Mid-term adequacy report

on the electricity supply-demand balance in France

2019 EDITION

MAIN RESULTS

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EXECUTIVE SUMMARY

The current level of security of supply

Contrary to conventional wisdom, security of supply does not mean "zero risk", which is, in any case, not achievable in any industrial sector.

It means that the power supply is guaranteed at all times, except for specific situations when RTE may intervene to adjust demand:

- Using "post-market" mechanisms (interruption of major industrial consumers paid for such situations, reduction of the grid voltage) which do not affect the consumer;
- As a last resort, brief and targeted power cuts ("load shedding").

This type of intervention does not amount to a blackout, on the contrary, it aims at preventing them.

The chosen security of supply "level" or "standard" in France is set by the public authorities: this is the "three-hour rule". This rule means that the expected time during which the balance between supply and demand cannot be ensured by the electricity markets, in all the configurations modelled by RTE, is three hours a year or less.

With this reliability standard, the main risk factor (but not the only one) is a period of extreme cold which may occur every 10 to 20 years. The risk periods are therefore during the winter, both in the evenings at around 7 pm and in the mornings. Other factors (simultaneous unavailability of several nuclear reactors, very light wind conditions in several European countries) can also have a significant impact.

This rule is all the more difficult to grasp as the French generating capacity has had "overcapacities" in the past years, i.e. the generating fleet was oversized compared with peak requirements.

The concept of inadequacy between electricity supply and demand has therefore remained theoretical and unknown to the general public, unlike power cuts, which may affect some consumers following technical or clearly identifiable meteorological incidents (for example, storms).

Over the past 15 years, France has moved away from an overcapacity situation to, now, reach a level of security of supply very close to the national reliability standard.

This is mainly due to the closure of oil and coal-fired facilities. A large number of these types of power plant (with a cumulative power of almost 12 GW) have been shut down since 2012, for environmental reasons (as these facilities were amongst the highest producers of greenhouse gas emissions in the fleet) and economic reasons (they operated very few hours).

At the same time, the availability of the nuclear power fleet during winter has decreased.

Following these changes, the security of supply is still ensured as defined in the regulatory standard, but there is no longer capacity margin.

This explains why security of supply has become an increasingly important topic. Any negative change in the generating capacity will now have a direct impact when assessing the risk level of the power system.

The challenge of successive French Adequacy Reports is therefore to assess on a five-year period how to implement the public energy policy while ensuring compliance with the national standard and all the other rules for operating the power system.

Changes between now and 2025

Over the next few years, the national ambitions – now clarified by the energy-climate law – will lead to the closure of around 5 GW of centralised generation capacity: 1.8 GW with the decommissioning of the two Fessenheim nuclear reactors and 3 GW of coal-fired power plants.

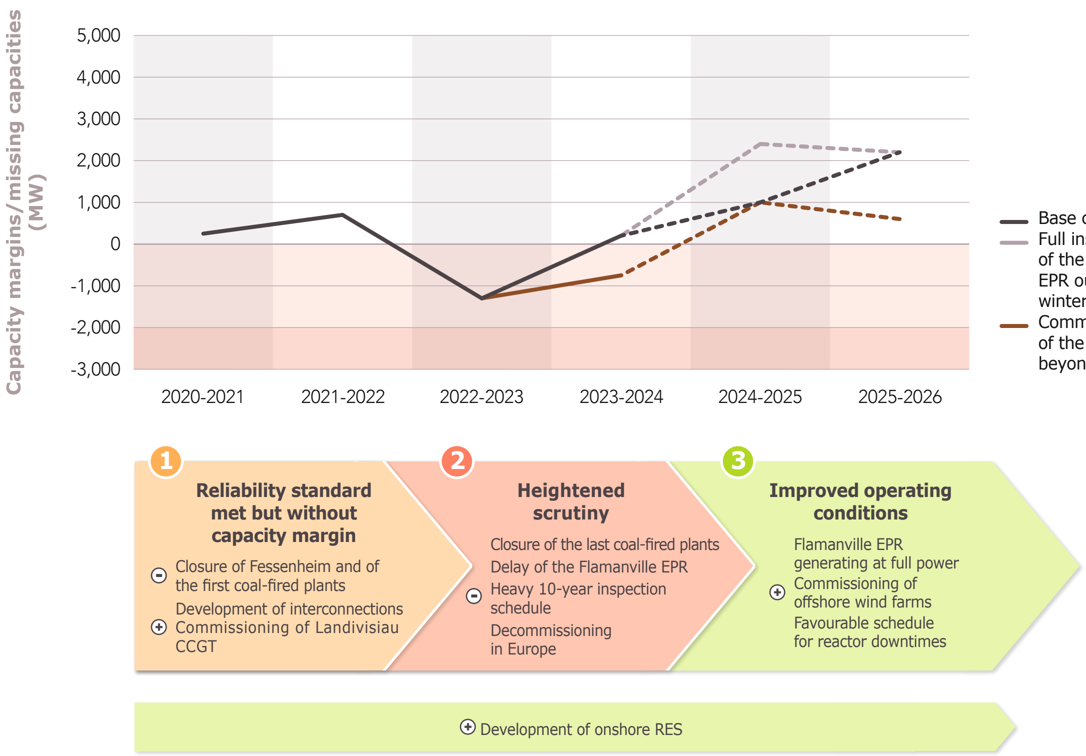
These decommissionings are being carried out in a context of major changes: (i) the commissioning of the Flamanville EPR (European Pressurised Water Reactor) has now been postponed, (ii) the nuclear power fleet is entering a maintenance and reinvestment programme causing long downtimes under the supervision of the Nuclear Safety Authority, and (iii) all the European countries are simultaneously involved in programmes to close centralised generation capacities. In the last few years, several of the paramount assumptions of the French Adequacy Report have therefore been revised in an adverse direction.

The analysis provided by RTE in the Mid-term Adequacy Report 2019 identifies three key points for the period 2019-2025.

1. Firstly (up to 2021-2022), the level of security of supply can comply with the French national reliability standard, even with the first planned closures of coal units in France. The ability to maintain this balance in 2021 depends on (i) keeping the current nuclear schedule under control, (ii) commissioning the Landivisiau gas power plant and two interconnections with Italy and the Great Britain, and (iii) compliance with the onshore wind energy foreseen capacity growth.

2. A second period will begin after the last coal-fired power plant have been decommissioned (from 2022 onwards in the base case). In this configuration, the public reliability standard would not be met in most of the sensitivities

Figure 1. Capacity margins in the base case of the Mid-term Adequacy Report



studied in this Adequacy Report, and the specific problem about maintaining the voltage level in western France would worsen significantly. This period combines two major risk factors: (i) A particularly heavy maintenance programme for the nuclear fleet with numerous simultaneous ten-year inspections, (ii) The final shutdown of nuclear power plants in Germany and the closure of coal-fired power plants in a large number of European countries.

3. Between 2023 and 2025, based on the last schedule for the Flamanville EPR, the level of security of supply in France should improve. During this period, some of the projects started in recent years should show their contribution (commissioning of several offshore wind farms, turning points in the trajectories for onshore wind and solar energy). The nuclear fleet maintenance programme also looks more favourable by this time, although a conservative approach has been adopted in this Adequacy Report.

At a local level, RTE's analyses give the following results:

- There is no specific local risk in Alsace or Lorraine (with the announced closure of the Fessenheim and Saint-Avold power plants), in Provence-Alpes-Côte d'Azur (Gardanne power plant) and Normandy (Le Havre power plant);
- However, there is a specific risk in western France, and particularly in Brittany, if the closure of the Cordemais power plant is not counterbalanced by the commissioning of Flamanville EPR.

The Winter Adequacy Outlook and the Mid-term Adequacy Report contain numerous sensitivities, which are given in the full report. The assumptions have been discussed in a public consultation carried out in the spring 2019 with all stakeholders. The following conclusions emerged from the consultation:

- The actual level of security of supply currently depends on numerous parameters, which, when taken individually, may have an important effect on the result. Several of these parameters do not come from the national energy plan (e.g. actual availability of nuclear energy) or depend on the changing situation in neighbouring countries.
- In all the sensitivities studied, the period 2021-2023 is the most sensitive and accounts for the majority of the risks. The size of the nuclear fleet maintenance programme and the changes announced across the European fleets are the main factors requiring attention in this period.
- There are still many uncertainties in the period up to 2022, which may affect the actual level of security of supply, either improving or worsening it.

Levers for security of supply

The additional analyses on the supply-demand balance submitted by RTE to the minister on 3 April 2019, identified three levers that could improve the security of supply at national level:

1. Controlling demand, especially during peak periods;
2. Optimisation of the schedule and duration of nuclear reactor downtimes;
3. Maintaining the Cordemais power plant or converting one or two units to biomass.

These levers are also examined in the new French Mid-term Adequacy Report 2019. Each of them can lead to an increase of at least 1 GW on the capacity margins by 2022, thus enabling compliance with the security of supply standard.

With regard to controlling demand, RTE is carrying out a more in-depth assessment and providing a quantified assessment of the various possible actions, concerning both structural actions (control of energy demand), short-term actions (control of power demand during winter peaks) and eco-gestures.

RTE suggests to generalise the EcoWatt information system at national level for winter 2020, and to study solutions to enable one-time actions for certain types of consumption (advertising boards, etc.) during periods of strain on the grid.

With regard to optimising the schedule and duration of nuclear reactor shutdown, the discussions initiated by the State have not, at this stage, enabled to identify much leeway on the announced schedule, in particular concerning ten-year inspections. Strict compliance with the ten-year nuclear reactor inspection schedules, as announced by the operators, would give an increase of around one to two gigawatts depending on the winter weather.

For the third lever, the conducted investigations confirm the conclusions presented in April 2019 on the need to maintain the Cordemais power plant or convert one or two units to biomass (with unchanged standards in terms of security of supply). Several operating modes have been assessed for this power plant in the report (including various limits on the number of operating hours): all these modes can lead to ensuring security of supply in western France and compliance with the national security of supply standard.

A power system in transition

The analysis carried out in the context of the French Mid-term Adequacy Report illustrates the transformation of the power system taking place over the next few years, beyond the simple question of the effect of closing Fessenheim and the coal-fired power plants.

It shows that, even considering gradual trajectories for the development of renewable energies, they should account for almost 30% of the electricity production mix by 2025, as against around 65% for nuclear energy and approximately 5% for fossil fuel powered thermal generation.

With a fleet that is 95% low-carbon, from which the plants with the highest emission levels have been removed, greenhouse gas emissions associated with electricity generation in France should continue to fall, and should stabilise at a level of between 10 and 15 $MtCO_2$ by 2025 (at normal temperatures and with reference availability of the nuclear power fleet). This is one of the lowest levels in Europe.

Despite the daily and seasonal variability of wind and solar generation, in these timescales their development is not dependent on the development of storage solutions. In most cases, the growth of renewable generation in France will lead to the replacement of gas and coal-fired generation outside France, and therefore contribute to the reduction of greenhouse gas emissions on a European scale.

In this context, and even incorporating a downscaled estimate of nuclear power generation (due to the size of the ten-year inspection programme), the export-oriented nature of the electricity exchanges between France and its neighbours should continue, or even increase:

- France should continue to export most of the time, even taking into account the renewable energy development programmes announced by neighbouring countries.
- The net export balance could increase and reach levels of more than 80 TWh by the end of the period (at normal temperatures and with reference availability of the nuclear power fleet).

The prospects for changes in electricity demand include the prospect of transfers of use in line with the rates given in the draft National Energy and Climate Plan and the National Low Carbon Strategy. Over the next few weeks, RTE will complete the work programme undertaken in the context of the consultation:

- On the development of e-mobility (main results published in May 2019);
- On the production of low-carbon hydrogen (main results to be published in December 2019);
- On thermal uses in buildings (joint study with ADEME) (main results to be published in spring 2020).

RTE produces the French Mid-term Adequacy Report each year in accordance with Article L. 141-8 of the French Energy Code.

All interested stakeholders are consulted as part of a public consultation on the assumptions, with a presentation of the interim results and a collective analysis of the priorities for studies.

The report is part of a work programme, which changes according to stakeholders' requirements, and is discussed at consultation meetings organised by RTE (System and Grid Prospects Committee). The subjects of some of the analyses presented in the context of the Mid-term Adequacy Report may, therefore, be investigated further (for example imports/exports, e-mobility, hydrogen or the building sector by 2030-2035). These reports on specific subjects are public and are available on the RTE website.

This report is the short version of the full Mid-term Adequacy Report (which includes the results for all the sensitivities).

CONTENTS

THE CURRENT LEVEL OF SECURITY OF SUPPLY

Security of supply: a broad term covering many challenges

Security of supply refers to the ability of a power system to provide a reliable electricity supply for consumers and to guarantee a certain level of service.

It is a very broad concept, encompassing a whole range of different issues. Considering the electricity supply, without taking any difficulties associated with energy independence or security of supply of critical raw materials and fuel into account, the following parameters can be identified:

1. **Generation fleet and demand-side response capacity:** This involves checking that the electricity mix has sufficient capacity to ensure a balance between demand and supply in the majority of conditions (excluding exceptional events), including cold waves, damage to production facilities and even extended periods of low wind. A statistical standard set by the government defines the acceptable level of risk for society in terms of an imbalance between supply and demand.
2. **Real-time operational safety** (frequency balancing): This involves checking that the power system is capable of responding rapidly to an unforeseen event (causing the loss of one or more power plants, for instance) affecting the balance between supply and demand on a European scale. The electricity mix must offer appropriate generation and flexibility measures, such as demand response and storage, to be able to react quickly to stabilise the frequency.
3. **Management of the voltage map:** This involves checking that the generation and distribution network infrastructure is capable of maintaining the nominal voltage level across the whole country. This issue is related to the geographical distribution of production facilities. Some of the regions with the fewest production facilities may require extra vigilance to mitigate the risk of voltage collapse in extreme conditions (e.g. a cold wave, simultaneous unavailability of power plants in the area or transmission network unavailability).

1 Generation fleet and demand-side response capacity

HOW MUCH generation and demand-side response capacity is needed to cope with certain extreme events, such as cold waves, reactor unavailability or low wind?

2 Real-time operational safety (frequency balancing)

HOW will this capacity respond in real time to an unforeseen event? Is it sufficient to stabilise the frequency?

3 Management of the voltage map

WHERE are the production facilities located? Are they distributed to ensure voltage stability across the whole country?

RTE employs a number of different measures to balance the power system in terms of demand and supply, frequency and voltage. These measures can be defined as "standard" (generation and demand-side response capacities driven via the market and the balancing mechanism) and "post-market" (eco-gestures, assistance contracts with European TSOs, reducing operating margins, adopting interruptible load schemes, and lowering the voltage on distribution networks).

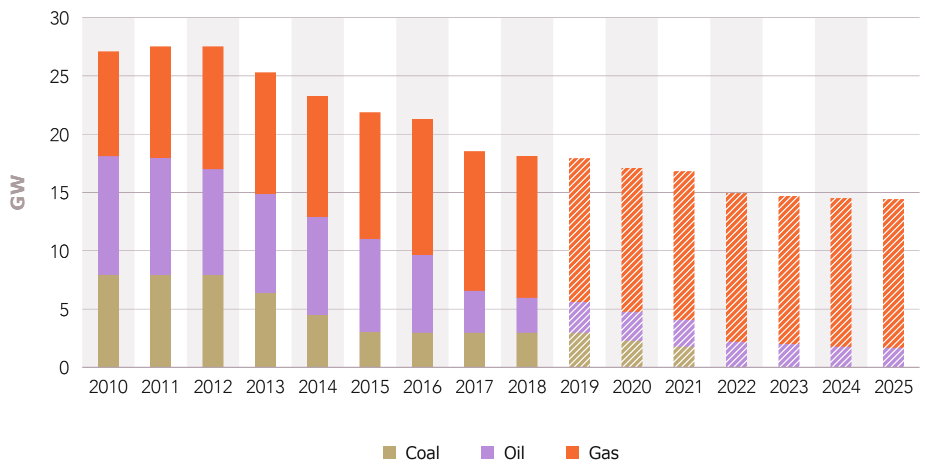
As a last resort, RTE could impose temporary, localised rolling load sheddings to ensure security of supply to the majority of consumers (thus avoiding a total blackout).

The generation fleet capacity is now sized at a level very close to the statutory "three-hour rule"

The French generation fleet capacity has always ensured compliance with the security of supply standard set by the government, which corresponds to a loss of load expectation of less than three hours a year[1].

The closure of coal and oil-fired power stations over recent years has nonetheless led to the surplus capacity being reabsorbed and lower margins for the power system, aligning the security of supply level much more closely with the regulatory standard.

Figure 2. Evolution of the installed capacity of fossil fuel plants in mainland France at the 31st of December of each year (historical data and forecasts)



1. The French government set out the security of supply standard (known as the "three-hour" standard) in its National Energy and Climate Plan by introducing the notion of loss of load, defined as a situation of imbalance between supply and demand requiring activation of post-market measures, and also imposing an additional standard on the expected level of load shedding, which should remain below an average duration of two hours per year. The first analyses conducted by RTE demonstrate that these two criteria are equivalent, given the volume of post-market measures available in France.

Compliance with the security of supply standard means that the level of risk of an imbalance between electricity supply and demand – also known as "loss of load" – is consistent with that defined in the regulations.

Currently, this risk essentially arises for extreme cold waves or periods of simultaneous unavailability in the nuclear fleet, such as when several reactors are shut down by the producer or at the behest of the French Nuclear Safety Authority (ASN).

The stress test analysis conducted in the Mid-term Adequacy Report 2019 (see Chapter 3 – Adequacy assessment) illustrates the extreme conditions presenting a risk of imbalance between supply and demand.

In such conditions, RTE activates the aforementioned post-market measures to avoid or at least limit the use of load shedding. Activation of these post-market measures is not a reflection of system vulnerability; on the contrary, in a balanced system compliant with the three-hour standard, the probability of having to resort to a post-market measure at least once a year is around 25%.

The challenges of the real-time system operations are now more apparent since the activation of interruptible load capacities in 2019

The power system has to contend constantly with real-time variations in supply and demand.

These variations are caused by random events, like unplanned downtime of a production facility or last minute changes to production schedules, or by forecast deviations, such as a deviation from the temperature forecast having a direct impact on consumption ones. They can affect the balance between production and demand and potentially disrupt the frequency of the entire European power system.

RTE has a number of different operating reserves that can be activated at any moment to counterbalance these variations relatively quickly and rebalance the system. The primary reserve – or primary frequency control – is the most responsive of all these reserves, and is the one that can be activated the fastest, allowing automatic rebalancing of the frequency within just a few seconds. The other reserves contracted by RTE (secondary, rapid and complementary reserves) can then take over to balance the system over longer timeframes.

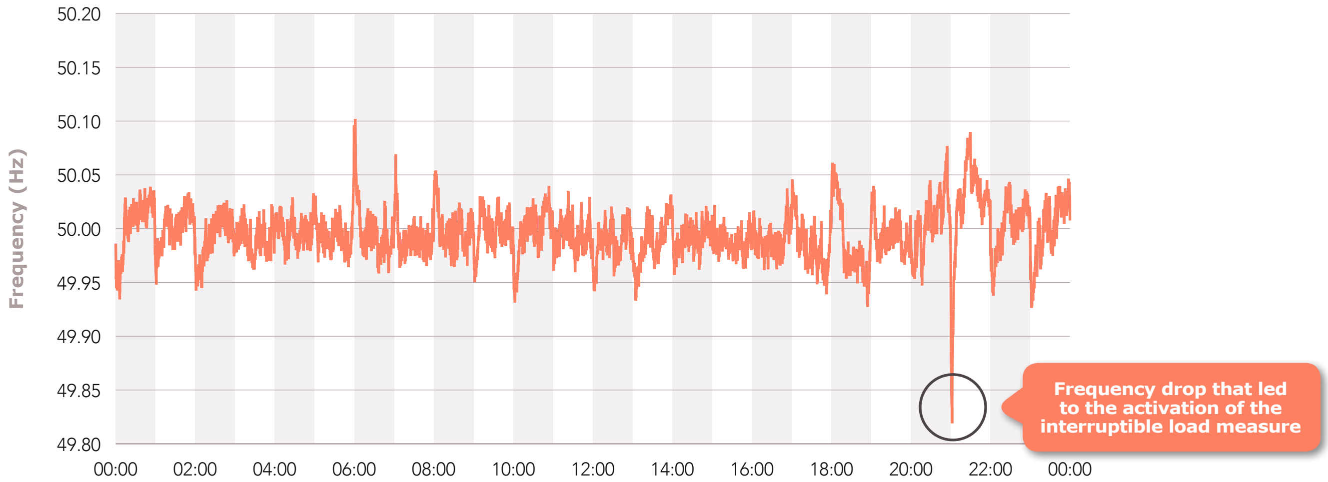
In the (seldom) case that activating these reserves does not re-establish the balance between supply and demand and stabilise the frequency, other operational measures like the interruptible load programme for large industrial consumers can be called upon. This service is available as part of an annual contract and provides the option to interrupt demand at designated sites for a few seconds at times of stress on the grid, or if the frequency on the European power system varies from its nominal 50 Hz level.

This measure had to be activated twice in 2019 to balance the frequency automatically; firstly, on 10 January and, secondly, on 7 October. Contrary to some explanations given in the press and on social media, activation of this device did not mean that France was on the verge of a blackout on these two days. It simply demonstrated that these highly responsive mechanisms can offer appropriate solutions in certain circumstances to manage certain operating conditions on the power system.

Articles published in the trade press did, however, illustrate the complexity of the involved mechanisms.

These activations indeed occured outside the normal configurations most often described as likely to disrupt power supplies. Numerous generation and demand-side response capacities were actually available on both 10 January and 7 October 2019. Automatic activation of the interruptible load programme in these circumstances did not,

Figure 3. Frequency modulation on 7th October 2019



therefore, reflect a deficit of supply on these two days. In fact, these events represented a difference in dynamics between the change in generation, which adapts to market mechanisms, and the change in demand for electricity, not only in France, but also around the whole European grid.

These structural imbalances take up a relatively large proportion of the reserves required to stabilise the frequency in response to an unplanned event, particularly on the production side.

Hence, in situations like this, occurring around the "round" hour, the system must be capable of responding to an urgent need to control the frequency, especially when (i) significant variations in electricity generation and exchange programmes at interconnections and (ii) one or more random events affecting production or the European grid occur simultaneously.

Frequency deviations of this magnitude are nothing new:

- These kind of deviations have been observed regularly for several decades, particularly on the "round" hour, at times when the generation and interconnection exchange programmes show substantial variations[2].
- **These frequency deviations are not linked to the development of renewable energies and would also have occurred in an electricity mix made up exclusively of nuclear, thermal and/or hydro power plants.**

In collaboration with its European counterparts, RTE has been researching market regulation solutions or changes aimed at improving frequency control and limiting the risk of significant deviations. Several combined factors help to manage these situations:

- Improving the speed of response of the primary reserve, the first measure activated to control frequency deviations in response to rapid deteriorations in supply, which can occur in just a few seconds;
- Having a variety of production balancing measures available that are adapted to the transient nature of balancing in these situations and which can be activated rapidly within very short time frames;

2. See the ENTSO-E report "Continental Europe Significant Frequency Deviations – January 2019"

- Reducing the programmed intervals for cross-border exchanges, which occur mainly on an hourly basis at present, and smoothing the variations associated with production.

RTE has decided, as an initial step, to enhance control of the technical capability of the generators providing the primary reserve, in such a way as to gradually prevent production units that do not meet the required responsiveness specifications from participating in frequency control actions (certain run-of-the-river hydroelectric generators, for instance).

The difficulty to manage the voltage map now only concerns the north west of France

The notion of balanced supply and demand does not really make sense on a regional level, since grids allow the generation and demand-side response capacities to be pooled and manage this balance at a national and even European level, which is much more efficient from both a technical and an economic viewpoint.

This broader balance is dependent on the grid's transmission capacity, which are not infinite.

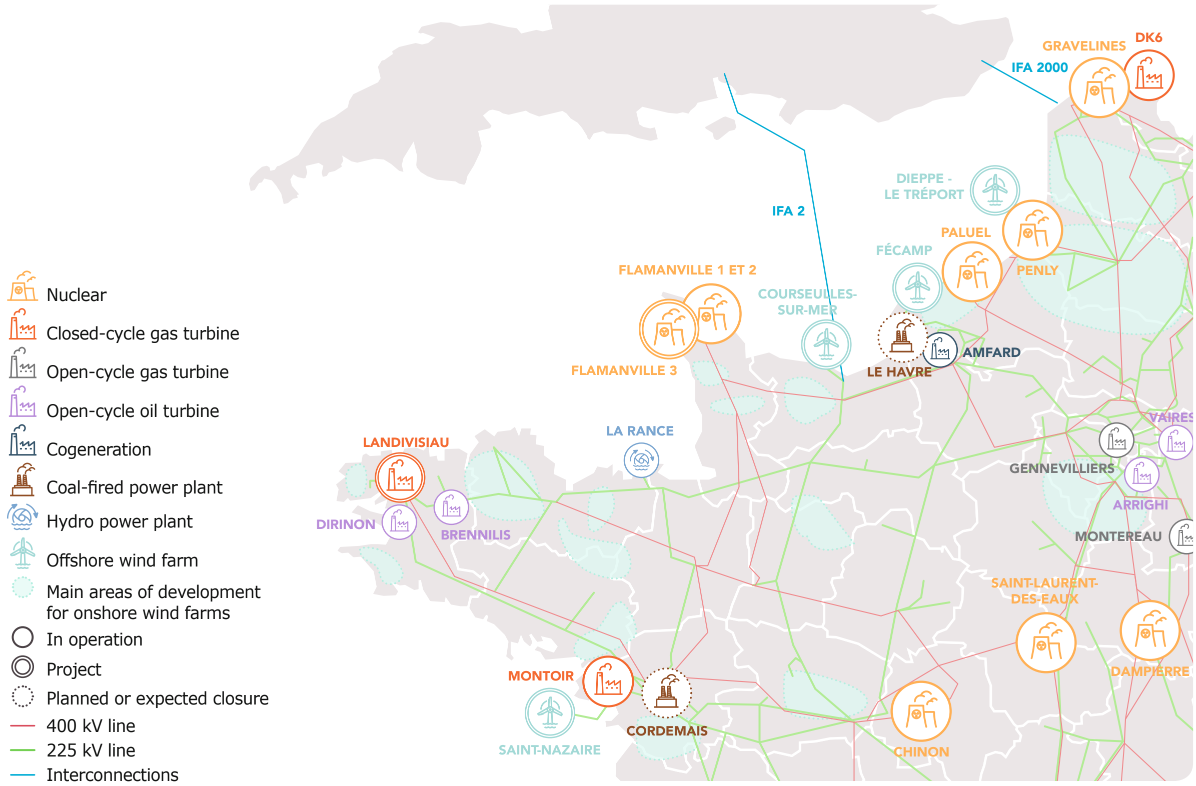
More specifically, maintaining the voltage on the grid can generate a need for specific scrutiny in regions with high demand levels and few production facilities. In the event of an extreme cold wave and/or the unavailability of certain capacities in these regions, there may be a risk that some facilities fail to maintain the voltage, leading to cascading failures and outages on large sections of the grid (known as the voltage collapse phenomenon). To prevent such a widespread incident, RTE can activate post-market measures, as described previously.

Only the north-west region of France is currently affected by this need for heightened scrutiny. This situation was described in detail in the latest publications on security of supply (Mid-term Adequacy Report 2018 and the paper on the Pays de la Loire region in the additional analyses report submitted in April 2019). **It calls for specific recommendations on how production at the Cordemais power station can be developed over the coming years** (see Chapter 3 – Adequacy assessment).

The eastern Provence-Alpes-Côte d'Azur (PACA) region, formerly referred to as an "electricity peninsula" like Brittany, is no longer in the same situation. Power supplies here have been secured by reinforcing the grid (known as the "PACA safety net") and developing production in the Fos industrial zone west of Marseille.

Eastern France is a region where electricity generation is very well developed, with a meshed grid: this means there are no local security of supply issues to report or consider here.

Figure 4. Map of the transmission network and the main production facilities in north-western France



TRENDS IN ELECTRICITY SUPPLY AND DEMAND OVER THE COMING YEARS

Electricity demand remains stable in France

The French electricity demand has been in a relatively stable phase since the early 2010s. This structural slow-down in consumption, which has also been observed in most European countries, is essentially due to the effect of energy efficiency measures and the "tertiarisation" of the economy (as the service sector consumes less energy than industry at an equivalent production level).

This trend continued in 2018 with electricity consumption (seasonally adjusted for climatic fluctuations) which was stable in comparison with the previous year. More precisely it was even slightly lower (-0.3%) due to economic factors, in particular slower economic growth than in 2017 and significant industrial action in the rail transport sector in the spring.

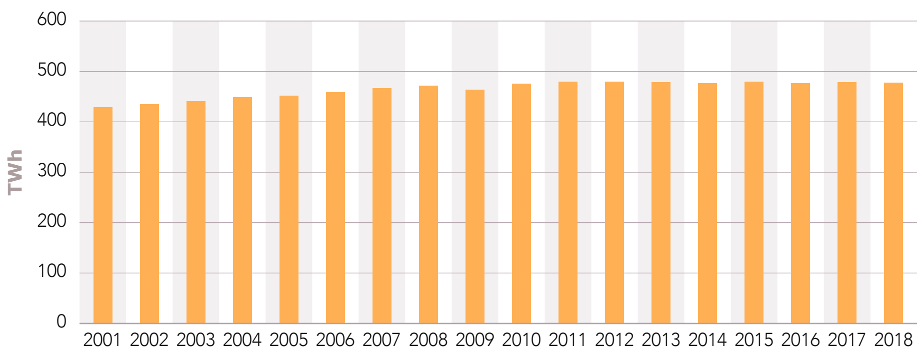
According to the provisional data available at the end of September, this trend also seems to have continued in 2019, and there may even have been a further slow-down, as electricity demand (adjusted for fluctuations) has felt by 0.5% over the first nine months of the year, in comparison with the same period in 2018.

The general trend towards stability or a slight decrease over the next few years has therefore been retained in the Mid-term Adequacy Report 2019.

For the next few years, the French Mid-term Adequacy Report 2019 base case assumes, like in the previous French adequacy report, a stable electricity demand in France up to 2025. Several sensitivities are also studied in order to reflect the uncertainty around this assumption and to assess the robustness of the results with regard to security of supply in the face of changing consumption.

The Mid-term Adequacy Report 2019 also includes an in-depth analysis of the initiatives to control demand and their potential impact on demand peaks (see the section on levers) and focuses on the introduction of new uses of electricity (electric vehicles, hydrogen, heating, etc.) over the coming years.

Figure 5. Electricity demand (adjusted for weather fluctuations) in mainland France, excluding uranium enrichment



The sector of demand-side response is still taking shape

Demand-side response (DSR) is a technical method that is particularly suitable for dealing with consumption peaks.

In-depth technical and regulatory work has been carried out for several years to open up all mechanisms to DSR (offered by suppliers or independent operators of DSR programmes). This work has been successful and there is genuine competition in this segment.

This technical work is accompanied by an explicit policy to support demand-side response in order to achieve specific targets for the sector, as set out in the National Energy and Climate Plan.

However, the growth of DSR and its contribution to the security of supply has been slower than initially expected. There are three reasons for this.

The potential amount of DSR to be installed over the coming years is being revised to make it more realistic. The draft National Energy and Climate Plan confirms the objective of developing the sector, with a target of 6.5 GW of demand-side response capacity by 2028, but has adopted a more gradual approach, introducing an intermediate target of 4.5 GW by 2023. This development target is still ambitious, as the current demand-side response capacity is estimated to be 2.9 GW (with 2.3 GW certified capacity in 2019 and 0.6 GW of implicit demand reduction).

In addition, **the issues of the reliability of the sector of demand-side response, identified several years ago, have still not been resolved.** As the suggested solutions (stricter controls) did not significantly improve reliability, a second set of measures has been set up **by RTE to provide a more robust overall view of reliability** (introduction of processes for "close" monitoring of DSR performance, and activation tests).

Recent analyses confirm that the reliability of demand-side response is below the one of other generation types, with a tendency to overestimate the available power and inaccurate activation. This lack of reliability must be monitored with regard to the contribution of DSR to security of supply and real-time load balancing of the power system.

This lack of reliability can be explained in part by the specific features of the sector (the demand that can be reduced depends on the level of consumption, which is by nature variable). However, it is not inevitable. RTE's analyses show a considerable disparity in the reliability of those involved in the sector, even amongst those operating on sites with similar profiles. Several operators have reliability levels significantly higher than the average for the sector. The downward trend in performance levels has been halted (with even a slight improvement in reliability in the first half of 2019 according to the provisional figures).

Finally, **one of the current objectives of the French government is "greening" the sector of DSR having a public support.** In fact, a large proportion of the DSR in previous dedicated calls for tender were carried out by means of power generators, thus leading to additional CO_2 emissions[3]. Part of the current transition therefore consists of changing the type of demand-side response and increasing the volume of "green demand-side response".

In this context, **the Mid-term Adequacy Report 2019 has adopted a conservative approach to assess sources of DSR over the coming years.** Therefore, in the base case of the study, the targets of the National Energy and Climate Plan are on the way to being achieved by 2023, with the possibility of a slight delay or improved reliability in comparison with today, but not meeting the theoretical target. Sensitivities on either side of the base case are also tested.

3. For example, activating a generator emits more than activating an oil-fired combustion turbine to deal with the peak.

Ambitious targets for the development of renewable energies are defined in the draft National Energy and Climate Plan, with a significant contribution to the security of supply

In November 2018, RTE stated in the French Adequacy Report that maintaining the development trajectories for renewable energies not only constituted a challenge for "greening" the mix, but was also necessary for security of supply.

This is still the case: the analyses of the Mid-term Adequacy Report 2019 highlight that the stated trajectories must be maintained with regard to wind energy (onshore and offshore) and need to be speeded up considerably for solar energy.

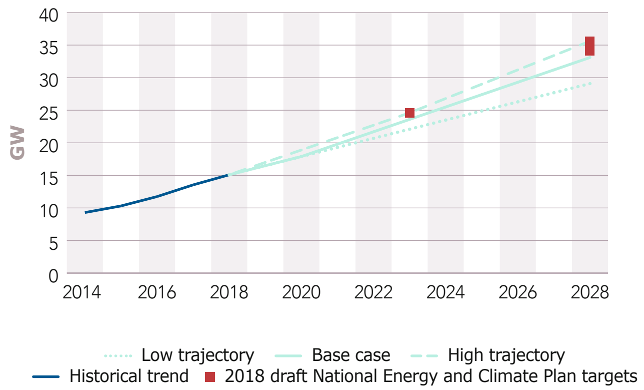
Hydropower is currently the main form of renewable energy. Over the coming years, the Mid-term Adequacy Report assumes a very low increase in total hydropower generation (the objectives set out in the draft National Energy and Climate Plan are essentially aimed at ensuring the sustainability of total hydropower generation, as no new large facilities are planned), which is second-order in relation to the capacity currently installed.

The French onshore wind sector has been developing fast in recent years. The implementation of the full regulatory framework, along with the simplification and acceleration measures that have been identified, should secure the sustainable development of the sector and meet the targets of the National Energy and Climate Plan. Since 2016, the development of wind energy has not led to any negative adjustment of the security of supply.

The development of the offshore wind sector now seems to be well under way. On 7 June 2019, after several years of litigation, the French Council of State dismissed the final appeal against the Saint-Nazaire wind farm. A number of other appeals, concerning the Fécamp, Courseulles-sur-Mer and Saint-Brieuc wind farms, have also been rejected. The Mid-term Adequacy Report base case adopts a trajectory in line with the project schedules of the first calls for tender, with commissioning of the first offshore wind farm in 2022, followed by five more farms, covered by calls for tender no. 1 and no. 2, between 2023 and 2025. This will provide a total installed capacity of almost 3 GW by 2025.

The photovoltaic sector is still not developing at the rate needed to meet the announced government targets. The Mid-term Adequacy Report base case has therefore adopted a more conservative development trajectory for this sector, in line with the observed historical rate for the next two years and then incorporating a turning point.

Figure 6. Evolution of the onshore wind and solar capacities



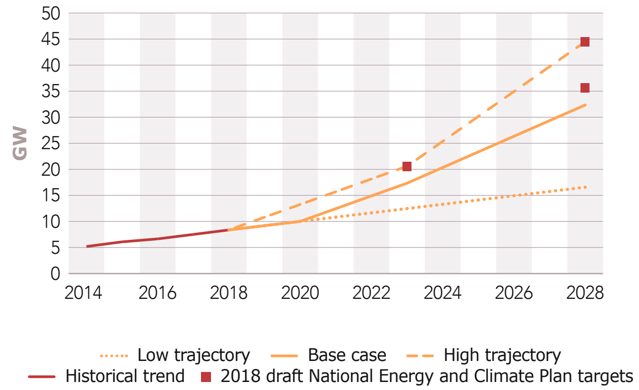
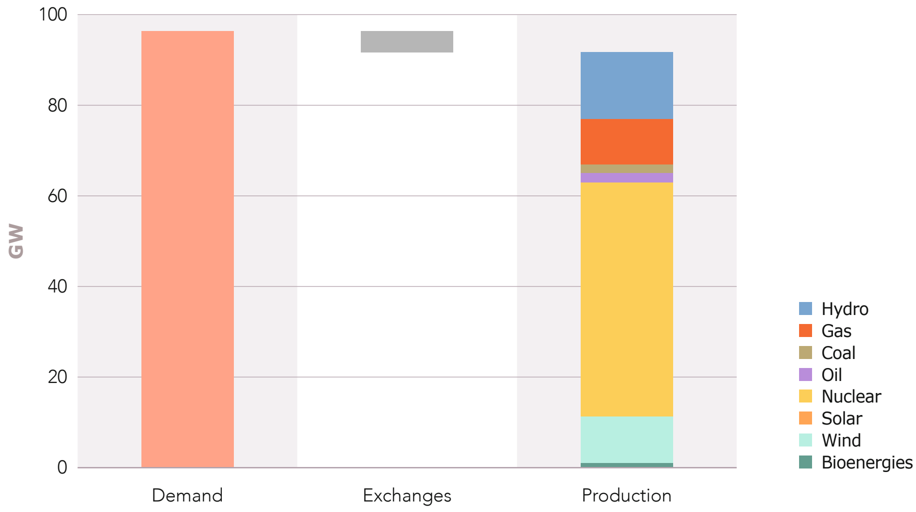


Figure 7. Production mix observed at 7 pm on 28 February 2018



Focus on demand
Demand: 96.6 GW
3rd highest recorded peak

Focus on nuclear
Production: 51.6 GW
7 reactors unavailable

Focus on wind
Production: 10.3 GW
Load factor: 75%

These sectors, in which production is by nature variable, make a significant contribution to the security of supply.

For example, the production mix on 28 February 2018 illustrates the contribution of onshore wind energy to the security of supply, in a situation of high demand (third highest annual demand peak in France) and reduced availability of nuclear energy (seven reactors unavailable). **The very high wind energy load factor, approximately 45% in the morning and 75% in the evening, ensured a balance between supply and demand. Although there was some strain on the power system, the situation was not close to a blackout:** it did not require any post-market lever to be activated.

This situation is not generally applicable and does not guarantee the availability of wind energy in every winter periods though: there are also periods during which the contribution of wind energy is very low, with load factors significantly below 10%. This example does however highlight that in some cases the peak production of this sector can contribute significantly to security of supply.

The representation used in the Mid-term Adequacy Report allows to identify periods of light wind (and periods of high production) based on very detailed climate modelling.

The mid-term horizon: a pivotal period for the nuclear fleet combining numerous uncertainties

The nuclear sector generates the majority of the electricity produced in France. It is therefore essential to carry out a detailed analysis of how it is changing.

The previous French Adequacy Report 2018 listed a number of uncertainties, which still exist, apart from the closure date of the Fessenheim power plant, which has now been clarified.

In its forecasts, RTE includes a downward trend in the availability of the nuclear fleet, listing three factors, which require monitoring:

1) The commissioning date for the Flamanville EPR (European Pressurised Water Reactor)

2) The schedule and duration of the ten-year inspections

3) The availability of reactors during other outages than ten-year inspections

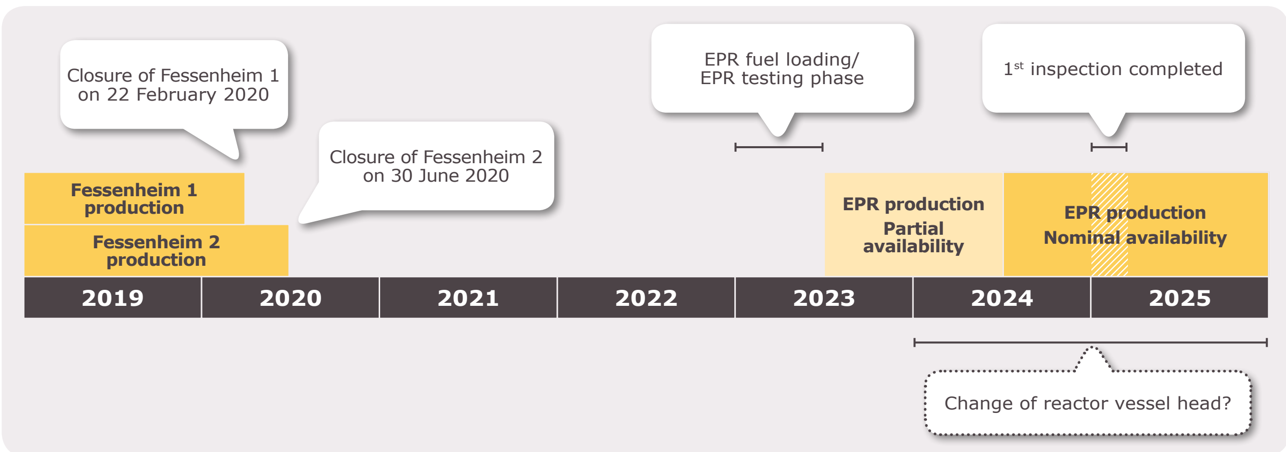
The closure dates for the Fessenheim reactors have now been clarified, but there is still uncertainty about the schedule for the start up of the Flamanville EPR

In early October 2018, following the announcement of another postponement of the commissioning date of the Flamanville EPR, the French Minister for Ecological and Inclusive Transition dissociated the Fessenheim power plant closure schedule from the Flamanville EPR commissioning schedule for the first time.

This scenario was studied in the French Mid-term Adequacy Report 2018. It did not reveal any problems in terms of security of supply connected with dissociating the closure of the Fessenheim power plant and the commissioning of the EPR, provided that the Flamanville EPR is commissioned by 2022 at the latest.

The draft National Energy and Climate Plan, published in January 2019, gave details of the closure schedule, announcing **the shutdown of both Fessenheim reactors in spring 2020, stating it is not conditional on the commissioning of the Flamanville EPR.** These schedules have been confirmed by the shutdown dates announced by the producer on the European Transparency Platform in May and by a press release issued at the end of September. EDF then submitted a request for approval to the French Minister and the Nuclear Safety Authority (ASN) for the revocation of operations and permanent shutdown of both reactors at the Fessenheim nuclear power plant. The closure

Figure 8. Evolution of nuclear capacity in the base case



of reactor no. 1 is now scheduled for 22 February 2020, and that of reactor no. 2 for 30 June 2020.

Although the shutdown of the Fessenheim power plant is now scheduled for the first half of 2020, the commissioning date for the Flamanville EPR has been postponed after the end of 2022 at the earliest. According to information issued in early October 2019, the scenario preferred by EDF for the repairs to the welds on the main secondary system (using remote-controlled robots) has not yet been validated by the ASN. If this scenario is validated by the end of 2020, EDF indicates that it can envisage a fuel loading date at the end of 2022.

This now means that there is no possibility of the Flamanville EPR being commissioned in the next two years (even though this was envisaged by EDF a year ago) and confirms that there will be a significant delay between the closure of Fessenheim and the commissioning of the Flamanville EPR, which will be much longer than had been considered until now.

There is therefore no doubt that the production capacity will be lower over the next few years. There is still considerable uncertainty about the date by which the Flamanville EPR will be producing at full power.

In this context, the Mid-term Adequacy Report 2019 has adopted a conservative approach:

- The assumption in the base case is commissioning of the Flamanville EPR in 2023, with only partial availability during the first few years of operation;
- Analyses are also carried out with a sensitivity involving commissioning after 2025, so that the assessment in the Mid-term Adequacy Report is not totally dependent on the assumption regarding commissioning of the Flamanville EPR.

The schedule and the duration of the ten-year inspections, and in particular the fourth inspections, must be managed

The actual availability of the reactors is a key factor in studies on security of supply, especially as the programme to extend the lifespan of reactors beyond 40 years is just about to start. Around forty reactors are due to undergo ten-year inspections during the period 2020-2025. For more than half of them this will be their "fourth ten-year inspection" (for reactors of 900 MW). As these inspections are the first ones of their type and the Nuclear Safety Authority has not yet published any generic opinion on the subject, this issue requires close monitoring in the analyses of this adequacy report.

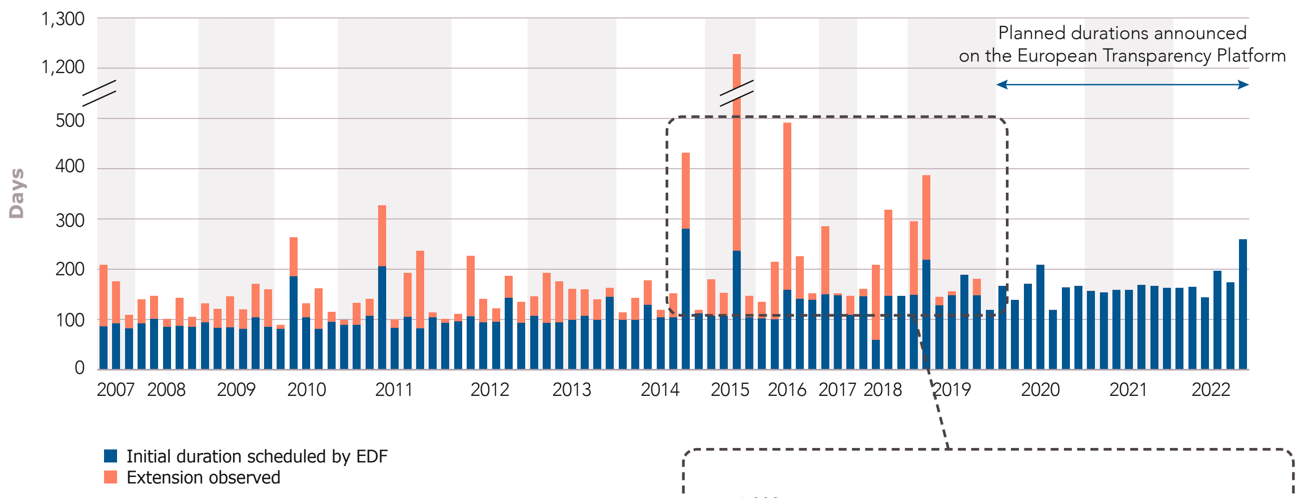
To take account of these issues, the analyses in the French Mid-term Adequacy Report 2018 were based on refined availability assumptions for the winter, according to the ten-year inspections schedule. This modelling was used to assess the specific situation of each of the coming winters according to the reactor outages already scheduled, and the consequences of any extensions of these stoppages beyond the projected timescales. It allowed to identify winters where there may be particular strain on the power system, in 2021-2022 and 2022-2023, with respectively four "risky" ten-year inspections (affecting the midwinter if extended by two months), and three ten-year inspections already scheduled for January. This modelling is used in the Mid-term Adequacy Report 2019.

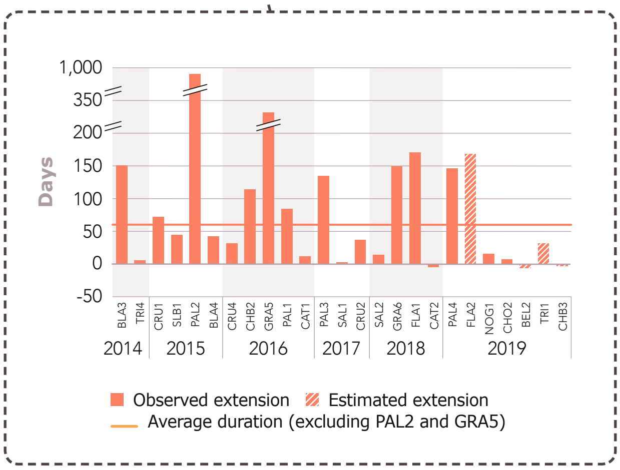
Likewise, the Mid-term Adequacy Report 2018 base case assumed that the average extension of the duration of the ten-year inspections was two months, based on data from previous years.

Since then, the tendency for the durations of ten-year inspections to be extended in relation to the initial schedule has continued (with an average of approximately 60 days). The analysis also shows considerable variability in the extensions observed (from 0 to 6 months, apart from the Paluel 2 and Gravelines 5 ten-year inspections that were considered as outliers, with 25% of the ten-year inspections extended by 4 to 6 months).

The base case of the Mid-term Adequacy Report 2019 therefore maintains the assumption of an average extension of two months for each of the scheduled ten-year inspections. The modelling is enhanced to take account of the variability of the lengths of the extensions around this average, by adopting a probabilistic representation of this extension.

Figure 9. Initial durations scheduled by the operator and extensions observed on 1st November 2019





Scenarios corresponding to compliance with the current schedules for the ten-year inspections and a scenario involving a higher deviation from the schedule are also studied.

Other outages (than ten-year inspections) have also become more frequent

The stoppages for ten-year inspections are well known, but they are not the only reasons for reactor outages.

Each reactor is stopped regularly between two periodic reviews, for refuelling only or for a partial inspection. Some of these stoppages can be quite long, especially if they include changing major industrial components (for example steam generators).

Several specific problems have been mentioned in recent months.

In September 2019, EDF informed the Nuclear Safety Authority (ASN) that the technical fabrication standard of some welds on steam generators were not compliant with the technical expectations. Although these non-compliances do not require the six reactors concerned to be shut down, the welds in question will have to be examined during future scheduled stoppages of the reactors.

At the same time, the ASN placed the Flamanville reactors 1 and 2 under "increased monitoring" following numerous issues encountered on this power plant in mid-2018. The availability of these reactors is crucial for maintaining the voltage level in western France (see Chapter 3 – Adequacy assessment). In January 2019 there was also a period during which both reactors were unavailable simultaneously, which led to very close monitoring of the power supply to north-western France. This monitoring is maintained for the coming winters, in particular winter 2019-2020, as the ten-year inspection of reactor no. 2 has been extended to 31 January 2020, i.e. almost six months later than the initial schedule for its return to service.

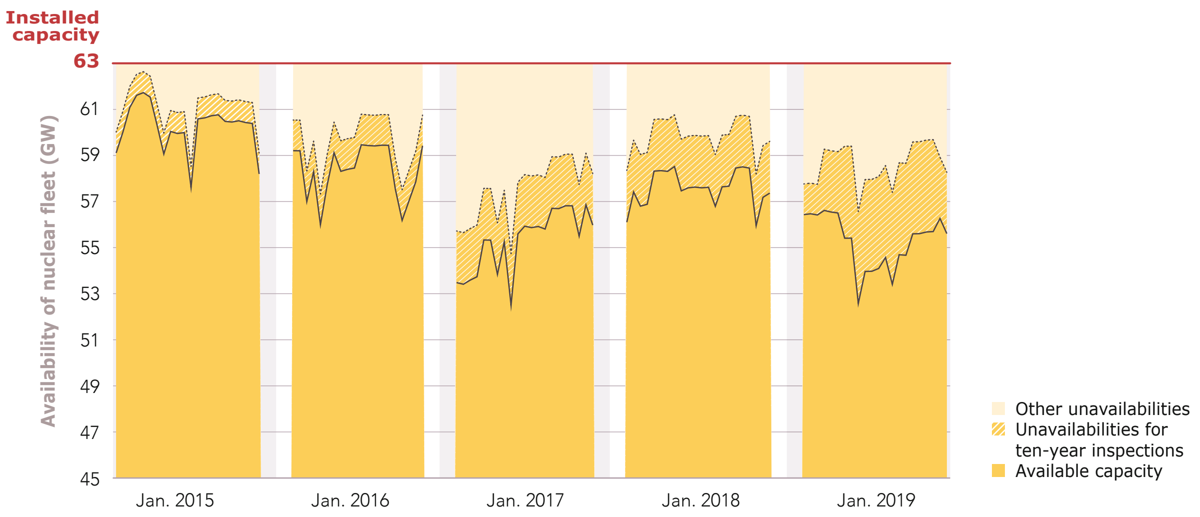
The reactor no. 1 was also stopped until at least 15 December 2019, after a ten-month stoppage in 2018.

There are also other extensions to scheduled outages, including on the Paluel no. 4 reactor. These large numbers of extensions have forced the operator to revise the nuclear production forecast downwards for 2019.

Over the coming years, some "risky" (potentially affecting the midwinter) scheduled outages have been identified in connection with the programme of extending the lifespan of the French nuclear reactors (for example changing the steam generators on the Flamanville reactors). These stoppages are simulated using a probabilistic approach in the model.

This shows that monitoring the unavailability of nuclear reactors must be maintained over the coming years, beyond the specific question of the ten-year inspections.

Figure 10. Unavailability of the nuclear fleet during working days in January (2015-2019)



The prospects remain unchanged for the fossil fuel fleet

Coal-fired power plants: the target to end electricity generation using coal by 2022 is maintained, with still some uncertainties on the closure dates of some units

The French coal-fired power plants are currently operating episodically.

The analysis of their production over the past few years shows a generating level that is now very low. This is explained by the industrial action that has affected the various coal-fired power plants in France, and also by a smaller potential market for these plants.

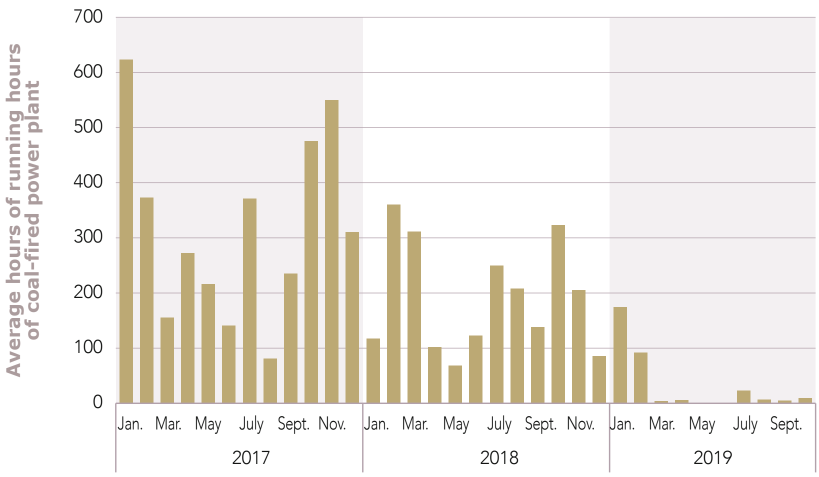
The steady development of renewable energies, the increased carbon price and the renewed competitiveness of gas-fired generation facilities are questioning more and more the economic viability of coal-fired power plants Europe-wide. This seems to be confirmed by the analysis of the changing production of the German coal-fired power plants, which was in sharp decline at the start of 2019.

The current draft National Energy and Climate Plan reaffirms the objective of closing the last exclusively coal-fired power plants in France by 2022. To this end, the energy-climate law passed by the French parliament in September includes provisions to substantially limit the generation of these power plants from 1st January 2022, in the run-up to their closure.

In the Mid-term Adequacy Report 2019, the base case has considered a trajectory for the closure of the coal-fired power plants, which is structured as follows: closure of one plant in 2020, one in 2021 and three in 2022. This trajectory includes the announced closure of the Le Havre power plant in 2021 and adopts a gradual closure of the other coal-fired plants, in the absence of any timetable established by the operators.

In addition, EDF is continuing to study the Ecocombust project to convert the Cordemais power plant to operate with a mixture of biomass (wood waste in particular) and coal. This conversion has not been included in the base case of the Mid-term Adequacy Report 2019, but is included in the sensitivities detailed later in this document.

Figure 11. Average monthly operating time of coal-fired power plants



Other thermal generation units: the commissioning of the Landivisiau combined cycle gas power plant is still planned for the end of 2021; overall stability of the rest of the thermal power capacity

In the context of the Mid-term Adequacy Report 2018 and the additional adequacy study published in April 2019, the commissioning of the future Landivisiau gas-fired power plant is seen as an important factor for ensuring security of supply in France generally and western France in particular.

In its report on April 2019, RTE set specific milestones to be met by Total Direct Énergie so that RTE can continue to consider the commissioning of the plant to be a credible solution for the security of supply by 2022.

These milestones – concerning the preparatory work and the connection to the electricity grid and gas network – have been met. In addition, the operator has provided RTE with evidence of the progress of the project, which makes commissioning by winter 2021-2022 a credible prospect, despite several appeals that are still awaiting judgement.

As a result, the commissioning of the Landivisiau combined cycle gas-fired power plant has been assumed to be in November 2021 in the Mid-term Adequacy Report base case.

No closures of combined cycle gas-fired power plants are planned during the period of the study.

Uncertainties concerning keeping oil-fired combustion turbines were resolved at the end of 2018. The closure of these units no longer seems to be on the agenda. In the absence of any opposite statements and specific government objectives for this sector, the Mid-term Adequacy Report 2019 **base case keeps all the combustion turbines** during the period of the study. A sensitivity analysis of the decommissioning of oil-fired combustion turbines from the first winter onwards is however carried out in order to take account of the uncertainties surrounding the future of this sector.

The fleet of small thermal units is currently making a significant contribution to the balance of the power system, in particular via market mechanisms. Attention must be continuously paid to **the evolution of this sector.** In a context of reducing greenhouse gas emissions, the future of this sector is uncertain. In particular, the draft National Energy and Climate Plan indicates that the development of the gas cogeneration fleet is not compatible with the climate targets and questions the future of government support for this sector. The base case of the Mid-term Adequacy Report 2019 maintains stability of the fleet of small gas-fired units and a gradual scaling-back of the oil-fired fleet. A sensitivity analysis incorporating a partial scaling-back of the gas cogeneration capacity is conducted.

Increasing the interconnection between France and its neighbours is under way, with new lines with the Great Britain and Italy

Interconnections are key to the operation of the European power system. Several interconnection projects are currently under way, and should be commissioned during the period of the study.

The estimated dates for the commissioning of the two new regulated lines, with Great Britain (IFA 2) and Italy (Savoie-Piémont), are being regularly reassessed and all the announced timescales are being met. The commissioning of these projects is currently scheduled for 2020. **To be conservative, the assessment in the Mid-term Adequacy Report considers that these links will be fully operational during 2021.**

The ElecLink interconnection project, which is also in progress, will increase the electricity exchange capacity with the Great Britain by approximately 1 GW. The uncertainties about when this interconnection will go live, initially scheduled for mid-2020, have not been resolved yet. The company Getlink, leading the project, has not yet received the necessary approval from the Intergovernmental Commission to run the cable for the future link through the Channel Tunnel. As a precaution, the commissioning of the ElecLink project is not included in the base case of the Mid-term Adequacy Report 2019. Its contribution to the security of supply is analysed in a sensitivity, with a commissioning in 2021.

Numerous simultaneous closures of coal-fired and nuclear power plants are due to happen in the short term in neighbouring countries

Europe is highly interconnected, and the changing situation in neighbouring countries is a factor that must be taken into consideration when analysing the risk on security of supply.

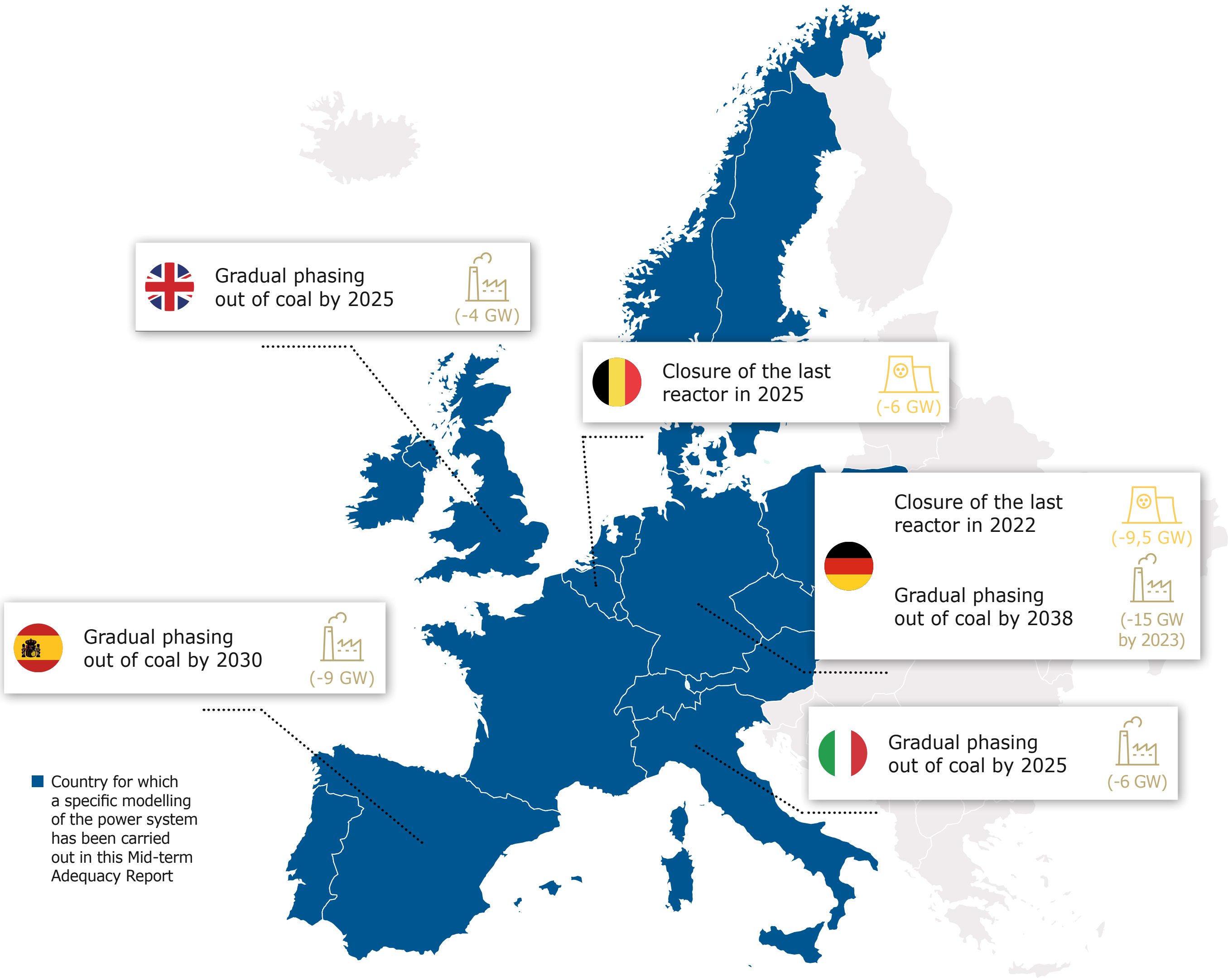
The general trend for reducing the fleet of large thermal or nuclear units will continue in the medium term. In general, the national energy-climate plans drawn up by each state stipulate rapid decommissioning of controllable facilities, together with acceleration of the development of renewable energies. Germany and Belgium have programmes to phase out nuclear power by 2022 and 2025 respectively. At the same time, the gradual closure of plants with the highest emission levels, mainly coal-fired plants, has been announced in most neighbouring countries.

The year 2022 seems to be a pivotal year, with the closure of the last nuclear reactors in Germany at the same time as the gradual decommissioning of the country’s coal-fired plants and the closure of the first nuclear reactor in Belgium.

The closure programme for the French coal-fired fleet must be considered in the context of the closures announced in neighbouring countries: it is only sensitive for France because (i) the French level of security of supply is already close to the national reliability standard, and (ii) it constitutes the completion of a move to close coal-fired plants and large oil-fired units over the past few years.

However, there are considerable uncertainties surrounding the changing European energy mixes, in particular concerning the actual trends of development of renewable energies and decommissioning of thermal facilities. **The coordination of the European decisions is analysed in depth in the Mid-term Adequacy Report 2019**, in particular testing the sensitivity of the assessment to accelerating or delaying decommissioning of thermal facilities in relation to the trajectories provided to date.

Figure 12. Main targets for decommissioning thermal facilities in Europe



Situation in 2025 in the base case and in the sensitivities of the Mid-term Adequacy Report 2019

Demand

	2018*	2025 Base case	2025 Sensitivities	
Consumption	478 TWh	= 478 TWh Stable consumption	↘ 472 TWh Decreased consumption	↗ 484 TWh Increased consumption
Demand-side response	2.9 GW	Increase to 4.1 GW	Sector stable	Increase to 5.3 GW

Renewable energies

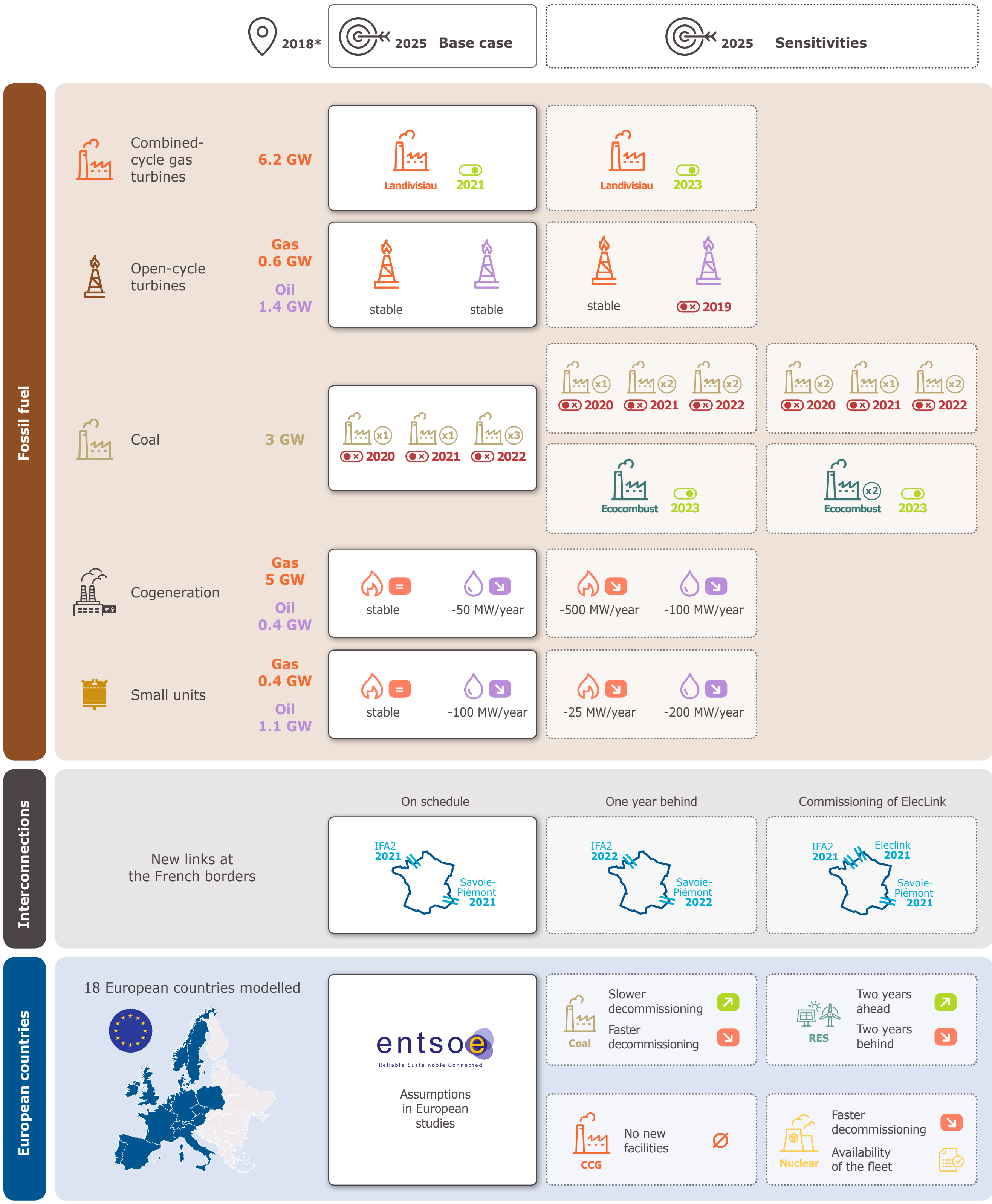
	2018*	Central trajectory	"Business as usual"	High trajectory
Hydro	25.5 GW	marginal change → 25.9 GW	stable → 25.5 GW	slight increase → 26.2 GW
Onshore wind	15.1 GW	→ 27.4 GW	→ 24.9 GW	→ 29 GW
Offshore wind	∅	x6 → 3 GW	x5 → 2.5 GW	x6 → 3 GW
Solar	8.5 GW	→ 23.3 GW	→ 14.1 GW	→ 30.2 GW
Bioenergies	2 GW	marginal change → 2.2 GW	marginal change → 2.2 GW	marginal change → 2.2 GW

Nuclear

	2018*	2025 Base case	2025 Sensitivities		
Generating fleet	63.1 GW 58 reactors	Fessenheim: 2020 (closure); EPR Flamanville 3: 2023	Fessenheim: 2020 (closure); EPR Flamanville 3: après 2025		
Fleet availability (ten-year inspections excluded)		10 years – Probabilistic modelling			
10-year inspection schedule		Average extension of two months in line with past years (+ 2 months)	On schedule (=)	Average extension of one month (+ 1 month)	Average extension of three months (+ 3 months)

* Situation as on the 31st of December of the considred year

Situation in 2025 in the base case and in the sensitivities of the Mid-term Adequacy Report 2019



* Situation as on the 31st of December of the considred year

ADEQUACY ASSESSMENT

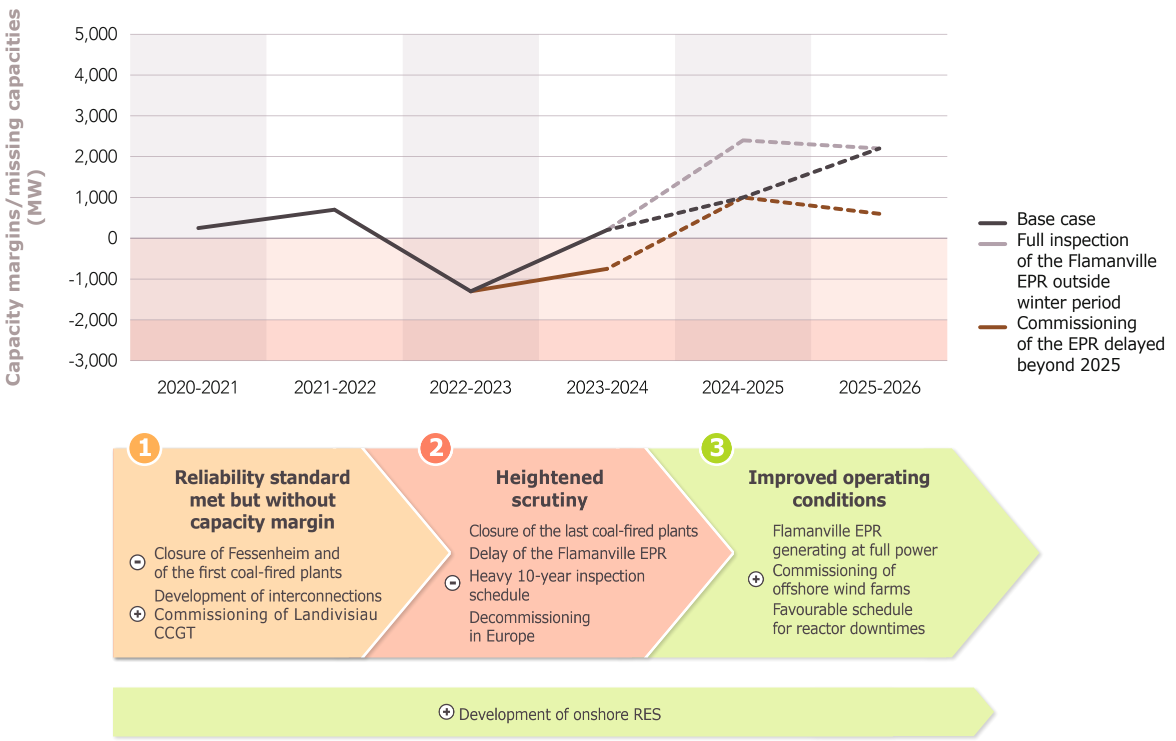
The closures outlined in the Energy-Climate law and the draft National Energy and Climate Plan will lead to the loss of around 5 GW of controllable generation capacity over the next few years (1.8 GW with the shutdown of the two Fessenheim nuclear reactors and 3 GW of coal-fired power plants).

These closures are being carried out at a time when (i) the commissioning of the Flamanville EPR has been postponed once again, (ii) the nuclear fleet has embarked upon an extensive maintenance and reinvestment programme, and (iii) all countries in Europe are simultaneously involved in programmes to shut down controllable generation capacities.

The base case in the Mid-term Adequacy Report 2019 now includes assumptions that were previously considered as unlikely, becoming close to the unfavourable scenarios of the additional analysis report of April 2019.

RTE identifies three key periods for the next few years.

Figure 13. Capacity margins in the base case of the Mid-term Adequacy Report



Period 1 - Up to 2021-2022, the power system is balanced from the perspective of security of supply, but without capacity margin

The French generating capacity leads now to a level of security of supply equivalent to the national reliability standard, and not just in theory

This balance of security of supply incorporates the contribution from interconnections. This clearly shows that **France cannot cope alone with winter demand peaks when the system is under high strains.**

France currently has an atypical position compared with its neighbours, given that the flexibility of its energy production capability is largely attributable to hydro and nuclear power. This has given rise to some exceptional CO_2 emissions performance levels, thanks to an electricity mix that is more than 90% low carbon. However, it means the system has some very specific operational issues, with a high dependence on the nuclear fleet.

In this context, the actual level of security of supply each winter can be heavily dependent on certain cyclical conditions.

For instance, a lower availability of the nuclear fleet leads to reduced operating capacity margins (as happened in the second half of 2019 with the outage extension on the Flamanville reactors, followed by the temporary shutdown of three reactors at the Cruas plant to carry out safety checks following an earthquake on 11 November). Social movements can also have a similar effect, causing unavailability on some reactors in the existing fleet, leaving the power system to cope with a real-time situation worse than expected. Similarly, specific events in neighbouring countries, like the unavailability of the nuclear fleet in Belgium in November 2018, can also have a significant impact on the security of supply in France.

These kinds of factors can only be reviewed in seasonal studies like the annual "Winter Adequacy Outlook" and "Summer Adequacy Outlook" reports published by RTE.

For the 2019-2020 winter period, the outlook is more favourable after January 2020 due to various cyclical factors, such as the increased availability of European fleets, adequate hydroelectric power reserves, and a better reactor outage schedule for the start of 2020.

The planned closures of the Fessenheim nuclear plant in 2020 and the first three coal-fired power stations by 2022 are compatible with the regulatory standard in the majority of studied cases

Aside from the re-scheduling of the ten-year inspection outages over the coming months, the outlook for winter 2020-2021 is looking favourable in principle from the perspective of the nuclear availability. This is a major factor explaining how the security of supply can be maintained in compliance with the standard, despite the closure of the two Fessenheim reactors.

Maintaining this balance the following year (when the Le Havre coal-fired power plant is scheduled for closure) depends on more conditions. The 2021-2022 winter period requires special attention in the ten-year inspection programme. Commissioning the Landivisiau plant and the interconnections with Italy and the Great Britain are both essential to comply with the regulatory standard. Keeping on track with the onshore wind farm rollout is another important factor.

Strict respect of the initial ten-year inspection schedule announced by the operator would also lead to additional margins.

Period 2 - A period of heightened scrutiny after 2021-2022

The adequacy assessment identifies a period of heightened scrutiny beyond the 2021-2022 period, which encompasses the closures of the last coal-fired plants and postponement of the Flamanville EPR commissioning phase. This period is also marked by two significant risk factors: (i) a nuclear maintenance programme with a considerable number of simultaneous ten-year inspections, and (ii) the permanent shutdown of Germany's remaining nuclear reactors and the closure of coal-fired power plants in many European countries.

In this configuration, the public reliability standard is not met in the majority of scenarios studied in the Mid-term Adequacy Report, and the specific voltage stability problem in western France worsens. This relates in particular to the 2022-2023 winter period, with significant capacity shortfall as one gigawatt in the assumptions of the base case.

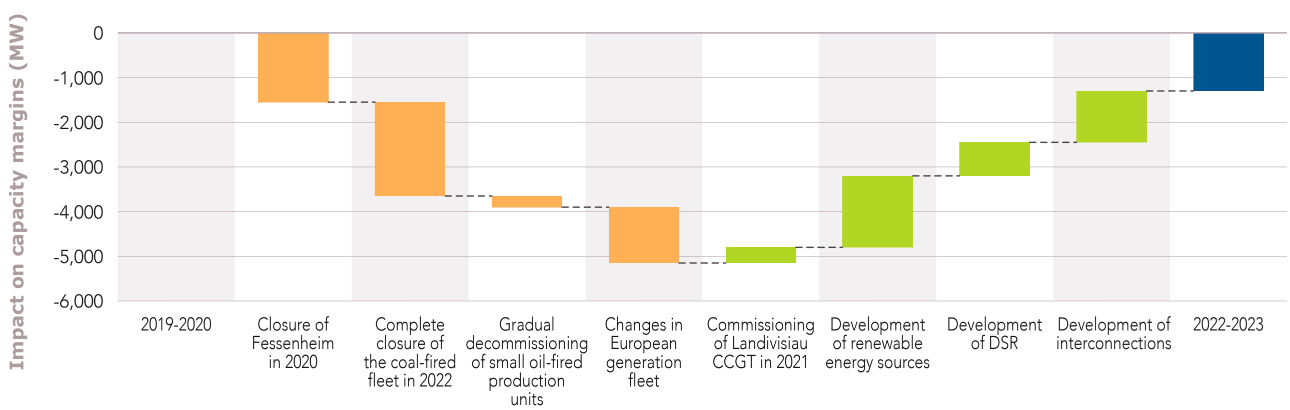
However, this potential deficit needs to be viewed in the context of the closure of around 5 GW controllable generation capacity by 2022 and incorporated into the base case (-1.8 GW corresponding to the Fessenheim plant and -3 GW of coal-fired power generation capacity).

Consequently, although the closure of the Fessenheim plant and of the first coal-fired power plants can be completed without adversely impacting the security of supply beyond the standard, **the decommissioning of the last coal-fired power plants by 2022 will mean that compliance with the public reliability standard will not be met in the majority of the scenarios studied in the Mid-term Adequacy Report.**

This conclusion, which is consistent with the Mid-term Adequacy Report 2018 and the additional studies conducted in April 2019, will depend on how the different parameters in the electricity mix develop over the next few years. The closure target could still be pursued either (i) by temporarily accepting a slightly higher level of risk, or (ii) by implementing the levers discussed in the additional analyses published in April 2019.

The three identified levers (controlling demand, optimising the schedule and duration of nuclear reactor outages and maintaining the Cordemais plant or converting units to biomass) are still valid now. Implementing them would establish significant operating margins and ensure security of supply during periods of the most strain on the grid. The Mid-term Adequacy Report 2019 gives a detailed analysis of the potential impacts of these measures.

Figure 14. Main developments in the French generation fleet between 2019 and 2023 and impact on capacity margins



Period 3 – The level of security of supply should improve after 2023, even become favourable once the Flamanville EPR is fully up and running

The period of heightened scrutiny on security of supply should only be temporary, coming to an end between 2023 and 2025 when the Flamanville EPR is finally fully operational.

In fact, the security of supply situation will develop favourably on a structural level beyond 2023, since:

- No plant closures are planned under government policies (once the last coal-fired power stations have been shut down) or expected from an economic perspective.
- The pace of development of renewable energy sources is accelerating, with the first offshore wind farms having an important contribution to the security of supply (with a much higher average load factor than onshore wind farms).

As far as the Flamanville EPR is concerned, it should be commissioned by 2023, resulting in a noticeable improvement in the security of supply by the following winter. This assumes that EDF sticks to its schedule for the planned weld repairs. Future scheduling of extended outages of the Flamanville EPR during its first few years of operation also cannot be ruled out (first full inspection, replacing the reactor cover, etc.)[4]. **Scheduling these kinds of outages during winter months would have a negative impact on capacity margins.**

If the Flamanville EPR is not up and running within this period, or if it only operates partially in its first few years of service, the period of vigilance could last until 2025.

There is a real improving trend in security of supply in all scenarios between 2023 and 2025, without reliance on interconnection capacities.

However, there are far too many uncertainties regarding this timeframe to be able to assess capacity margins in relation to the security of supply standard with any degree of accuracy at present. Operating experience gained from the first fourth ten-year inspections will go a long way in helping to clarify the assessment.

4. The Mid-term Adequacy Report 2019 is based on a rather conservative assumption that the EPR's first full inspection will be scheduled for winter 2024-2025 (18 months after commissioning in line with the timeframe announced by the operator). However, no assumptions were made regarding an outage to replace the reactor vessel head due to a lack of information at the time of the publication of this report.

The simultaneous decommissioning of many production facilities in Europe is a key issue

The French power system now relies on imports from neighbouring countries to cope with the highest demand peaks.

This contribution of interconnections to ensure the security of supply is part of economic optimisation and pooling of production resources on a European scale. It does, however, mean that the availability of capacities in neighbouring countries needs to be closely monitored to be able to study the security of supply; this monitoring is included in the analyses in the Mid-term Adequacy Report.

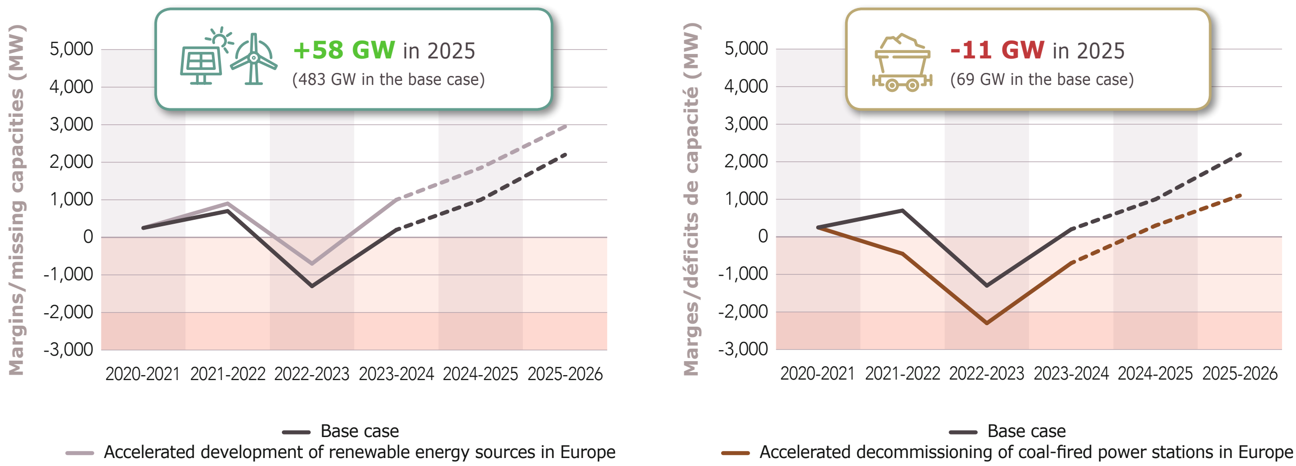
An update of the European assumptions in the Mid-term Adequacy Report 2019 reveals a slightly improved picture than the one painted in the previous analysis[5]. This is one of the few areas that has evolved favourably since last year and is helping to maintain margins in the French power system close to the security of supply standard.

Against a backdrop of considerable transition in the European electricity mix (described earlier), changes in the generation fleets in other countries require special attention. The sensitivity of the assessment of security of supply in France to developments in the production capacities in neighbouring countries is therefore evaluated on the basis of several defined sensitivities. These analyses are used to assess the impact of policy choices made in neighbouring countries on the capacities needed in France to guarantee security of supply.

A more favourable scenario for security of supply in France could happen if the pace of development of renewable energy sources accelerates on a European level and/or if decommissioning of certain plants is delayed. Conversely, the study on an accelerated decommissioning programme for coal-fired power plants in neighbouring countries highlights that the system would be placed under far greater strain if this is not offset by the development of new facilities. The shortfall in capacity for the period 2021-2025 could be much more pronounced in this situation.

Detailed analyses concerning the sensitivity to assumptions about European capacities are presented in the full report.

Figure 15. Capacity margins in the base case and in other scenarios of European fleets



5. Assumptions regarding developments in the generation fleet reported by TSOs in the European analyses (MAF 2019 and TYNDP 2020) are now broken down by year (compared with 2020 and 2025 only in previous reports), providing more accurate forecasts of decommissioning of existing production capacities and/or commissioning of new facilities.

The main risk factor remains the onset of a cold wave, more than nuclear reactor unavailabilities or windless periods

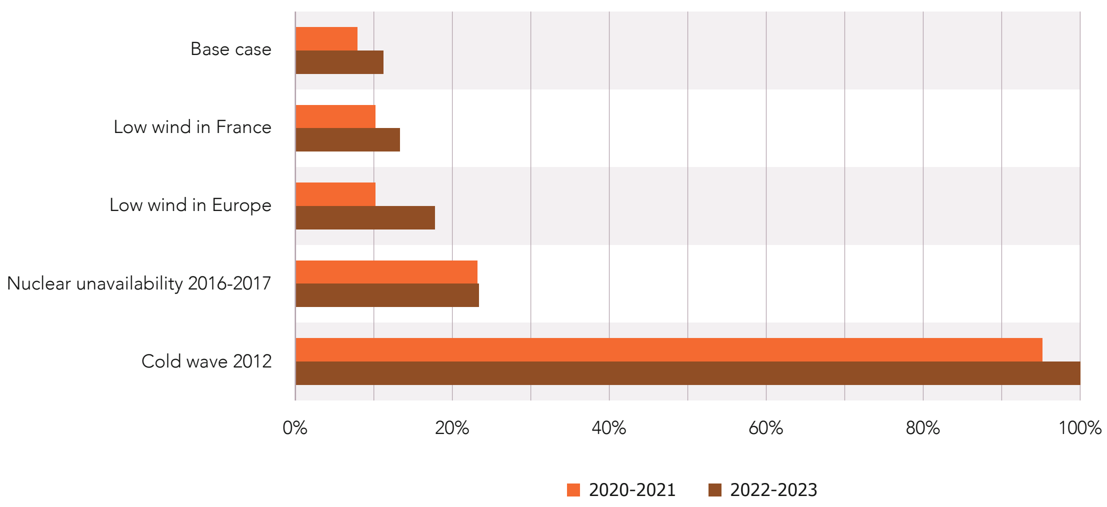
In line with regulatory provisions in the French Energy Code, the security of supply study in the Mid-term Adequacy Report is conducted with a probabilistic standard defined as a loss of load expectation of three hours a year.

To assess the most critical risk factors on security of supply and giving concrete insights, the probabilistic analysis is completed by focussing on system operation in certain specific situations.

Several stress test situations were thus analysed, based on actual situations that have occurred in recent years:

- **A prolonged cold wave** (like the European cold wave in February 2012, the coldest and longest on record in the past two decades, which led to a historic peak in electricity demand in France)
- **Prolonged periods of light or no wind resulting in extremely low wind energy production,** specifically in France (as occurred in early January 2017, when there was an intermittent load factor of just 1% in French wind farms) or more widely across Europe (like the end of January 2017, when an average wind load factor of around 13% was recorded in France and in neighbouring countries over a five-day period)
- **Simultaneous and unplanned unavailability of several nuclear reactors,** similar to the situation experienced at the beginning of winter 2016-2017, when the ASN demanded that several reactors be shut down following the discovery of a problem on some steam generators.

Figure 16. Loss of load probability over the simulated weeks[6] in the base case



6. The stress tests were simulated for the week presenting the highest loss of load expectation in the base case (second week of January).

Beyond the probabilistic approach which forms the basis of the Mid-term Adequacy Report, these analyses can also be used to illustrate the consequences of random events likely to impact the system.

- A cold wave similar to the one experienced in February 2012, which is "beyond design basis" in relation to the regulatory standard, would lead in practically all situations to the use of post-market measures, and potentially even load shedding. Indeed, these kinds of events are likely to have the greatest impact on system sizing, and particularly the prolonged cold waves.
- The unavailability of several reactors constitutes the second most critical event in terms of impact. Periods of low availability in the heart of winter, regardless of whether they are planned or unplanned, are likely to have a substantial negative effect on electricity supplies.
- To date, periods of low wind have had less impact. This means that they can only lead to activation of post-market measures if they occur in tandem with other random events. However, the onset of this kind of events should increase in the long term. Low wind situations occurring simultaneously in several European countries, thereby reducing the ability to import electricity from neighbouring countries, should be considered a greater threat than an almost total absence of wind in France alone.

An in-depth analysis was necessary to fully interpret these results. The details of this analysis are presented in the full report.

There are no "local" security of supply issues in Alsace, Lorraine, Normandy or in the PACA region – only north-western France requires specific scrutiny

The local impacts of the coal-fired power station closures were discussed in detail in the French Mid-term Adequacy Report 2018.

The report included dedicated papers relating to the Saint-Avold, Gardanne, Le Havre and Cordemais regions. These analyses were presented by RTE at meetings organised by the government involving local politicians, trade unions and producers held in Metz, Marseille, Le Havre and Nantes. RTE also hosted a meeting for all the relevant trade union federations to present their assessment.

These local issues have been the subject of new questions raised as part of a consultation on the Mid-term Adequacy Report 2019.

The absence of any specific risk for the local security of supply in the north-eastern and PACA regions of France as regards the closure of the Fessenheim, Saint-Avold and Gardanne plants has been confirmed.

However, attention is still required in terms of voltage stability in north-western France.

This scrutiny has been heightened further in response to the extended outages of Flamanville's existing reactors lasting several months (shut down since the 10 January and 18 September 2019 respectively) and the plans announced by the operator for a major steam generator replacement programme in 2021-2022.

The expected commissioning of new production facilities (the Landivisiau gas-fired CC plant, the Flamanville EPR and the first offshore wind farms) should ultimately lead to a net improvement in voltage stability.

In the meantime, the assessments presented in recent months are still valid:

- **The Le Havre plant can be closed without affecting the security of supply.**
- **In contrast, the Cordemais plant is, as things stand, essential to maintaining the current level of security of supply (in the west in general and in Brittany in particular) until the Flamanville EPR is fully operational (in the timeframe considered in this Mid-term Adequacy Report).**

Maintaining availability of the two Cordemais coal-fired plants or converting them to biomass facilities forms part of the measures proposed to ensure compliance with the security of supply standard (see Chapter 4 – Levers for security of supply).

This aspect of the assessment is valid for a given level of security of supply and for a defined period (2020-2025). Namely:

- RTE would be able to operate the power system without the Cordemais plant, although this assumes a level of associated risk (the likelihood of activating post-market measures, and even targeted load-shedding in Brittany, would increase as a consequence).
- If commissioning of the Flamanville EPR were to be pushed back even further, it would be feasible to find solutions to secure supplies in the north west, and in Brittany especially, that are not reliant on maintaining the Cordemais plant, by 2026, as long as reinforcements were made to the network in this region.

LEVERS FOR SECURITY OF SUPPLY

Three levers that will maintain a good level of security of supply in the least favourable scenarios (consequences of a significant delay in the commissioning of the Flamanville EPR and one interconnection) have been identified in the additional analyses published in April 2019.

- The first lever consists of initiating actions to **control electricity demand** during peak periods, using structural energy efficiency initiatives, or one-off actions to reduce consumption during periods of strain on the power system.
- The second lever consists of optimising the scheduling of **nuclear reactor stoppages** for ten-year inspections during the period 2021-2023, to reduce the risk of unavailability of reactors during the winter.
- The third lever consists of maintaining the availability of **two units at the Cordemais plant** (coal-fired or converted to biomass).

Each of these levers could **relieve stress during peak periods by approximately 1 to 2 GW.** Their implementation would be sufficient to ensure security of supply, as defined in the French Energy Code, in most of the scenarios identified.

As the base case of the Mid-term Adequacy Report 2019 is similar to the unfavourable configurations studied in the additional analyses, these levers are examined in greater depth.

Lever no. 1: controlling demand

The benefits of structural actions and controlling demand

RTE regularly updates the scenarios on changes in electricity demand.

The French Long-term Adequacy Report 2017 reported stable or declining prospects in the medium term (without considering cyclical variations), highlighting the potential effect of energy efficiency measures, in particular in the specific uses of electricity. The last reports of RTE have also stressed the importance of controlling demand in order to optimise the operation of the power system.

These scenarios are compatible with the acceleration of transfers of use to electricity (for example in the mobility sector) in response to climate change imperatives, as the electricity generated in France is predominantly low-carbon.

Initiatives to control demand – in particular structural actions – will provide some additional leeway, which will help to ensure security of supply and support policies for becoming carbon neutral by switching to electricity.

Controlling demand only has a marginal impact on national greenhouse gas emissions in the short term. Thus, contrary to conventional wisdom, "peak electricity periods" do not lead to high volumes of emissions in France: for example, emissions associated with combustion turbines, which are the main peak facilities for the French power system, account for less than 0.5% of the emissions from electricity generation in France.

The issue of the supply-demand balance does not only concern the "7 pm peak"

Electricity demand fluctuates throughout the day, according to users' needs, which are mainly dictated by business and domestic activities and the season: consumption is higher during the day than at night, during workdays than at weekends, and in winter than in summer.

The concept of "demand peak" can therefore cover widely different physical realities, depending on whether it refers to the intraday peak or the winter peak.

Maximum power demand occurs as a result of a combination of periodic structural variations (day, week and season) and unpredictable variations associated with meteorological factors (cloud cover and temperature in particular). As the highest load in the winter is usually at 7 pm, the "winter peak" concept is frequently associated with that of the "7 pm peak".

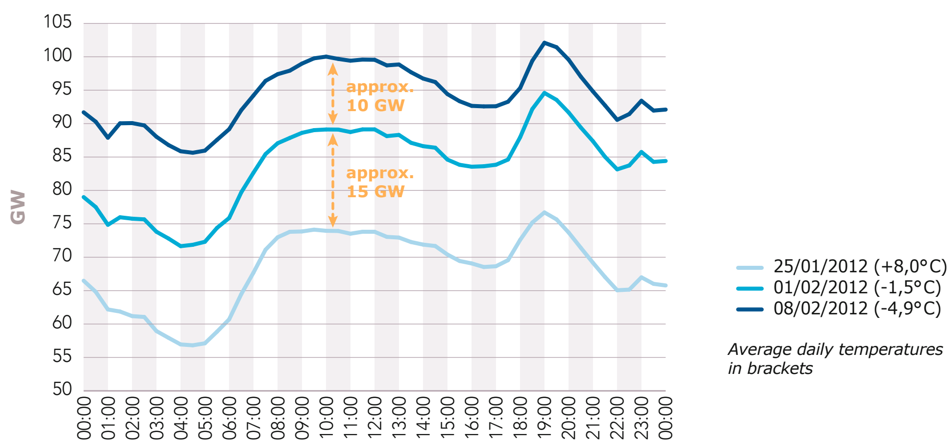
The issue of cold spells, in terms of power system balance and security of supply, is above all that of the particularly high average level of power demand over a period of several hours (or even days) rather than just that of the daily peak.

During cold spells, the relatively large proportion of electric heating in French consumption leads to an upward translation of the daily load curve. This requires the deployment of generating facilities or the implementation of demand reduction that can contribute to the supply-demand balance over periods of several hours, or even several days, and not just deal with the "7 pm peak", which is often highlighted in the news, as it corresponds to the intraday peak.

For example, record consumption was recorded during the evening peak on 8 February 2012. The middle of the night on 8 February 2012 is also noteworthy, as it reached the same consumption level as the mornings of the previous week, and was much higher than the evening peak in the week before that.

Controlling demand ensures better management of the power system and thus makes transfers of use easier, as has been illustrated in the case of e-mobility (see the report published in May 2019). In this context, it represents a positive lever for reducing greenhouse gas emissions.

Figure 17. Daily load curves during the cold spell in February 2012



Several types of demand initiatives can provide some additional leeway

In April 2019, RTE indicated that a specific effort on this point could provide an increase of around 1 GW and help meet targets for the closure of coal-fired power plants while complying with current levels of security of supply.

This topic has been developed by the association négaWatt, which published a document outlining a number of options in June 2019.

In the context of the Mid-term Adequacy Report 2019, RTE wants to move deliberations forward by trying to identify some orders of magnitude. Various levers – of varying types, and which can incur very different costs – have been listed and grouped into three categories:

- **Energy efficiency** initiatives to reduce consumption, and therefore the level of demand during winter peaks
- **Specific control of power demand** during the winter peak (and not just around 7 pm)
- **Eco-gestures** for one-off reduction of demand during periods of strain on the system

An assessment has been made of their effect on peak demand. It must however be treated with caution.

In particular, these measures correspond to additional actions compared to those already included in the consumption trajectories. Each of them can lead to a demand decrease during peak periods ranging from around a few dozen to a few hundred megawatts. This is not an exhaustive list and could be supplemented or described in greater detail depending on the measures that are actually implemented.

RTE offers to carry out a more in-depth assessment of these actions.

This work can be carried out as a follow-up of the electricity consumption working group, set up by RTE at the beginning of 2019 to share and coordinate the trajectories for change in electricity demand. It can inform current discussions on the flexibility of demand that can be accessed in the long term, in particular for analysing the operation of an power system with a large proportion of variable renewable energies.

Widespread use of the EcoWatt system will mean that all citizens are kept informed of the status of the power system and are warned if there is any risk

Following on from work to identify sources of energy savings, RTE is ready to contribute to information campaigns and to harness this potential.

The national rollout of smart meters, which will be widespread by 2022, and the population's growing awareness of the challenge of controlling energy consumption, offer new prospects for controlling power demand during peak consumption periods. Through its consultative bodies, RTE has initiated an education programme on electricity peaks, the temperature sensitivity of the French power system, and sources and courses of action that may be proposed for controlling and managing peaks. If necessary, this information can be shared more widely.

RTE is due to introduce the EcoWatt system throughout France in 2020. It is currently in place in the Brittany and Provence-Alpes-Côte d'Azur regions (areas that have been subject to close monitoring over the years associated with their situation as "electricity peninsulas").

Extending this system will meet the objective of warning all French consumers of days when there is most strain on the system in terms of supply-demand balance, to encourage them to moderate their consumption during these specific periods.

This would therefore lead to some types of lower priority consumption being postponed, some uses temporarily limited or even the stopping of some uses considered to be superfluous, in order to ensure availability of the power supply for essential uses (trains and public transport, residential lighting and heating, etc.).

A detailed analysis of these levers is given in the full report.

Figure 18. Main levers for controlling demand to provide some additional leeway by 2022-2023

	Lever for controlling demand	Estimate of avoided power in 2022-2023	Effect duration
Management of energy demand	**Renovation of buildings** 300,000 additional energy-efficient thermal renovations* in 3 years on electricity heated housing * Renovations reducing the heat requirements of housing by 60% (the base case already incorporates 170,000 a year, reducing the heat requirement by 40%)	**0.4 GW**	Long period
Management of energy demand	**Replacement of electric convector heaters by heat pumps** 300,000 additional air-to-air heat pumps* in 3 years replacing resistive heating systems * i.e. 160,000 a year as against 60,000 in the base case trajectory	**0.3 GW**	Long period
Management of energy demand	**Replacement of low performance electric convector heaters** Fitting higher performance heating devices (*smart heating*, gentle heat, etc.) in 600,000 additional housing heated using conventional electric convector heaters in 3 years	**0.1 GW**	Long period
Control of demand	**Devices encouraging demand postponement or demand-side response** For example, development of a new generation of offers encouraging customers to postpone or reduce demand with a target of 300,000 customers in 3 years	**0.3 GW**	Daily
Control of demand	**Smart charging of electric vehicles** Smart charging of 300,000 additional electric vehicles* in 3 years using simple solutions (peak/off-peak hours for example) * 90% of vehicles using smart charging as against 60% in the base case trajectory	**0.2 GW** at 7 pm during winter or even more with vehicle-to-grid systems	Intraday
Control of demand	**Time-of-use control of non-controlled water heaters** Time-of-use control using a peak/off-peak signal for 300,000 electric water heaters (of the 20% that do not already have this control) in 3 years	**0.1 GW** at 7 pm during winter	Intraday
Control of demand	**Specific control of domestic uses** Development of precise control of certain domestic uses (for example, refrigerators)	**Few hundreds MW** To be defined according to the uses concerned	Intraday
Eco-gestures	**Reduction of "superfluous" consumption** Reduction of "superfluous" consumption during peak periods (advertising screens, shop window lighting, etc.) and limiting the use of digital billboards	**0.1 GW**	Daily
Eco-gestures	**Socially responsible gestures** Examples: decreasing the heating temperature by 1°C, postponing washing/drying machines, dishwashers, etc.	**Few hundreds MW**	Intraday

Intraday: effects mainly noticeable over a few hours during the day
Daily: effects noticeable on a specific day
Long period: effects noticeable over the entire winter period

Lever no. 2: optimising the schedule and the duration of nuclear reactor outages

RTE confirms its analysis emphasizing the sensitivity of the adequacy assessment to the planning of the ten-year inspections

Like in previous studies, **the assessment of the Mid-term Adequacy Report encompasses in its base case an average extension of two months for ten-year inspections of nuclear units,** based on observation of the average overruns of these inspections in the past.

The sensitivities reproduce the uncertainty with regard to the progress of the ten-year inspections, in particular demonstrating the effect on the assessment of keeping to the schedule announced by the operator and the effect of an extension lasting more than two months.

Thus, keeping to the initial schedule provided by the operator, or to a lesser extent, a drift of less than two months, will provide significant capacity margins.

Optimising the scheduling of the ten-year inspections provides additional leeway

The additional analyses published in April 2019 have also highlighted **the positive impact on security of supply of rescheduling some ten-year inspections so that they do not take place during winter period.**

The Mid-term Adequacy Report 2019 analyses this further and takes account of the sensitivity of the assessment to different schedules for ten-year inspections. For example, the results of these studies show that, during the studied period, the most demanding ten-year inspection schedules are those for the winters of 2021-2022 and 2022-2023. Numerous "risky" ten-year inspections (close to or during the winter period) are scheduled for these winters. A more favourable schedule could provide significant capacity margins, or even comply with the security of supply standard.

Figure 19. Margins in the base case and in other scenarios of ten-yearly inspections

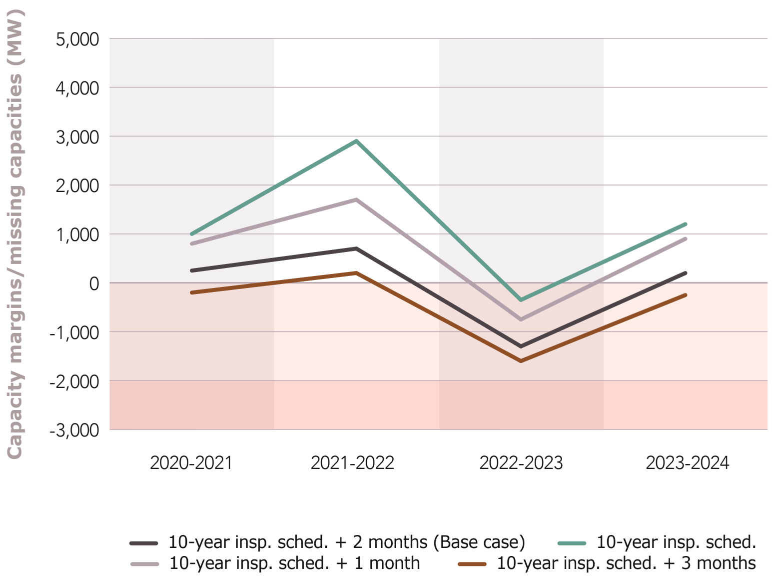
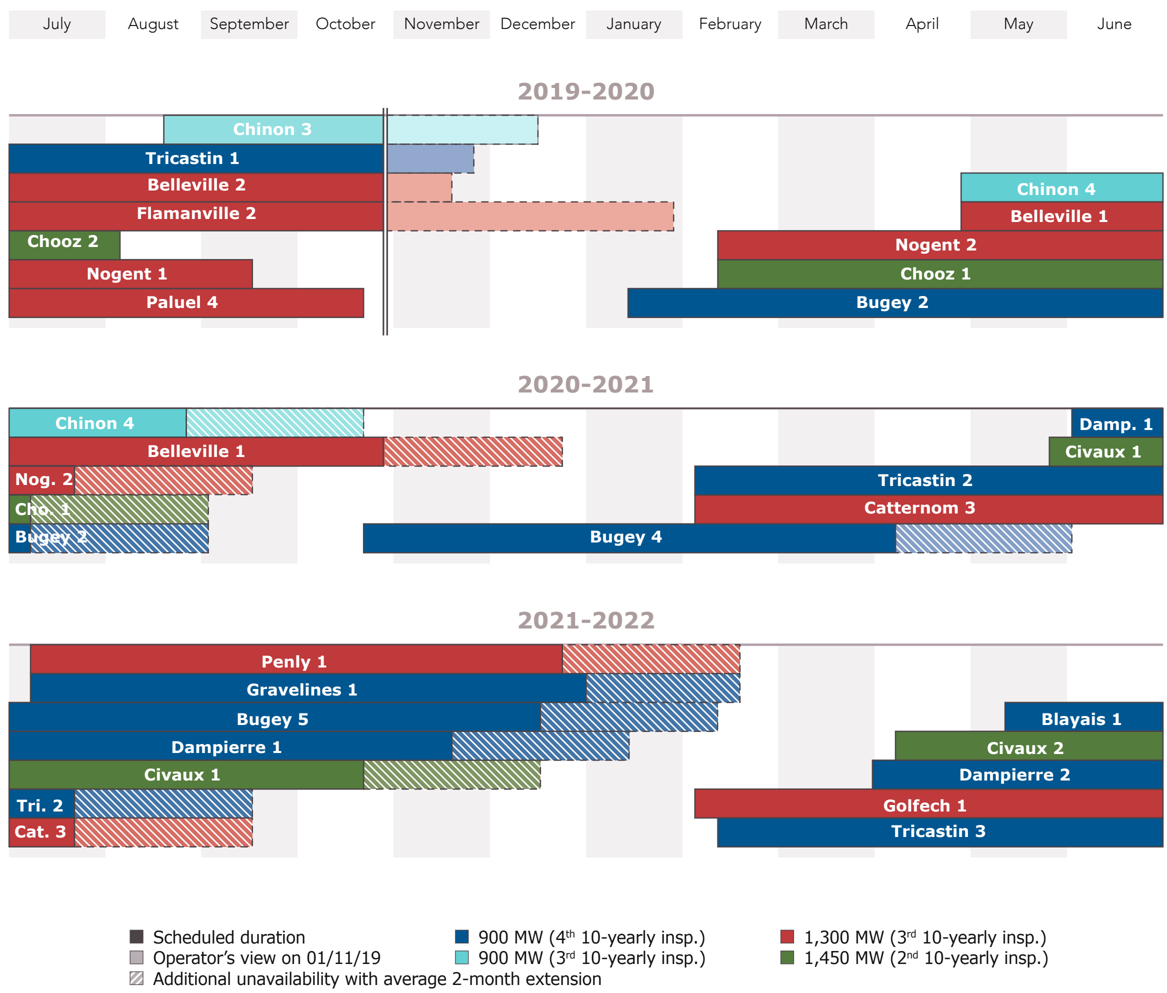


Figure 20. Provisional schedule for ten-year inspections of the nuclear fleet for the period 2019-2022 as at the 1st of November 2019 (source: European Transparency Platform)



These analyses do not assess the "technical" feasibility of optimisation of the schedule by the operator. However, they do **identify the winters with the highest risk schedules.**

The leeway for optimising the scheduling of outages is being discussed with the Ministry for the Ecological and Inclusive Transition

However the ability to reschedule some ten-year inspections is limited by various types of restrictions: safety restrictions associated with fuel management, regulatory restrictions (deadlines for submitting the review report or for carrying out the hydrostatic testing), and industrial restrictions (limited availability of resources for conducting several ten-year inspections at the same time), etc.

The leeway for scheduling reactor outages is now being discussed and closely monitored with EDF, the Nuclear Safety Authority and the government.

Lever no. 3: maintaining the availability of the Cordemais plant or converting it to biomass

Various scenarios for the future of the Cordemais power plant have been tested

Cordemais is the largest coal-fired power plant in France, with two 600 MW units. It currently plays a specific role in supplying western France.

This role should decrease with the commissioning of the Landivisiau gas-fired power plant (at the end of 2021) and/or the Saint-Nazaire offshore wind farm (2022). However, in the current configuration, it will only be finally reduced when the Flamanville EPR enters service. In the meantime, the future of this power plant must be monitored closely.

The energy-climate law of 8 November 2019 stipulates that, from the 1st of January 2022 onwards, power plants with an emission factor of more than 0.55 tonne of CO_2 equivalent per megawatt hour will be subject to an annual emission cap set by law. For coal-fired power plants, the current value of 0.7 kilotonne of CO_2 equivalent per megawatt of installed electric power corresponds to an annual limit of approximately 700 hours. Without regards to the effect on the economy of the facility, it is therefore possible, in the context of this limit, to retain the Cordemais coal-fired power plant.

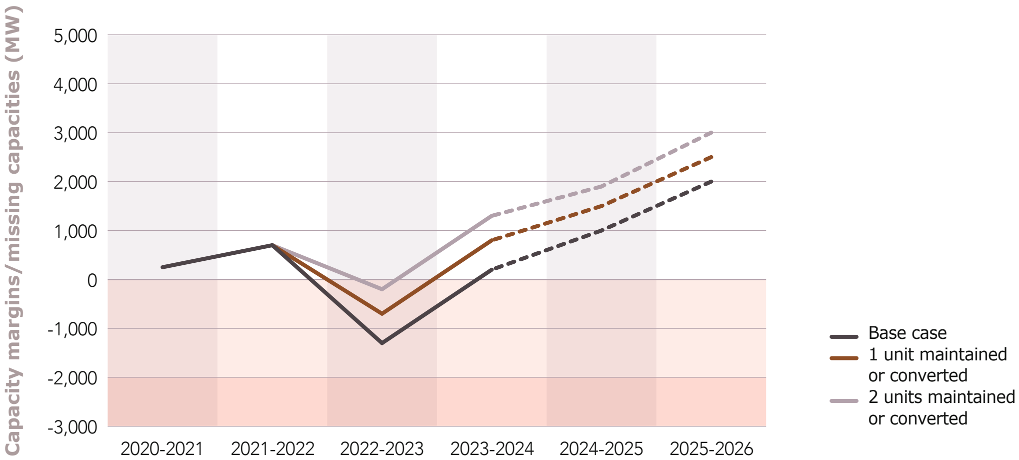
The existing options for the future of the site also include the possibility of changing the fuel (conversion to biomass) in one or two units, as a project studied by the operator.

This conversion would be carried out within the framework of an overall project to re-use wood waste that is currently discarded, with a prospect of increasing use of the fuel that is made from this wood (pellets) to replace coal in the industrial process in which it is still used. The Cordemais power plant would be the main outlet for pellets produced using collected wood for a maximum of four years. This project, called Ecocombust, was presented to RTE by the site's trade unions and EDF. However, it remains uncertain as of today, as the project is subject to numerous authorisation requirements.

A specific case study on the Ecocombust project has been requested by the Energy Minister in January 2019, with particular regard to security of supply in western France.

Beyond the base case, which includes the closure of all coal-fired power plants in 2022 at the latest, the security of supply study conducted in the context of the Mid-term Adequacy Report therefore considers several sensitivities for the future of

Figure 21. Margins in the base case and in scenarios with the Cordemais units maintained or converted to biomass



the Cordemais plant, including options in which it continues to operate beyond 2022:

- Retaining the current operating characteristics of its units or converting them to another fuel (such as biomass);
- Limiting the operating period of the units (for example by means of an annual limit) or imposing stricter restrictions (activation only when there is most stress on the system, at the request of the grid operator).

The technical operating characteristics of the Cordemais plant, in the context of the possible conversion of one or more units to biomass, could depend on tests that are currently being conducted. The assumption chosen by RTE involves retaining the main technical characteristics. The available power of the units would only be slightly lower (520 MW for operation based on 80% biomass, as against 580 MW for coal-based operation), and the response times to demand from RTE are assumed to remain the same as now.

This lever could lead to significant improvements in both national and regional security of supply in all configurations

Analyses show a significant improvement in the security of supply in all the configurations studied[7]:

- The risk of imbalance between production and consumption at national level is then maintained at the level of the regulatory standard, even if the Flamanville EPR is delayed;
- Western France will maintain the same level of security of supply than today.

Various limitations to the plant's operating period have been tested:

- Operation limited to approximately 700 hours, such as that resulting from the draft decree;
- Operation using biomass in the context of the Ecocombust project together with an annual operating limit of 400 hours (current plan of EDF) or 800 hours (letter from the minister dated January 2019);
- Operation as a reserve of last resort (which is not provided for in the current regulatory framework).

Without regards to the economic viability, these limitations do not, represent a problem for security of supply, if the units are maintained and actually started up during periods of strain on the power system. This should happen naturally, as periods of strain on the system (including locally) are those with highest market prices.

If the Cordemais unit(s) were treated as a post-market lever (thus operating in a different context from a normal power plant), their operating period would be very short (an average of around twenty hours) and highly dependent on the climatic conditions (250 hours maximum, in cold spells).

To conclude, the advantage of this lever (for one or two units) depends on the scenario and the level of risk against which the government wants to provide cover. Providing even short periods of operation beyond 2022 is in all cases a lever for limiting the risk of the security of supply being adversely affected if there are unforeseen events on some major projects and is of interest in the current context of uncertainty.

7. Strictly speaking, the analysis of the contribution of the Ecocombust project in relation to the standard of three hours' expected shortfall (i.e. three hours' use of post-market methods), depends on whether or not this method is classified in the post-market methods category. If the Cordemais units converted to biomass are considered to be post-market methods, they do not contribute the reduction of the expected shortfall. However, the expected load shedding is in all cases reduced by the maintenance or conversion of the coal-fired units.

CHARACTERISATION OF
A POWER SYSTEM IN TRANSITION

The share of wind and solar energy in the mix is fastly growing

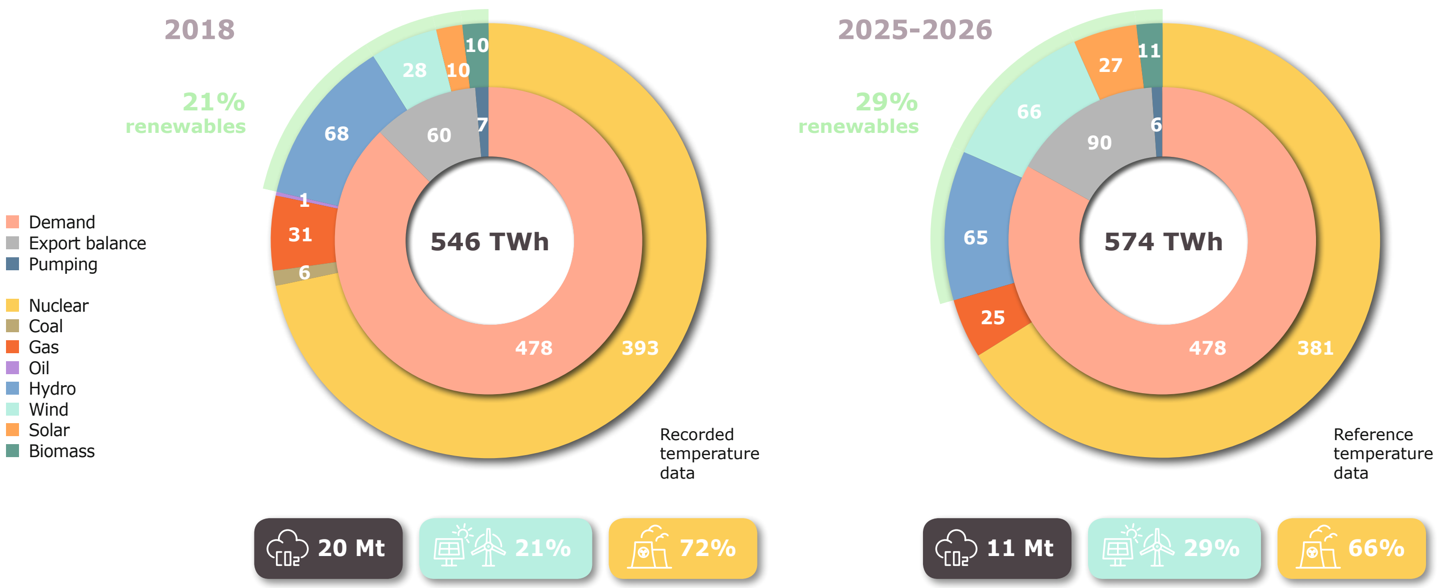
In addition to the decommissioning of several fossil fuel and nuclear power plants, developments in the French power system over the next few years should be marked by a rapid growth in renewable energy sources. **In the base case of the Mid-term Adequacy Report, which assumes steady trajectories although below the targets set in the National Energy and Climate Plan, production from renewable energy sources increases considerably, accounting for around 30% of electricity generated in France by 2025.**

This relies on a sustained growth in photovoltaic sources (a three-fold increase in capacity compared with today's levels), onshore wind energy (doubling current capacity) and offshore wind energy (with six farms generating around 500 MW versus none at present). In this timeframe, annual wind energy production could equal or even surpass hydropower generation to become the largest source of renewable energy in France.

In electricity generation terms, the growth in renewable energies will more than counterbalance the end of coal generated electricity or the decrease of the nuclear power generation. This will subsequently lead to one of the following scenarios:

- Either a rise in the net export balance (assuming that the announced interconnections are completed);

Figure 22. Generation mix in France (in TWh)



- Or a growth in the use of electricity in the transport sector (with electric vehicles), hydrogen production (by electrolysis) or buildings, in line with government decarbonisation policies.

In the studied timeframe, this growth in wind and solar energy is not conditional upon the development of energy storage systems, since the flexible options offered by hydro, thermal and nuclear power in France and Europe are sufficient to counterbalance their variability. Similarly, it will have little impact on nuclear power generation: downward modulations can certainly come into play at weekends or in summer, but overall, wind and solar energy are likely to replace thermal power plants in Europe, as long as the interconnections are not saturated.

Nuclear production thus still appears to be competitive on European markets, even considering the Europe-wide drive to develop renewable energies.

Nevertheless, the base case of the Mid-term Adequacy Report foresees a downward outlook for nuclear power generation based on several factors: the impending closure of Fessenheim, which is not initially offset by the Flamanville EPR; the extent of the reactor outage programme, especially the first fourth ten-year inspections of the 900 MW reactors; and the ongoing possibility of unplanned outages. **The growth in renewable power generation will lead to an overall increase in electricity generation in France and thus, in structural terms, to a slight contraction in the share of nuclear in the electricity generation mix,** which is set to fall to 66% by 2025 (versus 72% today).

As far as fossil fuel power generation is concerned, this will fall significantly due to the closure of coal-fired power stations. It could represent less than 5% of total production in France by 2025.

The decarbonisation of electricity generation in France goes on

CO_2 emissions from electricity generation in France are lower today than in most of neighbouring European countries (ten times lower than in Germany, for example) due to the structure of the mix and the predominance of nuclear and hydropower. Only a few countries in Europe with a greater reliance on hydro and nuclear power than France (Norway, Switzerland and Sweden) have lower emission levels.

With the closure of coal-fired power stations, total emissions from the French power fleet should fall further still compared with today's levels. An average annual volume of around 10 million tonnes is achievable within this timeframe, corresponding to a decrease in emissions by a third since 2010.

The significant drop in CO_2 emissions shown at the start of the study period correlates to the decline in production from coal-fired power stations initiated in 2018 due to rising fuel costs and the price of CO_2 on the allowances market being more favourable to gas.

Figure 23. Carbon intensities from electricity generation in Europe in the base case

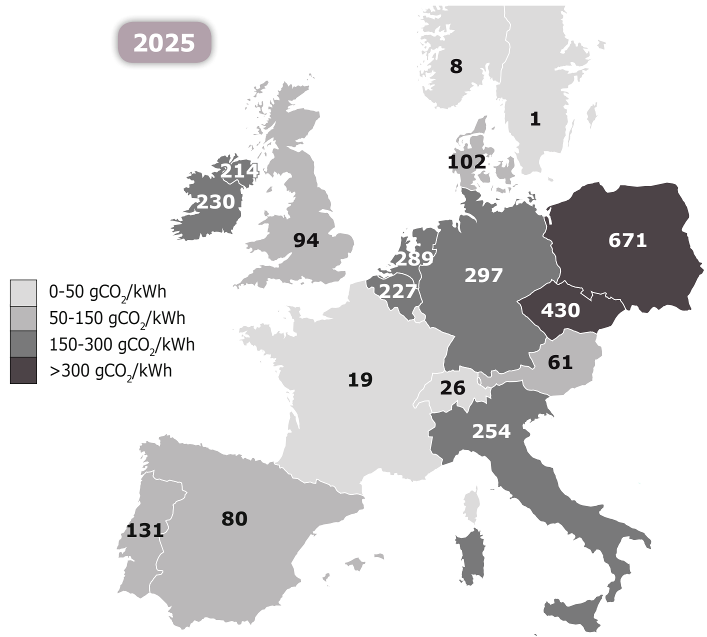
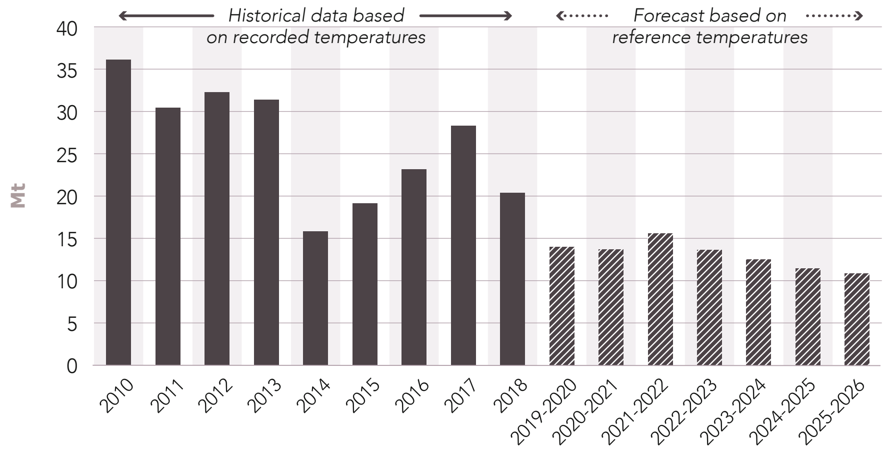


Figure 24. CO_2 emissions from electricity generation in mainland France (historical data and forecasts)



Forecasts given in the Mid-term Adequacy Report correspond to an average result derived from the simulations performed: they illustrate a trend, rather than constituting an accurate forecast of the changing levels of CO_2 emissions generated by the power system. **In practice, the change in emissions from one year to the next is likely to depend on cyclical factors such as meteorological conditions (temperature in particular) or availability of the nuclear fleet.** To illustrate this point, the slight rise in emissions forecasts for the 2021-2022 period is attributable to a rise in production from gas-fired CC plants against a backdrop of lower availability of the nuclear fleet.

The decommissioning of coal-fired power stations has no effect on the export balance of France, even trending upward from a structural perspective

During the studied period, **the French power system should increase its export balance,** even after the last coal-fired plants have closed down.

This rising export balance has already been highlighted in the French Long-term Adequacy Report 2017 (in the Ampere and Volt scenarios, which are consistent with the draft National Energy and Climate Plan published at the beginning of 2019) and was the subject of specific analyses included in an Appendix to the Long-term Adequacy Report[8].

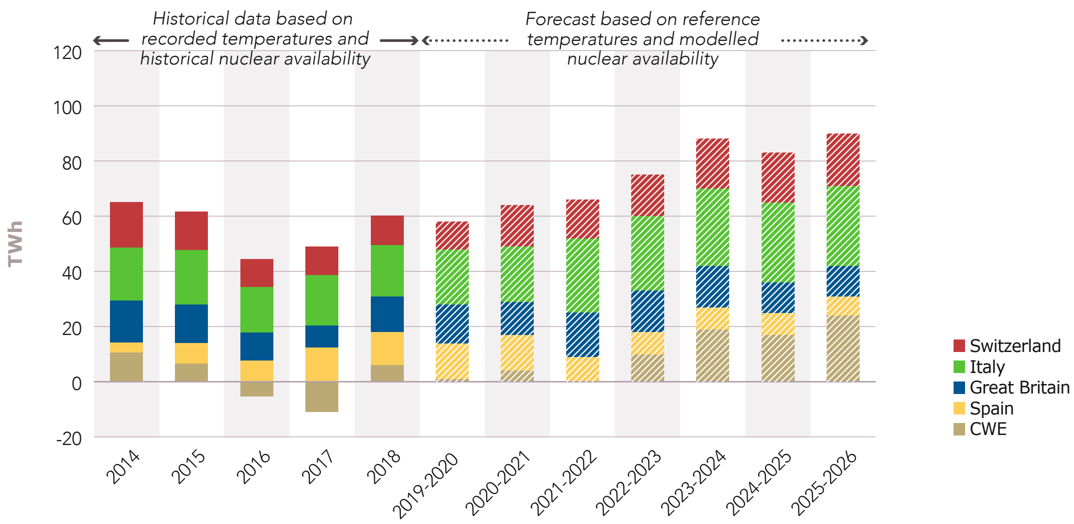
This has since been revised downwards slightly because of the lower expected availability of the nuclear fleet in France (between 2012 and 2018, nuclear production lost around 12 TWh capacity – equivalent to the annual production of two 900 MW reactors).

The structural growth of the export balance is the product of several factors:

- **Firstly, the development of renewable energy production, combined with maintaining the existing nuclear capacity in France** offers an important "base-load" power with low variable costs, making it very competitive on the European electricity market.
- At the same time, **the trend of closing coal-fired fleets and decommissioning nuclear reactors in some countries is gaining momentum in Europe,** which has the combined effect of withdrawing some production capacity from the European market and providing an economic role for productions with low variable costs in France (i.e. renewable energies and nuclear power). For instance, the volume of exports to Belgium and Germany should increase substantially from 2022, coinciding with the impending closures of nuclear and coal-fired plants in Belgium and Germany.
- Lastly, **the development of interconnections promotes cross-border electricity exchanges.** The volume of exports from France to Italy, for example, should increase substantially once the Savoie-Piémont interconnection project is up and running in 2020-2021.

As for CO_2 emissions, the results on the export balance forecasts apply as an average to all possible random event scenarios. Actual export volumes may vary marginally around this trend due to cyclical factors (availability of the nuclear fleet, meteorological events, etc.).

Figure 25. Electricity cross-border exchange balance (historical data and forecasts)



8. RTE, October 2018, Additional analyses on exchanges at interconnections in the scenarios outlined in the Long-term Adequacy Report 2017

Gas-fired power plants will play a major role in the transition period of the power system on both national and European scales

The economic area of gas-fired combined cycle power plants appears to be sustainable thanks to their contribution to the security of supply and economic opportunities on the European electricity markets

Given that the majority of coal and oil-fired production facilities have been closed in recent years or are due for imminent closure, gas-fired power plants in France should be able to continue operating into the long term in view of the more favourable, secure economic outlook.

Overall, these plants are more modern and their CO_2 emissions factors are lower than those of coal and oil-fired power stations. They are currently essential to the security of supply and will remain so over the coming years, in a climate where the French power system has no capacity margin to carry out the energy transition.

Yet maintaining their availability was by no means a foregone conclusion just a few years ago. A number of European gas-fired combined cycle plants were experiencing serious financial difficulties over the 2010-2015 period, resulting in many of them being mothballed due to a lack of economic opportunities. French gas-fired combined cycle plants, although modern, have been particularly beset by economic problems, with some of them being temporarily mothballed, either completely or just during the summer months. For example the French Mid-term Adequacy Report 2016 considered the possibility that eight gas-fired plants might be either mothballed or closed down permanently starting in 2017, which would have led to a level of security of supply significantly lower in the following winters.

The economic situation of these facilities has improved since, thanks to much more favourable prevailing market conditions because of several contextual factors.

Firstly, the introduction of the capacity mechanism, operational in France since 2017, has meant that all power generation facilities contributing to the national security of supply receive capacity remuneration.

Secondly, the multiple plant closures announced in Europe seem to have created a considerable number of economic opportunities for these gas-fired plants throughout Europe. In the merit order, French gas-fired CC power plants come in at third place behind renewable and nuclear energies, but ahead of older gas-fired plants (which have lower efficiencies). Recent changes in fuel prices (especially lower gas prices) and CO_2 prices (a substantial hike in the CO_2 price on the ETS market from around €5/t in 2017 to almost €25/t today) have also increased the competitiveness of gas-fired plants versus coal-fired power stations.

Revenues of "semi-base load" and "peak load" generation fleet are highly dependent on market conditions and the capacity mechanism

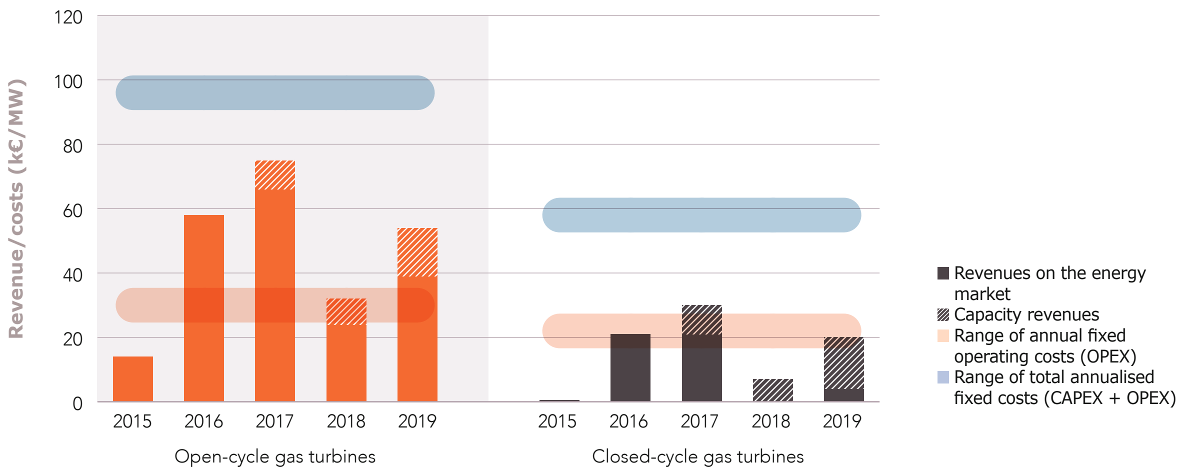
The simplified analysis of revenues of "semi-base load" and "peak load" power generation plants in recent years shows high volatility of annual revenues on the energy market, due not only to cyclical economic conditions (variations in electricity, gas and other fuel prices) but also to more random events, such as the occurrence or non-occurrence of cold waves, which have a major impact on the demand for electricity.

For certain years when temperatures were especially mild (2014 and 2015, for instance), annual revenue from gas-fired power plants was considerably below their fixed costs, even coming in at practically zero for combustion turbines.

The introduction of the capacity mechanism was a key factor in sustaining this type of gas-fired power plants and in preserving the security of supply.

This analysis also shows that the capacity mechanism sent price signals consistently with expected fundamental purposes (keeping gas-fired power

Figure 26. Net annual revenue (i.e. market revenue minus variable production costs)[9] for gas-fired combined cycle and combustion turbine plants from 2015 to 2019 and comparison with fixed cost assumptions[10]



plants running is necessary for the security of supply, but building new ones other than the Landivisiau plant is not essential to reach the adequacy standard).

The mechanism continues to evolve, in consultation with industrial stakeholders: a long-term call for tenders will complete the device with the aim of securing more capacity revenues from new capacities and an operating feedback exercise will be conducted during the first few years of operation of this mechanism. **The long-term call for tenders seems to be appropriate for new flexibility solutions (demand-side response and storage facilities), with successful bidders receiving a secure revenue for a period of seven years.**

9. Revenues are assessed on the basis of historical production and spot price data (assuming that all production is valued at the spot price). Revenues derived from balancing mechanisms and reserves are ignored. Variable production costs are assessed based on the spot prices of natural gas and CO_2 and the yields from each plant. Start-up costs are not taken into account. Finally, the DK6 facility is not included in this analysis due to the specific nature of its operation and economic profitability.

10. The fixed costs are represented by ranges of assumptions based on public analyses and feedback from a consultation conducted within the scope of the Long-term Adequacy Report 2017.

New electricity uses can be implemented in the power system in a bid to cut greenhouse gas emissions

In a drive to reduce French CO_2 emissions and become carbon neutral by 2050, the government's energy policy aim to ramp up the transition of energy use to electricity, specifically for the building and transportation sectors, and even for syngas production.

Integrating these "new uses" into the power system has been the subject of numerous issues raised by stakeholders during the consultation process. **To clarify the public debate, RTE has launched three further studies addressing the three uses offering major evolutions over the next fifteen years, namely (i) e-mobility, (ii) hydrogen production and (iii) heating systems in the building sector.**

A systematic approach has been applied to each of these focus areas to assess the impacts in detail from a technical (system operation), economic (for the community as a whole but also for end consumers) and environmental (primarily CO_2 emissions) perspective. The results are available in the public reports.

Overall, the analyses attested the capability of the power system to accommodate all the new uses considered in France's energy road map, and highlight the significant benefits in terms of CO_2 emissions.

These analyses focus on the year 2035: they assess the impact of mass deployment (of between 10 and 15 million electric vehicles, 20 to 40% of hydrogen produced by electrolysis, and the widespread use of heat pumps) in a mix made up of 50% nuclear and 45% renewable energies.

The trajectories will start to take off during the period 2020-2025, which will provide some preliminary feedback by comparing concrete results with the initial forecasts.

E-mobility – a mass deployment expected over the next few years

The transport sector today accounts for almost 40% of France's greenhouse gas emissions, making its decarbonisation one of the main levers for achieving climate targets.

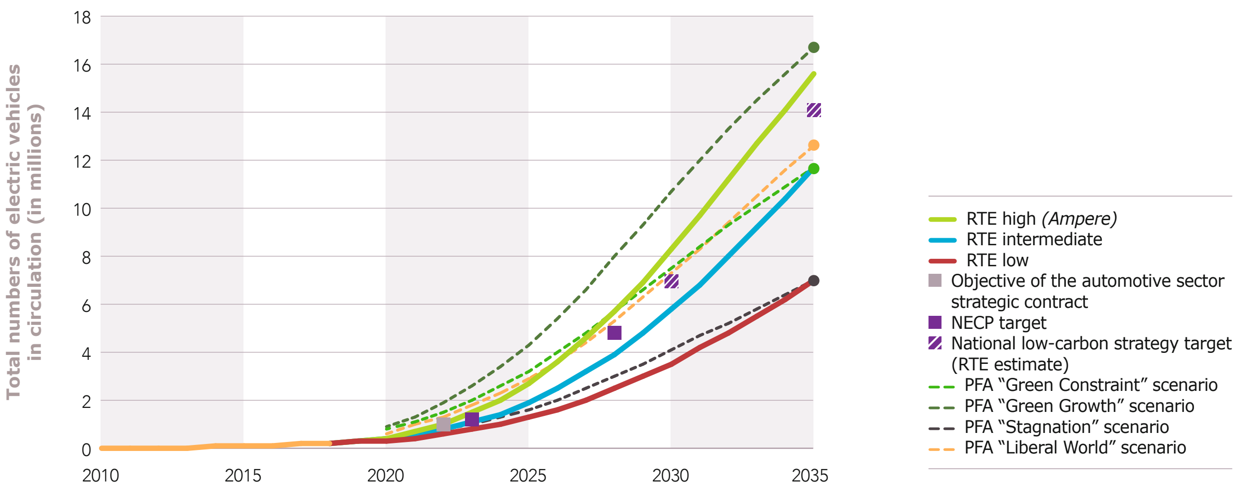
Like many other countries, France has ambitious plans to electrify its vehicle fleet, which is reflected in particular by the government's energy policy to ban sales of all new internal combustion engine vehicles by 2040. Manufacturers are also supporting e-mobility development over the coming years, with a number of electric vehicles now in circulation, which could represent an estimated 1 million units by 2022 and as many as 15 million by 2035 (equivalent to around 40% of the total number of light-duty vehicles).

RTE published a study[11] in May 2019 detailing the challenges associated with developing e-mobility for the power system by 2035. This study, conducted in consultation with stakeholders as part of a working group co-led by AVERE-France, shows that the French grid can support the mass development of e-mobility, without needing to introduce widespread smart charging solutions. Nevertheless, smart charging and vehicle-to-grid feed-in solutions offer very interesting economic opportunities for the power system and for electric vehicle users alike, as well as being a lever for cutting CO_2 emissions for the European power system.

By 2022, electric vehicles should no longer be a means of travel used by just a small population minority: based on the targets laid down in the "strategic contract" drawn up between the State and the automotive industry, around one million electric vehicles will be in circulation by this time.

11. "Integration of electric vehicles into the power system in France. Main results", RTE, May 2019 (https://www.rte-france.com/sites/default/files/rte_-_electromobility_report_-_eng.pdf)

Figure 27. Trajectories in the number of light-duty electric vehicles (private vehicles and light-duty commercial vehicles) in France, including all technologies: 100% electric vehicles (BEV) and plug-in hybrid electric vehicles (PHEV)



This level of deployment will not result in drastic changes in electricity consumption (estimates are around the 2 TWh mark). It will, however, be enough to draw some initial conclusions on charging methods and power demands.

In fact, the report published in May 2019 demonstrated, by examining five different mobility development scenarios *(Crescendo, Opera, Forte, Alto* and *Piano)*, that, for the same number of electric vehicles, the impact on the power system (in terms of consumption peaks and economic optimisation) could vary considerably.

By 2025, if there is still only a limited number of electric vehicles in circulation, development of smart charging methods could provide additional margins for the power system of around several hundred megawatts (see Chapter 4 - Levers for security of supply).

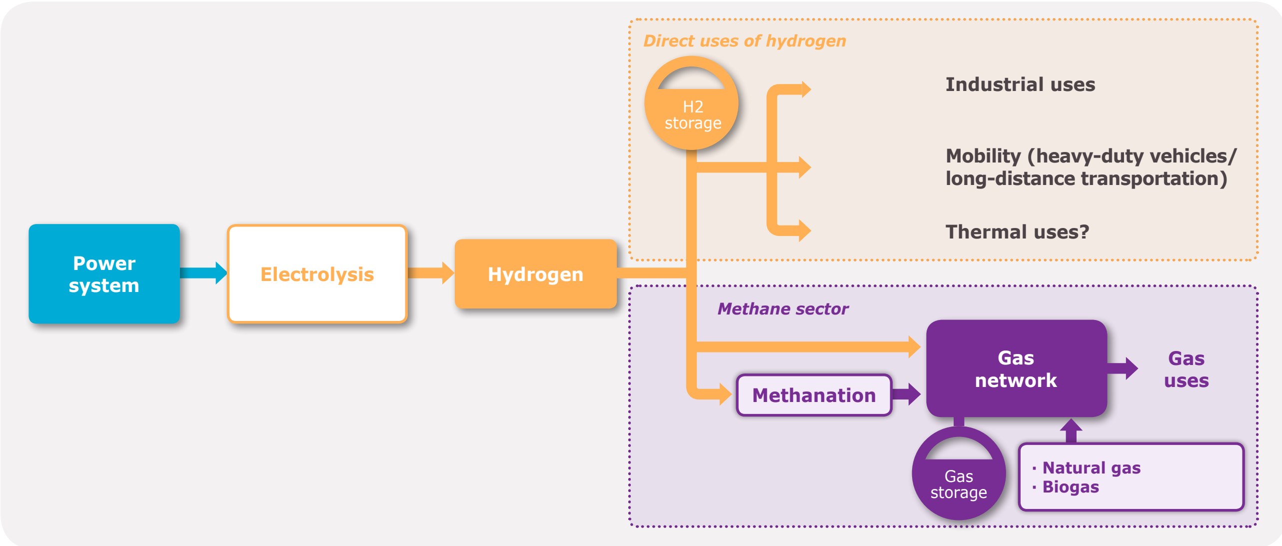
Low carbon hydrogen production – the first electrolysers will be commissioned over the next few years to meet statutory targets

The French government's National Low Carbon Strategy (SNBC) presented at the end of 2018 states that annual electricity consumption associated with electrolysis for the production of hydrogen could represent 50 TWh[12] by 2050.

This production method is, however, practically non-existent at present, given its comparatively high cost versus conventional methods, due mainly to a lack of industrialization of the processes involved. The government targets presented in the National Hydrogen Deployment Plan and the Energy-Climate law propose to develop electrolysis technology as a matter of priority for industrial uses, with the aim of reaching a 20 to 40% target for low carbon renewable hydrogen in total industrial hydrogen demand by 2030.

12. Summary of the French energy and climate reference scenario – Provisional version of the draft National Low Carbon Strategy and National Energy and Climate Plan – Energy and Climate Directorate, March 2019

Figure 28. Planned use of electrolysis to decarbonise the industrial uses of hydrogen, plus energy uses in the longer term



In 2019, RTE conducted several studies on integrating electrolysis in the power system by 2035, by assessing the associated economic and environmental challenges, as well as the opportunities for electrolysers to contribute to meeting the needs for flexibility in the power system. These analyses will soon be published in a special report.

To meet the public policy objectives, electricity-based hydrogen production must be well under way by 2023-2025.

A number of industrial projects for several hundred megawatts of electrolysis production by 2023-2025 are currently being studied, including H2V projects in Normandy and Hauts-de-France, and the Hygreen project in Provence. The economic models and operating methods for these projects may differ, but the power system can accommodate these projects by two different mechanisms: either the consumption from electrolysers is backed up by dedicated – preferably renewable – production sources; or electrolysers provide the required level of flexibility, which means they can contribute to demand-side response and balancing mechanisms.

Over the period examined in the Mid-term Adequacy Report 2019, the volume of electricity consumed for hydrogen production remains low, estimated at just a few terawatt-hours per year. Nevertheless, this volume is enough to study the operating modes of the first electricity-based hydrogen production units, their potential storage facilities, and the means of transmitting and distributing the electricity to the final consumer.

The building sector – major challenges in terms of renovation, heating system performance and cutting the use of fossil fuels

The residential sector alone accounts for 30% of final energy consumption in France, almost two thirds of which is attributable to heating.

In terms of final energy, electricity currently represents 17% of this consumption. The other main heating energy sources are gas (around 40%), wood (25%) and oil (14%)[13].

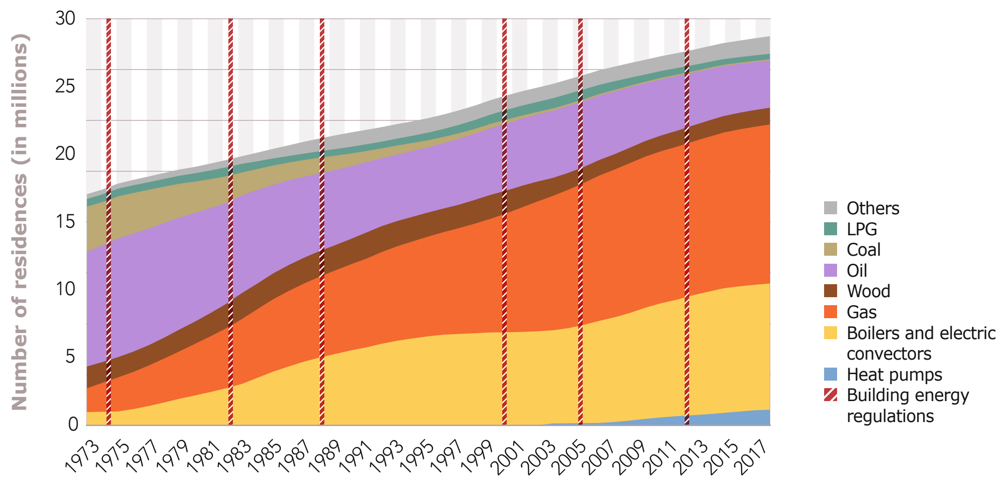
Heating therefore constitutes a sizeable proportion of total energy consumption, and is consequently a target for numerous planned energy-efficiency and low carbon schemes:

- To replace heating systems with more efficient, lower CO_2 emitting systems;
- To renovate old buildings, which represents a key sector for energy and climate policies to improve efficiency and reduce greenhouse gas emissions;
- To develop electrical heating systems as outlined in the national energy targets, based primarily on heat pump solutions, and accompanied by ambitious housing renovation targets.

The public policies implemented under the National Energy and Climate Plan need to start having a concrete impact on the trajectories in the next few years, even though the effects of measures relating to building or heating systems are inherently long term. By 2025, the end of coal and oil-fired heating in the residential sector and the wider focus on low carbon solutions should both have noticeable consequences on the level and structure of consumption.

RTE is frequently asked about the implications of these targets for peak electricity demand, emissions and system operation. In order to analyse these issues and shed some light on the public debate, RTE and ADEME are conducting a joint study on the impact of electrifying heating by 2035. Their corresponding report is due for publication in spring 2020.

Figure 29. Evolution of heating systems in the residential sector in France between 1973 and 2017



13. https://www.fedene.fr/wp-content/uploads/sites/2/2018/12/20171214_Rapport-global_restitution-enquete-2018-donnees-nationale-2017_v1.1.pdf

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MID-TERM ADEQUACY REPORT ON THE ELECTRICITY SUPPLY-DEMAND BALANCE IN FRANCE - MAIN RESULTS

2019 EDITION

Mid-term adequacy report

on the electricity supply-demand balance in France

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MAIN RESULTS