. Based on a system of pre-designed modules, it halves the construction time (from two years to around one year) and allows a faster response to connection requests from producers.

- **The primary substation industrialisation plan,** initiated in 2022. The main objectives are:

  - control of costs;

  - control of deadlines;

  - ensure that Enedis teams and contractors are able to carry out the work in a busy environment.

2.2. Enedis also develops the network to comply with regulations and matches third-party requests, for purposes beyond connections

In addition to connection requests, whether in withdrawal or injection, and network reinforcements discussed in 2.1, Enedis is also required to modify certain electrical structures due to requests, particularly regarding the integration of structures into the environment or compliance with regulations. The main actions that this may generate are described below.

2.2.1. Driven by local economic developments during constructions and works, Enedis carries out assets modifications

Local authorities may ask for structures to be relocated when changes are made to the roads leading to changes in the layout of the structures implanted there. For example, this can occur during urban development projects, construction of transportation lines (tram, metro, electric bus, bus rapid transit), roadworks, highway projects, etc.

Structural modifications can also be requested by third-parties (private individuals, companies, or local authorities), usually during building construction, demolition, or rehabilitation. This may involve changes to connections or network modifications: in this case, a financial contribution to the work is invoiced.

In general, a significant correlation is observed between the volume of work related to the relocation or modification of structures and the construction activity or major projects in regions or metropolitan areas.

2.2.2. The licensing authorities invest with Enedis to improve the aesthetic integration of assets into the environment

As described in paragraph 1.4, unless they choose otherwise, the licensing authorities are project managers for aesthetic improvement works on existing structures.

Such works by licensing authorities may involve removing bare LV wires, contributing to the improvement of power quality. Enedis and the licensing authorities share the objective of removing almost all bare LV wires by 2035. The "Article 8" agreements between licensing authorities and Enedis specify the conditions for removing bare LV wires, along with the financial contribution, typically 40%, provided by the licensed operator.

INFORMATIONAL PANEL XVII

MALTEN: neutral earthing

Changes in the regulatory framework in 2001 mandated distributors to limit overvoltages on the LV and telecom networks to ensure the safety of people and property.

Controlling overvoltages is directly related to managing the fault current in the event of an MV homopolar incident (fault between one or more phases and the ground or a grounded metal earth) on the overhead network in particular. Furthermore, the rapid development of underground MV cables has led to an increase in single-phase fault currents due to their capacitive effect, and the historical MV neutral point treatment (impedance earthed neutral) is no longer able to control these overvoltages.

A new technical policy was then implemented, introducing a solution known as “compensated neutral earthing”, which consists of earthing the MV neutral through a compensation coil combined with an automatic tuning system that compensates for the capacitive current of the network. The neutral earthing program (MALTEN in French) was launched in response to this challenge. This program involves transitioning to a compensated neutral system for a certain number of HV/MV transformers, requiring works at the primary substations. These works also necessitate an adaptation of the primary substation protection plan and works on the MV network, including the adjustment of fault detectors (with compensated neutral earthing, the fault current is lower and therefore more difficult to detect).

2.2.3. Illustrations of other actions by Enedis in response to regulations or third-party expectations

The topics covered are numerous. Examples include:

Concerning corporate social responsibility (CSR), Enedis aims for exemplarity, as detailed in chapter 7. This includes actions such as decontaminating assets containing asbestos and building oil capture devices under transformers. These actions are carried out annually to progressively reduce the associated health and environmental risks.

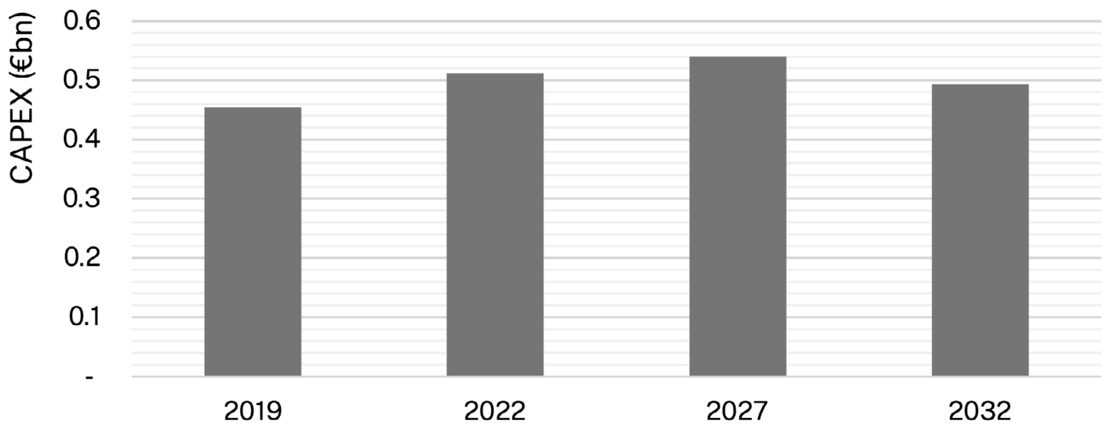
In connection with territorial development, actions are taken on networks operated by Enedis, for example, during the deployment of optical fibre and broadband internet which, in rural or suburban areas, are installed on the distribution networks supports.

In line with regulatory requirements, two examples illustrate some of the actions undertaken by Enedis:

- With regard to statement of work, Enedis has been engaged for many years in operations to improve the reliability of its mapping, aiming to facilitate the location and detection of assets located under roadways and susceptible to be impacted by works carried out by other underground network users.
- With regard to limiting overvoltages to comply with regulatory limits, Enedis has implemented new technical policies (see informational panel XVII: MALTEN).

Although these programs are expected to come to an end over the next decade, they will continue to have a significant impact for a few more years and will require a portion of the DSO’s investments.

Figure 28: projected annual investment trajectory in response to regulations and third-party requests (in billions of euros)



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2.2.4. Summary of investments related to the network evolution in response to regulations and third parties

Figure 28 aggregates the various actions mentioned above, the amounts of which vary from year to year depending on external requests.

Investment amounts related to regulations and third-party requests are generally stable around €500 million. Third-party requests for assets modifications are linked to economic activity. They are correlated with consumer connection requests, with some cyclical variations that may be linked to major urban development projects or significant events.

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3

Enedis invests to guarantee the long-term performance of the network

3

The quality of electricity supply is perceived by users through the supply continuity, outages duration, and, to a lesser extent, through the level of voltage delivered. Planned outages, which are sometimes necessary to carry out maintenance work on the network, should be distinguished from unplanned outages, which can occur on various components of the network.

In terms of outage duration, the average reliability of the network managed by Enedis is close to 99.99%. This means that the distribution network, built and improved over the decades following the discovery of electricity, now provides the service expected by users in a way that is virtually invisible.

The ability to ensure continuous supply at this level of performance is primarily due to the real-time management of the network, to operation and maintenance (3.1), modernisation policies of the network that increase its resilience (3.2) and to reliability on a daily basis (3.3).

3.1. Enedis modernises its electricity distribution network management and digital infrastructure

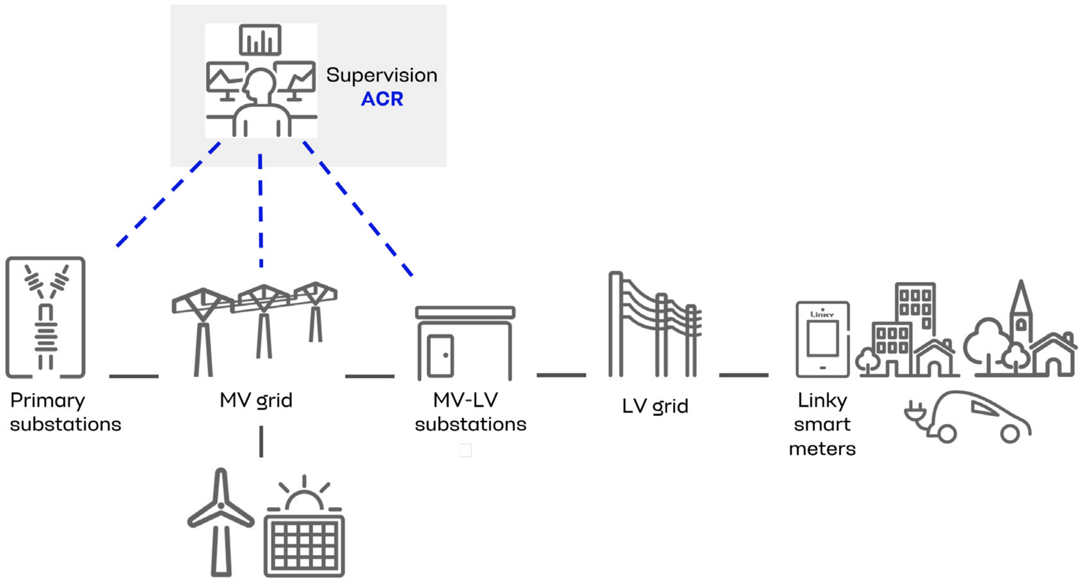
Activities related to network operation

Within network operation, Enedis distinguishes two main activities: operation and management. The operation activity consists of physically intervening on the networks and coordinating access to its assets, while management covers remote monitoring and centralised supervision. More precisely:

Operating networks consists of:

- intervening on networks to repair them in the event of an incident;
- managing and coordinating access to assets in compliance with safety for property and people;
- ensuring safety during maintenance or repair phases;
- if necessary, implementing re-supply means;
- activating emergency intervention means (FIRE) if necessary and coordinating them, etc.

Figure 29: illustration of the network supervision



Managing networks consists of:

- monitoring the networks based on real-time observation data and the results of simulation tools (consumption and production forecasts, calculation of forecast flows on the networks, etc.);

- coordinating with the management of the transmission network (TSO) and the networks of local DSO (ELDs), but also with customers according to established operating rules;

- adapting to the observed or forecast conditions to take into account contingencies or special operating conditions. This may involve, for example, carrying out maneuvers on the networks to temporarily modify their topology (changing the feeder or the HV/MV transformer supplying a consumption area, for example).

Primary substations and MV networks are operated and managed by regional operation control rooms (ACR)

ACRs continuously manage the electric current on MV networks, including primary substations, underground and overhead MV lines, and MV/LV substations. Their primary role is to ensure supply continuity. To do so, they monitor current or voltage sensors, and operate circuit breakers to change the network topology when necessary. Depending on the circuit breakers, these operations can be performed remotely or by dispatching an agent on site (see figure 29).

In coordination with operating offices (BEX), which are grouped together in network access supervision and management agencies (ASGARD), ACRs also participate in the management of works, especially the network's access authorisations that are mandatory to ensure the safety of field operatives.

Low-voltage (LV) networks, on the other hand, are not managed by ACRs: due to their non-looped structure and limited real-time observability, LV networks are "operated" but not "managed". However, information from the Linky smart meters allows for early network troubleshooting.

Network management is an essential activity for network's operation, backed up by a constantly evolving digital infrastructure

ACRs are essential to the smooth running of interventions that allow for the connection of hundreds of thousands of new consumer and producer customers each year. These interventions can often be carried out under, but some might require planned outages, which are then essential to ensure safety on site. In these cases, a portion of the network is de-energised, i.e., isolated from any source of electrical energy, for the duration of the intervention. The timing optimisation of the various works is therefore an important activity of network management, which requires means of forecasting electrical flows, over several periods.

Digital infrastructures, which are increasingly linked to the network and its management (see the details in the rest of the chapter), are thus becoming a key factor in its resilience and performance. They therefore have their place in this NDP, and this section 3.1 is dedicated to them.

3.1.1. Enedis is using new network management tools and automation to improve its ability to predict network behavior

The mass arrival of renewable energy, changes in the regulatory framework (network code, connection contracts, energy markets, etc.), the emergence of new uses (mobility, storage, etc.), constant technological developments, and the arrival of new players on the distribution network are transforming its management. This transformation **requires to be able to anticipate the network behavior** in order to optimise its operation and make the most of new flexibilities.

The Enedis predictive management project is developing new computerised management functions for the distribution network.

In this context, the network historic real-time management tool (allowing the ACRs to supervise and remotely control the network) has been supplemented with a refined energy flow forecasting module, in order to assist decision-making, simplify and optimise the actions to be taken on day-to-day basis. With its predictive management project, Enedis is working to identify, study and develop IT functions that allow it to anticipate possible constraints on the network at different time scales and optimise its operation by anticipation:

- The IT functions developed have been industrialised and integrated into Enedis' remote supervision system, and have been tested in particular on the Smart Grid Vendée demonstrator and within pilot ACRs. Their deployment to all Enedis ACRs was closely monitored during the second iteration of the MV & LV short-term predictive management project between 2018 and 2020; it also allowed the implementation of a constrained mixed-integer linear optimisation core.

- The third cycle of the MV & LV short-term predictive management project has the following objectives:
    - to make the STC predictive management software a "digital twin" of the real-time management tool, robust, reliable and fully integrated into the operational process of Enedis' ACRs,
    - to value the mixed-integer linear optimisation core in order to give a technical and economic reality to the optimal solutions (all levers used to adjust constraints) proposed by the tool,
    - to prepare the future of predictive management, by adapting the tool to Enedis' emerging uses, including flexibilities, by experimenting with low-voltage predictive management solutions, by studying the integration of innovative technologies (artificial intelligence, stochastic approaches, etc.) and by anticipating the evolution of the distribution network (storage, local automations, etc.).

French electricity system transformation also generates increased needs for discussions with RTE to maintain its balance

Beyond the management of constraints on the distribution network, the system balance is affected as a whole by the fast evolution of the French electricity system:

- the balance between generation and consumption,

- keeping TSO and DSO assets within their operating limits,

- availability of the systems that support the implementation of all these requirements and transformations.

Particularly in a system where renewable energies are becoming prevalent, the interactions between TSO and DSO will intensify in volume and frequency, both for the activation of ancillary services and for adjustment or capacity offers. Flexibility activations must be industrialised, by ensuring:

- perfect and enforceable traceability of flexibility activations, power limitations, etc.

- improved joint expertise of balance by developing system data exchanges between TSO and DSO;

- development of automations that will allow the DSO to comply with the telemetry values (power mitigation order) at the transmission/distribution interfaces by limiting TSO downstream intervention to the SAS emergency systems (alert and safeguard system).

In this increasingly connected environment, Enedis continues to equip the network with management tools over which it has industrial control

In particular, it continues to:

- develop the network management tool;

- equip the network with remotely controlled switchgear (OMT), automatic circuit reclosers (DRR), and other connected objects (IoT), and use the data;

- develop interface tools with producers, storage operators, etc. to activate all the services envisaged today and those that have yet to emerge (eDEIE: new generation of the exploitation information exchange device; EMIS: modular instrumentation and supervision equipment, etc.);

- meet cybersecurity challenges and French requirements.

Beyond network management equipment, there is the challenge of ensuring long-term industrial control and developing all the policies needed for its maintenance in operational condition (MCO) and cybersecurity (MCS).

Finally, Enedis is implementing change management to accompany these technical developments

The overall evolution of the ecosystem is leading to unprecedented changes in management trades, which Enedis will have to prepare for and support with appropriate training over the next few years.

3.1.2. The distributed control system and telecom of primary substations are undergoing major changes

The existing distributed control systems in primary substations are evolving significantly to meet several challenges, including:

- **the acceleration of industrialisation and digitalisation of electrical networks,** with the arrival of new objects such as digital distributed control systems in primary substations;

- **the improvement of the management of existing analog objects;**

- **the evolution of telecommunications following the obsolescence of GSM-Data, RTC, etc. technologies** and the consequent transition to IP, which is essential for the control of network telecommand organs;

- **the evolution of business needs,** such as the enrichment of exploitation and maintenance, remote administration of distributed control systems objects, the improvement of network observability via voltage and current sensors, and the automation of existing processes;

- **the reinforcement of operational safety** and the response to French cyber security requirements for industrial information systems.

Enedis is addressing these challenges through several primary substation modernisation programs, including:

- **renewal and digitisation of distributed control systems:** Enedis' goal is to digitise distributed control systems by 2040, with the transition to digital distributed control systems (PCCN);

- modernisation of telecommunications infrastructures:
    - increased connectivity (WAN/LAN);
    - deployment of satellite telecommunications for resilience to "blackout";

- reinforcement of physical security and surveillance of primary substations:
    - access management with mechatronic keys instead of mechanical keys, in order to combine "administrative" and physical access to assets;
    - fire telealarm;
    - remote presence detection, etc.

- monitoring of HV/MV transformers.

3.1.3. Enedis takes advantage of smarts grids technology to improve thr efficiency of network operations and maintenance

Enedis can rely on an observable and remotely controllable network thanks to its instrumentation, allowing it to secure the quality of supply and optimise management and operation of MV and LV networks.

To prepare for and accompany the major technological shift of the energy transition, Enedis is investing in many pilot projects in France and Europe. These projects are developing the networks of tomorrow, or "Smart Grids", where technologies from electrical engineering, information and telecommunications converge. The Linky smart meter communication system is the "first brick" of this new set (see informational panel XIX: Linky, a communication system essential to performance for customers).

Connected objects (IoT) in turn carry new information and allow for the enrichment of business processes related to the operation, control, maintenance and development of the distribution network (see informational panel XVIII: some connected objects at Enedis' service).

They contribute in particular to **fault diagnosis** through alarms for the operating manager with the DINO meter, help with the localisation of MV network faults thanks to connected fault location indicators (ILDc) and connected surge arresters (e-IPF). They improve the quality of supply thanks to the geolocation of faults (ILDc).

INFORMATIONAL PANEL XVIII

Some connected objects at Enedis' service

DINO sensors
These sensors can detect the beginning and end of a flood at a given level. They are placed in MV/LV substations and in LV box, where they help to secure the assets and limit network outages. In the event of a crisis, the alerts from the sensors allow for better planning and mobilisation of the appropriate teams.

ILDc
Connected fault location indicators help to locate MV incidents. Placed on the network, these detectors indicate whether the incident is located upstream or downstream, which helps to optimise the number of maneuvers to be carried out on the network to isolate the incident and thus limit the time of customer outages.

eIPF
Also known as a "connected surge arrester", this equipment, by making surge arresters communicating, helps in the diagnosis of incidents and facilitates the location of a fault.

The surge arrester, already used on the MV network, protects electrical equipment from high transient overvoltage via the principle of short-circuit localisation.

Monitoring transfo / AGATH boxes
Composed of a multitude of sensors, AGATH boxes allow for the monitoring of primary substations: placed on HV/LV transformers, they help to optimise the lifespan of primary substations as well as their maintenance. This considerably reduced the number of major incidents on HV/LV transformers.

They are configurable according to needs, thanks to the 70 measurements recorded.

In 2021, the network comprised approximately 500 AGATH boxes. Deployment continues to reach 4,000 poses (one AGATH box per transformer).

Connected generators sets
Connected generators sets are equipped with a sensor that allows for the transmission of several pieces of information such as the operating status and the critical state of tank capacity. This sensor solution is already deployed on a portion of Enedis' GE fleet. Experiments are currently underway on zero-emission electric generator, in order to address environmental challenges and on the possibility of transmitting more digital information.

They also allow for **optimised maintenance,** via alerts for the maintenance of HV/MV transformers ("monitoring HV/MV transformers") and the analysis of events raised by connected objects without network faults (ILDc, e-IPF).

Finally, they contribute to the **optimisation of the fleet of generators** sets and their maintenance (geolocation or connected generators sets).

3.1.4. Linky: a smart metering system for the benefit of customers and the network

About 35 million Linky smart meters have been deployed within Enedis' remit area. They have been installed at the sites of private or professional customers with a subscribed power of 36 kVA or less, replacing the previous meters. Linky is already an element of customer relations (see informational panel XIX: a communication system essential to performance at the service of customers).

Linky, the first step towards low-voltage network "smart grids"

Enedis is modernising the low-voltage network through the deployment of the Linky system. This allows it to have technical and contractual information flow at this voltage level. It also integrates remote configuration capabilities, which allow for faster contract management, serving the distributor, suppliers, and customers (remote commissioning, change of subscribed power, modification of tariff options).

Supervision center connects to Linky meters via dedicated devices: concentrators, physically located in the MV/LV substations.

To communicate with them, Linky uses the PLC (power line carrier) technology, which relies solely on the electrical network. This communication system allows for the collection and analysis of data relative to quality of supply, or even the location of faults, the assistance in the diagnosis of failures, and the reliability of databases, through specific tools developed by Enedis.

By relying on the information on withdrawal and injection, collected by the meter at a higher frequency (the traditionally biannual index reading becomes daily); Enedis improves the modeling of loads in its investment studies.

Linky therefore contributes to customer relations, but also to the operation and development of the distribution network (see figure 30).

INFORMATIONAL PANEL XIX

A communication system essential to customer service performance

Linky smart meter enables new services to consumers such as:

- providing customers with more tailored data (via Enedis' customer portal or their supplier), thus providing easy access to consumption data to better manage it;
- the possibility of being billed on actual consumption and not on estimates;
- the diversification of suppliers' tariff offerings.

It also facilitates the integration of renewable energies into the network, particularly in case of residential self-consumption. Lower connection costs are permitted for the customer by a simple meter configuration provided that the installed generation capacity remains lower than that consumed. This meter configuration is done remotely.

A communicating system that evolves over time

As shown in figure 31, Linky meters installation pursue its course along with the rate of connections, namely with the deployment of collective electric vehical charging infrastructure (see 2.1.2.3.3: for the connection of electric vehicle charging points in condominiums, the collective EVCI solution requires a number of Linky meters to be accounted for). By the end of the Network evelopment plan's time frame, it is necessary to start considering future developments of the smart metering system. The mass replacement of the smart meters current generation will begin beyond the time frame of the NDP.

Figure 30: benefits of the Linky system

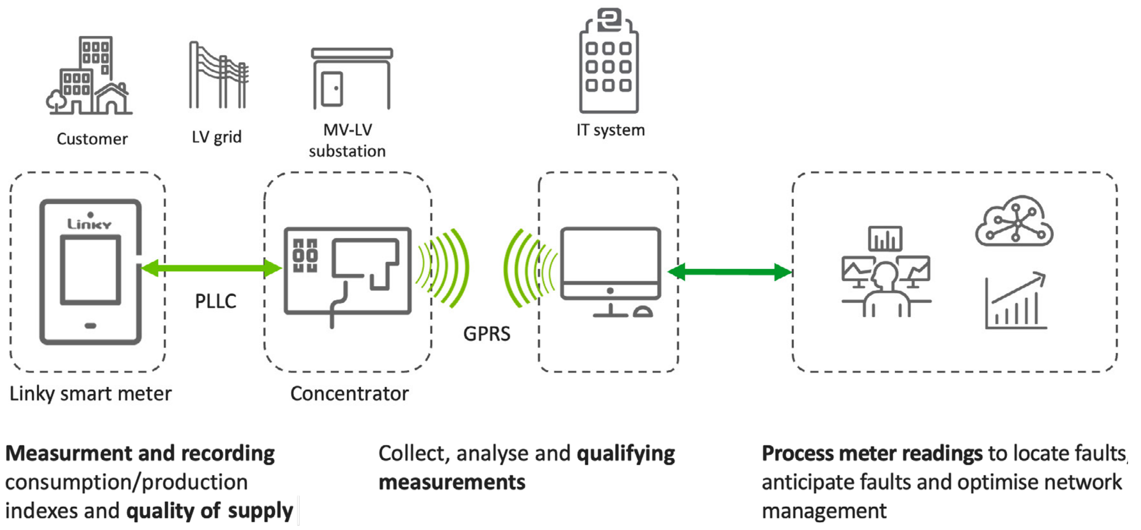
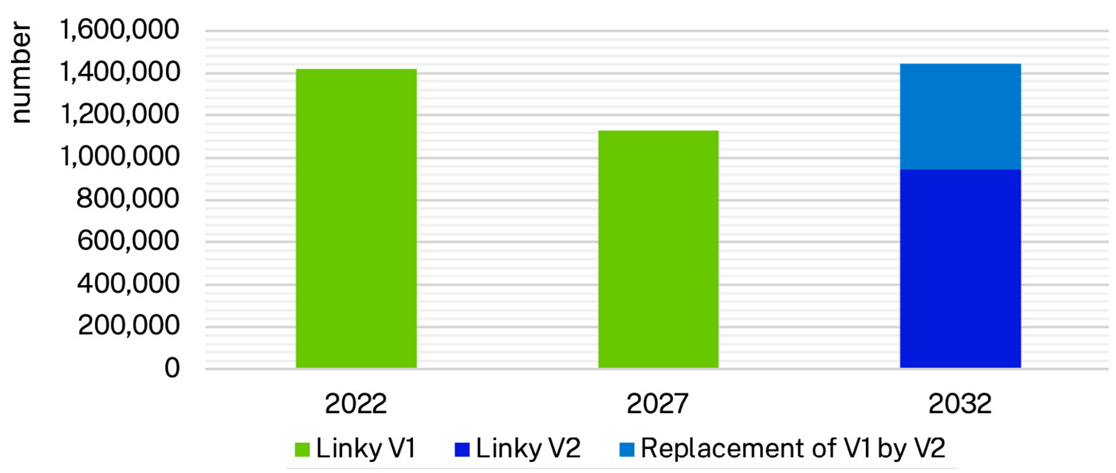


Figure 31: baseline scenario - annual number of smart meter installed



3.2. Enedis ensures the resilience of the network against climate and technological hazards

The general electrification of France, which was completed in the 1960s, and the increasing reliance on electricity since then, has made all activities dependent on its availability. However scarce, atmospheric phenomenon can lead to massive and lasting disruptions to the electricity supply in a given region or even large parts of the country, as happened during the storms of December 1999. Nowadays, such outages are socially difficult to accept.

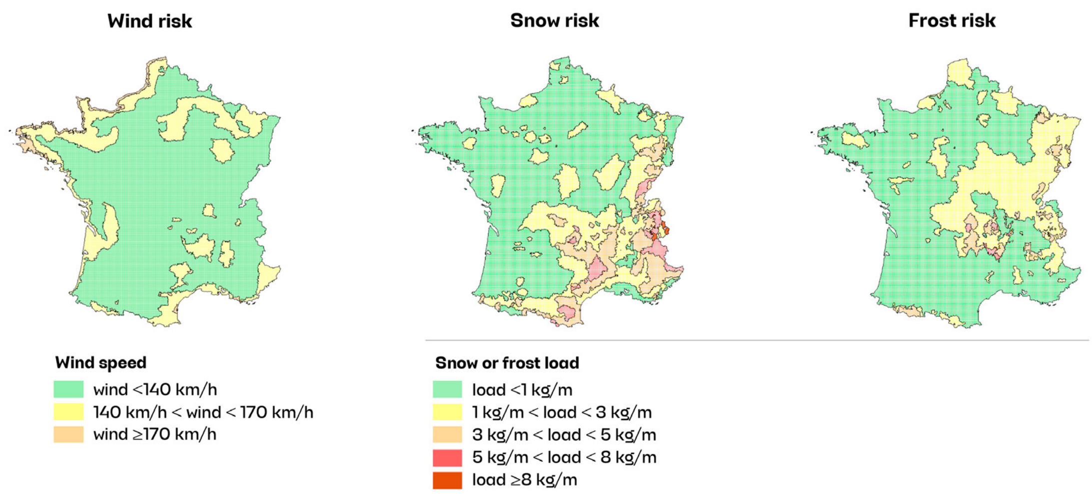
In the wake of these storms, EDF, of which Enedis has since become an independent subsidiary, committed itself to an objective for 2015, stipulating that in the event of a similar event, 90% of affected customers would be reenergised within five days. The creation of the electricity rapid response force (FIRE) was the first implementation of this commitment. This program allows, in the event of a meteorological alert, to pre-assign 2,500 technicians and the necessary equipment to the affected regions within a few hours. It also led to the creation of a large fleet of generators sets, then the formalisation of a climate hazard plan presented to the authorities in 2006, and whose subsequent evolutions and adaptations are explained below.

This climate hazard plan is based on three main principles that still underpin all of Enedis' actions on this subject today:

- Identify and map potential risks based on the probability of occurrence of various meteorological hazards (see figure 32).
- Diagnose the situation of all network components in relation to these hazards.
- Develop targeted action plans specifying the security objectives, actions to be taken, the mode of management, and the prioritisation criteria.

Enedis remains strongly committed to improve networks' resilience. It has strengthened this initial climate hazard plan by incorporating heat waves, floods, and complementary actions on resilience in relation to technological risks in urban areas. In addition, as part of its Industrial and Human Project, Enedis has set itself the target of restoring power to 90% of customers within 48 hours in the event of a major climate-induced outage on the network.

Figure 32: examples of climate hazard maps, for the vicennial (20-year) risk of wind, snow and frost



3.2.1. Enedis is working to improve the resilience of its overhead and underground networks to climate hazards

Investment policies are focused on the most prevalent climate hazards for different types of infrastructure:

- Overhead networks, which are vulnerable to strong winds, frost, or freezing rain, and to proximity to wooded areas.

- Underground networks, which are vulnerable to heat waves and floods.

The corresponding actions are outlined in the following sections.

3.2.1.1. Storms, freezing rain, wooded areas: Enedis' actions on overhead networks

On the overhead MV network, investment trajectories for 2032 include the undergrounding or consolidation of 20,000 km of the 48,000 km identified as an actual risk with regard to the climate reference and the presence of wooded areas (see figure 33).

After a significant effort to underground the most exposed structures carried out since the 2000s, the focus is now on antennas which figure an actual climate risk, with the aim of reducing the peak number of customers disconnected and facilitating re-feeding during a major climate event (see figure 34).

Figure 33: "climate hazard plan" MV network replacement program: length of network at proven climate risk

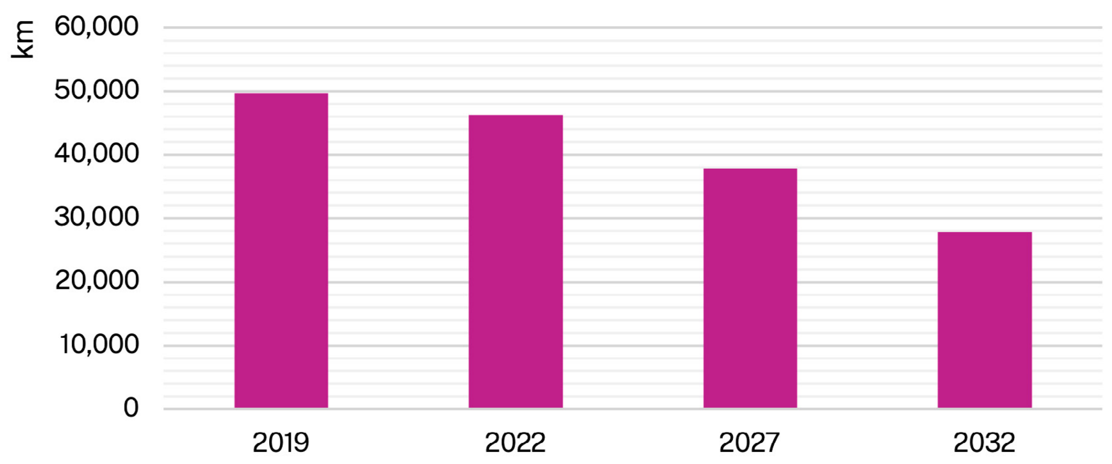


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Figure 34: dealing with antennas at proven climate risk

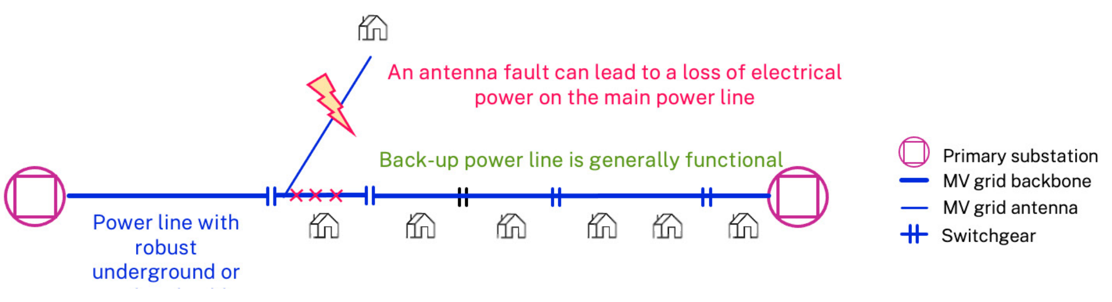

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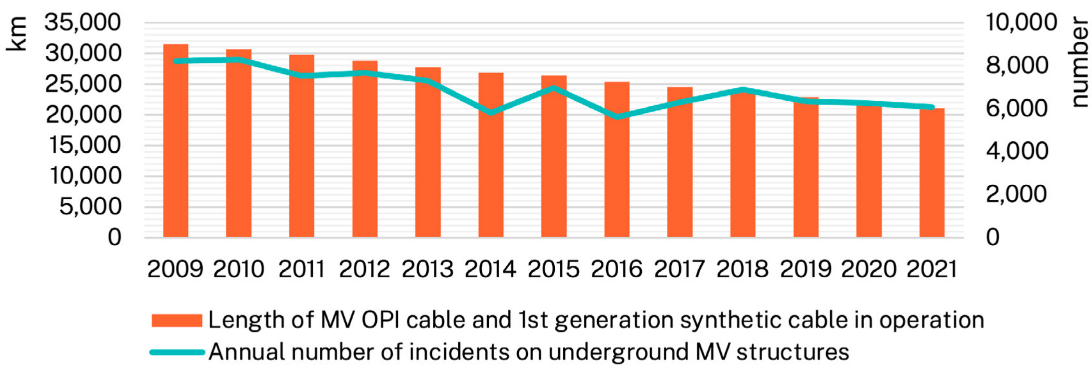
Figure 35: change in the length of MV OPI cable in operation and the number of incidents on underground MV structures



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Enedis is prioritising the accelerated removal of overhead low-voltage (LV) networks with bare conductors. These networks are more susceptible to damage in everyday use and are more vulnerable to climate-related hazards. They also significantly challenge to the reenergising the last customers once power has been restored to the medium-voltage (MV) network (see 3.3.3).

3.2.1.2. Heat waves: Enedis' actions on underground networks

Heat waves have become more frequent in France since the heat wave of August 2003. These heat waves have had a significant impact on underground networks, particularly oil-paper insulated cables (OPI), which were installed until the end of the 1970s. These cables are more vulnerable to heat than newer cables.

This risk is covered by a **targeted renewal program for these assets** which, beyond the climate hazards, concerns all OPI cables. More details can be found in section 3.3.4, which deals with cable renewal. In search for maximum performance, the implementation of this program was carried out by targeting the most fragile conductors. Assets that are most likely to exceed current- carrying capacity in the summer have been prioritised, followed by those with the highest probabilistic risk-impact score, as assessed by the diagnostics and network topology.

Figure 35 provides a visual representation of the high variability of incidents on MV underground cables due to heat waves. From an operational perspective, the simultaneous occurrence of incidents can lead to crises in areas with high population density. The sawtooth pattern of the graph highlights the peaks corresponding to summer crises, particularly in 2015.

In the long term, the number of underground incidents is expected to stabilise. This is due to fact that the gains generated by the targeted program will be offset by the increase in cable lengths. However, the peaks and crises linked to heat waves will have been eliminated.

3.2.2. In dense urban areas, Enedis is taking steps to secure primary substations against major technological risks that could impact many customers

Enedis faces a number of challenges in urban areas, including:

- meeting the expectations of metropolitan areas and large cities, supporting their development, and guaranteeing them a level of power quality comparable to their European and global competitors.
- maintaining a portfolio of complex infrastructure and improving its resilience to major risks, such as the total loss of primary substations supplying these areas, simultaneous failures of medium-voltage networks, floods, and inundations.

The reliability of power supply to major cities depends on increasing the level of safety of primary substations supplying these urban areas (around 500 primary substations) and the generalisation of action plans coordinated with RTE.

In order to mitigate the occurrence and impact of a major, long-lasting outage that could affect tens of thousands of customers for several days, this policy of improving the safety level of the concerned primary substations is divided into two complementary axes:

- **Securisation** aims to limit the consequences of the total loss of these primary substations by connecting them to a sufficiently sized high-voltage network, with support from neighboring primary substations, allowing the reenergising of low-voltage customers via a recovery plan that must define the resupply means (mobile generator sets) for remaining cut-off customers.

- **Enhancing the reliability of primary substations** reduces the risk of a total loss. This is done by following construction recommendations for major components, such as separating components and replacing older components.

This program was launched in 2013 and is scheduled to be completed at the end of 2025. Starting in 2026, meeting the requirements will require targeted investment, prioritising primary substations, whose risk level has changed due to occasional increases in load, to maintain their level of security.

3.2.3. Enedis is undertaking a program of network modernisation and restructuring to enhance its resilience to flooding

Although it has been taken into account since the beginning in the climate hazard plan, the risk of flooding has been the subject of increased attention since the flooding events that occurred in Île-de-France in June 2016 and January 2018. In this context, Enedis has implemented a flood risk management program. Its main purpose is to address the effect of prolonged flooding phenomena in urban areas and has the following objectives:

- to undertake actions to modernise and restructure the networks in order to gradually eliminate **"non-flooded cut-off pockets",** i.e. located in non-floodable areas but permanently deprived of electricity due to the network structures;

- to provide uninterrupted electrical supply to flooded populations, using devices that are safe for operators and equipment, and that are designed to operate in flooded conditions.

This program comprises the following actions:

1. To develop a **map of electrical vulnerabilities** based on regional hydrographic scenarios shared with the relevant authorities.

2. To improve the reliability of data for relevant structures (the types of equipment in substations and their altitude).

3. To modernise flooded MV/LV substations to ensure long-term electrical continuity on the MV network (submersible MV panels) and optimise the interruption of LV supply by detecting water levels (communicating sensors, automated shutdown devices).

4. To restructure the MV network opportunistically to eliminate non-flooded cut-off pockets, with a long-term view.

These actions are prioritised in frequently flooded areas causing electrical weaknesses, and can be applied up to the centennial[33] flood scenario. This program is currently being implemented mainly in Île-de-France, but its methodology is applicable, and is currently being studied, in other urban areas. See informational panel XX: use of 3D flood mapping.

33. The reference framework for climatic hazards used to dimension the entire overhead medium-voltage (MV) network (317,000 km) is vicennial, and is the result of a trade-off between the expected resilience of this network in the face of climate risk and the investments to be made. The flood risk management program follows the regional scenarios taken into account by local authorities (prefectures, local communities, etc.). In Île-de-France, the approach is therefore based on the centennial risk.

INFORMATIONAL PANEL XX

Use of 3D flood mapping

To establish a map of electrical vulnerability areas involves identifying and mapping, for each flood scenario:

- assets and customers directly affected by flooding, i.e. located in flooded areas;
- assets and customers located outside flooded areas but whose power supply is nevertheless interrupted due to the network topology: investment plans aim to reduce this impact.

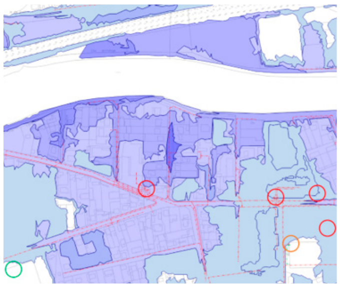
In order to reconcile the geohydrological data of the different flood scenarios with its related network, Enedis develops a tool based on the following factors:

- the position of each network component in relation to the hydrographic data (inundated area, corresponding water level when available);
- the characteristics of each network component (overhead line, underground cable, voltage level, technical level of equipment of the substations);
- the network topology (manual or remotely controlled cut-off devices, network meshing).

Example of an impact map for an MV grid

Installation of submersible MV equipment in substations, or modification of structures, enables MV electrical continuity to be maintained in non-flooded areas

Example of an impact map for an LV grid



Power to an LV grid in a flooded area must be cut off to ensure the safety of customers. Water level sensors in the substations enable action to be timed as near as possible to the event.

Maximum water height
- < 50 cm
- 50 cm-1 m
- 1 m–1,5 m
- 1,5 m-2 m
- > 2 m

MV/LV substations
- Substation in non-flooded area
- Substation in flood zone
- Substation in a non-flooded area but cut off due to flooding elsewhere on the MV feeder

Feeders
- Feeder in non-flooded area
- Feeder partly in flood zone

Enedis can thus identify investments to reduce the impact of the flood, and easily communicate areas of electrical fragility to the various regional stakeholders.

The resulting maps are intended to assist regional risk prevention efforts. They must therefore be based on shared hydrographic scenarios by all stakeholders: local and regional authorities, infrastructure managers.

In the future, this tool will also take into account data from water level sensors deployed on the network, and will therefore play a role in real-time flood management.

3.3. Enedis is implementing targeted network renewal programs to improve the resilience of the electricity network

3.3.1. Maintaining network's performance is necessary to ensure the quality of electricity supply on a daily basis

Enedis is pursuing a major investment and maintenance program to improve the quality of supply and adapt the public distribution network to the changes associated with the energy transition.

In order to reduce the number of failures that could affect the continuity of supply, assets with abnormally high failure rates are replaced with new and improved ones.

In 2021, over €1 billion was invested to modernise the networks to improve resilience and ensure continuity of supply on a daily basis. These investments are expected to grow in the coming years. Furthermore, Enedis has allocated more than €320 million to preventive maintenance activities.

The modernisation and renewal programs provide specific answers to the needs of increasing resilience and daily reliability, depending on the assets concerned and the resources available to carry out the corresponding work. These different programs are described in the following sections.

3.3.2. Planned refurbishment: a cyclical upgrade of the overhead medium-voltage network

The sustainable performance of the overhead medium-voltage network is achieved through a combination of targeted and optimised investments policies, which complements the climate hazards policy for identified sensitive networks outlined in section 3.2.

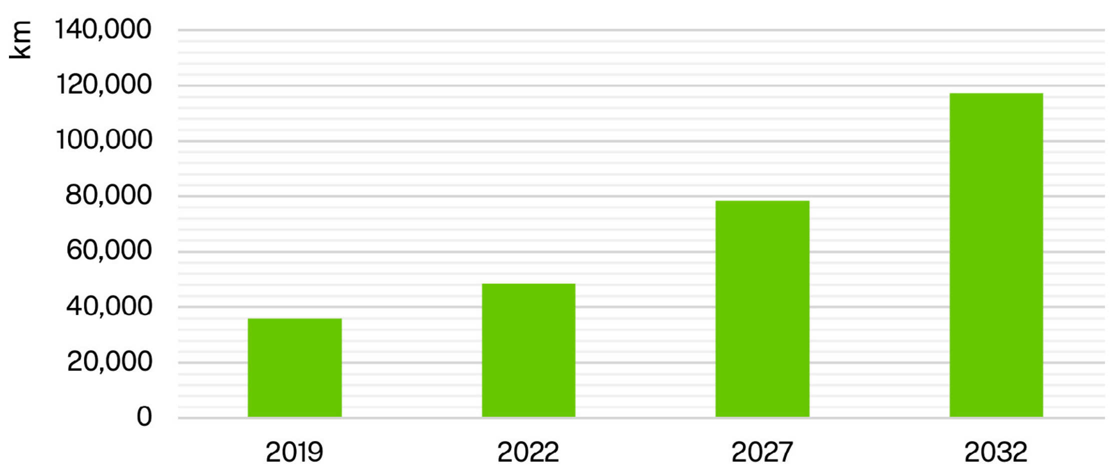
Therefore, the overhead MV network that does not present an actual risk, but which can suffer from the wear of its components exposed to atmospheric conditions, is subject to the planned refurbishment program. This program aims to restore and maintain the overhead MV network reliability to a level close to newly built assets. In order to invest efficiently, to mitigate environmental impact, and reduce carbon footprint, this program aims to replace non-technically compliant equipment.

The planned refurbishment program allows for the retrofit of all overhead MV lines in a 25 years cycle. Regardless of whether or not any equipment was replaced, lines that have undergone a diagnosis in year N are considered reliable for the following 25 years, and will therefore be subject to a new diagnosis around the year N+25. After a ramp-up period, this cycles will guarantee the reliability for approximately 9,000 km of overhead MV network yearly (see figure 36).

Eligible networks for planned refurbishment are prioritised using a large-scale data processing (known as "big data") based on incidentology (see informational panel XXI: use of "big data" for assets renewal prioritisation).

Solutions to industrialise planned refurbishment are underway, such as the use of an artificial intelligence (AI) module to facilitate diagnostics by drones or on-foot visits.

Figure 36: "planned refurbishment" program - cumulative network length handled under the program



INFORMATIONAL PANEL XXI

Use of "big data" for assets renewal prioritisation

The effectiveness of renewal (or planned refurbishment) programs for overhead medium-voltage (MV) networks is dependent on the accurate diagnosis of assets with the highest probability of failure. To improve this diagnosis, Enedis uses large-scale data processing (known as "big data") and statistical learning ("machine learning") techniques to establish short-term failure prediction laws applied to appropriate portions of assets (low-voltage feeders or MV pockets between two switching devices).

The purpose of "machine learning" is to determine the best correlation law between large amount of data (network description, incident history and location, environmental data, etc.) and known output data (incidents that occurred in the learning years that the model is trying to reproduce).

These processing operations rely on significant computing power. The law thus defined is then applied to the most recent network image to estimate the risk of failure for the considered portion of asset for the coming year. This is therefore a predictive approach.

Depending on the number of customers or the power delivered by the asset, this prioritisation is revised by an assessment of the failure's impact. They are thus classified according to a risk impact criterion.
This mathematical model is part of an ongoing improvement process: it is enriched each year with new data and incorporates the results of its processing from the previous year: which feeders actually had an incident and what factors may have influenced the occurrence or non-occurrence of an incident.

3.3.3. Replacement of overhead low-voltage bare conductors networks is a shared goal of the licensing authorities and Enedis

The ambition is to work with awarding authorities to eliminate almost all overhead LV lines with bare conductors by 2035. The incident rate of these lines is five to six times higher than that of low-voltage networks composed of twisted or underground cables. This should help to avoid around 15,000 incidents per year, improve the quality of supply on low-voltage networks, and make them more resilient to climate change.

To this end, the following levers will be combined:

- improvement of asset management databases;
- elimination of bare conductors by replacing all LV feeders that have poorly supplied customers (CMA, as defined in the "quality" decree; see informational panel XXIII: the regulatory framework for quality) or suffer from electrical constraints;
- acceleration deliberate renewal, by focusing on projects such as the removal of low-section lines that are the most sensitive to failure;
- coordination with the awarding authorities to ensure the optimal prioritisation of networks to be treated;
- managing the growth of assets removal unit costs.

3.3.4. Targeted and priority-based renewal of old-technology underground assets using statistical methods

As described in the previous section, the replacement of old-technology MV cables is a key factor in risk management in dense urban areas, especially during heat waves. More broadly, the targeted removal of these cables is essential for maintaining and improving the performance of urban networks.

These oil-paper insulated (OPI) cables, as well as the first-generation of synthetic-insulated cables, are less reliable than current synthetic cables overall: they have an average of 9 incidents per year per 100 km, compared to 1 incident per year per 100 km for synthetic cables in urban areas.

However, this average value masks a significant disparity in the behavior of the different segments that make up this inventory. Therefore, it is essential to maximise the investments efficiency by seeking a prioritisation based on an impact-weighted risk map of failure.

Currently, this map is based on the following elements:

- An assessment of the risk of failure based on statistical learning techniques ("big data") applied to each portion of the work (see informational panel XXI: use of "big data" for assets renewal prioritisation).
- Additional local analyses based on diagnostic truck results which give information on physical test of the section, additional local analyses, and feedback from operators.

This map also helps to reconcile economic performance with the multiple demands of urban road development, leading to improved work efficiency and greater satisfaction among local authorities.

In 10 years, this program has already allowed a 25% reduction of incidents on underground network. These efforts must be pursued in order to ensure sustainable performance of the network. Renewal projections are expected to contribute for 56% of the elimination of stock over the period 2022-2032. The residual stock, less susceptible to incident, will remain under surveillance.

It has become apparent that it is also necessary to replace first-generation synthetic cables (pre-1982), whose performance is comparable to that of OPIs, in order to improve the reliability of networks. As of the end of 2021, the renewal program covers a stock of 21,100 km of these cables (see figure 37).

Low-voltage OPIs and medium-voltage OPIs behave similarly, but the incidents on the former are scarcer and affect fewer customers. It is therefore even more important to target the sections to be replaced in order to invest in the works with the highest risk and thus ensure the efficiency of investments.

It is estimated that there is currently a stock of 21,000 km of underground low-voltage network of "oil-paper insulated cable" and "peripheral neutral" type. Big data-based prioritising methods allow for targeting investments on works with the highest probability of failure. Projections lead to the absorption of 37% of the identified cables by 2032.

3.3.5. Renewal within primary substations concerns specific equipment

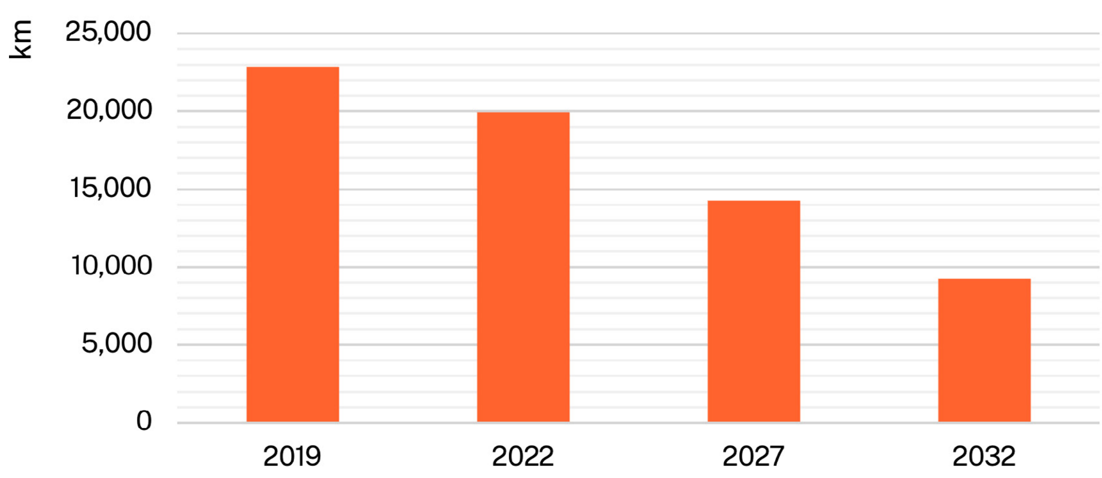
Primary substations are subject to maintenance and renewal programs for certain components based on their technical characteristics:

- **High-voltage (HV) circuit breakers:** renewed according to age, short-circuit current, and obsolescence criteria.

- **HV/MV transformers:** the oldest 100 MVA transformers are gradually being renewed, as well as transformers with aerial tap changer.

- **MV circuit breakers:** the MV circuit breaker fleet currently consists of many different types of equipment. Enedis is aiming towards normalisation of the MV circuit breaker fleet by combining renewal and renovation based on age, technology, and reliability.

Figure 37: renewal program for incident-prone MV cables - length of MV OPI cable and 1st generation synthetic cable in operation

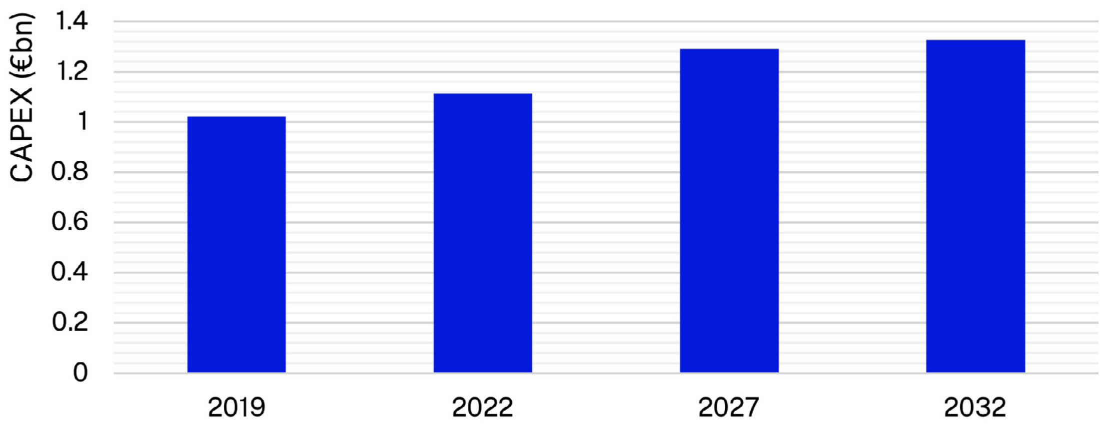


3.4. Summary of network modernisation investments

The projected investments dedicated to improving the resilience and reliability of assets are shown in figure 38. Annual amounts may vary depending on the programs in order to allow precise targeting of assets to be replaced, and by adjusting the schedule for the most relevant works.

Investments in the modernisation of assets to maintain a good quality of supply and improve resilience to external risks, especially the ones due to climate change, represent just over €1 billion per year in 2022. These investments have been increasing since 2008 and will continue to do so. Overhead MV networks require the most significant investment. It represent nearly 320,000 km, of which 48,000 km are exposed to climate hazards. To address climate change sensible networks and maintain the long-term reliability of the other networks (272,000 km) at an equivalent to new networks performance, a major planned refurbishment program (see 3.3.2) on a 25-year cycle is under development and will reach it cruising pace in 2032.

Figure 38: trajectory of annual investments planned for network modernisation (in billions of euros)



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4

Summary of key assumptions and contextualisation of investment trajectories

4

In summary of chapters 2 and 3, which provide detailed insights into the investments made by Enedis in the distribution network, this current chapter brings together all CAPEX trajectories and their associated assumptions (4.1). It sets out the context of Enedis' investment landscape, emphasizing that these investments address multiple challenges, span the entire network, and lay the groundwork for the future.

The total investment trajectory is presented and discussed, offering a context that includes a comparison with Enedis' historical investment patterns (4.2).

4.1. Enedis' national investment trajectory by 2032

4.1.1. Key assumptions of the baseline scenario in the NDP

The considered perspectives for establishing the projected investment trajectories, include in the connection domain (see figure 39):

- **Stability in consumer connections,** due to a combination of slowing demographic growth and a decrease in the average number of inhabitants per dwelling forecast by INSEE. **The annual evolution of the number of housing units remains comparable to current trends.**

- **A significant development of Electric Vehicle Charging Infrastructure** (EVCI), with a trajectory corresponding to 13 million registered electric vehicles by 2032 (27 million electric vehicles by 2040). There is a strong correlation at this horizon between the number of vehicles and the number of EVCI.

- **Strong development of renewable energy facilities,** with a trajectory starting at current achievements, aligning with the guidelines of the multi-annual energy plan (PPE, French NECP) in 2026, and continuing to rise to remain consistent with these national ambitions. It reaches over 70 GW of renewable energy facilities by 2032, with a milestone in 2027 at 52 GW: 19 GW more than in 2022.

In the field of modernisation, the assumptions align with the actions presented in chapter 3 to implement the resilience objectives and major renewal programs.

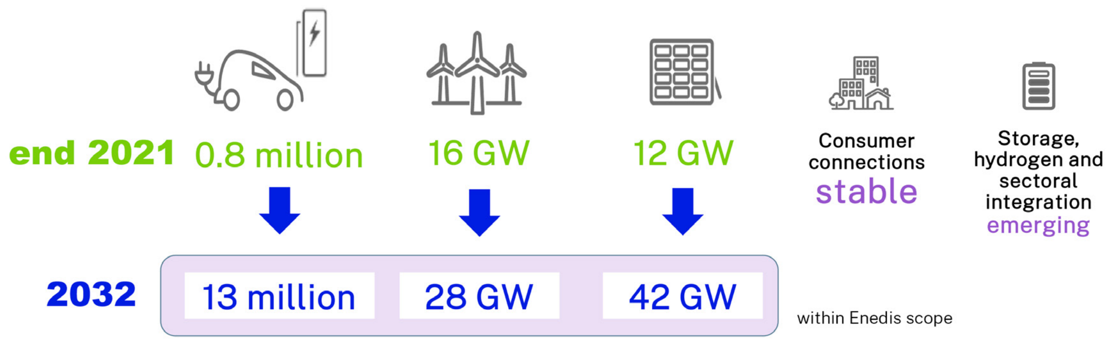


Figure 39: key figures from the baseline scenario

4.1.2. Investments with multiple challenges, explored by their main purpose

Investments generate benefits beyond their primary triggering cause, including contributing to the network's renewal and preparing for future connections

While it is possible to categorise them based on their main triggering cause, it is more complex to break them down according to their effects. An investment often brings, beyond its primary purpose, various benefits to the network.

For example, the climate hazards plan (see 3.2.1), which aims to underground overhead MV networks exposed to climate risks, may lead to restructuring the network. It contributes not only to the network's resilience to climate risk but also to the overall improvement in the quality of supply for customers in the area.

Investments made in the network also benefit future customers. Investments in network renewal, reliability, or resilience can generate greater capacity due to the use of equipment ranges, optimal cable choices (see 5.2.3), and consideration of the future load evolutions.

The network created for connecting new consumer customers or for adapting to the increased needs of existing consumer customers can also later serve to accommodate producer customers, and vice versa.

Finally, whenever investments addressing a specific challenge lead to the substitution of new facilities for existing ones, they contribute to the overall renewal of the network.

Many investments are also designed, from the outset, to simultaneously address multiple challenges

Often, these multiple purposes are considered during the asset's conception. Enedis then seizes an opportunity of intervening on the network to simultaneously address several challenges. In many cases, this allows to avoid later works or to reduce the overall cost of addressing the various identified challenges.

An illustration is the replacement program of Oil-Paper Insulated cables (OPI cables), detailed in 3.3.4. This program aims to improve the network's reliability by replacing equipments of lower reliability technology than today's standards and to increase the network's resilience to climate risks such as heatwaves (OPI cables are more sensitive to heat).

Another emblematic example of an investment addressing multiple challenges is the creation of a new primary substation. Beyond an initial causality often linked to the local emergence of a significant need for connection of consumption or production, the creation of a primary substation can also address multiple challenges: the need to improve network performance (the creation of a primary substation leads to reconsider all backup schemes in the area, the improvement has therefore a ripple effect on multiple other areas), or the prevention of a specific local risk (flood, technological risk, common mode, etc.).

Thus, the creation of a new primary substation is often the guarantee of a unique and relevant response to multiple challenges.

Trajectories associated with the main purpose of investments

In this context, specific to network industries, it is not possible to break down expenses associated with an investment according to the various benefits it brings. Therefore, the NDP lists historical and projected expenses based on the main objective of investment decisions.

An approach aimed at covering the entire network

The approach implemented by Enedis is intended to cover all assets in the public distribution network. The diversity of challenges addressed within the framework of the network development plan is illustrated in figure 40.

4.1.3. An upward investment trajectory to support the energy transition and enhance network performance

The analysis of various challenges presented in chapters 2 and 3 leads to a significant growth in investment expenditures for Enedis over the next ten years, excluding investments from licensing authorities. Figure 41 illustrates this trajectory, along with the current situation (actual for 2019 and scheduled for 2022).

Note: "the operating resources and IS" and Linky CAPEX have not been detailed in previous sections of the NDP but are presented here for completeness, providing a comprehensive view of Enedis' CAPEX.

In summary, Enedis' total investments will increase from just over €4 billion per year currently to consistently over €5 billion per year in 2027 and 2032. This represents an increase of approximately 20%.

In 2019, the massive deployment program of the communicating meter Linky was underway and required over €800 million in CAPEX. This program was completed at the end of 2021.

In 2022, after the health crisis period, the economic activity experiences a particularly strong dynamic, resulting in significant increase in connection requests for withdrawal, in a context of rising construction work prices. In parallel, the implementation of the energy transition is materialising with

Figure 40: a set of programs covering all assets

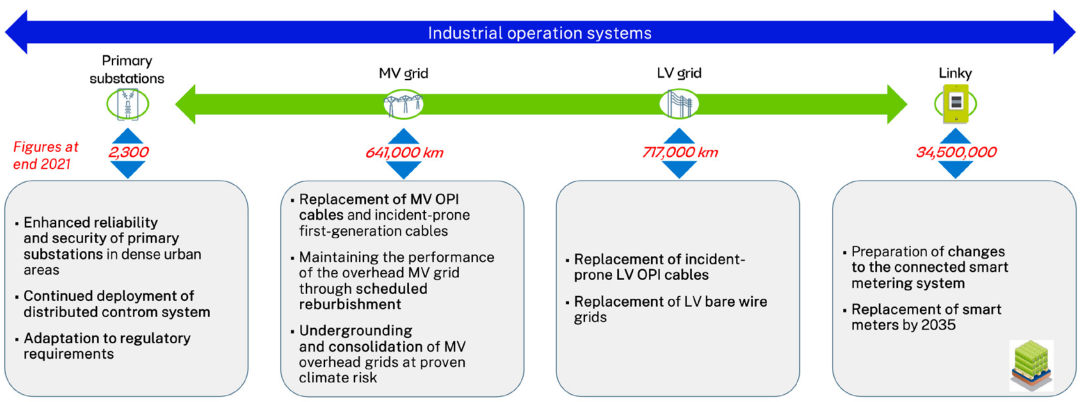
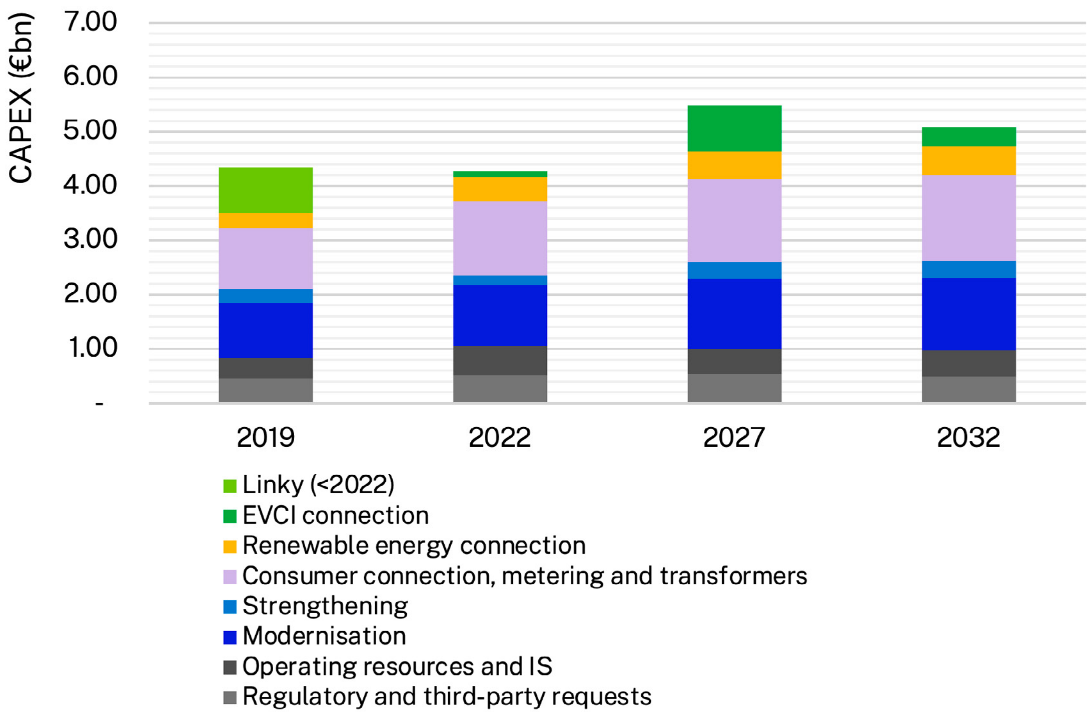


Figure 41: annual investment amounts within Enedis' remit by 2032, broken down by main investment purposes



a strong development of renewable energies. The investment needs to connect these new customers in withdrawal and injection generally align with the CAPEX released by the end of the Linky smart meter deployment program, bringing the investment level in 2022 to a level similar to that of 2019.

The development of renewable energy in the period that aligns, in the scenario chosen for the NDP, with the ambition of the PPE (French NECP) for 2028. Thus, an increase of 17% in renewable energy connection CAPEX is projected for 2027 compared to 2022, followed by a 4% increase in 2032 compared to 2027.

Over the same period, the development of electric mobility will require significant investments to connect electric vehicle charging infrastructure. The construction of collective EVCI in existing collective buildings will result in a peak of investments around 2027. The requests will then be lower and more spread out over time, for the creation of individual branches, as parking spaces are equipped upon demand.

Simultaneously with the connection investments, Enedis conducts ongoing programs for the modernisation and renewal of assets, to ensure a high level of quality of service and to make the networks resilient to climate changes. Investments are targeted and prioritised based on risks, as outlined in chapter 3. These investments amount to approximately €1 billion in 2022. They grow continuously and will reach around €1.3 billion in 2027 and 2032.

Enedis' total investments also include expenses to meet regulatory obligations (see 2.2) and costs related to operating means and IT systems, necessary for the distribution system operator's activity. These expenses remain relatively stable, at just under €1 billion in 2027 and 2032.

4.2. Placing the investments trajectory in perspective with Enedis' historical investments

The trajectory of the network development plan baseline scenario, presented in section 4.1.3, can be contextualised within the historical framework of investment volumes related to electricity distribution carried out since the year 1980 by EDF, then ERDF, and finally Enedis.

An investment growth that aligns with the trend of last decade, driven by the development of renewable energies and end-use electrification

Ecological transition implies a transformation of energy uses and production modes, which impact on Enedis' investments is mainly visible in the chronicle of investments related to the connections of network users. These investments, rather stable until the end of the 1990s (around €800 million per year), have grown until today, and the projected trajectory indicates that they will continue to increase to reach sustainably over €5 billion in 2032. This continued growth results from several effects:

- the increase in the number of connection requests, particularly to accommodate renewable energies and electric mobility;
- the increase in unit costs of connections.

An investment trajectory varying in line with the major network modernisation programs, reaching, after a dip, the levels of the 1990s

Investments related to network modernisation, reinforcement, and work tools have been more variable over the past forty years. A first peak appears in the early 1990s and extends throughout the decade. It can be associated with the implementation, from 1987 to 1995, of a policy to improve network quality. This policy involved modifying the network's structures by increasing the number of primary substations, reducing the lengths of MV feeders, and renewing obsolete assets. In 1992, EDF also made environmental commitments to public authorities, leading to the undergrounding of a portion of the electrical network each year.

Since 1995, after a clear improvement in the overall quality of service of the territory,[34] the focus on targeted improvements in customer satisfaction has replaced the goal of a uniform progress across the entire territory.[35] Economic calculation then took a key place in decision-making process. This quality policy revolved around three challenges: meeting the expectations of each customer category, combating climatic incidents, and improving technological safety in urban areas.

The upward trend observed between 2000 and 2002 reflects the impact of the December 1999 storm, an exceptional climatic event that caused significant damage to the overhead network for about a third of the metropolitan territory. Investment decisions were initially made to cope with the circumstances, and the expenses of the years 2000 and 2001 focused on the affected areas, within the framework of a "consolidation" and then "reconstruction" operation.

In the early 2000s, the climate hazards plan was structured to make the networks insensitive to climate risks (wood, snow, frost, wind) and meet the public service contract objective of restoring power to 90% of customers within 5 days. Following this program, a risk-based investment strategy was gradually deployed for all categories of assets (primary substations, underground MV networks, then LV networks). Thus, modernisation investments have doubled since 2008.

In parallel, investments related to connections have increased, in line with economic growth and its cyclical uncertainties, and in recent years, they have already been driven by the connection of renewable energy facilities.

34. The criterion B of the network operated by Enedis, measuring the average outage duration for a low-voltage customer, decreased from 3 hours and 40 minutes in 1988 to 1 hour and 17 minutes in 1995.
35. These efforts resulted in a further reduction of the overall average outage time, decreasing from 1 hour and 17 minutes in 1995 to 57 minutes in 2002.

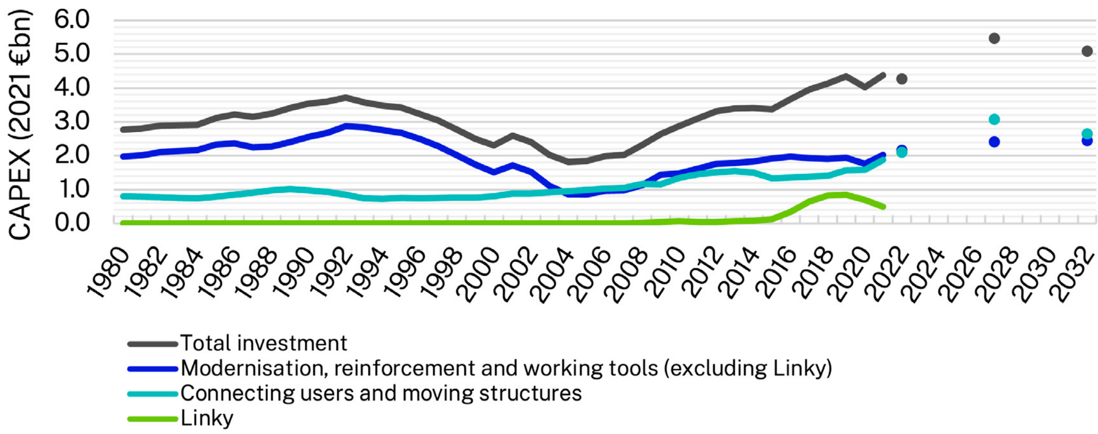
High levels of future investment, in line with the ambitions of the energy transition

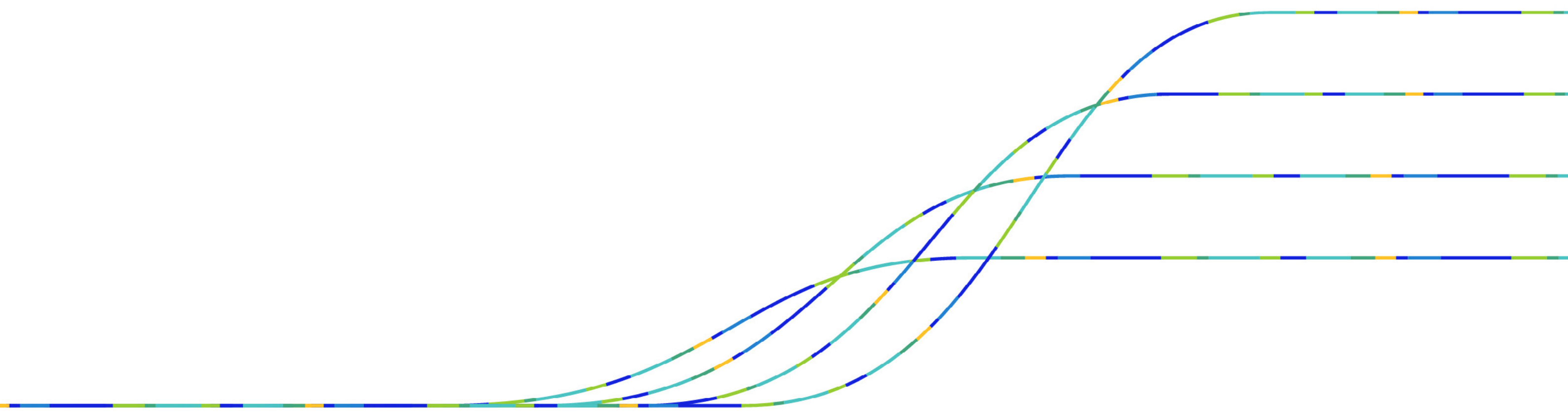
Over the next five to ten years, investments will continue to grow, increasing from €4 billion to consistently over €5 billion, addressing a triple challenge:

- The connection of electric vehicle charging infrastructure (EVCI), including the development of collective EVCI.
- The rapid acceleration in the pace of connecting renewable energies driven by the photovoltaic sector.
- The systematic handling of at-risk assets in the context of climate change.

As a whole, the trajectory of the network development plan baseline scenario implies an increase of about 20% in Enedis' CAPEX over the period 2022-2032, reaching over €5 billion annually. This is more than €2 billion above the historical annual average of €2.9 billion over the period 1980-2020 (+75%). At the end of the considered time frame, this level will be approximately 40% higher than the maximum investment amount observed in the 1990s. It reflects Enedis' commitment to serving the energy transition, actively supporting the development of new uses and the connection of renewable energies to a reliable and high-performing network.

Figure 42: chronicle of Enedis' CAPEX by main categories





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5

Enedis relies on sizing methods aiming for a technical and economic optimum for the national community

5

In order to be an efficient DSO, Enedis positions itself within the general framework of seeking a cost-quality optimum for the community.

The pursuit of this optimum relies on defining a set of assumptions to assess costs and benefits. The decision for optimal investment must ensure the operability of the network and take into account long-term perspectives (5.1).

These overall objectives set for the planning of distribution networks are detailed in the form of a technical reference framework consisting of significant strategic choices (5.2).

The technical and economic methods and tools that maximise the collective value of the network and seek the optimal investment decision in each case, whether it is a connection or a network reinforcement in response to evolving customer needs, are described in section 5.3.

5.1. Collective economy of a slowly changing network operated on a daily basis

5.1.1. Enedis seeks the cost-quality optimum for the community

Enedis invests optimally on behalf of all network users

Enedis fulfills its public service mission within a regulated framework: the **Energy Code** requires it to be an **efficient** network operator, which implies a perpetual search for **a cost-quality optimum for the community.**

Regarding Enedis' investments, studies aimed at this optimum:

• Are conducted within the scope of the national community, meaning that the impact of investments on society as a whole is taken into account. These studies should not be confused with a "business plan" type of analysis, which is conducted solely within the scope of Enedis.

• Consider the **overall costs and benefits** for the community, **without taking into account the internal financial distributions within that community.** Therefore, taxes (VAT, etc.) are not considered in the cost evaluation, and the way costs will be financed by different stakeholders is not examined: the debate here is not about who pays but about quantifying the overall cost for the community.

• Assess the desired **quality of supply** for the community through the use of a societal value of outage, called the value of non-distributed energy (see informational panel XXIV: value of lost load). The use of this value to estimate the cost of outages for society as a whole, rather than the penalties imposed on Enedis by incentive regulation (see informational panel XXII: the B criterion), illustrates that investment decisions are made within a collective logic, and not a financial logic at the Enedis company level.

The pursuit of this cost-quality optimum guides the choice of investment. It is not necessarily:

• the one that will minimise the inconvenience associated with valued outages, which could be extremely costly;

• nor the one that will only minimise explicit costs related to investment and operation (including technical losses, see informational panel XXVIII: technical losses) and could ultimately lead to a degradation in the quality of service experienced, and thus a loss of value for the community.

The optimal investment decision is the one that minimises the overall costs, including those related to non-distributed energy.

When there is no constraint on the investment time frame (this excludes connections, for example, as they need to be completed within a short period), it is also important to judiciously choose the investment date. This may mean making the investment as early as possible, or waiting for one or more years. In some cases, it is possible to effectively extend this period by using alternative levers such as flexibilities in the meantime. Therefore, **the realisation date is one of the components of the optimal investment decision.**

Since the collective optimum is, by nature, within the scope of the community, some decisions may not always be optimal from the perspective of the distribution network. For example, the connection of a high-power producer may not be made to the nearest primary substation, even if it could accommodate it, to consider constraints and saturations on the transmission network: the producer will then be connected to another more distant primary substation.

INFORMATIONAL PANEL XXII

The B criterion (SAIDI)

DEFINITION

The "B criterion", French equivalent for SAIDI (System Average Interruption Duration Index) is an indicator of power supply continuity. It represents the average annual interruption duration per low-voltage connected consumer installation, expressed in minutes.

The B criterion=

$$\frac{\sum \text{Duration of long outages for LV customers}}{\text{Total number of LV customers}}$$

There are two main B criterion metrics:

• The "TCC" B criterion, for all causes combined: It measures the quality of power supply as perceived by users, considering all upstream causes that generate a power interruption for customers.

• The "HIX excluding RTE" B criterion: This is the B criterion excluding exceptional events (defined in Annex 7 of the deliberation no. 2020-318 dated of the 17th December 2020: TURPE 6 HTA-BT) and incidents due to the transmission network.
It is one of the key indicators used to measure the performance of the distribution network within the framework of the incentive regulation defined by the TURPE. In 2021 for Enedis, the TCC B criterion was 62 minutes, and the HIX excluding RTE B criterion was **56 minutes.**

INCENTIVE REGULATION

Incentive regulation is a set of mechanisms integrated into the TURPE aimed at encouraging Enedis to control its costs, improve its performance, and enhance quality of service through incentives on its remuneration. The CRE's objective for the B criterion indicator (HIX excluding RTE) in the TURPE 6 framework is 62 minutes. The associated financial incentive is €6.4 million per minute difference between the actual and target values (as a bonus or penalty).

LINKY SMART METER

In its latest deliberation on 21st January 2021, regarding the decision on the tariff for the use of public electricity distribution networks (TURPE 6 HTA-BT), the CRE requests Enedis to enhance the reliability of the B criterion through a gradual automation of its calculation, in particular taking acount of Linky data. The CRE's objective is to implement a B criterion calculation process using smart meter data by the end of 2024.

5.1.2. Aiming for this optimum, Enedis bases its planning studies on societal expectations

The regulatory framework conveys societal expectations regarding safety and quality of service to the network manager in the form of benchmark values.

Regulatory requirements governing electricity distribution in terms of electrical safety and quality of service, including the "quality" decree (see informational panel XXIII: the regulatory framework for quality), reflect societal expectations regarding electricity distribution. The DSO ensures to fulfill its mission in accordance with this general framework.

External parameters guide Enedis' economic decisions regarding investments

To achieve the cost-quality optimum for the national community, Enedis relies also on parameters to complement its vision. Three main technical and economic parameters are used nationwide to consider the preferences of the national community during investment planning:

- **The value of non-distributed energy** (VOLL, see informational panel XXIV: value of lost load): reflects the value assigned by the community to access to electrical energy.

- **The discount rate:** this rate allows for trade-offs between benefits and costs occurring at different time horizons, based on the overall economic and social context.[36] Enedis chooses to adopt the value defined by France Stratégie, intended for the evaluation of public investments: Enedis currently uses a discount rate of 4.5% in its studies, currently subject to revision to account for new recommendations from France Stratégie.[37]

- **The long-term energy cost:** this cost reflects the mix of the electricity generation system, hence economic and societal choices in this regard. It is used as an input parameter to assess the non-injected energy[38] value and the cost of energy intended to compensate for losses related to cable and transformer heating (see informational panel XXVIII: technical losses). Enedis relies on external references to determine the long-term market cost.

It is worth noting that the impact of Enedis' activities on carbon emissions is a parameter whose importance is increasing, in line with ecological transition objectives. It is currently implicitly considered through long-term energy cost references, which include a market value for CO_2 emissions.

For the sake of coherence, discussions are held with RTE to standardise the use of these parameters by both the Transmission System Operator (TSO) and the DSO Enedis. Enedis is committed to meeting local expectations as closely as possible.

These general principles, described in greater detail in the following sections, are complemented by regular dialogue with the licensing authorities, regional authorities, and networks operators interfacing with the network managed by Enedis (TSO, ELD). This aims to refine investment choices, taking into account local issues and challenges, especially when they may not be perceived or represented through accessible technical and economic tools, and to seize opportunities for restructuring and modernising the network.

36. Enedis' investments, in line with its public service mission, are based on a discount rate, which is distinct from a financial interest rate or weighted average cost of capital.
37. France Stratégie is updating its recommendations, particularly regarding the consideration of risk in determining the discount rate for public investments. See: Guide for socioeconomic evaluation of public investments - operational supplement I - Revision of the discount rate, France Stratégie, October 2021, https://www.strategie.gouv.fr/sites/strategie.gouv.fr/files/atoms/files/fs-guide-evaluation-i-taux_dactualisation-23novembre-final.pdf
38. The non-injected energy is the energy that a producer could have fed into the grid but that is lost for some reason. For instance, this may occur when a network equipment failure leads to the temporary disconnection of the producer's installations. It can also happen when the injection is interrupted by an instruction sent by the DSO, such as in the case of an ORA with power modulation.

INFORMATIONAL PANEL XXIII

The regulatory framework for quality

In accordance with the legislative obligations imposed on public network managers, the "quality" decree No. 2007-1826, codified at the end of 2015 within the Energy Code (D322-1 to D322-10), and the decree of 24th December 2007,[39] in force, establish the quality levels and technical requirements for the quality of public distribution and transmission networks for electricity. Enedis, as a public network manager, must comply with these requirements regarding the quality levels of electric current.

These official texts concern voltage stability and the continuity of electrical supply, which, "except in exceptional circumstances", must meet a level of quality:

- Global (statistical), which must be respected at the departmental level, measured by criteria such as "no more than x% of customers in the department experience...";

- Minimum, which must be ensured for every customer (consumer).

VOLTAGE STABILITY

The defined voltage variation range is the same for both low-voltage (LV) and medium-voltage (MV) customers. A network user is considered to be a "poorly supplied" customer (CMA) if, at least once a year, the voltage at their delivery point reaches an effective value less than 90% of the nominal voltage or more than 110% of this nominal voltage.

The "global" quality level is not met if the percentage of CMAs exceeds 3% both at the departmental and concession network levels (Article 3 of the 2007 decree amended by Article 2 of the 2010 decree).

CONTINUITY OF THE POWER SUPPLY

The continuity of electrical supply is characterised by:

- The number of long-term interruptions (> 3 minutes), whether accidental or scheduled, experienced by a customer during a year;

- The number of short-term interruptions (1 second to 3 minutes) experienced by the customer during the year;

- The maximum cumulative duration of these interruptions.

For each of these three criteria, a reference value is defined, and a customer is considered "poorly supplied" if at least one of the three reference values is exceeded.

The global continuity level is not met if, for at least one of the "zones," the percentage of poorly supplied customers exceeds 5% both at the departmental and concession network levels.

CONSEQUENCES OF NON-COMPLIANCE WITH ESTABLISHED REQUIREMENTS

The regulations explicitly specify the consequences of non-compliance with the established requirements. For example, when the results of the overall assessment in continuity (or voltage) - measured at the departmental and concession levels - do not meet the thresholds set by regulations, the network manager must submit to the organising authority a program to improve the quality of electricity on the network.

39. Decree of 24th December 2007, implemented in accordance with the decree n° 2007-1826 of 24th December 2007, regarding the quality levels and technical specifications for the quality of public distribution and transmission networks of electricity

INFORMATIONAL PANEL XXIV

Value of lost load

One of the key parameters in cost/benefit analyses conducted by Enedis is the cost to society that should be attributed to a potential power supply failure, as this cost conditions a possible decision to invest in reinforcing the network:

- What cost should be assigned to a short-term interruption? What cost should be assigned to an interruption lasting several hours?

- How to determine the consumer customers' assessment of this cost, which varies over time and according to usage?

In the economy of the electrical system, these questions have long been addressed by estimating a socio-economic variable known by several different names: non-distributed energy, Value Of Loss Load (VOLL), etc.

Enedis estimates the VOLL by conducting surveys among a representative panel of consumers connected to the distribution networks it operates (*Enedis, Quelle est la valeur socio-économique de la continuité d'alimentation du Réseau Public de Distribution géré par Enedis ?*). The aim of these surveys is to assess the inconvenience associated with a power supply outage in different periods of the year and for different interruption durations, and then translate this inconvenience into a socio-economic value. This value is thus constituted of:

- direct costs to the interrupted consumer: loss of production for an industrial, for example;

- indirect costs for the rest of society: a business, not having been delivered due to the power supply interruption of a manufacturer, may also be affected by the outage;

- directly monetisable values: the loss of perishable goods from a freezer for an individual, for example;

- indirectly monetisable values: the loss of comfort, such as the time spent restocking the freezer, etc.

The resulting VOLL has two components:

- A VOLL in €/kWh: representing the variable or proportional part of the inconvenience that depends on the duration of the outage.

- A VOLL in €/kW: representing the fixed part of the outage. This value measures the inconvenience regardless of the duration of the outage.

The current VOLL is thus €31/kWh (variable part) and €10/kW (fixed part).

If a consumer is informed in advance of an outage, they can then implement means to limit the associated inconvenience: an industrial, for example, can synchronise the maintenance of a production line with the power outage to limit associated production losses, an individual can take certain measures to moderate the impact of the outage during the announced period, etc. A separate VOLL is therefore used for outages with advance notice.

The current VOLL with advance notice is thus €21/kWh (variable part) and €5/kW (fixed part).

5.1.3. Enedis invests to ensure the day-to-day operation and long service life of assets

The investment rules used must take into account the daily network management and operation

The set of sizing rules has been defined so that the network is always operated in compliance with safety and regulatory requirements. It ensures this in two ways:

- most of the time, by ensuring that the sizing of the facilities meets these requirements;
- the rest of the time, by giving enough levers to the network operation teams to ensure it.

In situations where network operation teams have to intervene, the power supply to some customers may no longer be guaranteed. Therefore, efforts are made to limit their occurrence. Choosing the risk of occurrence of these situations is one of the challenges in seeking the cost-quality optimum. This choice is implemented through the definition of network sizing reference situations described in section 5.3.

It is necessary to prepare, from its design, the operability of the network, i.e. the ability to carry out maintenance and repairs efficiently once in service. It may include the ability to control certain elements in real-time. To achieve this, the sizing rules take into account the network operation and management rules, so that the operation teams have then the ability to operate the infrastructure.

This can be illustrated concretely through the example of network equipment maintenance. This may require de-energising part of the network. In general, the MV network meshing (see 5.2.2) allows to set up an alternative network scheme on this occasion, to limit the impact of this maintenance on customers. This will only be possible if the operating teams have the necessary room for manœuvre: there must be enough operating devices on the network, and the "backup" network elements (that will temporarily carry the additional load) must have sufficient technical capacity.

Flexibilities and smart functions, which will be detailed in chapter 6, generally lead to rethinking these principles by increasing the frequency of situations where operation teams must intervene. While these new functions are implemented in cases where they minimise collective cost, which is of course desirable, they must nevertheless be developed in a controlled way, so that the distribution network remains operable in the service of all.

Investment decisions on the network are made for long-term

Given that **Enedis invests in assets with a long service life, on the order of several decades,** and whose usage patterns evolve slowly, it is all the more important to take into account all costs and benefits for the community in the search for the optimal investment solution.

This implies that **investment studies be conducted on theoretical situations**, not simply based on situations observed in the past. The choice of the network installed today must take into account the variety of future needs and the associated uncertainty.

This also leads to favoring a certain stability of the DSO's technical choices: **we inherit past choices and constrain future ones. For example, the decision, at a given date, to install assets intended to be operated at a certain voltage level will encourage choosing this voltage level again in the future to optimise the cost related to the compatibility of assets with each other.**

5.2. Enedis transposes the general objectives of planning into a technical reference: the major structuring choices

5.2.1. Technical limits to be respected, defined by the DSO: the voltage management scheme and the constraints

In order to transpose the general framework outlined in 5.1 into its investment decisions, Enedis defines acceptable ranges for the variation of electrical parameters of the network, namely voltage, current, and short-circuit currents, taking into account the technical operating limits of the equipment. These limit values are defined by the voltage management scheme, the maximum permissible currents, and the protection plan.

Voltage management

The HV voltage delivered by RTE at the interface of the distribution network, upstream of the primary substations, is transformed to 15 or 20kV downstream by HV/MV transformers. This voltage varies along the distribution networks that extend from the primary substation, depending on connected consumers and producers.

The central historical issue for DSOs concerning this voltage evolution along the network was, in a world of centralised production: how to control the voltage drop at the end of low-voltage networks, up to the final customer ? With the progressive undergrounding of cables and the arrival of renewable energy, each contributing to local voltage increases, the voltage issue is changing. It is no longer rare that the connection of renewable energy requires network work due to locally too high voltage during peak generation.

The solutions that spontaneously come to mind (which would involve making technical choices to lower the network voltage near the producer requesting connection) would be contrary to the interests of the consumer customers in the area. If a static solution to lower local voltage is chosen to accommodate production, when the producer does not produce energy (due to lack of wind or sunlight) consumers would get voltages far too low for their devices, falling below the thresholds of the "quality" decree.

The **voltage management scheme,** drawn up by Enedis, defines the voltage margins granted to the various users. It allocates the range of possible margins (specified by the "quality" decree) among the different types of users and must aim for a compromise solution that is acceptable to both consumers or producers. The voltage management scheme relies on the models and technical levers available to define how their combined use can ensure compliance with the regulatory requirements (see informational panel XXV: the voltage management scheme).

Potential evolutions of the voltage management scheme are currently under discussion within Enedis to find the best collective economic compromise regarding the sharing of margins, etc. It may also rely on smart means of regulating or adjusting voltage, if they are available and economically viable. These alternative means are examined in section 6.2.

Constraints

The voltage management scheme, therefore, defines the acceptable limits of voltage variations, both upward and downward, along the MV and LV feeders. Similarly, the technical limits of equipment, which can be weighted to account for local effects favoring overheating (such as passage through conduits or proximity of multiple conductors), define the maximum permitted currents in various elements of the network. Finally, the protection plan defines the maximum and minimum short-circuit currents for MV and LV feeders. These thresholds are defined in Enedis' reference technical documentation (DTR), which is public (see https://www.enedis.fr/documents).

In the context of planning, Enedis uses the term "electrical constraint" to describe cases where the current or voltage exceeds the ranges defined by these sizing rules, **in the reference situations considered by Enedis for its network planning studies** (defined in section 5.3). These constraints indicate a structural vulnerability of the network since they mean that, in plausible and demanding situations of consumption and generation, the current in a conductor could exceed the maximum threshold of that equipment, or the voltage delivered to certain customers could fall outside the regulatory range.

On the contrary, measuring a current or voltage outside the specified ranges does not necessarily imply a structural vulnerability of the network. The cause may be circumstantial (such as an exceptional consumption situation, exceeding the reference situation), or due to an equipment failure or an uneven distribution of customers between the LV phases (which can be resolved without investment).

An illustration of the influence of the topology of assets on the types of constraints likely to appear is provided in the informational panel XXVI: the different network typologies influence the types of constraints likely to appear

INFORMATIONAL PANEL XXV

The voltage management scheme

The regulatory framework requires Enedis to supply its customers with a voltage ranging from -10% to +10% around the nominal voltage (Un). Additionally, the connection contracts for MV customers stipulate that the supplied voltage must be within -5% and +5% around the contractual voltage value, which is set by Enedis between -5% and +5% around the nominal voltage (usually at Un).

Enedis has few levers at its disposal to control network voltage:

- At the primary substation level, an On-Load Tap Changer (OLTC) maintains the voltage downstream of the HV/MV transformer at a set point value (provided that the HV voltage remains close to its nominal value). For most primary substations, remote control of the voltage set point is not possible.

- At the MV/LV substations, a No-Load Tap Changer (NLTC) allows changing the MV/LV transformation ratio (usually, the NLTC provides a choice between three values, giving a downstream voltage at Un, Un + 2.5 % or Un + 5%). This NLTC cannot be maneuvered when the transformer is under load, so changing the setting is a significant intervention that requires temporarily de-energising all customers downstream the MV/LV transformer, and sometimes even requires cutting off part of the MV feeder supplying the substation.

Once the set point voltage is fixed at the primary substation level, the voltage on the downstream MV and LV network changes according to consumption and production on this network. Thus, on a generally consuming feeder, the voltage will gradually drop as the distance from the primary substation increases. Conversely, on a producing feeder, the voltage will rise. These voltage variations are even greater when the transmitted current is high, and the resistivity of the conductors is high. The figure next page schematically illustrates voltage variations on an MV and LV network in two situations: maximum generation and low consumption in pink, and zero generation and high consumption in green.

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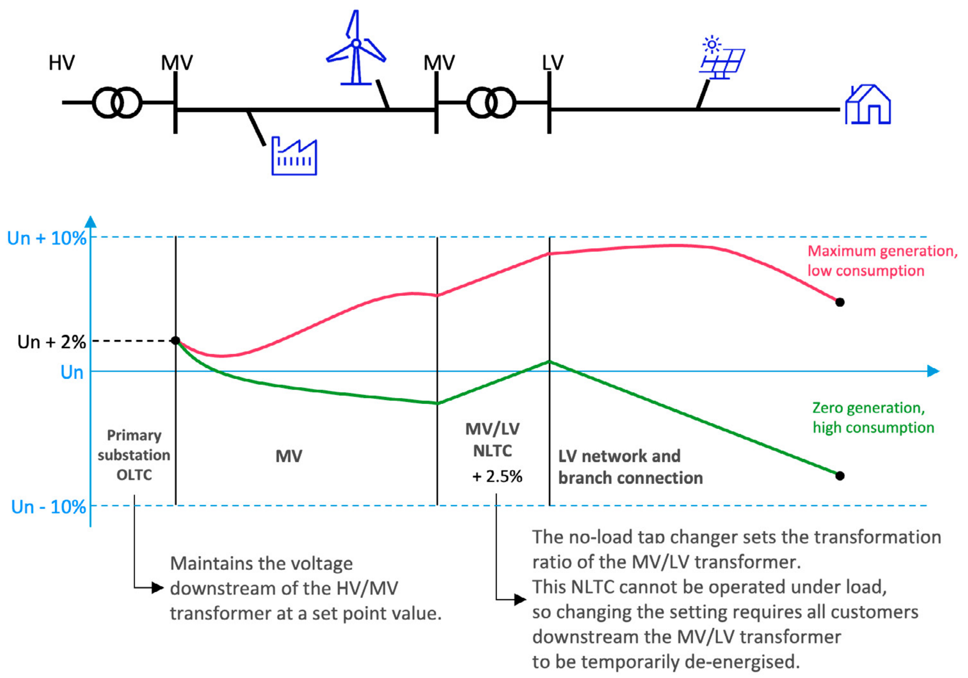
Figure 43: illustration of possible voltage variations on a network, in situations of maximum generation and low consumption, or zero generation and high consumption



To ensure that the voltage delivered to customers remains within acceptable limits, Enedis designs the network to limit these voltage variations along the feeders. The so-called "voltage management scheme" is therefore a set of rules that define:

- the set point voltages that can be chosen at the level of the primary substations;
- the maximum voltage drops and rises along the MV feeders;
- the fixed tap values that can be chosen at the MV/LV substations;
- the maximum voltage drops and rises along the LV feeders.

These rules, which must be uniform at the national level, de facto define a sharing of margins among users: MV and LV customers, producers, and consumers. In practice:

- The higher the allowed voltage variations along the MV feeders, the less space there is for significant voltage variations in LV. Thus, facilitating the connection of MV customers has the counterpart of making it more difficult for LV customers to connect.

- The higher the maximum voltage rise along an MV feeder, the lower the wished set point voltage at the source substation, and therefore the less room there will be for significant voltage drops on other MV feeders. Thus, facilitating the connection of MV producers has the counterpart of making consumers connections more difficult.

INFORMATIONAL PANEL XXVI

The different network typologies influence the types of constraints likely to appear

Different types of constraints affect the network sizing in various ways:

- Constraints related to the protection plan primarily limit the length of feeders and the possibility of having both overhead and underground cables on the same feeder.

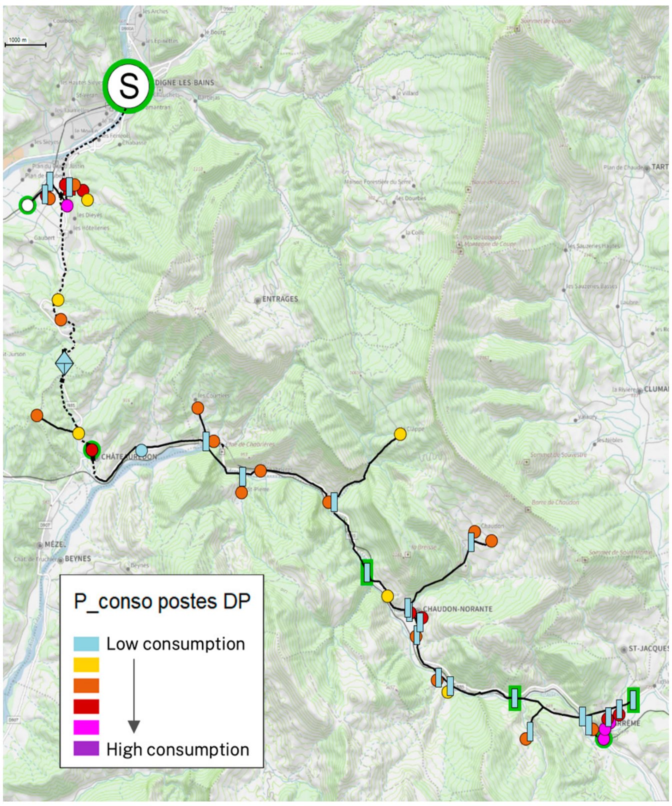
- Current constraints restrict the load per feeder and per transformer.

- Voltage constraints depend on both the load and the length, limiting the connection of excessively high loads too far from the substations.

As a result, the various types of constraints are generally encountered in different network typologies:

- Low voltage issues mostly occur in rural areas due to the network length between primary substations and customers (see figure 44).

Figure 44: example of an MV feeder likely to experience low voltage constraints, due to its great length (partly due to geographical relief) and the presence of significant loads at the end of the feeder



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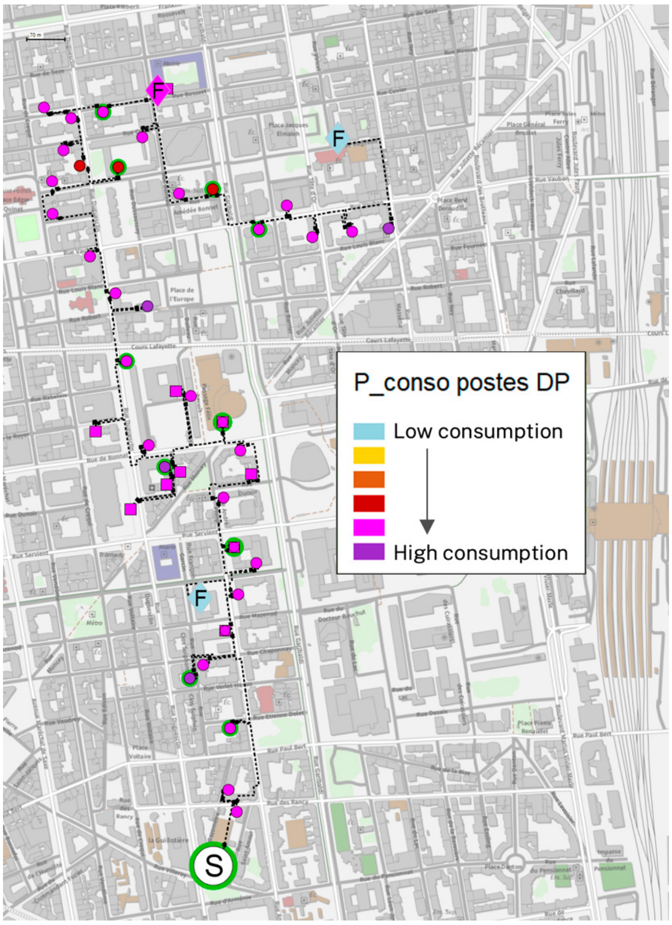
- High voltage is a more recent issue, arising as a result of massive distributed generation and networks undergrounding. Symmetrically to low voltages, high voltages are more likely to occur in rural areas, on long networks with low consumption but significant generation. Moreover, an MV network composed of long length underground cable may feed reactive power back to the transmission network (see informational panel XXXVI: reactive power), which raises its voltage.

- Overcurrent is more common in urban areas due to the density of consumption (See figure 45).

Figure 45: example of an MV feeder susceptible to experience current constraints due to the high density of loads



5.2.2. A target structure to favor operations, for the benefit of the daily quality of supply for customers

The construction of a meshed MV network allows the operation staff to enhance the quality of supply for customers in case of incidents or maintenance

The significant value placed by society on a continuous electrical supply leads to a development of the MV network taking into account situations of incidents or maintenance on the network that could lead to a service interruption for customers.

One of the available solutions to reduce the impact of these events is to provide the regional operation control rooms (ACRs in French) with the means to temporarily modify the electrical path leading to a customer. This is prepared during network planning, ensuring that an area or a customer is connected to the network through different electrical paths, which can be switched by the regional operation control rooms, either remotely using automated devices placed on the network or manualy through maneuvers performed by operational teams. The majority of areas served by Enedis' MV network are thus currently supplied by different paths (MV feeders): the MV network is "meshed".

However, this possibility does not means that customers can be supplied simultaneously through several feeders: the network is not operated as a “close loop”, which means that at any given moment, through the use of automatic and manual circuit breakers, a single electrical path under tension connects a given area. This network operation practice, referred to as "open-loop operation", may differ from that of certain transmission networks, which can be "closed-loop" operated.

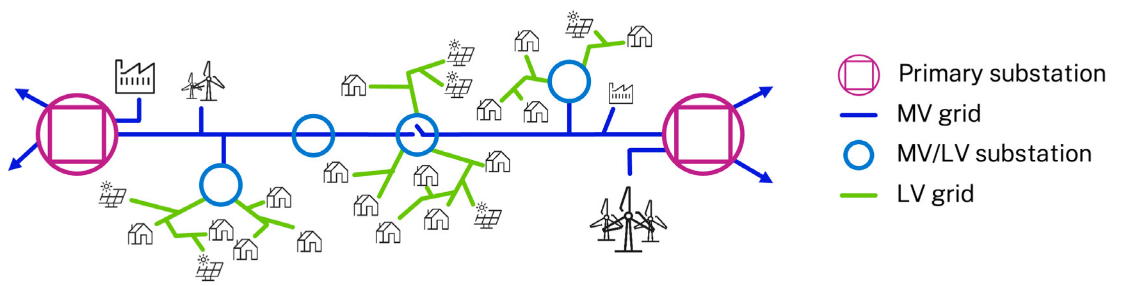
The target structure defined by Enedis for the MV network enables an effective meshing of the network

In accordance with the objectives outlined in section 5.1.1, Enedis aims to develop these redundant structures efficiently. In a context where the network evolves slowly, as discussed in section 5.1.3, and mostly through a succession of multiple investments of limited scale, it would not be reasonably feasible to redefine the optimal redundant structure for each new investment in a given area. Therefore, Enedis proposes to its network designers and network project managers to aim for a gradual convergence towards a given target for the network structure.

For the MV network, this target structure is the “source-to-source structure” (see figure 46). Two cables from different primary substations, i.e. two MV feeders, form a primary substation to primary substation corridor. This “source-to-source” structure is not always achievable, particularly because of natural obstacles (e.g., near the sea) or the geographic location of customers. The target is then to connect together feeders from the same primary substation, where junction points are feasible.

In this structure, for each pair of interconnected MV feeders, an electrical opening point is defined, located by a switch in a MV/LV substation or on the overhead network. This switch establishes the usual boundary between the two primary substations and remains open when the network is not in a

Figure 46: description of a source-to-source structure



maintenance or incident situation. This situation is defined as the "normal operating scheme."

This structure is simple and efficient for network operation and management: it allows for a variety of operating schemes depending on the chosen location of the opening point. It also provides a high level of security in the event of an incident (loss of a primary substation or of a section), work, maintenance, or temporary overload. In these different scenarios, changing the operating scheme helps limit the number of customers affected.

It's worth noting that this basic scheme, while simple at the individual level, becomes complex to visualise once generalised: a primary substation typically supplies between ten and twenty MV feeders, backed up by networks from an average of five other primary substations. The topology of this meshing is illustrated by the concrete example of the Alençon area in informational panel XXVII: network mapping -example of the Alençon area.

A target structure that is not intended to be achieved everywhere, nor at any cost

While the benefits of a meshed and redundant network structure on the quality of service are clear, they do not always offset the cost of the necessary investments.

The technical and economic principles defined in section 5.1 allow Enedis to determine the appropriate level of network meshing to aim for.

INFORMATIONAL PANEL XXVII

Network mapping - example of the Alençon area

A representation of the network topology is available on Enedis' open data website (https://data.enedis.fr/).
In 2015, Enedis was the first European distributor to publish aggregated energy data in open format. Since then, it has expanded this initiative for all stakeholders in the energy transition. This website allows, among other things, to visualise the mapping of MV and LV electrical networks. An illustration of the map for the MV overhead and underground network supplying the Alençon area is shown in figure 47.

Figure 47: map of the MV network, both overhead and underground, supplying the Alençon area

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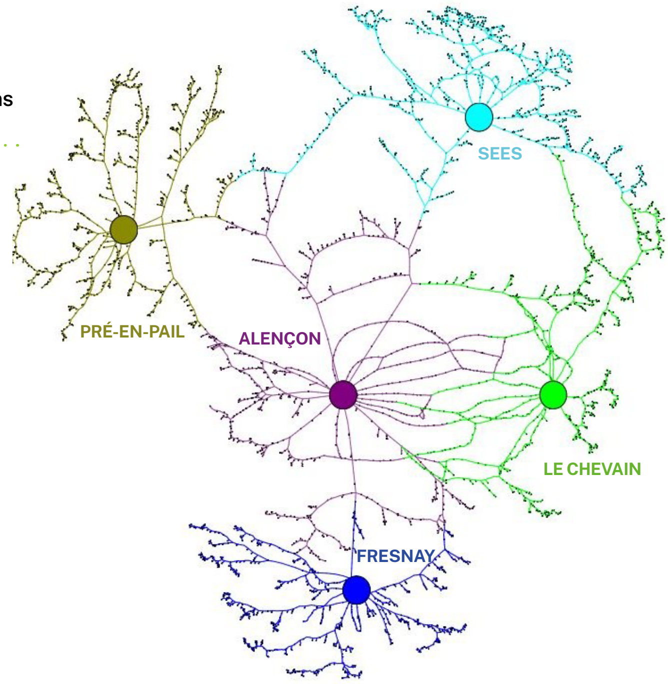
This cartographic representation shows the precise location of primary substations and the entire MV network, reflecting the network's meshing. To understand the electrical logic, however, it is more suitable to move away from this geographical representation and adopt a technical and schematic representation. Figure 48 illustrates the representations used by Enedis teams, still in the case of the Alençon area. On average, there are approximately five "back-up" or "support" primary substations for each of Enedis' primary substations. Thus, the Alençon primary substation represented here can be backed up by the PRE EN PAIL, FRESNAY, LE CHEVAIN, and SEES substations. Their own back-ups are not represented here.

Figure 48: simplified visualisation of the networks supplied by the Alençon primary substation and its back-up primary substations



Design resulting from considerations that go beyond an individual asset

Since this structure connects primary substations and networks to each other, investment decisions related to an MV asset typically result from taking into account existing neighboring assets or even a larger area including multiple primary substations.

As a result, the sizing of these facilities cannot be assessed by considering them as isolated objects. In particular, this intricate structure allows for multiple operation and recovery schemes, depending on the choice of the opening point. This weakens any impact study relying solely on the examination of the load curve history of a primary substation taken in isolation from its environment.

In this context, it becomes natural to observe that the transit peak of a primary substation, measured over a limited historical period, is often far from its maximum technical capacity. This reflects the existence of additional capacity available and used, if necessary, to supply the customers usually fed by other primary substations in the area.

A low-observable LV network structure

The level of observability achieved in MV through the deployment of sensors, and the enhanced controllability facilitated by automation, are not replicated in LV. The target structure is simpler, tree-like, without connections between the feeders, and is designed to handle the variability of loads connected to its branches. In the event of an incident, the load can be progressively reenergised by interventions carried out directly on the network by operational repair teams. Given their radial (and not meshed) structure and their limited real-time observability, low-voltage networks are "operated" but not “managed”.

5.2.3. Equipment ranges associated to usage recommendations

A range-based approach to ensure the efficiency of equipment purchases and the feasibility of unit studies

Enedis is a leading industrial player in France, and it can provide its customers with a better cost-quality ratio by streamlining its procurement policy, particularly concerning the purchase of transformers and cables. Limiting the number of references used not only helps to reduce the costs of qualifying these equipment, but also enables suppliers to offer more competitive manufacturing prices, and simplifies logistics and maintenance.

Therefore, Enedis applies a range-based approach to its main network equipment. To implement the principles presented in section 5.1, usage recommendations for these materials are provided to network designers and network project managers.

The long lifespan of the network infrastructure mentioned in section 5.1.3 also requires adapting investments to future loads. There is a balance between the savings allowed by installing equipment that precisely matches the load it will carry when it comes into service, and the cost of replacing that equipment later if its capacity becomes saturated. In the case of network infrastructure, whether cables or transformer substations, a significant portion of the investment costs is associated with civil engineering works. It is therefore crucial to install electrical equipment adapted with the network's future developments.

Choice of cables

When installing a cable, Enedis applies an approach of "reference economical cross-sections" (see informational panel XXIX: economical cross-sections): depending on the expected load and its growth prospects, one of the cable references in Enedis' cable range is recommended, according to its cross-section and technology. This choice is facilitated by the use of simplified calculation charts to find the technical and economic optimum.

Cables chosen following these efficiency criteria often have a maximum capacity greater than the value of the maximum potential power that was evaluated at the time of their installation.

INFORMATIONAL PANEL XXVIII

Technical losses

CONTEXT AND DEFINITIONS OF LOSSES

On the distribution network, electrical losses are the energy injected into the network but not billed to customers. They cannot be measured, and are therefore calculated by balancing flows.

There are two types of electrical losses: non-technical losses, resulting from non-contractual consumption, fraud, or metering malfunctions, and technical losses, which correspond to energy dissipated in the form of heat during the transmission of electricity on the network. Technical losses are of two kinds:

- Losses dependent on the flow of electricity: caused by the Joule effect in conductors, they vary quadratically with the load; $Losses_{Joule}=R.I^2$.

- Losses independent of the flow of electricity (as a first approximation): iron, hysteresis, and dielectric losses, occurring particularly in the core of transformers.

The main drivers of technical losses are mainly:

- Load on the conductor: the higher the electricity flow through a cable, the greater the losses.

- Distance to be covered to supply the load: the longer the distance, the more losses.

- Conductor cross-section: smaller cross-sections result in higher losses.

- Conductor material: higher cable resistivity leads to more losses.

IMPORTANCE OF LOSSES

Losses are significant for Enedis in terms of finance (purchases on the market), corporate social responsibility (contributing to the carbon footprint), and resource efficiency.

COST OF LOSSES IN TECHNICAL AND ECONOMIC STUDIES

Losses are valued at the long-term energy cost.

OPTIMISING TECHNICAL LOSSES WHEN DESIGNING STRUCTURES

Optimising technical losses over the lifespan of an installation is one of the key parameters considered in network planning when choosing the technically and economically optimal investment strategy (see informational panel XXXI: choice of the best investment strategy).

The choice of the optimal conductor cross-section (see informational panel XXIX: economical cross-sections) thus optimises the cost of losses, but not at any cost, as other factors are also taken into account. Reducing technical losses cannot be an isolated objective.

INFORMATIONAL PANEL XXIX

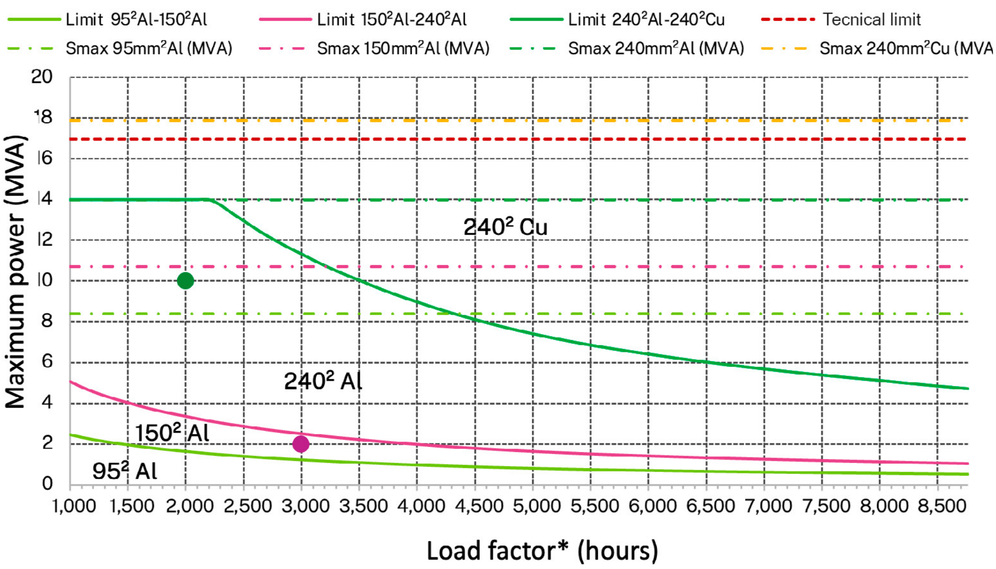
Economic cross-sections

Enedis has a finite range of conductors (overhead lines and underground cables) which have been qualified, and for which contracts have been established with suppliers. These conductors are mainly characterised by their material and the cross-section of the conductor part. These parameters have an impact on the maximum permissible current and on the conductor resistivity. For conductors of the same material, the larger the cross-section, the greater the maximum permissible current and the lower the resistivity, leading to a reduction in Joule losses and conductor heating.

When installing a conductor, Enedis selects the type of asset that can carry the expected current while minimising costs over its lifetime. The costs to consider are mainly the initial cost of the asset and the cost of Joule losses that will occur over the asset's operational life – spanning several decades – requiring the generation of additional electricity and its routing to the cable (see figure 49).

While the initial cost of a conductor increases with its cross-section, the Joule losses incurred decrease to carry the same current. There is therefore a

Figure 49: economic cross-sections for consumers in 20 kV



The economic cross-section of a cable is chosen according to its load condition: maximum power that it will carry, load factor.

The power that could technically be carried by the chosen cable may be much higher (see the two examples opposite).

Pmax: 2 MVA for 3,000 hours/year	cross-section chosen: 150 mm² alu this cable could carry 10.7 MVA: 8.5 times more
Pmax: 10 MVA for 2,000 hours/year	cross-section chosen: 240 mm² alu this cable could carry 14 MVA: 1.4 times more

* The load factor is the annual duration of use of the maximum power to be transmitted over the cable.

>>>

>>>

balance between the initial cost savings from installing a cable with a smaller cross-section and the additional costs incurred in subsequent years as a result of the increased cable heating.

This balance depends on the long-term energy cost, which is used to assess the cost of losses incurred during the cable's lifetime. The discount rate, which enables comparing the cost of the initial investment cost and the future costs, even at distant horizons, is another essential parameter for assessing this balance.

The optimal section resulting in the lowest cost over the lifetime is therefore a compromise between these two effects and is always greater than the minimum cross-section that would allow the expected current's transmission.

In its sizing rules, Enedis takes into account this issue through "economical reference cross-sections" calculation charts. These calculation charts are regularly updated when underlying economic parameters, such as equipment or energy prices, change.

The order of magnitude of the cost difference between cables of two different cross-sections is lower than the expenses involved in installing the cable, mainly due to the associated civil engineering works (as illustrated in information panel I: investment in the distribution grid involve civil engineering works). As a result, the optimum cross-section differs significantly from the minimum cross-section that would allow the expected current to flow.

Choice of transformers for MV/LV substations

A range-based approach is also implemented for MV/LV substation transformers. The factors considered for establishing these ranges include Enedis' environmental choices and regulatory obligations (see chapter 7).

Methods similar to those described for cable selection, based on calculation charts, are applied to the selection of these transformers.

Therefore, at the time of their commissioning, the capacity of the transformers installed is often significantly higher than the maximum power they must be able to transmit.

5.2.4. The network resulting from these structural choices is not at the constraint limit

The result of these major strategic choices, for the network new assets, is a technical capacity far greater than the power they will be required to carry when they are commissioned. As these structural choices result from a constant quest for a technical and economic optimum based on societal preferences, it is worth to underline that **a well-sized distribution network is not at the constraint limit**.

This point required clarification during the consultation phase of the network distribution plan, especially during workshops organised with network users. It is essential to distinguish, for each asset, two time scales:

- The first is that of network design, at the time of the investment decision. Here, the right choice is not to create the minimum infrastructure. It is necessary to rely on technical and economic foundations to anticipate the future, taking into account potential load growth, future modification costs of assets, equipment range choices, and creating redundancy, where effective, to be able to provide a quality of supply aligned with societal expectations. This is why a "well-sized network is not at the constraint limit".

- The second time scale is that of daily operation, once the investment is made. Starting from the moment the asset is installed, Enedis will use it to its maximum capacity, especially to match load growth or to connect new users.

5.3. Methods for unit studies providing a coherent framework for customer connections and network reinforcement

Enedis invests to address the challenges identified in chapters 2 and 3

As a network operator, Enedis must invest to meet the connection requests (from consumers or producers), third-party requests, and regulatory requirements. Enedis also has to carry out network reinforcements to meet consumption evolution. Finally, it ensures the network's performance in terms of reliability and resilience of the assets.

To achieve this, Enedis relies on two distinct methodologies

Enedis chooses the best way to address these challenges by establishing an investment decision framework:

- **Unit technical and economic studies** are used for customer connections, alleviating specific constraints (in terms of electrical constraints regarding current or voltage, or quality-related risks during assets unavailability or operational difficulties), anticipating load growth, or requests for assets relocations.

- **National plans,** on the other hand, allow for the examination of issues that cannot be modelled in unit technical and economic studies (and/or for which individual assessments would be more costly than the national plan correct adjustment and updating of the issues). These **programs, following the same economic fundamentals as unit studies**, address the network's **resilience** to climate or societal risks, or the equipment obsolescence. They enable long-term investments on these subjects to be **spread out year by year** and **prioritised.**

On a day-to-day basis, this is reflected in a number of investment-triggering processes

Dealing with connection requests, to which Enedis must respond within a timeframe defined by regulations, requires conducting a study each time to check that the connection does not create new constraints on the network and to determine the optimal connection solution (see 5.3.1).

When dealing with requests from third parties (municipalities, individuals, companies, etc.) to relocate an asset, bury an overhead line, etc. if the requested modification is significant, a study may be conducted to check that it does not create new constraints on the network.

Regular diagnosis of potential network vulnerabilities (which may appear as a result of increased load) leads in conducting a technical and economic study each time a vulnerability is detected, to determine the optimal solution (see 5.3.2). This type of study and investment is referred to as "proactive".

National resilience and renewal plans are monitored, leading to annual investment targets in each region for the relevant issues, and to criteria for prioritising the assets on which these investments should focus.

This chapter examines unit technical and economic studies

The principles of national resilience and renewal plans were addressed in sections 3.2 and 3.3. Consequently, this section deals with unit technical and economic studies.

Connection studies and **proactive studies,** based on a **common foundation** of methods and tools, are presented in sections 5.3.1 and 5.3.2.

In the interest of efficiency and to ensure reasonable connection delays, Enedis must use simplified study methods to address numerous similar requests of low unit investment amounts. Hence, the methods differ on certain points between studies involving primary substations, the MV network, or the LV network, although the underlying principles remain the same.

5.3.1. Connection studies: network sizing reference situations and regulations

Enedis' connection rules are identical **across the territory** and are made **public** through Enedis' technical reference documentation. The aim of this section is to describe them in an informative description.

Every customer is connected so that they can withdraw or inject the power they require, referred to as the connection power at the time of commissioning (see informational panel XXX: overestimation of connection powers). The purpose of the connection study is thus to check that, in the reference situations (detailed below), the withdrawal or injection of this power does not create electrical constraints on the network. It also allows for determining the reference technical connection solution, which, if necessary, must include any adaptations to the existing network needed to resolve new constraints created by the connection.

For **consumer connections,** the network sizing reference situation studied is as follows:

- the network is in a nominal situation (no asset failure);
- the power of the customer studied is equal to the connection power;
- the power of already-present consumers corresponds to peak consumption; the most common network sizing reference situation represents the **combination** of a **peak consumption** and a **severe cold weather** (see 5.3.3), but in some areas there are also network sizing reference situation related to a peak consumption in summer;
- all generation connected to the studied network is inactive.

The **connection of an economic development zone** is a particular challenge that requires in-depth dialogue with the developer, so that the construction of electrical infrastructure in economic development zones meets the needs of future occupants in terms of providing connection capacity and quality of supply. However, the sizing of these infrastructures and the implementation of works are carried out ahead of the connection of end-users, on the basis of planned uses and the energy choices made by the developer. Given the uncertainties about the timing of load arrival and even about the total load ultimately reached, there is a significant risk that the created network may not be optimal. Dialogue with the developer should help the load assumptions used for the studies, and allow to anticipate the coincidence and the progressive arrival of customers.

For **producer connections,** the network sizing reference situation studied is as follows:

- the network is in a nominal situation (no asset failure);
- the power of the producer studied is equal to the injection connection power, which corresponds to the maximum net injection power declared;
- other already-present producers are also at their injection connection power;[40]
- the power of consumers corresponds to a consumption trough.

A unit connection study may lead to the need to adapt the existing network, up to the primary substation, at a prohibitive cost for the requesting producer. Therefore, to avoid hindering the connection of renewable energy installations, the **S3REnR** (described in section 2.1.3.3) has been established. At the level of the administrative region, they provide visibility on connection projects to the networks managed by Enedis and RTE. They enable to **share a provisional plan** (5 to 10 years), to **anticipate and optimise investments** in primary substations, and to **pool costs** among producers.

For the connection of LV customers (both consumers and producers), the studies are usually simplified. Given the volume of requests, it is essential to favour a clear and simple solution (including in terms of billing, through flat-rate tariffs), enabling connection within an acceptable timeframe. Moreover, the impact on MV is only studied (and billed) in the case of an MV/LV substation creation. The gradual emergence of MV constraints due to the accumulation of LV connections will be detected through regular network diagnostic, leading to proactive studies (see 5.3.2).

40. Work is under way to take better account of the coincidence between wind and solar generation.

NFORMATIONAL PANEL XXX

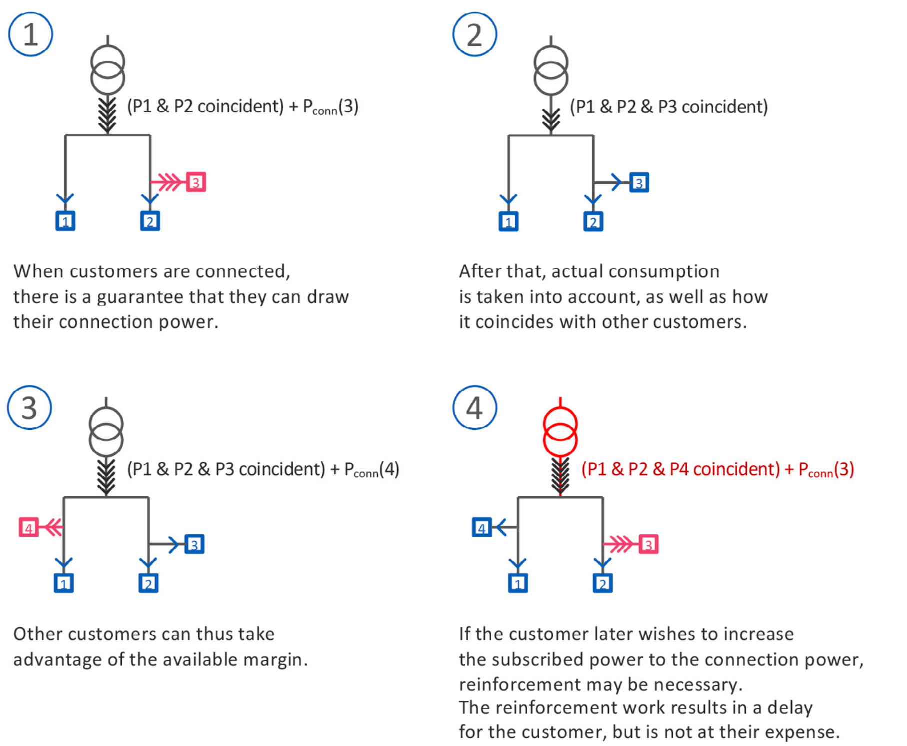
Overestimation of connection powers

Consumer customers often overestimate their connection power compared to their subsequent contracted power (and, therefore, compared to their actual peak power). This creates a local "margin" on the network that is made available to other network users since the actual consumption of this customer is taken into account, as well as the way it synchronises and coincides with other customers (see figure 50).

If the customer expresses later on a need for more capacity, Enedis will allow an access to it at no cost, as long as the demand remains below the initial connection power. However, it is possible that network adaptation work may be required if the arrival of new customers in the meantime has reduced the available "margin." A delay related to these works will then be necessary before the customer can effectively increase the power.

Collective efficiency over time is the goal here. Enabling all customers to access their connection power at all times without delay would require sizing the network based solely on these connection powers, without considering actual consumption or coincidence of the load. This would lead to a significantly oversized network, thus much more costly for the community.

Figure 50: network sizing during connection and subsequent use



5.3.2. Proactive studies for network reinforcement: network sizing reference situations and rules

5.3.2.1. Main factors and drivers of proactive studies

The changes in loads beyond connections (and, for MV, the accumulation of LV connections) can lead to the emergence of constraints or suboptimal infrastructure. Regular diagnostics conducted by Enedis detect these constraints. Studies aiming to find solutions to address constraints or improve situations for the benefit of the community are called proactive studies.

These studies anticipate trends in load evolution (growth, stagnation, or decline) so that the implemented solutions remain relevant over time. These trends are determined at the primary substation level, based on the evolution of peak power over the past few years. It is estimated that this trend is valid for a few years. In the long term, there is greater uncertainty, and the trend derived from historical data is therefore tempered.

5.3.2.2. The three decision-making stages in a proactive study

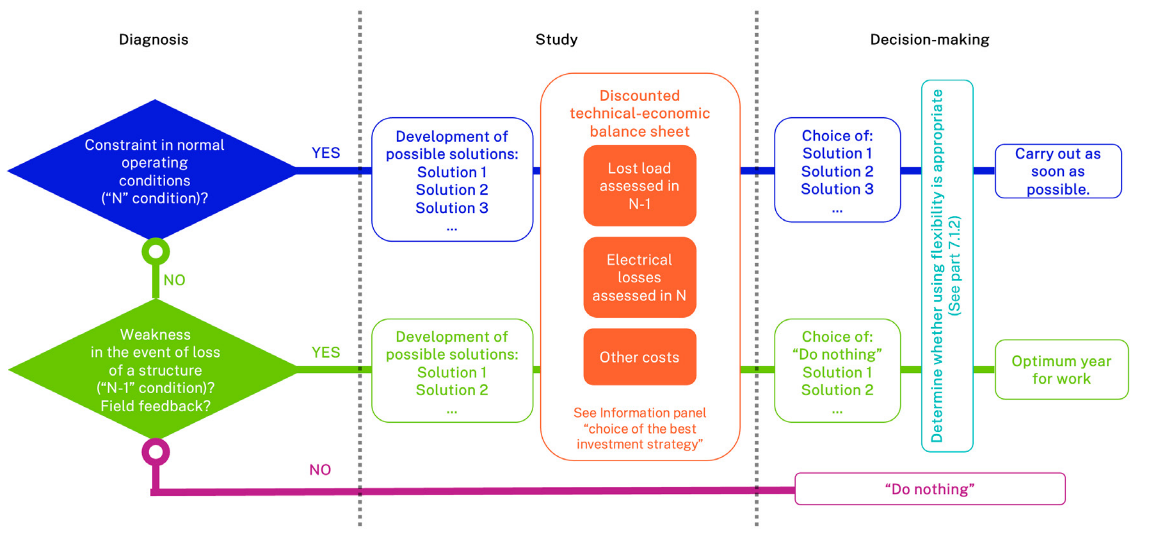
The complete process of a proactive study is schematically represented in figure 51 and is detailed below:

Diagnostic phase

Calculations are performed annually under normal network operating conditions, referred to as "N", to identify possible electrical constraints in two reference situations representing a peak consumption and a peak generation.

For peak consumption, the most common network sizing reference situation represents the **combination** of a **peak consumption** and **severe cold weather** (see 5.3.3). In some areas, there are also network sizing reference situations related to peak consumption in summer. For peak generation, the selected network sizing reference situation is 100% generation simultaneous with a consumption low point. In these peak consumption or generation situations, loads are modelled in the same way as existing loads are during connection studies.

Figure 51: decision-making process of a proactive study



Studies are also conducted in areas without electrical constraints under normal operating conditions if either:

- The diagnostic has shown potential infrastructure vulnerability in case of the loss of an asset (referred to as "N-1"): risk of insufficient recovery in the event of a power outage, heavily loaded networks, etc.

- Field reports, following a past event, have highlighted issues related to recovery in the event of a power outage, to difficulties in operating the structure, etc.

Study phase: discounted technical and economic balance

When the initial diagnostic identifies an area with a vulnerability that needs to be resolved, the search for the best solution involves the preparation of a discounted technical and economic balance, that quantifies the costs and benefits for each of the possible solutions, in order to compare them.

The cost of outages due to equipment failures is assessed in the event of the loss of an asset. The method used simulates the loss of an asset in a given area to determine the cost of the failure. The simulation analyses the recovery plans that will be implemented after the failure and calculates the number and duration of outages caused by this failure, deducing the socio-economic cost. Thus, **various possible network incidents** in the study area are simulated, and their **probability is calculated using failure rates** derived from past years analyses for each asset type. In addition, each of these incidents is simulated in the different possible network states of load, which are modelled and probabilised using a "load monotonic". The weighted sum of the results of all these simulations allows the determination of the probabilistic average cost of outages in the study area. Outages due to network works or other maintenance generally create less lost loads, because they can be anticipated and scheduled at times of low load; hence, they are not modelled nor taken into account in the technical and economic balances.

The cumulative **costs of losses** in the study area is evaluated under normal network operating conditions. The valuation of losses includes the purchase of energy dissipated on the distribution network as well as the indirect impact on the cost of transmission by the upstream network.

These two key parameters (value of lost loads and losses costs) are calculated for each of the different possible solutions. After adding the investment costs, these solutions are compared using discounted technical and economic balances to determine the optimal strategy considering the costs for the community (see informational panel XXXI: choice of the best investment stategy).

Decision-making phase and implementation schedule

Once the best investment strategy has been determined, assumed it is not the "do nothing" solution, **systematic search is conducted to check whether there is any flexibility that could allow the investment to be deferred (see 6.1.2). If an investment decision is taken, the implementation schedule** must be determined:

- If the studied network shows a constraint in the normal operating conditions, Enedis takes actions to resolve it as soon as possible, considering the available resources and other electrically constrained assets. The chosen solution is the one that removes the constraint under normal operating conditions and has the best technical and economic balance.

- In all other cases, the optimal strategy is only implemented if it is economically justified. One of the possible solutions is, therefore, to do nothing. This is the case when the local problem's nature is not of a sufficient cost to the community to justify an investment, even the best one. If an investment is decided because it is technically and economically justified, the optimal year for the work will be determined as the year when deferring the investment would no longer have any economic value.

The diagnostic and study phases are generally simplified for LV networks: since the LV network is not meshed, there is no systematic diagnostic of VOLL in case of N-1; it is only the N constraints or field reports that trigger a study. Furthermore, technical and economic balances are only used for the most complex studies, typically involving the creation of an MV/LV substation or an LV feeder.

INFORMATIONAL PANEL XXXI

Choice of the best investment strategy

During proactive studies aimed at resolving a local vulnerability, there are usually several possible investment strategies. Therefore, a "minimum technical" solution is always sought, representing the minimum investment required to address any constraints diagnosed in "N" under the network sizing reference situations (if there are none, the "minimum technical" solution is "do nothing"). This solution is then compared to other strategies (typically network reinforcement and/or reconfiguration) that require more investment but reduce losses and/or improve quality (by reducing the lost loads in the case of N-1).

The choice of the strategy to implement is made by comparing the discounted balances of these strategies. These balances consist of the sum of the costs to the community for each of the strategies, including:

- investment costs;
- lost load costs (socio-economic cost of outages in the event of a network asset failure);
- costs of technical losses;
- operation costs (typically maintenance costs related to the necessary tree pruning around overhead lines).

Figure 52: calculation of a discounted balance

Investments: Cost of work

Failure costs: Power cut off and lost load (IVOLL)

Costs of technical losses: Joule effect losses (conductors) and iron losses (transformers)

Operating costs Upkeep, repairs, maintenance

$$B_{disc} = \left(\sum_{n=0}^{N} \frac{I_n + C_n^{def} + C_n^{per} + C_n^{exp}}{(1+i)^n} \right) - \frac{V_u}{(1+i)^N}$$

B_{disc} = *Discounted balance sheet of the strategy*
I_n = *Investment amount in year n*
C_n^{per} = *Cost of losses in year n*
C_n^{def} = *Cost of failure in year n*
C_n^{exp} = *Operating cost in year n*
V_u = *Value in use of the investment in year N*
i = *Discount rate*
N = *Study time frame*

These costs are calculated for the geographical area of the study, over a 30-year period, and are discounted. Additionally, the investment's utility value, i.e. the residual value of the assets at the end of the calculation period (due to their longer lifetime), is subtracted from the balance.

The selected strategy will be the one with the lowest discounted balance, minimising the costs for the community. However, the discounted balance should be considered more as a decision support tool than an absolute principle for justifying investments. If two strategies have relatively similar balances, practical considerations not taken into account by these balances may favor one strategy over another.

5.3.2.3. Main technical solutions considered at the study stage

Several types of solutions are possible depending on the situation to solve:

- **Rebalancing:** changing the opening point, shifting an MV feeder from one transformer to another at the same primary substation, loas balancing for each phases, changing the tap at the MV/LV substation, etc.

- **Increasing network capacity** by replacing existing assets: changing transformer (replacing it with a higher-capacity transformer), replacing a cable with one of larger cross-section, etc.

- **Restructuring**: modifying the route of the main power line, etc.

- **Creation:** adding a transformer in a primary substation, new MV feeder, etc.

- **Use of an innovative technical approach** (see chapter 6).

These are the various solutions that will be compared through the unit discounted technical and economic balances.

In areas where a significant change is planned (elimination of an outdated voltage level, significant arrival of new customers, etc.), a broader examination is conducted to define strategies for the next 10 and 30 years. This allows for strategies that cover several issues, which are potentially more relevant than if each issue was addressed through a unit study.

5.3.3. Load modelling and reference situations: the basis for technical and economic studies

Reference situations for the scenarios examined in the studies

Load modeling is the foundation of technical and economic studies, since the calculations performed in simulations require assigning a power value to each customer, to then determine the current and voltage at all points on the network. Load modeling is the process that determines the power to assign to each customer in the different reference situations.

This process relies on real consumption measurements (as detailed below), which are continually improving thanks to data collected via Linky smart meter. However, this does not mean that the network is only dimensioned based on past situations. Load modelling in planning aims to represent "plausible" loads over the duration of the study, reflecting both current and future network usage in network sizing reference situations (challenging situations for the network). This is largely achieved by capturing the intrinsic variability and thermosensitivity of loads from available measurements, and projecting the load in reference situations:

- Combination of peak consumption and a severe cold weather: the reference cold scenario is based on the minimum base temperature, defined as the 30th coldest value in the last 30 years.

- Summer peak consumption: this situation is the network sizing reference situation for some touristic or agricultural areas.

- Combination of a consumption trough and a generation peak.

The results of this load modelling for primary substations are regularly shared with RTE, to contribute to joint discussions on network reinforcement needs.

Consideration of load diversity and coincidence factor in electrical calculations

A fundamental principle of load modelling is to accurately represent the coincidence of loads, i.e. the fact that customers do not consume at their maximum simultaneously. For example, for a primary substation supplying more than 9,000 customers, if the sum of subscribed powers is around 90 MVA, the withdrawal peak at the primary substation might be about 23 MVA.

Because of the available data, the modelling of loads and their coincidence differs between MV and LV:

- For MV, measurements at the primary substations and for each feeder are available, and used to calculate the reference powers. As these measurements are taken upstream of a set of loads, they directly reflect the effects of these loads coincidence.

- For LV, power profiles for each customer types are used, based on meter reading values (historically semi-annual, but now daily thanks to Linky meters). A statistical model is used to retroperspectively determine the reference power at various network nodes, considering the coincidence of loads. These profiles are constantly evolving to account for new uses (electric vehicles, heat pumps, etc.) and are determined by recording the load curve of a customer panel over a fairly long period.

5.3.4. Common rules for asset design are established with the licensing authorities

Within the framework of shared project management of investments in the distribution network with the licensing authorities, Enedis and the national associations representing the licensing authorities jointly establish common rules for the construction of assets (see informational panel XXXII: the asset design guide). These rules aim to standardise the design practices of the two project managers and enable Enedis to manage and operate the assets built by the licensing authorities.

Enedis will inform the FNCCR and France Urbaine of any significant modifications or additions made to the DSO's technical documentation. The FNCCR, France Urbaine, and Enedis will periodically review the need to update the guide.

INFORMATIONAL PANEL XXXII

The asset design guide

Historically, Enedis and FNCCR have shared and developed common rules for the design of electric distribution networks operated by Enedis and built under the supervision and management of the licensing authorities.

Article 14 of the specifications for the new concession contract model established by FNCCR, France Urbaine, Enedis, and EDF reiterates this principle. It stipulates that work under the project ownership of the licensing authorities must be carried out in accordance with the current design guides for the distribution network. These guides are developed in consultation between the national associations representing the licensing authorities and the DSO.

Article 8 of the framework agreement between FNCCR, France Urbaine, Enedis, and EDF regarding the new concession contract model also states that the parties must jointly update these design guides for the distribution network and supplement them as needed to cover the full range of licensing authority project management activities (LV pipelines, MV/LV substations, MV pipelines).

It is in this context that FNCCR and Enedis are currently working on the development of an asset design guide, as the network must now meet the challenges of the energy transition: integration of producers, arrival of new uses such as electric mobility, environmental issues, etc.

The purpose of the asset design guide is to define the construction process for all assets that may be built under the supervision and management of a licensing authority, at the interface between the licensing authority and Enedis, as well as the design of MV and LV networks and branch connections (underground and overhead) and MV/LV substations. It also includes a reminder of certain applicable regulatory provisions.

The draft guide consists of five chapters. Chapter 1 covers general informations, chapter 2 deals with the construction process for assets at the interface between the licensing authority and Enedis, chapter 3 concerns design rules for MV networks, chapter 4 covers design rules for MV/LV substations and switchgear cabinets, and finally, chapter 5 addresses design rules for LV networks.

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6

Enedis develops new solutions to enhance network performance

6

Enedis develops two alternative solutions to the traditional grid development methods presented in previous chapters:

- **Flexibility, its contribution to the NDP trajectories having already been noted in chapter 2, is dealt with in 6.1 with an explanation of the various technical flexibility proposals suited to new connection requests, followed by a description of the methods to economically assess of the potential for flexibility and the call for tenders.**

- **Technical levers available to Enedis as an alternative to grid reinforcement, to deal with the changing voltage challenges faced by the grid due to the mass arrival of decentralised generation facilities, are developed in 6.2.**

The contribution of storage, for which use by distribution system operators is limited by law and still forward-looking in technical terms, is described in 6.3.

6.1. Flexibility offers an alternative to standard connections and network reinforcements: assessment and implementation

Chapter 2 provides a general overview of the different types of flexibilities, specifies those within the scope of the NDP, and outlines the investment savings brought by flexibilities, primarily demonstrated by the REFLEX project to date.

This chapter delves deeper into these concepts. It presents Enedis' methods for assessing the economic value of flexibility and explains their implementation.

It begins by reminding the two types of flexibilities that fall within the NDP's scope, as mentioned in section 2.1.1.

Local flexibility for connection

Two variations of local flexibilities for connection can be distinguished. Their detailed descriptions are provided in section 6.1.1.

Variant 1: the alternative connection offer with power modulation (ORA-MP in French), for individual benefit, in the context of an individual connection (see informational panel XIII: power modulation ORA for producers).

ORA-MP is an **individual** connection offer: it is chosen by customers as an alternative to the reference connection offer (ORR in French). Its main features include:

- Customers benefit from ORA-MP through **reduced costs and/or shorter connection times.**

- In return, customers commit to occasionally limit their power consumption or injection upon request from the network operator, without compensation.

- The customers weigh the gain achieved during connection against the financial losses resulting from this curtailment.

- Under ORA-MP, customers are responsible for considering the potential consequences of these limitations in their contractual commitments with other parties, including their balance responsible entity.

Variant 2: REFLEX, for collective benefit in the framework of a shared connection of producers

REFLEX is a component of optimal network planning, at the S3REnR level. It aims to provide collective benefits (see informational panel XIII: the REFLEX project).

Its logic can be summarised as follows. The initial Cost-Benefit Analysis (CBA) of REFLEX compares two scenarios: the first, in which networks are developed according to current rules (reference connection offer, without flexibility); and the second, where the possibility of curtailing generation is considered, to find an economic balance between the cost of curtailments and the reduction in investment needs. The CBA demonstrated that the second scenario results in overall savings and allows for more production to be connected at a given investment cost.

Enedis is committed to this approach, with ongoing experiments that will be followed by feedback before full-scale implementation. Where sizing would be optimised by considering injection curtailment, a market-based approach will be pursued to seek other sources of flexibility, to alleviate the need to curtail renewables In all cases (market-based flexibility or curtailment), Enedis commits to neutralise the effects of its flexibility activations within the perimeter of the balance responsible entities.

Local flexibilities to defer an investment planned by Enedis to solve withdrawal congestion

The aim here is to postpone an investment deemed necessary by Enedis in a given area, by relying on a local flexibility service provided by flexibility service providers (such as a site or a flexibility aggregator). Such flexibilities serve a collective benefit and are further detailed in section 6.1.2.

Their implementation relies on four key elements:

- The value brought by the flexibility lever must outweigh the value associated with the investment deferral it allows, raising the question of value comparison between flexibility and investment.

- The provided flexibility, meaning the power modulation requested by Enedis from one or more network users, is remunerated.

- The call for tenders is the natural way to identify and select the flexibilities that can contribute to an effective investment deferral.

- Enedis follows the economic principles of the electric system, including measures like the neutralisation of the effects of flexibility activations by Enedis on the stakeholders within this ecosystem.

Contrasting values for flexibilities depending on their aim to solve congestion issues stemming from injections or withdrawals

As discussed in section 2.1.1, the value of the different types of flexibilities is currently diverse. Only flexibilities intended for connecting producers with a substantial potential (the REFLEX project) have been incorporated into the trajectories of the NDP. Figure 53 assesses the flexibilities designed for connecting producers or for integrating consumption from the perspective of their respective requirements.

Figure 53: technical comparison of flexibility levers designed to alleviate congestion issues stemming from injections and withdrawals ages (1/2)

Means of reducing or defer an investment	**Levers**	**Main objective of the conventional investment**	**Enedis assesses the framework in which using flexibility could achieve this objective, while reducing or deferring traditional investment**	
			When should the flexibility be activated?	**How to characterise the corresponding occasions ?** It is necessary to assess...
Injection (generation) moderation	ORA-MP	**Guarantee to the connected producer, and to other producers** already present on the network, that they can **inject safely and in all circumstances up to their maximum requested power** (connection capacity). See 5.3.1.	New producers commit to curtail their injection whenever the capacity of the network to which they are connected would be reached.	... possible future **weather variations**, and to reflect their impact on producers injections at the scale of an MV feeder (see 6.1.1.1).
	REFLEX	**Guarantee to the connected producer, and to other producers** already present on the network, that they can **inject safely and in all circumstances up to their maximum requested power** (connection capacity). See 5.3.1.	Flexibility from consumers (increased withdrawal) or producers (reduced injections) is necessary whenever injections by producers in the area, net of consumer withdrawals, might exceed the capacity of the primary substation transformers.	... possible future **weather variations** and to reflect their impact on producer injections, at the scale of an area (primary substation) (see 6.1.1.2).
Withdrawal (consumption) moderation	ORA-MP	**Guarantee that the connected customer can safely draw power up to the requested maximum power** (connection capacity), **even when other connected customers consume significant power** in the event of extreme cold weather, without degrading the quality of their supply (see 5.3.1).	New consumers must be prepared to curtail their withdrawal power whenever the capacity of the network to which they are connecting could be reached.	... potential future **weather variations**, to reflect their impact on the withdrawals of consumers from this network, and also to model the significant variability of these withdrawals attributable to the **random nature of human behaviors** and the fluctuating economic activity (see 6.1.1.3).
	Deferral of withdrawal investments planned by Enedis	**Resolve, by seeking the best technical and economic optimum for the community, a network vulnerability** that arises as a result of changes in load: the inability to ensure a proper quality of supply to consumer customers in the area **when they consume high power** during extreme cold or **in the event of limited network failure (« N-1 »)** (see 5.3.2)	In this case, one must rely on consumer flexibility (reducing withdrawals) or producer flexibility (increasing injections) whenever the capacities of the assets could be exceeded.	... potential future **weather variations**, to reflect their impact on the withdrawals of consumers from this network, and also to model the significant variability of these withdrawals attributable to the **random nature of human behaviors** and the fluctuating economic activity and, in some cases, to characterise **the failure probabilities of the assets** in the area and their impact on the network capacities (see 6.1.2).

Figure 53: technical comparison of flexibility levers designed to alleviate congestion issues stemming from injections and withdrawals ages (2/2)

Enedis assesses the framework in which using flexibility could achieve this objective, while reducing or deferring traditional investment		**Maturity**
Complexity of identified frameworks The need for flexibility is...	**Implementation requirements** If flexibility is not activated when needed, there is a risk for all customers in the area (producers and consumers); to prevent this, network control operators may need to...	
... essentially rythmed by infrequent weather conditions at the scale of an MV feeder.	...**completely cut-off the newly connected producer** (who benefits from the investment reduction). This results in a limited cost to the community, equivalent to the value of the **non injected energy**. This option thus remains an acceptable solution to ensure the supply and security of other network users.	The experiments conducted have led to implement as business as usual this scheme on the MV network, and it is already attracting users.
... essentially rythmed by infrequent weather conditions at the scale of a primary substation.	...**cut off the new consumer** (who benefits from the lower-cost connection). The resulting costs will be significant, as they correspond to the societal cost of the outage (**VOLL**). These costs impose an additional constraint on the consumer, who may directly bear a significant cost if they cannot provide a reliable flexibility service, despite its random occurrence.	The REFLEX system is undergoing **experimentation** based on a regulatory sandbox, which releases over 210 MW of capacity across a set of approximately ten primary substations distributed across two regions (the Landes and Picardy).
... more random, at the intersection of weather variations and the unpredictable network consumers' behaviour.	**... cut off the new consumer** (who benefits from the lower-cost connection). The resulting costs will be significant, as they correspond to the societal cost of the outage (**VOLL**). These costs impose an additional constraint on the consumer, who may directly bear a significant cost if they cannot provide a reliable flexibility service, despite its random occurrence.	A **limited number of experimentations** were carried out. This may reflect difficulties some consumers face in opting for random and demanding operating constraints, or in assessing the impact of such constraints at the time of their connection.
... more random, at the intersection of weather variations and the unpredictable network consumers' behaviour, and in some cases, the probability of network failures.	**...cut off consumers** in the area. The associated cost to the community would be significant, as it is evalued at the level of the **VOLL**. This is why the flexibility provider must guarantee a reliable service.	Enedis now **systematically evaluates** the feasibility of implementing flexibilities in cases where network reinforcement is in the collective interest. However, the **calls for such tenders** initiated by Enedis **have so far not been successful.**

6.1.1. Flexibility provides new technical solutions suited to connect renewable (ORA-MP, REFLEX)

6.1.1.1. Flexible (non-firm) connection for MV renewable energy producers: a flexibility use case now business as usual, incorporated in Enedis' DTR

ORA with power modulation (ORA-MP) for MV renewable energy producers has been integrated into Enedis' DTR on the basis of shared feedback

ORA-MP for MV producers (those with a power greater than 250 kW) were tested starting 2017. The feedback, shared with Enedis' stakeholders, including the DGEC, the CRE, and producer federations, was positive. It validated the economic principles and technical solutions. The resulting regulatory framework was established through a decree published in March 2020, further detailed by an order published in July 2021. ORA with power modulation for renewable energy producers connecting at the MV level is now Enedis business as usual since the publication in Enedis' DTR in October 2021.

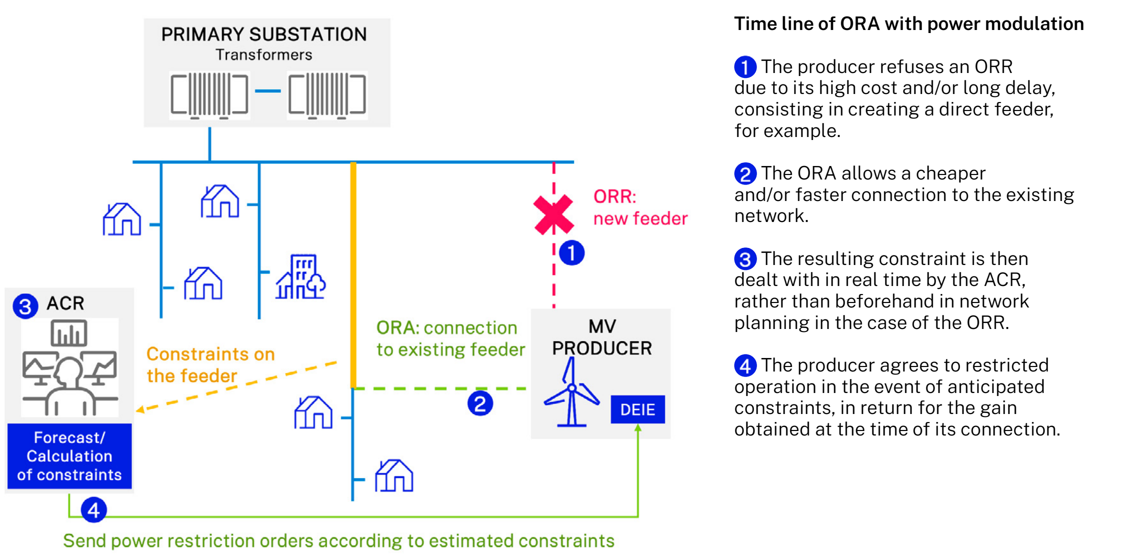
ORA-MP provides an alternative response to connection requests, based on customer flexibility

In response to a producer's connection request, Enedis must always propose the reference connection offer (ORR in French) established on the basis of the requested connection power. Under normal network operating conditions, it guarantees the producer the ability to inject 100% of this power at any time.

However, renewable energy producers do not continuously inject at their maximum power, as their generation often depends on sunlight and wind conditions. Hence, a technical solution sized for peak generation may be rarely fully exploited, while being sometimes more costly and/or time-consuming to implement.

Therefore, Enedis has designed an alternative connection offer that incorporates customer flexibility. This ORA-MP proposes reduced MV works compared to the ORR, in exchange for occasional curtailment (see figure 54). Thus, when a producer expresses interest in an ORA-MP when submitting their connection request, and if it is technically relevant, Enedis provides a study quotation.[41] As the producer benefits from lower connection costs and shorter timelines through this offer, no compensation is paid for curtailment, and the balance perimeter is not adjusted. Enedis guarantees the producer a minimum injection power (more than 70% of the requested power) and a maximum volume of curtailed energy (less than 5%), with the final contractual values depending on each specific situation.

Figure 54: schematic diagram of an ORA with power modulation for an MV producer



41. For further details, refer to Enedis' technical reference documentation

A new approach to network operation, which required an experimentation phase

By design, the technical solution chosen in this type of offer does not guarantee the injection of the full connection power without imposing constraints on the network (such as exceeding maximum allowed current or voltage levels). After the connection, it is necessary to prevent the appearance of these constraints by activating the customer's flexibility (curtailing generation) to avoid the constraint. This new approach to network operation required an experimental phase.

As part of the Smart Grid Vendée project, three MV generation installations were connected using this experimentation offering. These were two wind farms (8 MW and 11.75 MW) and a photovoltaic installation (5 MW). The combination of forecast models, calculated every 30 minutes using an electrical engineering calculator, alerted the operations control room in the event of a forecasted constraint, while providing a power limitation value sufficient to avoid these constraint. Once validated, the curtailment order was sent to the producer (via its operational information exchange device – DEIE in French). Compliance with this curtailment was then verified through remote generation mesurement (via the DEIE).

Conducted with the assistance of Enedis regional network control operators in *Pays de la Loire*, the experimentation validated the ability to avoid constraints on the network. Curtailment orders were issued, and the feedback confirmed Enedis' ability to meet its commitment of a minimum injectable power that was estimated during the connection study.

The forecasting chain demonstrated its reliability, and improvement suggestions, such as incorporating existing local voltage regulations or enhancing low voltage forecasts, were considered in the prediction models currently being implemented as well as in the real-time SCADA/EMS.

6.1.1.2. A new concept to size primary substations for generation: REFLEX, currently under experimentation through a regulatory sandbox approach

REFLEX aims to reduce the costs to the community of connecting renewable energy

Similar to ORA-MP, REFLEX is based on the principle that it is possible to limit the investments required for connecting renewable energy producers in return for occasional injection curtailment. Unlike ORA-MP, REFLEX specifically targets shared assets investments defined in the S3REnR (as described in section 2.1.3.3), meaning investments at the primary substations. As these assets connect multiple producers, the decision to use REFLEX is not made by the customer but by Enedis, with an objective of optimising costs for the community.

REFLEX is thus designed to optimise S3REnR by allowing the connection of renewable energy capacities downstream of an MV/LV transformer exceeding its technical capacity. From the S3REnR design phase, and in partnership with RTE, the process takes into account this flexibility to plan investments.

The methodology used to determine the optimum between investments and flexibility, and the differences with Enedis' existing S3EnR sizing method as described in the DTR, are detailed in informational panel XXXIII: calculation of the capacity released under REFLEX.

Once the producers are connected, Enedis' operation control rooms assess the need for flexibility through short-term forecasts of generation and consumption, adjusted by production measurements and network sensors. If market-based flexibility is available, it will be activated; otherwise, Enedis will resort to the fallback solution, which is curtailing generation.

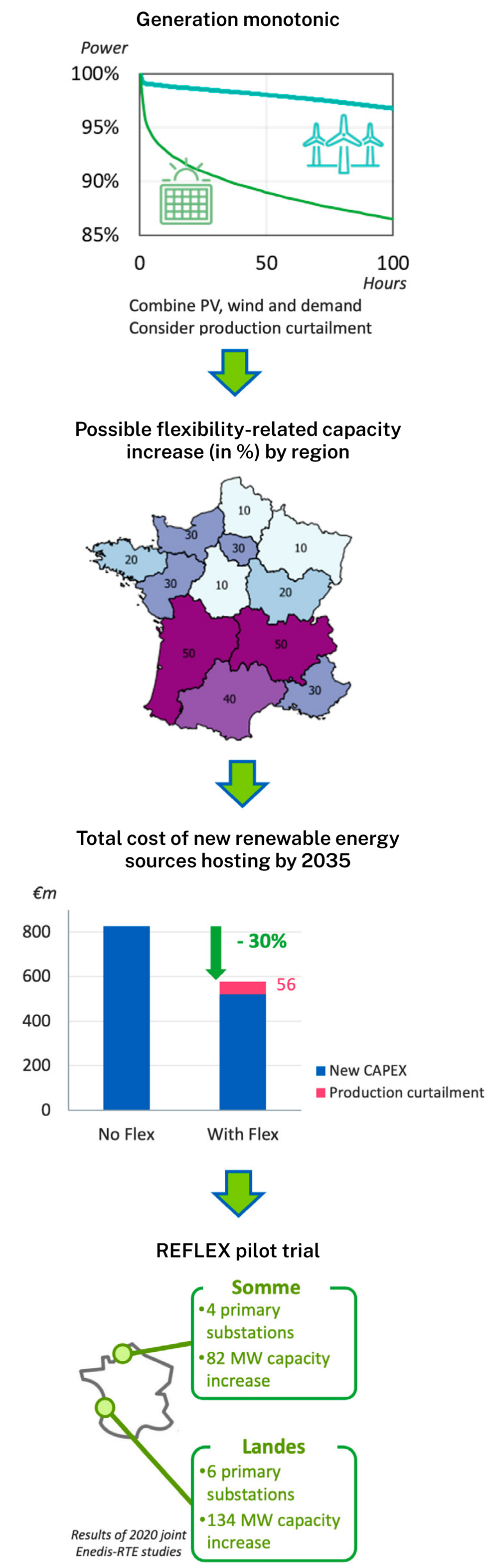
The REFLEX approach, which promises significant gains across France, currently undergoes experimentation

An assessment of the gains that could be achieved by implementing REFLEX throughout France was conducted considering the regional production mixes anticipated in the PPE (French multi-annual energy plan). In *Nouvelle-Aquitaine* for example, 50% more renewable energy installations could be connected than under the current rules. This evaluation showed that, at the national level, the amount of work needed to accommodate all new renewable energy installations could be reduced by 30% between now and 2035 (i.e. cumulative savings of €300 million). The generation curtailment would remain very limited, accounting for less than 0.06% of the generation potential of the new installations connected by 2035. This represents a shortfall in terms of non-injected energy of approximately €50 million. The net benefit (€300 million - €50 million) is significantly positive: €250 million, making REFLEX the primary source of savings for Enedis through flexibilities and a tool to accelerate the connection of renewable energy by rapidly increasing the connection capacity.

To test this new connection mode, an exemption was requested and granted in July 2021 within the framework of the regulatory "sandbox" system. The national projections presented in figure 55 result in a capacity increase of 210 MW on the ten primary substations involved in the experiment compared to current rules, potentially avoiding the addition or change of several transformers.

The purpose of the experiment is to test, on a full-scale basis, the entire chain: sizing, connection studies, constraint detection algorithms, and the activation of flexibilities as needed, to validate the system. If the feedback is favorable, the REFLEX system would be extended and implemented during the revision of each S3REnR. The approach to the experiment is described in the documents published by Enedis: (*Enedis, Projet REFLEX: Enedis dégage des capacités d'accueil supplémentaires dédiées aux EnR*), and for further details (*Enedis, REFLEX (Flexibilités des énergies Renouvelables) – Note méthodologique de l'expérimentation*).

Figure 55: process for assessing the benefits of implementing REFLEX



INFORMATIONAL PANEL XXXIII

Calculation of the capacity released under REFLEX

GENERAL PRINCIPLE OF REFLEX SIZING

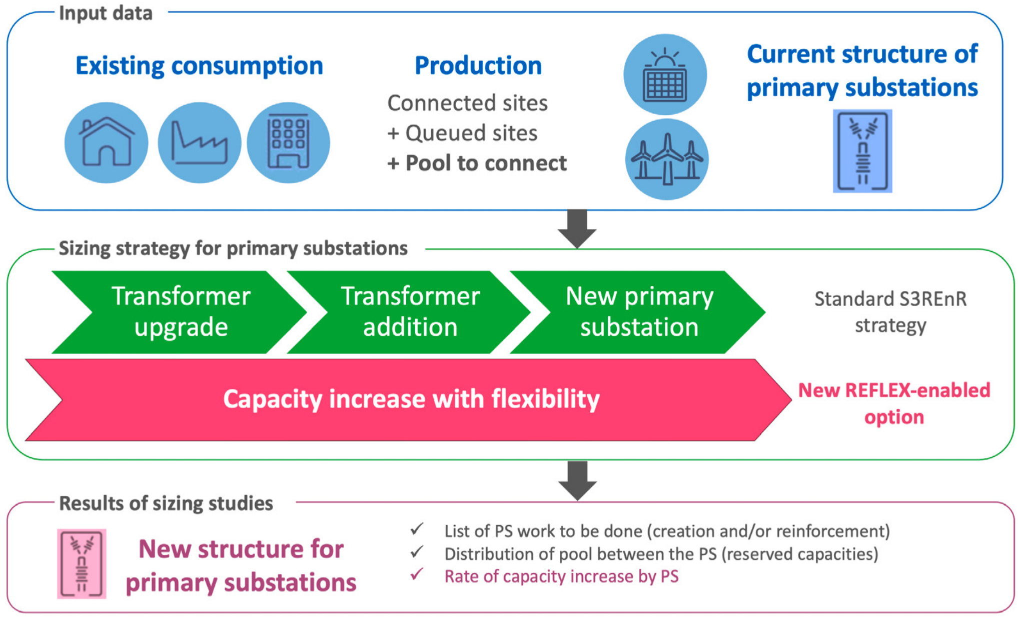
The additional capacity determined for each HV/MV transformer is the result of an economic trade-off over the TSO-DSO networks perimeter to find the best balance for the community to connect existing generation and consumption, queued generation, and the expected generation over the planning exercise timeframe. This trade-off only applies to works on primary substations and the TSO network (and not on the downstream network).

A new option enabled by REFLEX in the primary substation sizing strategy

This trade-off is based on the same methodological principles as those used to draw up an S3REnR, and therefore involves comparing the economic balances of multiple sizing solutions for HV/MV primary substations and the HV network to accommodate the expected generation installations. The compared sizing solutions fall into two categories (see figure 56):

- The standard investment solutions used in the development of S3REnR (HV/MV transformer change and assets creation: addition of transformers or construction of primary substations).
- **A new technical option:** allowing the connection of renewable energy capacities downstream of an HV/MV transformer exceeding its technical capacity, with the use of flexibility.

Figure 56: sizing process within the REFLEX framework



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A comparison of economic balances

As part of the process of establishing investments included in the S3REnR schemes, various investment strategies are jointly compared by the DSOs and TSO on the basis of technical and economic balances that take into account the costs of investments in the transmission and distribution networks within the scope of an S3REnR (see figure 57).

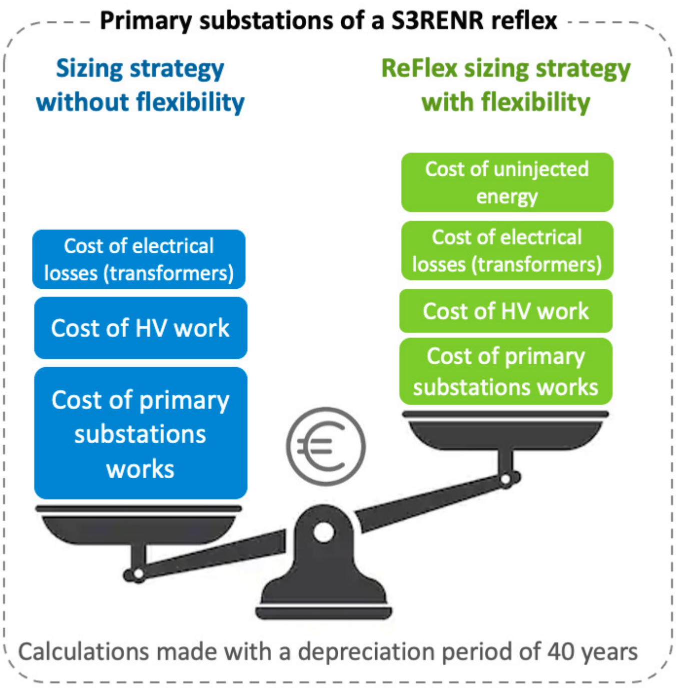
Within the framework of the REFLEX project and the use of flexibility, the economic balance components of the different sizing strategies include:

- network investments (creation or reinforcement of an asset);
- costs of electrical losses in HV/MV transformers, as the transits or the number of transformers may change depending on the chosen solution;
- costs of uninjected energy generated by generation restrictions when using flexibility.

These annual components are calculated over a 40-year period[42] and are added to the costs of works on the DSO and the TSO networks.

The sizing strategy chosen for a particular area will be the one that can connect to the network the entire renewable energy generation potential in technically satisfactory conditions and at the lowest cost for the community.

Figure 57: components of economic balances for sizing strategies of DSO assets within an experiment scope, in the context of using REFLEX flexibility



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42. 40 years for DSO assets and 45 years for the TSO.

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METHODOLOGICAL APPROACH

To carry out the comparison previously described, two sequential steps are used to define the required network infrastructure and/or the use of flexibility:

- Similar to the methods employed for sizing S3REnR, the collection of data related to:
    - MV generation installations: in service, queued, and the cumulative expected generation potential in the area[43] and over the defined timeframe;
    - cumulative existing and future LV generation;
    - cumulative consumption;
    - the initial state of the primary substations and their technical development possibilities.
- The calculation of power balances for each primary substation and for each sizing strategy investments in primary substations and/or use of flexibility), enabling the determination of the technical and economic balance components described earlier.

Several scenarios for distributing the generation potential across all primary substations in the experimental area and for using flexibilities are studied. Economic balances (combining TSO and DSO costs) of scenarios with flexibilities within the experiment perimeter are compared to those of scenarios without flexibilities across the entire experimental area.

The scenario for distributing the generation potential across the different primary substations and the sizing strategy that results in the best economic balance is selected.

Determining the capacity increase rate for each transformer is then based on the choice of the sizing strategy which allows the connection of the entire renewable energy generation potential in an area, in technically satisfactory conditions and at the lowest cost for the community.

43. Scope of the experiment defined in agreement with the distribution network users comitee.

6.1.1.3. ORA with power modulation for MV consumers - a concept at the demonstration stage

ORA-MP for MV consumers is currently in the stage of developing technical solutions and demonstrators to validate technical and economic principles.

Since September 2018, Enedis has initiated experiments with ORA-MP for MV consumers in various technical and contractual configurations (see figure 58 and figure 59), to identify the key success factors for such alternative connection offers.

Aim of the experimentations

The objectives include:

- Assessing, through practical cases, the adequacy of the necessary power modulation to avoid network adaptation work and to assess the impact of the limitations experienced by the customer (on their business model, industrial processes, etc.).
- Outlining the ORA-MP eligibility conditions for MV consumers to create value for the community.
- Testing various technical implementation methods for consumption limitations at sites connected with power modulation.

Figure 58: location of ORA with power modulation experiments for MV consumers

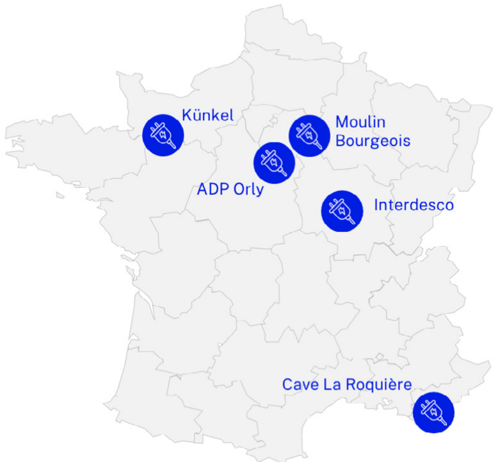


Figure 59: characteristics of ORA with power modulation experiments for MV consumers

	Moulin Bourgeois	Cave la Roquière	Interdesco	Künkel	ADP Orly
Type of constraint	MV - Low voltage	MV - Low voltage & current	MV - Low voltage	MV - Low voltage	Primary substation - Current
Type of request	Increase in connection power (without CCU* contribution)	Increase in connection power (without CCU* contribution)	New connection (without CCU* contribution)	Increase in connection power (without CCU* contribution)	Increase in connection power - MV back-up (without CCU* contribution)
Type of restriction	Dynamic curtailment	Power range	Power range & Dynamic curtailment	Power range & Dynamic curtailment	Dynamic curtailment

* CCU: authority in charge of town planning ("Collectivité en Charge de l'Urbanisme" in French).

Technical feasibility analysis

Depending on the load profile of the consumer benefiting from an ORA, different solutions can be considered to address the constraints identified in the reference connection offer.[44]

When a consumer has a load profile that complements that of the distribution network in the area, **contractual seasonal** limitations may suffice. For example, this may occur if the consumer's activity is seasonal and coincides with periods when the network is not constrained. This solution involves contracting for several different levels of guaranteed power. It is a **"static" solution** as it does not require real-time action nor information exchange. This type of solution must be consistent with the TURPE framework.

When the consumer's activity contributes to increasing the peak consumption of the distribution network in the area, real-time curtailment is necessary. To avoid the network adaptation work identified in the reference connection offer while complying with the operating limits of the assets, the peak consumption must be capped by limiting the consumer's withdrawal. This is thus a "dynamic" solution that requires real-time observation and actions. It applies to flexible industrial processes whose industrial tool can be controlled.

The implementation of real-time curtailments on consumption sites may require adaptations:

- of the consumer's installation, to deploy telecommunication devices with Enedis' regional network control agency;
- of Enedis' load forecasting systems to anticipate network constraints and activate limitations with advance notice compatible with the site's industrial process (e.g. stopping a production line must be planned the day before).

Initial experience feedback

The maximum injection capacity of a generation power plant is clearly identified. For example, for a wind farm, it is the sum of the installed machine powers. However, experience feedback shows that consumer customers may have relative difficulty in assessing their actual power needs. For instance, an industrial customer may need to estimate the natural coincidence of the load between its different production lines to calculate their actual power needs. They must answer the question of "when will these different lines be in service, and what will be the power requirement for each of them at that time?" This estimation can be complex for an existing customer looking to increase their power in anticipation of expanding their facilities or intensifying their uses. It becomes even more challenging for a new customer, faced with more unknowns. Such anticipation is also easier when electricity is at the core of the customer's business model (EVCI, energy storage, hydrolysers, etc.) compared to cases where electricity is a simple commodity needed for the site operation. The difficulty customers have in identifying their future power needs makes it all the more complicated for them to implement an ORA.

44. The reference connection offer guarantees the ability to inject 100% of the requested connection power at any time.

It should also be noted that, for some MV consumption connection operations, the local authority responsible for urban planning contributes to financing the work. Unlike MV generation connection, the cost savings from connection may therefore exclusively benefit the local authority responsible for urban planning rather than the consumer accepting the limitations. This could limit the interest of ORA-MP for MV consumers.

Since these various cases are still in the demonstration phase, no industrialisation plan is currently considered for ORA-MP for MV consumers. Furthermore, they are not listed in laws or decrees, and therefore have not been included in this NDP. If their maturity evolves, the content of future NDPs will be adjusted accordingly.

6.1.1.4. ORA with power modulation for LV customers - still a distant maturity

ORA with power modulation for LV producers is currently in the stage of developing technical solutions and demonstrators to validate technical and economic principles, much like all other types of flexibility for addressing low voltage constraints. The maturity of these solutions seems too distant for their potential effects to be integrated into the NDP. As with all the other topics with an uncertain future, subsequent versions of the NDP will provide an adjusted perspective on this subject once sufficient maturity is reached.

6.1.2. Flexibility offers the possibility to defer withdrawal reinforcements on the basis of an economic assessment and a call for tenders

Consider an investment deemed necessary by Enedis in a given area. The approach is to assess whether local flexibility can compete with the investment and allow its deferral.

Since late 2021, Enedis has systematically compared investments in primary substations and MV feeders designed to address constraints arising from changes in local consumption, with the option of using flexibility services. Enedis then issues a call for tenders for all identified opportunities.

6.1.2.1. Economic principles for assessing investment deferral flexibility

Assigning an economic value to investment deferral flexibility consists of precisely comparing two different worlds (investment and flexibility) with very different sets of assumptions and characteristics, with three key considerations.

Investment inherently guarantees the creation of value, whereas flexibility consists in a promise today for a service tomorrow

Local flexibility represents a transfer of risk from network development to network operation (real- and close to real-time), and from resources managed by Enedis to services provided by sites connected to the distribution network.

As a result of this transfer, the reliability of a flexibility service is an integral part of the service. It is necessary to ensure compliance with thresholds (voltage, current, etc.) resulting from regulatory obligations and safety of people and property. Hence, there is a need to ensure, in real time, that flexibility is actually creating value: this value creation must be anticipated when the flexibility service is contracted, and captured in real-time, whereas an investment guarantees it by design.

Comparing investment and flexibility must address the exact timing of the constraint

Flexibility studies require **an approach that breaks from current study methods and tools**: they necessitate detailing the temporal evolution of constraints on a specific asset, whereas a normative approach is sufficient in "traditional" studies, which do not determine the exact timing or duration of the constraint but rather its potential occurrence according to baseline scenarios.

This step of accessing the timing of potential constraints and load curve forecasting models is a prerequisite to describing the expected flexibility need and evaluating its implementation cost.

Comparing investment and flexibility must consider all their respective benefits

A network investment, intended to resolve an identified constraint, has a cost that must be weighed against its various benefits:

- It resolves the identified constraint (this is its primary justification).

- It offers additional possibilities for reducing non-injected energy and thus improves quality of service. In many cases, investments can make additional operating schemes accessible, providing new back-up possibilities and reducing outages in the event of an incident.

- It also reduces technical losses. For example, the investment may strengthen existing assets with larger cross-section cables that generate less losses.

Flexibility, on the other hand, provides only one of these three services: the first one. It resolves the constraint (within the limits of activation time, power, and service duration) by modulating loads on the network at the moment the constraint occurs. The total valuation of its benefits is therefore inherently lower than that of the benefits provided by the investment, which apply throughout its lifespan.

Thus, an on-demand flexibility service, regardless of its nature, must be evaluated, taking into account all its impacts and comparing them in full to the service provided by an investment, whose effects are present at all times (reduced losses, additional possibilities for recovery in case of incidents, etc.).

Regarding the nature of flexibility, only the effect seen from the network's perspective matters: a reduction in withdrawal has the same effect as an increase in injection, regardless of the method used within the customer's internal installation. Additionally, a legislative provision requires Enedis to be non-discriminatory in the purchase of flexibility services; this is why the call for flexibility services is referred to as "technologically neutral".

6.1.2.2. The first step in the process of deferring an investment to solve withdrawal constraints is to identify flexibility opportunities

Enedis uses a two-steps process to decide whether or not to contract flexibility when seeking to defer an investment to solve withdrawal constraints.

In the first step, the optimal reference investment solution is compared, according to the principles set out above, to an ideal flexibility (with no limits on power or duration, an ideal activation time, ideal location, and zero cost) by comparing the technical and economic balances. A flexibility opportunity for deferring reinforcement is identified if (and as long as) reinforcement is "beaten" by ideal flexibility with regard to the changes observed each year in the area (growth or decline of loads, disappearance of flexibility potential) – see information panel XXXIV: identification of a flexibility opportunity.

This method initially makes the simplifying assumption of the existence of **an ideal flexibility service, meaning:**

- unlimited capacity in terms of duration and power at the time of an event causing a constraint (in normal operation or during incidents);
- perfect response (total reliability of the flexibility service);
- ideal location of flexibility for each incident (including sharing flexibilities in multiple points for the same incident, always being "on the right side" of the incident to help reenergising the accessible network);
- an ideal activation time.

Moreover **not all constraints represent opportunities for flexibility.** In many cases, constraints require investments because they stem in addition from topological constraints, regulatory obligations, renewal needs, burial decisions, requests for quality improvement, or the need to develop new projects, etc. Thus, flexibilities can potentially resolve only a portion of the identified constraints. This is why Enedis uses the terms "flexibility opportunity zone" (see the example of the informational panel XXXV: focus on the case of Moussac).

The second step is a market call to assess the flexibility opportunities in terms of service and price. Enedis thus publishes the areas where the aforementioned studies allow the use of a flexibility service. Enedis will evaluate the offers from flexibility service providers according to the service and price they offer. The flexibility service is the best solution only if the collective value, considering residual lost loads and the cost of the service for Enedis, is better than that of the network reinforcement solution.

INFORMATIONAL PANEL XXXIV

Identification of a flexibility opportunity

THE OPTIMAL INVESTMENT STRATEGY HAS BEEN IDENTIFIED IN ADVANCE

The search for a flexibility opportunity occurs after having identified the technical solution for network adaptation that presents the best balance for the community between its long-term benefits and costs.

DETERMINING THE OPTIMAL INVESTMENT YEAR

When the investment strategy is decided, the optimal investment year is selected. This is year N, the time when:

- an earlier investment entails an additional cost compared with investing in year N+1;
- this additional cost is offset by the fact that the lost loads can be resolved the earliest possible and losses reduced.

Investing in year N+1 reduces the investment cost, but entails an additional year of lost loads and additional losses (see figure 60).

Considering a flexibility service to defer an investment is akin to comparing the situation "Invest in year N" to the situation "Invest in year N+1 and use the flexibility service in year N" (see figure 61). Therefore, the comparison is between:

- the early investment, lost loads and losses when investing in year N;
- the lost loads and losses when investing in year N+1, reduced by the use of flexibility in year N.

The better of the two strategies is the one that presents the lower overall costs for the community. Comparing these two strategies amounts to comparing the costs of lost loads (reduced by flexibility use) and losses of the "Invest in year N+1 + use the flexibility service in year N" strategy to the costs of lost loads and losses of the "Invest in year N" strategy, taking into account the cost of early investment (investment amount times the discount rate).

Figure 60: illustration of the optimal investment date and the cost of early investment

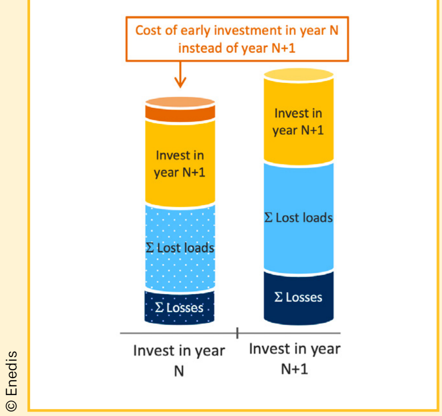
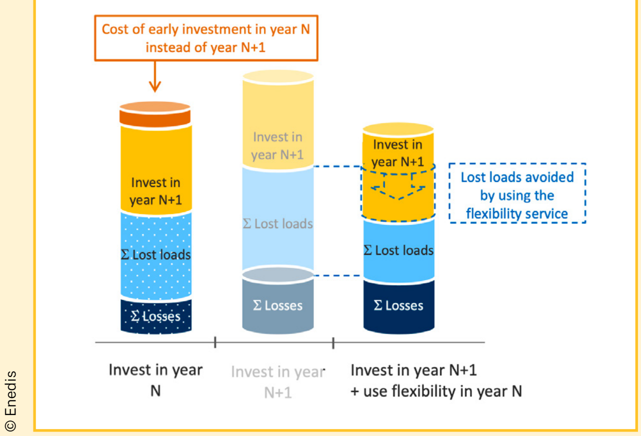


Figure 61: illustration of the use of flexibility to defer an investment



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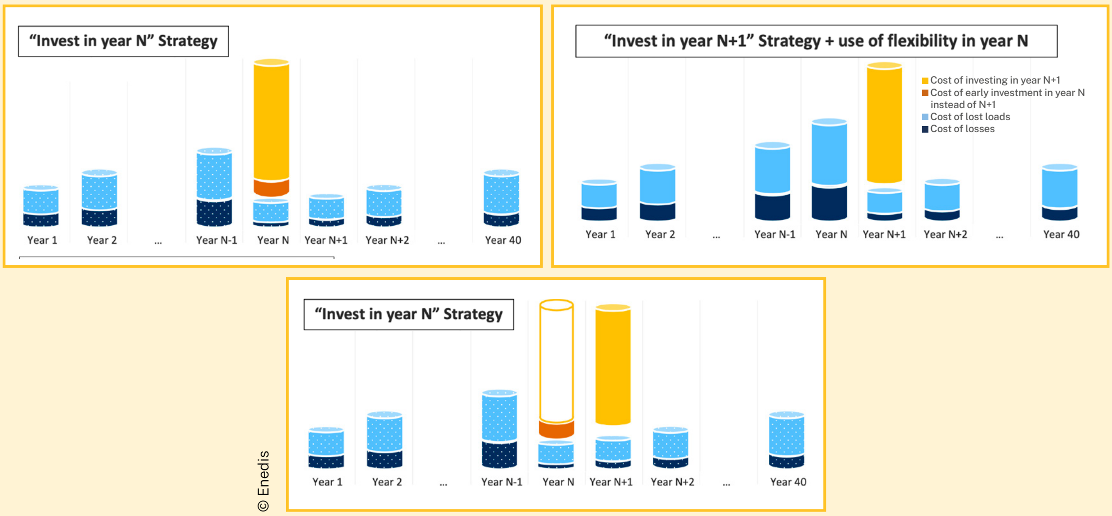
YEAR BY YEAR COMPOSITION OF THE TECHNICAL AND ECONOMIC BALANCE

Here is the decomposition over time of the technical and economic balances of figure 60.



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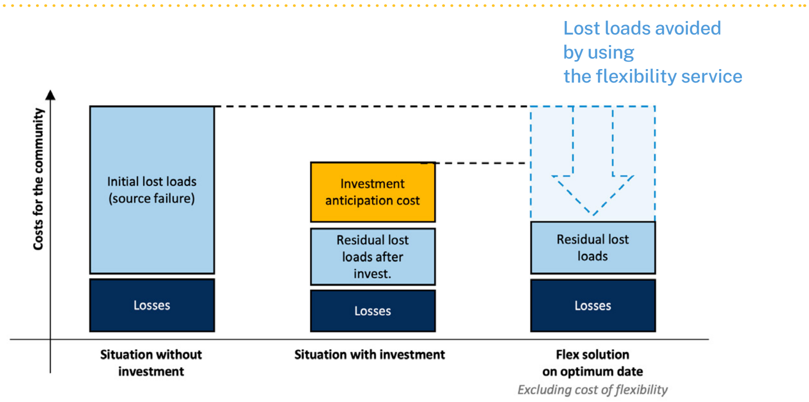
To simplify the comparison of all these costs, in the "Invest in year N" strategy, the investment cost is moved to year N+1 on the graph (this modification will not impact the total cost over all these years). It can then be seen that all costs before the optimal date N (from year 1 to year N-1) and after the optimal date (from year N+1 to the 40th year) are identical for both strategies. Therefore, comparing the total costs for the community between the two strategies is equivalent to comparing the costs of lost loads and losses of the two strategies at the optimal year N, as represented in the following illustrations in 2 dimensions (see figure 62).

Figure 62: representation of the use of flexibility to defer investment



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ASSESSMENT OF A FLEXIBILITY SERVICE

The next step is to estimate the benefits provided by a theoretical ideal flexibility service at the date defined as the optimal date for making this investment.

Two scenarios are then possible:

- In the case presented in figure 63, a flexibility service (denoted "Flex 1") reduces lost loads in the situation without investment, but the investment strategy provides a better benefit for the community. Therefore, investment deferral cannot be considered.

- In the case presented in figure 64, a flexibility service (denoted "Flex 2") provides more significant benefits than the first scenario, as it reduces more the lost loads to the point that the overall cost for collectivity is lower than in the situation without investment. Flexibility is thus better for the community than the investment strategy, making investment deferral possible.

Figure 63: situation where an ideal flexibility service is less efficient than investment

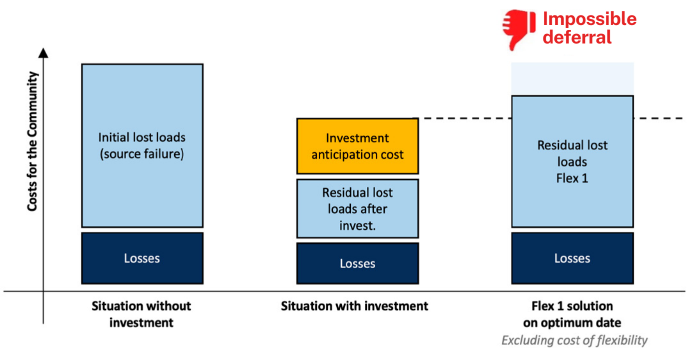
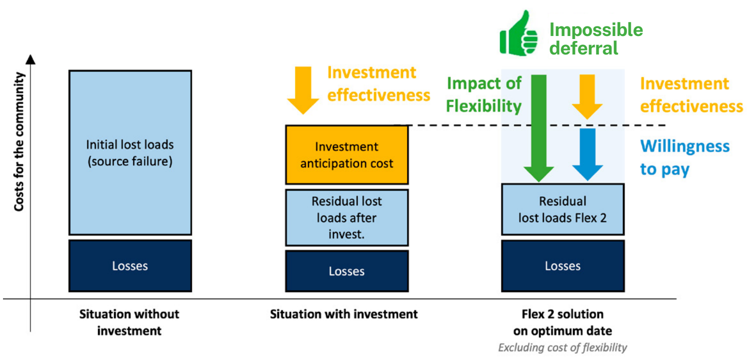


Figure 64: situation where an ideal flexibility service is more efficient than investment



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CALCULATING THE WILLINGNESS TO PAY

When deferral can be considered, Enedis calculates the community's willingness to pay to defer the investment through the flexibility service. It can be obtained by substracting the efficiency of the investment from the impact of flexibility (see figure 65).

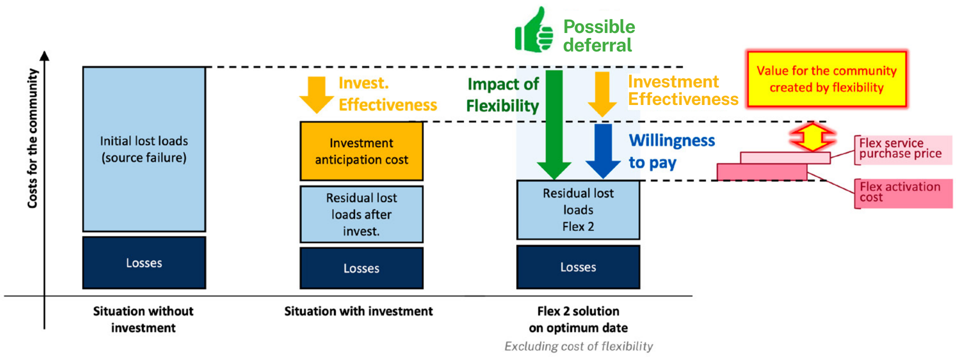
This value of willingness to pay includes:

- the cost of implementing the use of the flexibility service;
- and the purchase price of the flexibility service.

Therefore, to determine the value generated by a flexibility service for the community (represented in figure 65 for the flexibility service "Flex 2"), the implementation cost and the service purchase price must be substracted from the willingness to pay value. In other words, the willingness to pay represents the value for the community of a free flexibility service with zero implementation cost.

From a collective point of view, a flexibility service must outperform the optimal investment strategy to be considered as a means of avoiding costs. If this condition is met for a theoretical ideal flexibility, an actual potential flexibility service can be sought in order to defer that investment.

Figure 65: the community's willingness to pay to defer investment thanks to a flexibility service, and the value created for the community



INFORMATIONAL PANEL XXXV

Focus on the case of Moussac

CONTEXT OF THE MOUSSAC CASE

In the Moussac primary substation area (a primary substation with a single HV/MV transformer), there are no constraints in the normal network operating conditions. However, the following points should be noted:

- significant outage at the Moussac primary substation in case of a loss of its transformer;
- no constraints on transformers of neighboring primary substations.

Without investment, if an incident occurs on the Moussac primary substation transformer, depending on the load level, voltage drop constraints with variable magnitude (withdrawal constraints) may appear independently on three feeders, referred to as "corridors" because they connect the primary substation and its backup primary substation (see figure 66). In the event of an incident, restoring power to Moussac primary substation customers by the neighboring primary substation is limited, leading to a lost load cost for the community.

The investment to add a second transformer in the Moussac primary substation is the network adaptation strategy that provides the greatest benefit to the community at the optimal date. One must then assess if it is possible to defer this investment through the use of flexibility.

KEY POINTS FOR USING FLEXIBILITIES IN THE MOUSSAC AREA

The possibility of using flexibilities depends primarily on the **location of the flexibility services** offered.

When the supply of Moussac primary substation's customers is switched to its neighbour substation following an incident, the effectiveness of load modulation of a given customer to alleviate a voltage drop constraint on a corridor depends on the exact location of the customer along that corridor.
To account for this location-dependent phenomenon, which is linked to the location of the flexibility that could be used, the corridors have been divided into areas of equivalent efficiency (see figure 67).
The modulation of one load within a zone of equivalent efficiency is deemed to have the same impact on the constraint of that corridor as any other load within that zone.

There are three distinct corridors ("FORET", "BOISSE", and "DOMESS") where an upward flexibility offer, i.e. an increase in injections or a decrease in withdrawals, would locally reduce the number of customers in the corridor subject to power outage. The effectiveness of each flexibility offer depends on the zone of equivalent efficiency in which it is located.

The **extent in volume of the potential outage** is a decisive factor for the use of flexibility.

In the case of Moussac, a flexibility service provider will need to recruit a significant volume of consumers willing to change their behaviour in order to achieve a significant impact after an incident.

Figure 66: illustration of a transformer incident at the Moussac primary substation (PS)

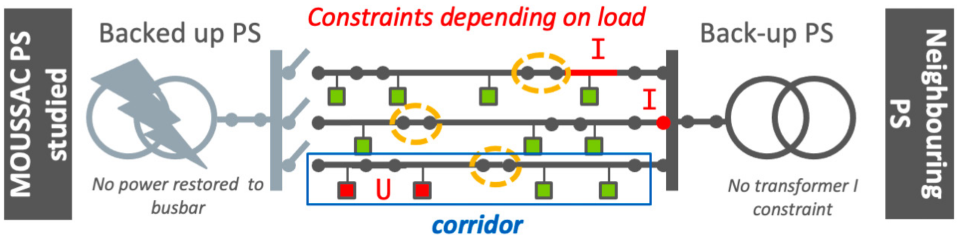


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Figure 67: the three corridors for which a flexibility offer could be considered

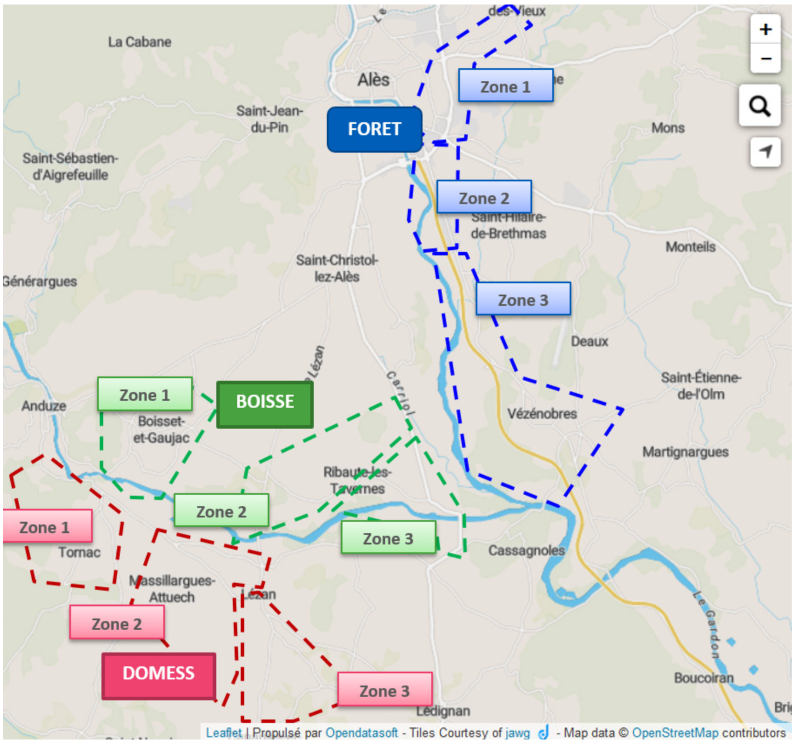
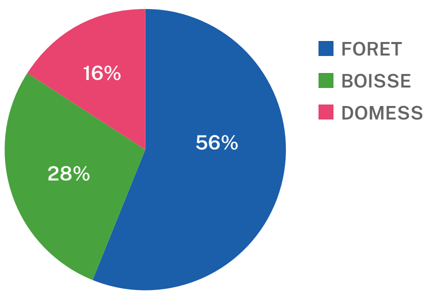


Figure 68: constraint distribution over the different corridors



The **spatial distribution of potential outage** that may occur is itself a significant factor.

The flexibility service provider will have to prioritise load reductions in corridors with a high proportion of potential outage (see figure 68) in zones of high efficiency. Additionally, since the flexibility source potential in each zone is limited and the constraint rate remains high, recruitment will have to be carried out over geographically large areas.

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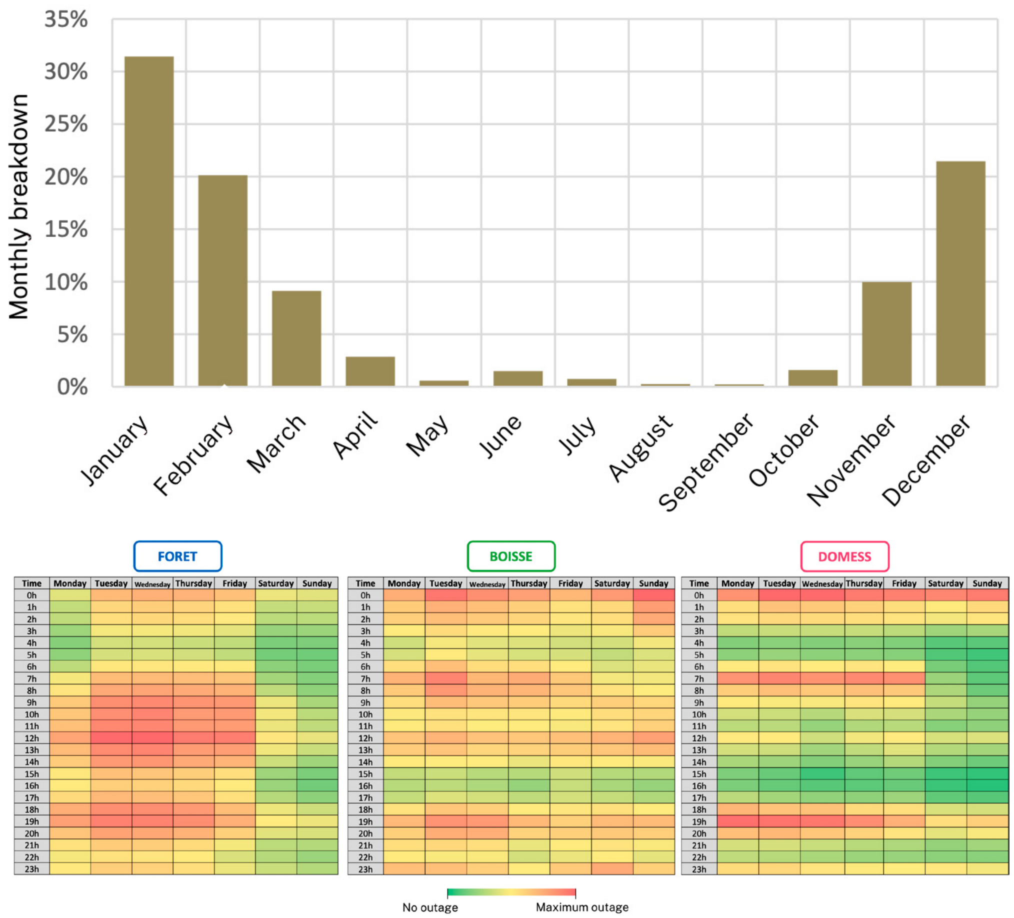
Figure 69: temporal distribution of outages by month, day of the week, and time slots



Finally, the **temporal distribution of possible outages** defines the times when the availability of flexibilities is expected (see figure 69).

Outage occurs when the transformer of Moussac primary substation experiences a technical or material incident. When this event occurs, flexibility must be implemented as quickly as possible and provide the longest activation period in order to avoid significant outages. However, even if all temporal parameters are wisely chosen to significantly reduce the outage level, the flexibility service cannot provide benefits beyond the resolution the network currently presents (the number of substations and associated power).

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In conclusion, a flexibility service to defer an investment aimed at alleviating a withdrawal constraint must be at least as effective as the investment to hope to create value for the community. Therefore, to significantly reduce outages, it requires:

- a marked change in consumer behaviour;
- the mobilisation of load reductions over several geographical areas of high effectiveness, if possible;
- recruiting services that can be activated as quickly and for as long as possible during periods with significant potential.

ENEDIS HAS PROVIDED FLEXIILITY SERVICE PROVIDERS WITH A TOOL TO ASSESS THE EFFECTIVENESS OF PROPOSED FLEXIBILITY SERVICES

Enedis has developed a web application for assessing a flexibility service offered by a service provider:

- When the calculated value for the proposed flexibility was zero, based on the technical elements presented earlier, the application indicated that the proposed service would not be selected at the end of the tender process (deferral of investment with this service could not be considered).
- When the calculated value was strictly positive, deferral of the investment could be considered using this service, and the service provider could submit a financial proposal.

A service provider could also rank the different flexibility services they were considering. This tool came with a user guide to help flexibility services providers choose the types of services providing the highest value for the network.

A TYPE OF FLEXIBILITY WITH A RESTRICTIVE FRAMEWORK

The results of the call of tenders showed that Enedis' demand did not yield to a locally available flexibility service. Additionally, flexibility service providers pointed out the complexity related to the detailed description of the flexibility value assessment framework.

This example illustrates the difficulties of implementing flexibility to defer an investment to solve withdrawal constraints. Enedis continues its efforts in collaboration with the flexibility service providers to enable the use of these services as long as they are effective.

6.1.2.3. The second step of the process involves a call for tenders to service providers able to offer local flexibility services

6.1.2.3.1. A call for tenders with a coordinated schedule and process

Article 32 of the Directive concerning common rules for the internal electricity market (EU 2019/944) of the Clean Energy Package opens the possibility for DSOs to use local flexibilities, it if it proves to be technically and economically more attractive than the traditional solutions available to them. DSOs shall procure such services in accordance with transparent, non-discriminatory and market-based procedures unless the regulatory authorities established that the procurement of such services is not economically efficient or that such procurement would lead to severe market distortions or to higher congestion.

Enedis anticipated the transposition of this article into French law.[44] it publishes its flexibility opportunities and, since November 2019, launches calls for tenders to subscribe to flexibility services from flexibility service providers.

For each identified opportunity, Enedis publishes:

- the geographical location, which includes all sites eligible for participating in the expected service, via a map of LV networks and MV sites, accompanied by a tool to check site eligibility on the basis of their supply point or measurement reference point number;

- the specifications for the expected service (power and duration, activation time, time slots in hours of the day, days of the week, months, years), and its availability characteristics (with or without capacity reservation, see below);

- draft contracts and consultation rules.

If the service offered by the flexibility service provider is technically and economically superior to the "traditional" solution, Enedis will procure it.

Enedis has established a process for procuring flexibility services based on rules shared with stakeholders consultations comitees. This process evolves to take account of feedback, exchanges with flexibility service providers, the investigation of technical or contractual issues, and the gradually evolving regulatory framework.

This call for tenders aims to develop the local flexibility market and the associated competition: Enedis' goal is to obtain flexibility services at the best price for the community.

Depending on the use cases, Enedis does not expect the same service from flexibility service providers. Therefore, it has established two types of flexibility service contracts:

- A contract with capacity reservation – in exchange for a fixed remuneration, the service provider guarantees the availability of their flexibility for a defined period as specified by Enedis.

- A contract without capacity reservation – the service provider does not receive a fixed remuneration. The flexibility service provider is committed to delivering the service only after accepting the activation request sent by Enedis.

Flexibilities deferring investment to solve withdrawal constraints fall into the first category: the service provider must guarantee the availability of their flexibility. At the time of the investment decision, Enedis chooses the best economic alternative with a guaranteed outcome: either network reinforcement or flexibility service with capacity reservation (which entails deferring the investment).

6.1.2.3.2. Fair and non-discriminatory market rules

To ensure fair market access and consistency with the mechanisms already in place at the national level (RTE already uses market mechanisms for supply-demand balance and network congestion management, see 2.1.1), Enedis has established its market in accordance with the following principles:

An open and fair market

- The market is open to all flexibility service providers (suppliers, aggregators, individual sites, etc.).

- In the absence of specific legal provisions, the valuation of the opportunity (remuneration, penalties) depends solely on the service provided: Enedis is technologically neutral.

- Aggregation is allowed: the service can thus be provided by one or more sites without discrimination.

- Enedis allows participation at all voltage levels, regardless of the connection power of the flexible site.

45. Amendment to the 322-9 Energy Code Article following the Order 2021-237 of the 3rd March 2021.

Common service contracts for all flexibility service providers

• Enedis uses two contract models, with or without capacity reservation.

• Enedis requires a service with a result obligation from flexibility service providers. Therefore, Enedis includes penalties to cover the risk of failure.

Transparent and non-discriminatory access to information

• Enedis is transparent about its procurement process and selection criteria, which are widely shared with its stakeholders (see below).

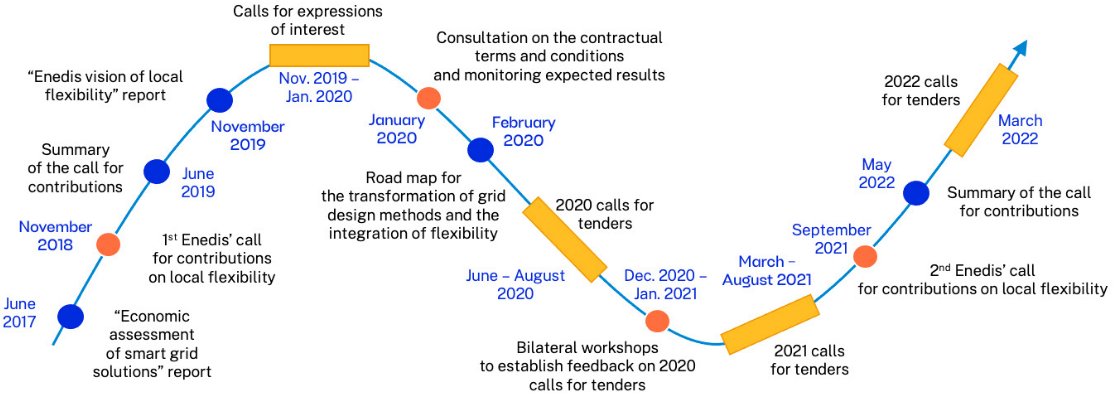
• The data is public and accessible on the https://flexibilites-enedis.fr website (flexibility opportunities), on the "*Co-construire les flexibilités*" page of the Enedis institutional website https://www.enedis.fr/consultation-flexibilites, as well as on the website of the distribution network users committee (CURDE in French). Enedis thus makes the entire document corpus of call for tenders available to all: contract models, specifications, consultation regulations, and, more broadly, all documentation related to flexibilities (report, roadmap, workshop support, etc.).

• Through the https://flexibilites-enedis.fr website (described in 6.1.2.3.5), Enedis allows anyone to check the eligibility of sites to bid for flexibility opportunity and provides flexibility service providers with data to facilitate their canvassing activities in compliance with data sharing rules (GDPR, ICS).

Coordination with RTE

Enedis coordinates with RTE to ensure integration into existing mechanisms from a regulatory (balancing perimeters adjustments, supplier interface, etc.), contractual (participation in multiple mechanisms simultaneously), and operational perspective (information exchange upstream and in real time between network operators). Enedis aims to enable service providers to freely and easily participate in flexibility markets for both the transmission and distribution system operators.

Figure 70: historical stages in the construction of Enedis' call for tenders



6.1.2.3.3. Milestones in the joint construction of the market with flexibility service providers

Enedis has published several documents on the principles of the call for tenders, and maintains an ongoing dialogue for a joint construction with its stakeholders. Figure 70 shows the main milestones achieved over the period 2018 to 2021.

Here is a summary of these milestones:

- **June 2017:** publication of a report on the economic assessment of smart grid solutions (*Enedis et ADEeF, Valorisation économique des Smart Grids*), which details the unit value of flexibility for the community, whether to alleviate withdrawal constraints or injection constraints.

- **November 2018**: Enedis presented its vision of the call for tenders in its first call for contributions on local flexibilities in order to initiate a discussion base with stakeholders. A summary of the feedback was presented in June 2019.

- **November 2019:** publication of a report (*Enedis, Les flexibilités au service de la transition énergétique et de la performance du réseau de distribution*) that formalises the use cases of local flexibility identified in the Economic assessment of smart grid solutions report (*Enedis et ADEeF, Valorisation économique des Smart Grids*) that Enedis will industrialise:

  - improving delays and costs of new connections;

  - improving the cost-effectiveness ratio of the network by deferring investment or substituting flexibility for other measures (e.g. mobile means of restoring supply).

- **January 2020:** consultation on the contractual terms and the envisaged results control methods[46] in upcoming calls for tenders.

- **February 2020:** communication of the roadmap for the transformation of network planning methods and flexibility integration (*Enedis, Feuille de route pour la transformation des méthodes de dimensionnement des réseaux et l'intégration des flexibilités*).

Enedis also conducts bilateral exchange workshops with stakeholders to provide feedback on its calls for tenders and improve its procurement process. In September 2021, Enedis launched a second call for contributions on local flexibilities to provide visibility on the upcoming topics to be addressed.

46. https://www.enedis.fr/media/2372/download

6.1.2.3.4. Overview of the calls for tenders launched by Enedis

2019-2020 call for tenders

For its first call for tenders for flexibility services in 2020, Enedis proceeded in two stages.

An expression of interest period took place from November 2019 to January 2020. Enedis received 40 declarations of interest from 18 service providers, which validated the launch of the call for tenders.

A call for tenders (June-August 2020) subsequently led to the signing of two contracts without capacity reservation on the Flex Mountain opportunity (*Enedis, Résultats des Appels d'Offres de flexibilités locales 2020*). See figure 71.

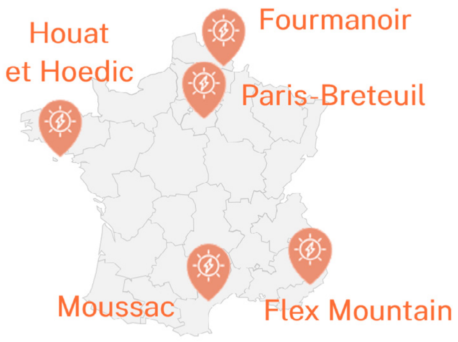
Two opportunities were related to investment deferrals as described in this NDP (section 6.1.2.1), and three others were for "network management assistance" opportunities. Enedis called for tenders for all flexibility opportunities, and not just those related to the NDP (see various flexibilities in section 2.1.1).

2021 call for tenders

Tenders were launched from March to August 2021, with no prior expression of interest.

Enedis published three opportunities with the same contractual basis as the 2020 calls for tenders. The tenders were related to "network operation assistance" flexibility, and not opportunities for deferral of investment to solve withdrawals constraints.

Figure 71: map of the 2020 calls for tenders

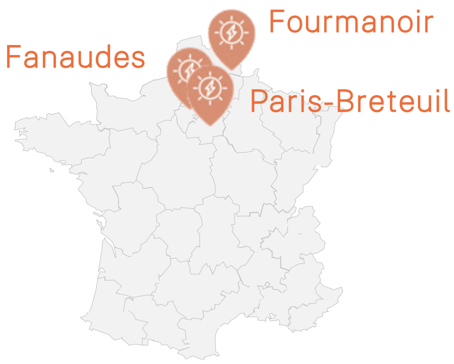


Enedis did not sign any local flexibility services contracts following this call for tenders.

2022 call for tenders

For the third consecutive year, Enedis published eleven opportunities for operations-related services (see figure 72).

Figure 72: map of the 2022 calls for tenders



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6.1.2.3.5. Enedis develops mapping solutions to inform flexibility service providers about local flexibility opportunities

From the perspective of flexibility service providers, the expectation is to understand what Enedis needs, so that the flexibility offer can meet the network operator's demand.

Therefore, Enedis has been publishing flexibility opportunities since 2019 on a dedicated website: https://flexibilites-enedis.fr. All types of opportunities (investment deferrals, operations-related flexibility, and soon REFLEX), at various stages of development (closed, ongoing, and planned), are freely available on this public website.

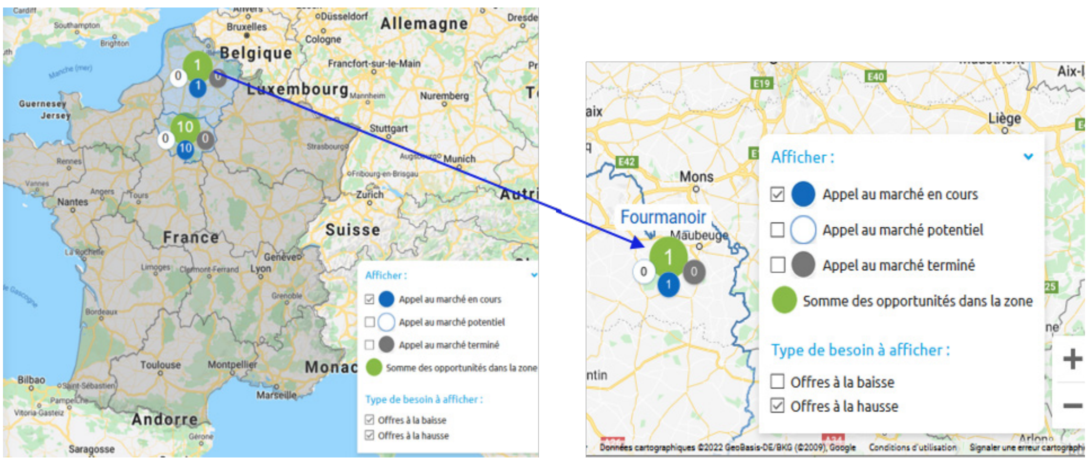
For each opportunity zone, Enedis provides geographical and technical data as well as tools to assist flexibility service providers to bid in Enedis' calls for tenders.

Geographical data

Enedis outlines the opportunity area on the map (see figure 73) with a dual purpose:

- Facilitate the identification of existing capacities by service providers in their portfolio and their canvassing for new capacities within the opportunity area;
- Assist service providers in their decision regarding the placement of new flexibility means in the area.

Figure 73: flexibility opportunity map



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Calls for tenders

During calls for tenders, Enedis presents a simplified version of the product characteristics expected from flexibility service providers (see figure 74): these data reflects the specifications and are binding for Enedis. The purpose of this module is to enable flexibility service providers to quickly assess their potential interest in the area: type of remuneration, opportunity period, power, duration, etc.

A flexibility service provider can instantly check the eligibility of one or more sites for flexibility tenders from their supply point (see figure 75).

This check is essential because of the very local nature of the flexibility required to alleviate constraints on the distribution network.

The data integrated into the tool is regularly updated to account for new connections in the area and potential network restructuring.

Figure 74: illustration of the expected flexibility product characteristics

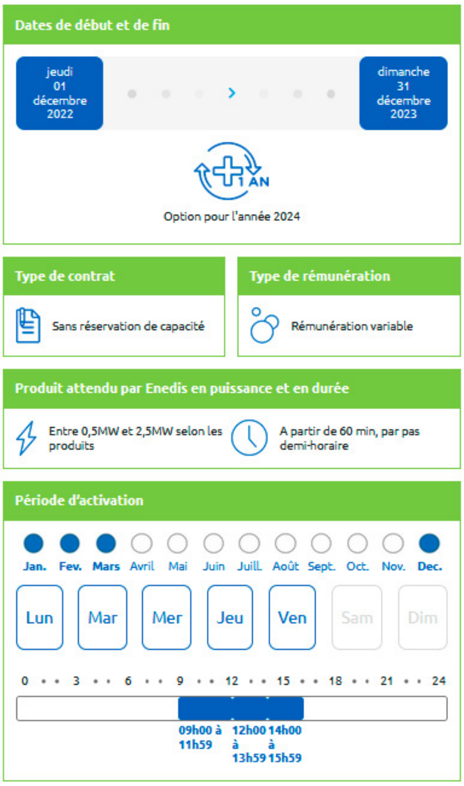

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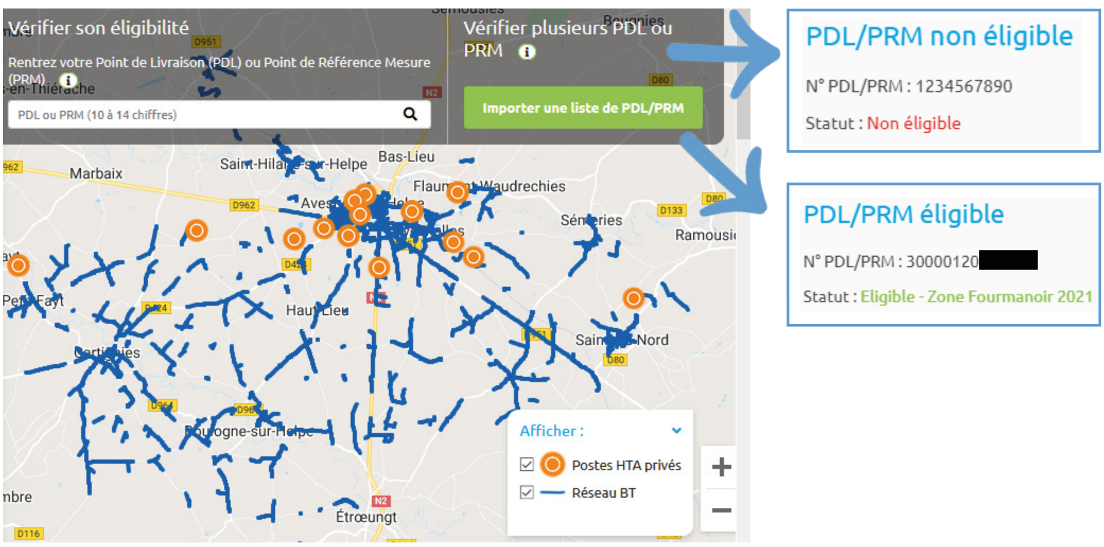
Figure 75: tool to check the eligibility of supply points for a flexibility opportunity



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6.2. Enedis progressively embeds technical solutions beyond network reinforcement to facilitate the integration of renewable energy, in line with the voltage management scheme

Connecting producers may require network reinforcement to avoid high voltage constraints

As mentioned in 5.2.1, the development of renewable energies and new uses on the distribution network gradually leads to increased high voltage constraints. The network can no longer be dimensioned solely on the basis of downward flows and low voltages during peak winter times. It must also be able to withstand increases in voltage linked to:

- generation;
- reactive energy flows (see informational panel XXXVI: reactive power) generated by underground cables and by customers. This phenomenon has been increasing for several years, due to the undergrounding of overhead lines and the new power supplies of residential, tertiary, and industrial electrical appliances. These flows have a more significant impact in situations of low transit in the lines and transformers, as the reactive energy consumed in the latter then decreases significantly;
- imbalances in low-voltage networks;
- situations in which the regulator[47] of HV/MV transformers has reached its limit and can no longer maintain the set point voltage at the primary substation.

To address the increasing range of voltage variations in the network, Enedis is studying and implementing a set of complementary solutions:

- A review of the voltage management scheme is underway.
- Various material solutions are under study (and some are in the implementation phase) to provide a range of solutions that are less expensive than network reinforcements. These potential solutions are briefly presented below.

Reactive power capacities of producers are already used in MV, and will be used in LV as well

Among the MV producers connected to an MV feeder that includes other connected sites, some have already adopted a fixed tan(φ), going as low as -0.35 (the limit of constructive capacities defined by regulations). An alternative solution has been proposed by Enedis and included into its technical reference documentation for adjusting reactive power according to a law Q = f(U), i.e. dependent on the supply point voltage. This solution is studied at the request of producers wishing to connect, and can facilitate the connection in some cases. Other reactive power adjustment laws are being studied to assess their relevance for the community, within the limits defined by regulations.

Furthermore, for several years now, Enedis has been supporting updates to the regulation concerning reactive power from LV producers. There is significant potential here to reduce voltage rises caused by the active power of LV producers, thereby facilitating their connection. The regulation has evolved (order of June 9, 2020), as well as the TURPE in 2021. To account for these new reactive power billing modalities in LV, the CARD-I contracts were modified on August 1, 2021. At the beginnings of 2023, after consultation with producers, Enedis' technical reference documentation will be updated, and all new LV generation installations will be required to consume reactive power, with the target value of tan(φ) defined by the constructive capacities set by regulations (tan(φ) = 0.35).

47. A device that adjusts the voltage set point of the HV/MV transformer by a few percent, thereby offsetting some of the impact on voltage caused by equipment, consumers and producers.

INFORMATIONAL PANEL XXXVI

Reactive power

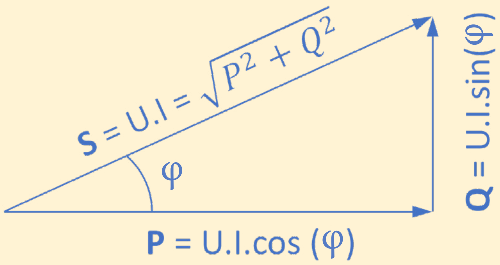
In an alternating current regime, three types of power are distinguished:

- The active power, denoted P and expressed in watts (W), corresponds to the power actually used by loads.

- The apparent power, denoted S and expressed in volt-amperes (VA), corresponds to the product of the root mean square values of voltage and current. It is often used as a substitute for current in equipment sizing (for example, the rated capacity of a transformer is expressed in kVA, as is the subscribed power of a low-voltage customer).

- The reactive power, denoted Q and expressed in reactive volt-amperes (VAr), which appears in any circuit with capacitive (capacitors) or inductive (coils) components.

The relationship between these powers is illustrated by the power triangle, where φ is the phase shift angle of the current relative to the voltage (which can be positive or negative).



On the distribution network, reactive power flows are primarily determined by:

- The reactive behaviour of loads. Historically, they were mostly inductive (consuming reactive power, i.e. with a positive φ angle), but equipment evolution, particularly with the widespread use of electronics, are making loads consume less and less reactive power, even with a trend toward producing reactive power.

- The reactive behaviour of producers. Regulations impose certain constructive capacities on producers; a generation installation is thus able to consume or produce reactive power, depending on the chosen setting.

- The consumption of reactive power by transformers and overhead lines.

- The generation of reactive power by underground cables.

Mastery of reactive power flows in the distribution network is key issue because:

- For the same active power, the transit of reactive power contributes to increasing the current circulating on the network, and thus the Joule losses.

- These flows contribute to voltage variations along feeders and in transformers: reactive power consumption leads to voltage drops, while reactive power generation leads to voltage rises.

Several hardware devices are currently under experimentation in MV

To alleviate high voltage constraints, Enedis is searching for alternative solutions to MV network reinforcements by installing hardware devices on the network. One type of experimented device modifies the flow of reactive power in the network. Enedis has been experimenting fixed reactors since late 2019 in *Corrèze* and *Creuse*, that continuously consume reactive power. This initial experimentation led to the decision to test more flexible devices, called switchable reactors, starting in 2022 as part of the Flex#Cantal project. It is important to emphasize that the potential decision to industrialise these devices can only be made after gaining enough experience during these experiments. It will also depend on their cost, operability, and their ability to effectively reduce voltages in a satisfactory manner. Finally, when it comes to consuming reactive power and thus controlling high voltages, reactors are much less expensive than batteries or other active power storage devices.

More complex devices that modify voltage in a static or dynamic manner will also be exprimented. Examples includes devices like auto-transformers and line voltage regulators. As part of the Flex#Cantal project, Enedis has decided to experiment an MV voltage regulator as soon as possible. The main advantage of this equipment is its ability to adjust the voltage precisely on a single MV feeder. Additionally, it allows dynamic adjustments of the set point voltage ("compounding"), providing significant adjustment margins. However, its cost is high.

In LV, some simple devices have been in use for a long time, while others, more complex, are under study. However, their technical and economic potential is limited

Several voltage regulation devices have been successively used by Enedis in LV. These include the voltage transformer and adapter, three-phase/single-phase converter, and, most importantly, the three-phase network balancer. However, their use has remained very limited in volume, as they are adapted to very specific network situations.

Other more recent devices, such as voltage regulators and MV/LV transformers with load regulators, have been the subject of studies and experiments in recent years. In the case of the latter equipment, the study showed that there was very little potential interest. However, additional analyses may be initiated to account for changes in the technical context and the level of renewable energy integration.

Dynamic voltage control at the primary substation is a promising solution, currently under experimentation

The set point voltage for MV at the HV/MV transformers is fixed. It should allow for both avoiding excessively high voltages during generation periods and preventing low voltages during high consumption periods. However, it is possible to equip the primary substation with a specific device to dynamically adjust the set point voltage throughout the day to adapt to different situations. In other words, dynamic set point voltage adjustment enables lowering the set point voltage when voltages are generally high across the downstream network and raising the set point voltage when voltages are generally low across the downstream network. This technology is promising but is still in the experimental stage. Enedis is currently testing its operation at six primary substations in France.

In the longer term, a revision of the very structure of the MV network could be of interest

"Looped" operation of the MV network is an interesting prospect for the future of distribution networks. This approach could facilitate the connection of renewable energy and also greater connection of consumption on existing networks. Research and development studies are under way to assess this concept's potential. However, this solution is still far from a potential industrial deployment, as it would require adjustments to the current protection plan and disrupt current network management and operation practices.

6.3. Storage: a flexibility resource that may provide valuable services to the distribution network, as a complement to their main business model

Requests to connect storage installations to the distribution network are increasing:

- On the MV network, this mainly consists of single batteries, sometimes downstream of renewable energy generation sites. At the end of the third quarter of 2022, 197 batteries were connected with approximately 259 MW in service. There were 113 projects under way with a total power of around 164 MW, including 71 projects with batteries alone.

- On the LV network, small batteries are coupled with PV panels for self-consumption and self-generation. By the end of the third quarter of 2022, there were 8,800 batteries of less than 36 kVA.

Enedis connects storage installations, offers a contractual framework for network access, and collaborates with storage stakeholders on the technical specifications applicable for these installations. These installations can be seen as sites that can act as either producers or consumers, at different times.

Storage offers an interesting flexibility profile for the electricity system and also for networks:

- **An inherent system and network purpose, due to their lack of links to specific uses,** which means it can potentially provide increased availability (unlike other generation or consumption flexibility, which are generally less flexible due to their link to specific uses).

- **A rapid response capability** related to the ability to discharge or charge with high reactivity within the storage's energy stock limits.

- **The possibility of mobile and localised use on the network,** depending on the needs, thanks to the transportability and mobility of storage installations (modularity and containerisation of batteries, for example).

As a result, storage can offer many services to various stakeholders within the electricity system:

- To market service providers, for trade-offs on wholesale markets, to participate in national markets (supply-demand balance, curtailment, capacity, adjustment, etc.). The primary application of stationary storage, due to the fast response time of installations, is currently in providing frequency regulation system services (primary frequency regulation).

- To electricity producers, to optimise or smooth their production.

- To transmission and distribution system operators, to provide a local flexibility lever for network optimisation.

The Electricity Market Directive of the European Clean Energy Package does not allow DSOs to own, develop, manage, or operate energy storage installations, unless the storage is integrated into the network or in approved exceptional cases. The provisions of the Directive are transposed into French law (Article L. 352-2 of the Energy Code). A decree from the State Council is expected to clarify the exceptional situations in which DSOs can own and/or operate storage installations.

In the context of rural electrification (new CAS FACE provisions), licensing authorities may decide to invest in storage installations on the LV distribution network to avoid or defer network adaptation work. The status and operational procedures of these storage installations will have to be defined.

INFORMATIONAL PANEL XXXVII

2020-2021 experiment of the flexibility offered by a storage installation on the network

To overcome a low voltage constraint on the MV network, Enedis conducted an experiment in 2020 and 2021 in *Poitou-Charentes* region, involving the use of flexibility provided by a storage installation. The request to connect a 1 MW/1 MWh battery on the network offered a dual opportunity:

- for Enedis, it allowed testing the legal, technical, and economic aspects of flexibility in reactive power (as well as on voltage constraints);
- for the operator, it provided an opportunity to experiment with the simultaneous provision of several network services.

The storage site was used for RTE's primary reserve mechanism (active power) and also injected reactive power into the distribution network as part of the project.

The service expected by Enedis included injecting reactive power and limiting active power consumption.

The experiment took place in two phases:

- First experimental phase: the services were separated, with the operator responding either to the primary reserve or to Enedis' flexibility service on a given day.
- Second experimental phase: the services could be activated simultaneously to test the storage installation's capacity to provide both active and reactive services at the same time.

To enable free participation in the primary reserve, Enedis adapted its operational process:

- Notification on D-2 for activation on D-day.
- Activation in 4-hour slots, synchronised with the primary reserve.
- No intra-day activation requests, even if additional constraints were forcasted.

The experiment was successful for Enedis. The injection of reactive power had the expected effect of reducing voltage drops. Tests were conducted under real conditions, and Enedis deferred the investment decision initially made for the duration of the experiment.

The storage operator was also satisfied with the experiment. The battery behaved in accordance with Enedis' active power limitation and reactive power set point instruction.

The experiment concluded in June 2021. Enedis is continuing this initiative:

- Additional work is required to industrialise the voltage constraint detection system at the feeder level so that notification of activation can be given on day D-2.
- The reference technical solution is to be examined. This could involve the implementation of specific equipment on the network (such as reactors, STATCOM, etc.).

Enedis can already access third-party storage installations to meet its flexibility needs. A storage installation can bid in a call for tenders launched by Enedis for an opportunity area (see section 6.1.2.3) if it meets one of the following conditions:

- the storage installation has already been connected and commissioned in the area before the launch of the call for tenders;

- the storage installation was commissioned in the area after the launch and before the end of the call for tenders, provided that Enedis is informed of the commissioning and eligibility for the call for tenders.

A storage operator wishing to bid on a call for tenders with a new storage installation will thus have to connect and commission their installation in the flexibility opportunity area concerned before the end of the call for tenders. In practice, this timeframe is too short to allow for the connection and commissioning of a new installation in one of the flexibility opportunity areas.

In terms of financial income, a storage installation bidding for a tender is one flexibility option among others, and its activation will depend on its ranking compared to other flexibility offers, if applicable.

Although the mere offer of services to the distribution network does not yet justify an investment in a storage asset, it could nevertheless constitute an additional source of revenue for a storage operator to enhance the profitability of their asset.

In summary, the flexibility that storage can offer to the distribution network will likely be provided through responses to Enedis' call for tenders and will only be a potential complement to its main business model.

In addition to these general principles, Enedis continues to evaluate these solutions for its needs, as part of ongoing experimentations (see information panel XXXVII: 2020-2021 experiment of the flexibility offered by a storage installation on the network).

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7

Enedis' ambitious approach to corporate social responsibility

7

The current climate change is unprecedented on such a short time scale. The average global temperature has already increased by approximately 1°C since the pre-industrial era. This global warming results in a rise of sea levels, a higher frequency and severity of natural disasters depending on world's region, and contributes to an erosion of biodiversity worldwide. Climate hazards, whether physical or transitional, are a tangible reality whose evolution could critically alter the purpose and resilience of the electricity distribution network in the long term.

Within the scope of the investments described in this NDP, corporate social responsibility (CSR) is first and foremost reflected in the social aspect (7.1 to 7.3), then in the purchasing strategy (7.4), and also in environmental actions (7.5).

7.1. Enedis places its corporate social responsibility commitments at the heart of its projects

Given the distribution assets' lifespan and global climate policies, including the Paris Agreement, Enedis has drawn up a climate change adaptation plan for 2050, focusing on two of the four IPCC climate scenarios: the "pessimistic" RCP[48] 8.5 W/m^2 scenario and the "reasonably optimistic" RCP 4.5 W/m^2 scenario. This plan is factored into the investment trajectories included in this NDP.

Convinced that industrial and economic performance cannot exist without social and environmental exemplarity, Enedis places its CSR commitments at the core of its business project, namely:

- Reducing its carbon footprint with an objective of a 20% decrease in CO_2 emissions by 2025 compared with 2017 and a contribution to carbon neutrality by 2050 across all three scopes, for example:
    - reduction of the waste induced by Enedis' activities and the development of the circular economy, such as the recycling of scrapped meters replaced by smart meters (34 million at the end of 2021), the recycling of cables or poles replaced during planned refurbishment work, etc.;

48. In preparation for the IPCC's Fifth Assessment Report, published in 2013-2014, experts defined four RCPs (representative concentration pathways): representative trajectories of greenhouse gas concentration evolution for the 21st century and beyond.

- equipment, materials, and furniture reconditioning through the deployment of a refurbishment platform (with a 99% target of waste recovery by 2025), supported by the development of eco-designed equipment;

- investing in electric mobility: Enedis aims for a 100% electric fleet: in light-duty vehicle by 2030 and before 2050 for heavy-duty site machine;

- gradual replacement of existing generators sets, with low-carbon battery or hydrogen solutions by the end of 2025.

• Environmental exemplarity, with numerous initiatives to protect the environment and biodiversity, including:

- stopping the use of pesticides, with the effective implementation of "zero pesticides" in 2020 for the upkeep of green spaces adjacent to Enedis' tertiary sites, and from 2024 for industrial sites (primary substations);

- improving of tree pruning techniques to take into account protected or endangered species, plant and animal, or the use of new nature-based solutions to reduce the volume of work;

- strict compliance with regulations and anticipating them as early as possible (laws on water, land take, classified facilities, protected areas, etc.) with a commitment to "Eliminate - Reduce - Offset" shared with stakeholders in the interest of sustainable development.

• Sustainable and responsible equipment and purchasing policies, in line with the requirements of the CSR charter for suppliers and service providers and those of the "responsible supplier relations and procurement" (RFAR in French) label.

7.2. By controling technical losses, investments contribute to reducing carbon footprint

Technical losses are a key element in terms of the energy efficiency of the network (see informational panel XXVIII: technical losses). They increase the carbon footprint of the electricity system. Tempering technical losses is at the heart of the methods used in studies for the design and sizing of distribution networks. It is also an essential selection criterion in the design of network assets and their operation.

For each new cable laid, Enedis selects the appropriate cable range, which minimise the cumulated cost of investment and losses over its lifetime: this principle is referred as the economic cross-sections (see informational panel XXIX: economic cross-sections). Furthermore, whenever network reinforcement studies reveal several technically feasible solutions, Enedis opts for the solution that minimises the collective cost, including the cost for losses (see informational panel XXXI: choice of the best investment strategy).

In addition to these systematic economic optimisation practices, which include the evaluation of the forecasted cost of losses at the early stage of networks design, Enedis also chooses transformers that reduce technical losses, by requiring them to meet the specifications detailed below.

EU Regulation No. 548/2014 of 21 May 2014 on implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to small, medium and large power transformers, established eco-design requirements for placing on the market or putting into service power transformers with a minimum power rating of 1 kVA. Enedis considered this in the drafting of its tenders for the establishment of transformer markets.

Regulatory compliance alters transformer design. As of today, they must meet the following criteria:

- transformers with a power equal or lesser than 3,150 kVA shall not exceed the boundaries for load and off-load losses set out in the Regulation;
- transformers with a power exceeding 3,150 kVA have their performance defined by a minimum Peak Efficiency Index (PEI) value, a function of values defined by the Regulation.

Enedis now only acquires transformers that meet these characteristics.

7.3. Minimising the visual impact of networks and substations

Enedis works to minimise the visual impact of its network and substations and to integrate them into the environment:

- As described in section 1.4, specific funding is planned to improve the aesthetic of existing works, which may include the undergrounding of low-voltage electrical networks (these investments are falling under "Article 8"). As a reminder, new MV and LV networks are mostly built using underground technology.
- For over 20 years, Enedis has been working with insertion associations, local authorities, street artists, and Enedis technicians to enhance its industrial heritage and better integrate its infrastructure into the environment. Through its partnerships, neighbourhood associations have launched numerous insertion projects to improve the external appearance of distribution substations.

7.4. A sustainable procurement strategy

Enedis' procurement activities are carried out in accordance with regulatory requirements, corporate policy, and stated differentiating ambitions through external reference labels.

7.4.1. Regulations to ensure free competition

Member States are obliged to implement the principle of free competition, as set out in the Treaty of Rome of 25th March 1957 and the Treaty on the Functioning of the European Union – known as the Lisbon Treaty – in force since the 1st December 2009.

Enedis is a company operating in a sector among the ones known as sensitive, such as water, energy, transport, and postal services. Due to their particular situation in the general economic fabric and as contracting authorities, companies operating in sensitive sectors are subject to the European DirectiveNo. 2014/25/EU of 26th February 2014, as transposed into national law, which imposes the following three principles in particular:

- competition;
- transparency;
- equality of treatment.

These texts aim to guarantee suppliers free access to public procurement, by opening markets to competition regardless of their value.

7.4.2. Enedis' procurement policy

Enedis' procurement policy strives to ensure that the company's supply chain is efficient and effective, and that it delivers high-quality goods and services to users at a competitive price, all while complying with all applicable regulations.

- In a full-cost approach, it takes into account the expectations of the industrial policy, subcontracting, and "supplier" risk management.
- It contributes to the performance of Enedis' activities, in all its components: technical, economic, intellectual property, financial, social, and environmental.
- It addresses the requirements of Enedis' CSR policy.
- It aims to preserve Enedis' image and the respect of its values by all internal and external stakeholders.

This policy aims to strengthen synergies between buyers, prescribers, and market users by **a better understanding of all the issues associated with procurement and supplies.**

To strengthen responsible procurement, Enedis' procurement policy has been updated, in the wake of the CSR policy modification, to include the following fundamentals:

1. cooperation between actors;

2. compliance with laws and internal legal, ethics and compliance rules;

3. compliance with payment deadlines;

4. labour relations and conditions;

5. environment;

6. local integration, and the use of the protected and adapted work sector (STPA in French) and structures for integration through economic activity (SIAE in French);

7. total acquisition cost;

8. the Enedis CSR charter for suppliers and service providers;

9. monitoring and control of indicators.

The Enedis CSR charter for supplier and contractor aims to share Enedis' commitment to environmental protection, respect for human rights and labour standards, and tackling corruption. It applies to all contractual relationships that Enedis maintains with its various suppliers.

7.4.3. Enedis, RFAR-certified since 2019

The Corporate Ombudsman is a government-run initiative that helps companies to adopt more responsible procurement practices. It aims to promote sustainable and balanced relationships between businesses and their suppliers. The National Purchasing Council (CNA in French) is an association of over 10,000 buyers whose aim is to promote the strategic role of purchasers, professionalise the procurement function, and anticipate and identify changes in the profession.

The Responsible supplier relations and procurement (RFAR in French) label, created by these two entities, recognises companies that build sustainable and balanced relationships with their suppliers on a daily basis. It was the first label of its kind to be awarded by the government. It is granted for a period of three years and subject to annual follow-up assessments. It was first awarded on 20th December 2012 to the companies of Legrand, Société Générale, SNCF, and Thalès. Since then, around fifty companies have been certified.

The government first awarded the RFAR label to Enedis in 2019, which has been renewed in 2021 with the unanimous support of the committee. It was based on a “broadly favourable” opinion from an independent audit firm that thoroughly assessed the company’s CSR initiatives across its supply chain

This award is a recognition of the values that drive Enedis’ teams and the actions it undertake. It is also a commitment to continuous improvement, particularly in relationships with its suppliers.

7.5. Conservation of the environment and biodiversity

7.5.1. Reducing SF6 emissions from Enedis-managed assets, and using alternative insulators

SF6 (sulfur hexafluoride) is a gas widely used in high-voltage applications. It is an excellent insulator (2.5 times better than air), has good arc-quenching properties (10 times better than air), and is not toxic nor flammable. It is found in high-voltage and medium-voltage equipment at Enedis-managed primary substations and public distribution MV/LV substations.

Although SF6 is an unmatched dielectric medium in high-voltage equipment, it has a global warming potential of 23,500 kilograms of CO2, making it the most potent greenhouse gas according to the IPCC. Therefore, its release into the atmosphere is a major risk to the environment.

The European regulation on fluorinated gases known as F-gases (EU Regulation No 517/2014 of 16 April 2014) aims to protect the environment by reducing emissions of fluorinated greenhouse gases.

As a result, Enedis’ SF6 policy includes the following measures:

- reducing SF6 emissions from primary substations, in particular by mending leaks or replacing the least airtight metal-enclosed substations (PSEM in French, a technology that uses SF6). This action is part of Enedis’ environmental management plan ;
- sustaining a specific disposal/recycling system for decommissioned equipment ;
- deploying a SF6-free solution for new metal-enclosed switchgear at MV areas of primary substations, based on vacuum-switching technology ;
- the upturn of modular integrated substation technology as an alternative to PSEM at HV areas of primary substations when possible (footprint constraints) ;
- conducting trials of SF6-free solutions for MV switchgear in partnership with suppliers, and opening the switchgear procurement market to these solutions in the near future.

7.5.2. Decontamination and disposal of PCB-containing equipment

Polychlorinated biphenyls (PCBs) are almost non-flammable electrical insulators with excellent dielectric and thermal conductivity properties. This is why they were widely used in older generations of transformers, but also for other uses such as paints. Since 1987, the use and manufacture of PCBs have been banned in France due to their toxic properties.

In accordance with the specific plan for decontamination and disposal of equipment containing PCBs that it has established, Enedis is continuing its work to eliminate and decontaminate transformers containing PCBs (more than 50 ppm).

In accordance with the regulations in force, including Article 4 of the Decree of 3rd July 2014, all concerned transformers will have been treated by the end of 2025.

7.5.3. Enedis' asbestos policy

Enedis has established contracts that enable it to implement its asbestos policy in accordance with the relevant regulations. In particular, periodic assessments are carried out on MV/LV substations that contain asbestos. Enedis has taken steps to safeguard the safety of substation workers and prevent asbestos exposure.

7.5.4. Acting for biodiversity

Regarding biodiversity, Enedis joined the alliance of "Companies Committed to Nature" (formerly Act4Nature) in 2021. This labelling is reflected in Enedis' adoption of eight specific commitments, in addition to ten generic ones, which are specifically designed to preserve biodiversity.

These commitments also affect Enedis' investment policy. For example, for more than 10 years, Enedis has been investing in reducing the impacts of the public distribution network on birdlife, including by improving the visibility of power lines for birds by installing spirals or beacons, equipping them with protections (see figure 76), installing perches on poles, and burying lines. With the help of local naturalist associations and in partnership with the French NGO "*Ligue pour la protection des oiseaux*" (LPO), Enedis defines an action plan, as well as intervention periods that are not disruptive to birdlife.

Figure 76: birdlife protection

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Appendices

8.1. Glossary

ACR
Network control operation room (*Agence de Conduite Régionale*)

ADEeF
Association of French electricity distributors (*Association des Distributeurs d'Electricité en France*)

AI
Artificial Intelligence

AODE
Licensing authority, or electricity distribution concession authority (*Autorité Organisatrice de la Distribution d'Electricité*)

ASGARD
Network access supervision and management agencies (*Agence de Supervision et de Gestion des Accès au Réseau de Distribution*)

BEX
Operating offices (*Bureau d'EXploitation*)

CAPEX
CAPital EXpenditure

CARD
Distribution network access contract (*Contrat d'Accès au Réseau de Distribution*)

CARD-I
Distribution network access contract for injection sites

CAS
Special account (*Compte d'Affectation Spéciale*)

CBA
Cost-Benefit Analysis

CMA
Poorly supplied customer, as defined in the "quality" decree (*Client Mal Alimenté*)

CRAC
Licensed operator's activity annual report (*Compte-Rendu d'Activité de Concession*)

CRE
French energy regulatory commission (*Commission de Régulation de l'Energie*)

CSDPE
French public electricity distribution system committee (*Comité du Système de Distribution Publique d'Electricité*)

CSR
Corporate Social Responsibility

CURDE
Distribution network users committee (*Comité des Utilisateurs du Réseau de Distribution*)

DAC
Annual screening file (*Dossier Annuel de Criblage*)

DDDP
Detailed diagnostic and recommendation file (*Dossier de Diagnostic Détaillé et de Préconisation*)

DEIE
Operation information exchange device (*Dispositif d'Echange d'Informations d'Exploitation*)

DGEC
French Directorate-General for energy and climate (*Direction Générale de l'Energie et du Climat*)

DRR
Automatic circuit reclosers (*Disjoncteurs à Ré-enclenchement en Réseau*)

DTR
Enedis' public reference technical documentation (*Documentation Technique de Référence*)

DSO
Distribution System Operator

eDEIE
New generation of the operation information exchange device (DEIE)

eIPF
Connected surge arresters (*Indicateur de défaut ParaFoudre connecté*)

ELD
French local distribution companies (*Entreprise Locale de Distribution*)

EMIS
Modular instrumentation and supervision equipment (*Equipement Modulaire d'Instrumentation et de Supervision*)

EMS
Energy Management System

EV
Electric Vehicle

EVCI
Electric Vehicle Charging Infrastructure

ER
Rural electrification (*Electrification Rurale*), as defined by Decree No. 2020-1561 of 10th December 2020 on aid for rural electrification

FACE
Rural electrification cost amortisation fund (*Fonds d'Amortissement des Charges d'Electrification*)

FIRE
Emergency intervention means (*Force d'Intervention Rapide Electricité*)

FNCCR
National federation of licensing authorities and public utilities (*Fédération Nationale des Collectivités Concédantes et Régies*)

GDPR
General Data Protection Regulation

HV
High Voltage. Voltage greater than 50,000 V, within the meaning of Article 3 of Decree No. 88-1056 of 14th November 1988 implementing the provisions of Book II of the Labour Code (Title III: Health, Safety and Working Conditions) concerning the protection of workers in establishments where electrical currents are used.

ICS
Commercially Sensitive Information

ILDc
Connected fault location indicators (*Indicateurs Lumineux de Défaut Connectés*)

INSEE
French national institute of statistics and economic studies (*Institut National de la Statistique et des Etudes Economiques*)

IoT
Internet of Things

IPCC
Intergovernmental Panel on Climate Change

IS
Information Systems

LPO
French NGO "*Ligue pour la Protection des Oiseaux*", for birds protection

MALTEN
Enedis' Neutral Earthing Program (*Mise À La Terre du Neutre*)

MAPTAM
Modernisation of territorial public action and the affirmation of metropolitan areas (*Modernisation de l'Action Publique Territoriale et d'Affirmation des Métropoles*)

MCO
Maintenance in operational condition (*Maintien en Condition Opérationnelle*)

MCS
Maintenance in CyberSecurity (*Maintien en Condition de Cybersécurité*)

MV
Medium Voltage. Voltage greater than 1,000 V and less than 50,000 V, within the meaning of Article 3 of Decree No. 88-1056 of 14th November 1988 implementing the provisions of Book II of the Labour Code (Title III: Health, Safety and Working Conditions) concerning the protection of workers in establishments where electrical currents are used.

NDP
Network Development Plan. This document is a preliminary version of the NDP: it referred to as the "NDP" for simplicity throughout the text.

NECP
National Energy and Climate Plan

NLTC
No-Load Tap Changer

NOME
Law n° 2010-1488 of december 7, 2010 on the new organisation of the electricity market.

OLTC
On-Load Tap Changer

OMT
Remotely controlled switchgear (*Organe de Manœuvre Télécommandé*)

OPI
Oil-Paper Insulated [cables]

ORA
Alternative connection offer (*Offre de Raccordement Alternative*), as described in the DTR.
The term ORA includes:

- a certain number of cases that differ from the ORR (for example user connection to another primary substation). In this case, users have no additional cost to pay if they have not requested this specific connection.
- the case of the ORA with power modulation, which is a flexibility requested by the user to allow an optimised connection in the user's interest.

ORA-MP
Alternative connection offer with power modulation (*Offre de Raccordement Alternative à Modulation de Puissance*)

ORR
Reference connection offer (*Offre de Raccordement de Référence*)

PCB
Polychlorinated biphenyls

PCCN
Digital distributed control systems (*Poste Contrôle Commande Numérique*)

PEI
Peak Efficiency Index

PDL
Supply Point (*Point De Livraison*)

PLC
Power Line Carrier

PPE
Multi-annual energy plan or NECP (*Programmation Pluriannuelle de l'Énergie*)

PPI
Multi-year investment planning (*Programme Pluriannuel des Investissements*)

RFAR label
Responsible supplier relations and procurement label (*Relations Fournisseurs et Achats Responsables*)

RTE
French TSO (*Réseau de Transport d'Electricité*)

S3REnR
Regional renewable energy connection master plan (*Schéma Régional de Raccordement au Réseau des Énergies Renouvelables*)

SAS
Alert and safeguard system (*Système d'Alerte et de Sauvegarde*)

SCADA
Supervisory Control And Data Acquisitio

SDDR
French ten-year network development plan, is one of the responsibilities entrusted to RTE by law (*Schéma Décenal de Développement du Réseau*)

SDI
Investment master plans (*Schéma Directeur des Investissements*)

SDIRVE
Master plans for the deployment of electric vehicle charging infrastructure (*Schéma Directeur pour les Infrastructures de Recharge pour Véhicules Électriques*)

SF6
Sulfur hexafluoride

SFEC
French energy and climate strategy (*Stratégie Française Energie-Climat*)

SIAE
Structures for integration through economic activity (*Structures de l'Insertion par l'Activité Economique*)

SAIDI
System Average Interruption Duration Index, in French this indicator is called the B criterion

SNBC
French national low carbon strategy (*Stratégie Nationale Bas-Carbone*)

SRADDET
Regional spatial planning and sustainable development scheme (*Schéma Régional d'Aménagement, de Développement Durable et d'Egalité des Territoires*)

STATCOM
STAtic COMpensator

STC
Remote control simulator, predictive management software (*Simulateur de téléConduite*)

STPA
Protected and adapted work sector (*Secteur du Travail Protégé et Adapté*)

TRV
Regulated sales tariffs (*Tarif Réglementé de Vente*)

TSO
Transmission System Operator

TURPE
Public electricity networks utilisation tariff (*Tarif d'Utilisation des Réseaux Publics d'Electricité*)

VAT
Value Added Tax

VOLL
Value Of Lost Load

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8.3. Table of informational panels

8.4. Table of figures

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Enedis is a public service company managing the French electricity distribution network. It develops, operates and modernises the electric grid and manages the associated data. It carries out customer connections, 24/7 troubleshooting, meter reading and all technical interventions. Acting on behalf of the local authorities which own the electricity networks, it is independent of the energy suppliers responsible for marketing and managing electricity supply contracts.

Enedis - Tour Enedis
34, place des Corolles
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Limited Company with Executive Board
and Supervisory Board with a capital
of EUR 270,037,000 - R.C.S. Nanterre 444 608 442

Communication and CSR Department - January 2023
Ref. 053 - Design and layout : ici Barbès