Electricity Report 2017
Contents

**Consumption**
- Demand stable in 2017
- Breakdown by sector
- Impact of temperature sensitivity and changes in end-uses

**Generation**
- Generation capacity stable at 130 GW
- Wind power
- Solar power
- Bioenergy
- Hydropower
- Thermal generation
- Renewable coverage of power demand: 18.4%
- CO₂ emissions

**Territories and regions**
- Consumption in the French regions
- Solar power
- Wind power
- Other renewables in the French regions
- The generation/consumption balance

**Europe**
- European vision for electricity
- Coverage rates across Europe

**Markets**
- Market prices higher in Europe
- France again a net exporter
- CWE region
- Spain
- Italy
- Switzerland
- Great Britain
- RTE keeping pace with cross-border exchange mechanisms
Flexibility

- Activities of the balance responsible parties
- Balancing mechanism
- Demand response
- Capacity mechanism

Transmission network

- How the network evolved in 2017
- New and replaced lines
- 2017 highlights
- Map of main projects brought into service
- RTE investments
- Map of main projects under way
- Electricity quality
- Loss rate
Summary

2017 highlights

Generation
The generation mix continued to change, with the share of renewable capacity increasing while oil-fired power plants were shut down. Installed capacity was flat year-on-year, ending 2017 at 130,761 MW. Electricity production decreased slightly in 2017 due to declines in nuclear (-1.3%) and especially hydropower output (-16.3%). Solar and wind power generation increased by 14.8% and 9.2%, respectively, relative to 2016.

Consumption
Annual power consumption adjusted for weather impacts stabilised for the seventh year in a row in France, with total consumption (excluding the energy sector) reaching 475 TWh. The rise in consumption by heavy industry (+3.5%) reflected the uptick in economic activity in that sector.

Markets
Significant imports during the cold spell of January 2017 caused the exchange balance to decline to 38 TWh, the lowest result on record since 2010. However, an increase in interconnection capacity allowed two new exchange records to be set: exports reached 17 GW on Thursday 30 March and imports climbed to 10.6 GW on Saturday 2 December.

Flexibility
Demand response volumes activated on the balancing mechanism jumped to 27 GWh from 16 GWh in 2016. More demand response capacity was certified through the capacity mechanism for 2018 (94,235 MW) than for 2017 (89,598 MW), as power producers predict better availability of plants.

Network
To help guarantee a successful energy transition, RTE is upgrading the power network and making it more secure. A total of €1,393 million was invested during the year, notably to bring into service the Brittany safety net, to build new interconnections between France and England (IFA2) and France and Italy, to restructure the 225 kV lines for the Haute-Durance and 2Loires projects, and to digitise substations. These investments also helped reduce the number of overhead lines and increase underground ones.

RTE prepares and publishes the Annual Electricity Report to provide a general overview of the power system during the previous year.

The 2017 edition shows that the effects of the energy transition are becoming visible in France.

The report was prepared based on data available as of 31 December 2017. More thorough and accurate data may become available for inclusion in subsequent publications.
**Glossary**

**ADEeF**  
Association of Electricity Distributors in France

**Adjusted consumption**  
Power that would have been consumed if temperatures had been the same as reference temperatures, and if there was no 29th day in February for leap years

**ARENH**  
Accès Régulé à l’Electricité Nucléaire Historique, or Regulated Access to Incumbent Nuclear Electricity: Refers to suppliers’ right to buy electricity from EDF at a regulated price, in quantities determined by French energy regulator CRE

**Balance responsible party**  
An electricity market player that has a contract with RTE under which it must settle the cost of any differences between energy injected and withdrawn, as recorded after the fact, across the entire portfolio for which it is responsible

**Balancing mechanism**  
Mechanism designed to ensure that, at any given time, RTE has sufficient power reserves it can activate if supply and demand do not balance

**Business customers**  
Customers getting power from the public distribution grid with contracted power of 250 kVA or more

**Capacity factor**  
Ratio between the electrical energy effectively generated over a given period and the energy that would have been produced at nameplate capacity over the same period

**CCGT**  
Combined-cycle gas turbine

**Coverage rate**  
Ratio between power generated and gross domestic consumption at a given time

**CWE**  
Central West Europe, region including France, Belgium, Germany, Luxembourg and the Netherlands within which electricity market prices have been coupled since 2010

**EDF-SEI**  
EDF-SEI is an integrated operator that generates, purchases, transmits, distributes and supplies electricity in non-interconnected island territories

**Enedis**  
A distribution system operator in France

**ENTSO-E**  
European Network of Transmission System Operators for Electricity, which has 34 member countries and 41 transmission system operator (TSO) members. Its purpose is to promote important aspects of electricity policy such as security, renewable energy development and the power market. ENTSO-E works closely with the European Commision and is the backbone of the European electricity market

**Equivalent outage time**  
Energy not supplied as a result of customer power cuts, expressed as a ratio to total annual power supplied by RTE to its customers

**Exceptional events**  
High impact, low probability atmospheric phenomena as well as cases of force majeure

**Generation: Bioenergy**  
“Bioenergy” includes biogas, paper/paperboard waste, municipal waste, wood-energy and other solid biofuels

**Generation: Fossil-fired thermal**  
“Fossil-fired thermal” includes fuels like coal, oil and gas

**Generation: Hydropower**
“Hydropower” includes all types of hydropower facilities (pondage facilities, run-of-river, etc.). Consumption resulting from pumping at “STEP” (pumped storage stations) is not deducted from total output.

**Generation: Nuclear**

“Nuclear” includes all nuclear power plants. Consumption by auxiliary generator sets is deducted from generation.

**Gross consumption**

Power consumed across France, including Corsica and factoring in losses.

**Heavy industry**

Final customers getting electricity directly from the transmission system operator.

**Industrial output**

The indicator used is based on INSEE’s industrial output indices, weighted to reflect power demand in the different segments of each sector.

**Intraday**

Refers to electricity trades conducted on very short notice, almost in real time.

**ITER**

International Thermonuclear Experimental Reactor.

**LDCs**

Local Distribution Companies. These are, along with Enedis, the operators of the distribution system, intermediaries between the transmission grid and final customers. There are approximately 150 LDCs across France.

**Lightning density**

Number of times lightning strikes per year and per km² in a given region.

**Demand response**

Mechanism by which consumers cancel or postpone all or part of their power consumption in response to a signal.

**Market coupling**

Process by which electricity supply and demand are matched across different markets, within the limits of the interconnection capacity between these markets. An algorithm simultaneously determines prices and implicitly allocates available cross-border capacities, resulting in identical price zones when interconnection capacities do not limit cross-border trades.

**Multiannual Energy Programmes**

Multiannual Energy Programmes (Programmation Pluriannuelle de l’Energie – PPE) are a new tool used to set priorities to guide the actions of public authorities as they relate to the energy transition, in accordance with the commitments outlined in the energy transition law for green growth.

**MWp**

Megawatt peak corresponds to 1 million Watt-peak units. A Watt-peak is a measuring unit for the output of photovoltaic panels, corresponding to the production of 1 Watt of electricity under normal conditions for 1,000 Watts of solar radiation per square metre at an ambient temperature of 25°C.

**NTC**

Net Transfer Capacity, the transfer capacity made available to the market for imports and exports, calculated and published jointly by the system operators. Transfer capacity depends on the characteristics and availability of interconnection lines and internal constraints on individual countries’ power grids.

**Outage frequency**

Ratio between the number of short or long outages and the number of distributors and industrial customer sites supplied by RTE. An outage is considered short if it lasts between 1 sec and 3 min and long if it lasts more than 3 min.

**Power line circuit length**

Actual length of one of the conductors that form a power line or the average length of the conductors if they differ substantially.

**Professional customers**

Customers getting power from the public distribution network for professional use with contracted power of 36 kVA or less.

**PTS**

Public Transmission System, over which electrical energy is carried and transformed, linking generation sites to consumption sites. It includes the primary transmission and interconnection grid (400 kV and 225 kV) as well as the regional distribution networks (225 kV, 90 kV and 63 kV). This very high voltage and high voltage grid provides electricity to heavy industry and the main distribution system operators.

**Reference temperatures**

Averages of past temperature series considered to be representative of the current decade. Based on Météo France data, the temperatures are calculated by RTE for France as a whole thanks to 32 weather stations throughout the country.

**Residential customers**

Customers getting power from the public distribution network for residential use with contracted power of 36 kVA or less.
Residual demand
Residual demand corresponds to demand from which must-run generation has been subtracted

Retail customers
This is another name for the residential sector, which includes customers that get power from the public distribution network for residential use with contracted power of 36 kVA or less

Seasonally-adjusted datasets
Chronological series from which the seasonal component has been removed. Changes in statistical series can usually be characterised as reflections of trends, seasonal components, or irregular components. Adjusting for seasonal variations is a technique used by statisticians to eliminate the effects of seasonal fluctuations on data, thereby revealing fundamental trends

SER
"Syndicat des Énergies Renouvelables", France's renewable energy association

SMEs/SMI
Final customers to which distribution system operators provide medium- and low-voltage power, with contracted power of 36 kVA or more

Spot price
Average electricity price negotiated for delivery the following day in 24 one-hour timeslots

Water reserve
The water reserve in France is the weekly average aggregate filling rate of all water reservoir and hydro storage plants. The upper energy is energy that can be generated from the (only) production unit directly connected to the reservoir, depending on its filling rate. The data published constitutes only the reserves related to upper energy and is expressed in MWh
Consumption
Demand stable in 2017

Gross consumption unchanged

Gross consumption ended 2017 at roughly 482 TWh, down 0.3% from a year earlier. This very small decrease was attributable to higher average temperatures (+0.6°C) and to a calendar effect, as 2016 was a leap year.

Why are adjustments made to gross consumption?

To better identify structural trends

When it is very cold outside, electricity is used for heating. When the weather is very hot, people use power for cooling. To better analyse structural trends from one year to the next, power consumption data is adjusted to strip out “weather effects”. Once this is done, electricity demand corresponds to what would have been consumed if temperatures had been the same as reference temperatures.

Adjustments can also be made for other factors as well. For instance, February has an extra day in leap years. To strip out this calendar effect, consumption is adjusted in such a way as to count only 365 days.
Adjusted consumption was also flat

Excluding the energy sector from the calculation, consumption adjusted for weather and calendar effects (adjusted consumption) reached 475 TWh in 2017, up 0.2% from 2016.

The main structural drivers of this trend were economic growth, changes in France’s industrial fabric, the shift in economic activity toward services, and the effects of demand-side management.

Note: In calculating adjusted consumption, it is necessary to exclude the energy sector because the adoption of a new uranium enrichment process in 2012 severely impacted the sector and caused a steep decline in consumption.
Deviation from reference temperatures in 2017

2017 was a year of contrasts

The deviation from the average reference temperature was small in 2017 (+0.15°C).

An analysis of daily statistics nonetheless reveals some contrasting trends, with:

- Two cold spells in the early part of the year;
- Very warm weather in late winter, spring and summer: February, March, May, June and August all counted among the hottest months on record between 1900 and 2017. Two heat waves occurred during the year, one from 18 to 22 June and one from 26 to 29 August.
- Weather in the autumn and early winter months was variable: October was one of the hottest months on record in the 1900-2017 period, while September was the fourth coolest month of September in 20 years. December saw two winter storms – Ana and Bruno – sweep through France.

Adjustments are made for these changes in analysing consumption in order to better identify structural trends.

Temperature trends in France relative to reference temperatures

éCO2mix: Everything you want to know about electricity in France and your region or city

Eco2mix is an educational tool designed to promote transparency. Whether you are an ordinary citizen trying to better understand electricity to become a more responsible consumer, a knowledgeable amateur or an energy professional, you can use éCO2mix in a fun or expert manner to monitor power system data at the national, regional and city level. It can also be used to understand your power consumption and get advice on how to reduce it and take simple actions to prevent or reduce the risk of a system imbalance in the event of a power warning.

http://www.rte-france.com/eco2mix
Breakdown by sector

Little change in sector breakdown

The breakdown of consumption by sector was comparable to 2016.

The residential sector was again the largest consumer of electricity, accounting for about 36% of final consumption, followed by the business sector (26%), heavy industry (17%), SMEs/SMI (11%) and professionals (10%).

Who are RTE’s customers?

RTE works on behalf of society and its own customers – producers and distributors of electricity, industrial firms and traders – to offer solutions that help keep power system costs in check and thus preserve economic activity.

As the transmission system operator, RTE plays a central role in the power system and is responsible for ensuring that power generation always matches demand. It works around the clock, seven days a week, to direct electricity flows and optimise the functioning of the power system for its customers and society at large. RTE carries electricity to all parts of France, from generation sites to the industrial sites that are directly connected to its network and to the distribution grids that deliver it to final consumers.

Find out more about our customers here
SMEs/SMI, professional and retail customers: Slight decrease in consumption

Electricity consumption (including losses) by SMEs/SMI and professional and retail customers connected to distribution networks declined slightly between 2016 and 2017.

The application of directives and regulations on the energy efficiency of equipment contributed to this decline. Another factor was slower growth in the share of new buildings heated with electricity due to the application of the 2012 Building Energy Regulation.

Rise in consumption by heavy industry

Electricity consumption by customers in heavy industry* directly connected to the public transmission system reached 68.2 TWh in 2017, which was 3.5% more than 2016, reflecting the uptick in economic activity.
Trends in different segments of heavy industry

Consumption increased in most segments

Consumption trends varied from one segment of heavy industry to the next in 2017. Paperboard was the only segment in which consumption contracted (-1% versus 2016). All others saw increases, a sign that the economy is recovering. The biggest gain was in steel (+8.6%), followed by chemicals (+4.2%), car manufacturing (+1.6%), metallurgy (+1.4%) and rail transport (flat).

![Consumption by metallurgy](chart.png)

A more detailed analysis of these sector trends can be found in the 2017 Generation Adequacy Report.
Energy efficiency in heavy industry

Power consumption in heavy industry is closely correlated to industrial output. However, improved processes, and in some cases changes in means of production, have made energy use more efficient. Shown here is a graphic analysis of industrial output and power demand curves. Consumption and output levels move closer to one another – this is notably visible in the chemicals and car manufacturing segments – which can be explained by increased energy efficiency, assuming no transfers in end-uses.
Impact of temperature sensitivity and changes in end-uses

Record peak demand

Electricity consumption peaked for the year at 94 GW at 7:00 pm on Friday 20 January, during a cold spell. This was the third highest peak ever recorded in France.

Demand was at its lowest point in 2017 on Sunday 13 August, when it fell to 30.2 GW.

What drives peaks and valleys in demand?

Consumption in France varies greatly depending on the season, day of the week and time of day.

Electric heating causes demand to reach higher levels in winter than in summer. Similarly, people are more active during the week than on weekends, so demand is higher on weekdays.

Over the course of a day, the use of power for lighting and cooking for example, particularly in the evening, when people tend to return home, explains the spike observed at around 7:00 pm.
Profiles by end-use and sector

Power demand at a given point in time (also referred to as the load curve) represents the addition of the varying profiles of different sectors and end-uses, which change with the seasons.

Demand by end-use

The hourly loads* on the two charts below show substantial seasonal variability. This is due in large part to the use of heating in winter.

* Note that these charts show power demand at reference temperatures. Actual demand is much more variable. For more information, return to the section on temperature sensitivity by clicking on “Return to content” at the bottom of this page.
Demand by sector

A comparison of the breakdown of demand by end-use and by sector over one year reveals:

- Significant reliance on electric heating in winter, reflected in power demand in the residential sector and, to a lesser degree, in the tertiary sector
- A brief dip in demand in the tertiary sector and industry late in December, when economic activity slows due to the year-end holidays. Decreases are also seen in both sectors during the school holidays (in August, for example).
In winter, demand increases by 2,400 MW with each degree Celsius drop in temperatures.

Power demand in France is very sensitive to temperatures, particularly in the winter months, due to the widespread use of electric heating.

RTE uses a model that distinguishes between temperature-sensitive and non-temperature-sensitive demand to calculate weather-adjusted consumption. It is the temperature-sensitive share that shapes the overall trend in demand.

The temperature sensitivity of power demand varies over the course of a given day. It is estimated at about 2,400 MW per degree Celsius in winter on average.
Changes in end-uses are likely to reduce the temperature sensitivity of demand over the next few years

The type of heating installed in new homes can have a significant influence on temperature sensitivity. Since the 2012 Building Energy Regulation took effect, the share of electric heating in new build has shrunk to a third of the 2008 level. This shift is liable to keep temperature sensitivity in check going forward. However, new homes only make up a very small portion of housing stock (about 1%), so the impact will only be visible over the long term.

Other end-uses besides heating (primary and backup systems) also contribute, to a lesser degree, to determining the share of power that is temperature sensitive, including domestic hot water, cooking and cold production.
**Energy efficiency: Households consuming less electricity**

Household appliances are increasingly efficient. Though this efficiency does not make consumption in France less temperature sensitive, it does help households save on their energy bills.

It is estimated that households consumed an average 2,350 kWh for domestic electricity uses in 2016. This consumption would be halved if households were equipped exclusively with efficient appliances (A+++).

<table>
<thead>
<tr>
<th>Unit energy consumption of appliances</th>
<th>Energy efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>White</strong></td>
<td></td>
</tr>
<tr>
<td>Refrigerator</td>
<td></td>
</tr>
<tr>
<td>C 473 kWh</td>
<td>-75%</td>
</tr>
<tr>
<td>A+ 221 kWh</td>
<td></td>
</tr>
<tr>
<td>A+++ 119 kWh</td>
<td></td>
</tr>
<tr>
<td>Standalone freezer</td>
<td></td>
</tr>
<tr>
<td>C 492 kWh</td>
<td>-73%</td>
</tr>
<tr>
<td>A+ 247 kWh</td>
<td></td>
</tr>
<tr>
<td>A+++ 135 kWh</td>
<td></td>
</tr>
<tr>
<td>Washing machine</td>
<td></td>
</tr>
<tr>
<td>C 251 kWh</td>
<td>-39%</td>
</tr>
<tr>
<td>A+ 183 kWh</td>
<td></td>
</tr>
<tr>
<td>A+++ 154 kWh</td>
<td></td>
</tr>
<tr>
<td>Clothes dryer</td>
<td></td>
</tr>
<tr>
<td>C 434 kWh</td>
<td>-67%</td>
</tr>
<tr>
<td>A+ 242 kWh</td>
<td></td>
</tr>
<tr>
<td>A+++ 142 kWh</td>
<td></td>
</tr>
<tr>
<td>Dishwasher</td>
<td></td>
</tr>
<tr>
<td>C 303 kWh</td>
<td>-43%</td>
</tr>
<tr>
<td>A+ 216 kWh</td>
<td></td>
</tr>
<tr>
<td>A+++ 172 kWh</td>
<td></td>
</tr>
<tr>
<td><strong>ICT</strong></td>
<td></td>
</tr>
<tr>
<td>42” TV</td>
<td>-83%</td>
</tr>
<tr>
<td>C 138 kWh</td>
<td></td>
</tr>
<tr>
<td>A+ 54 kWh</td>
<td></td>
</tr>
<tr>
<td>A+++ 24 kWh</td>
<td></td>
</tr>
<tr>
<td>IT equipment</td>
<td></td>
</tr>
<tr>
<td>Desktop 250 kWh</td>
<td>-96%</td>
</tr>
<tr>
<td>Laptop 50 kWh</td>
<td></td>
</tr>
<tr>
<td>Tablet 10 kWh</td>
<td></td>
</tr>
<tr>
<td><strong>Cooking</strong></td>
<td></td>
</tr>
<tr>
<td>Electric cooktop</td>
<td></td>
</tr>
<tr>
<td>Cast iron 300 kWh</td>
<td>-40%</td>
</tr>
<tr>
<td>Ceramic glass 230 kWh</td>
<td></td>
</tr>
<tr>
<td>Induction 180 kWh</td>
<td></td>
</tr>
<tr>
<td>60 L oven</td>
<td></td>
</tr>
<tr>
<td>C 315 kWh</td>
<td>-73%</td>
</tr>
<tr>
<td>A+ 155 kWh</td>
<td></td>
</tr>
<tr>
<td>A+++ 84 kWh</td>
<td></td>
</tr>
<tr>
<td><strong>Lighting</strong></td>
<td></td>
</tr>
<tr>
<td>800 lumen lamp</td>
<td>-83%</td>
</tr>
<tr>
<td>Incandescent 60 kWh</td>
<td></td>
</tr>
<tr>
<td>Eco halogen 43 kWh</td>
<td></td>
</tr>
<tr>
<td>LED 10 kWh</td>
<td></td>
</tr>
</tbody>
</table>
See the Generation Adequacy Report

Detailed consumption forecasts and trends linked to end-uses can be found in the 2017 Generation Adequacy Report.
Generation
Renewable energy capacity up 2,763 MW

Electricity generation capacity in mainland France decreased by 94 MW (-0.1%) from a year earlier, to end 2017 at 130GW.

<table>
<thead>
<tr>
<th>Installed capacity at 31/12/2017</th>
<th>Capacity in MW</th>
<th>Change relative to 31/12/2016</th>
<th>Change in MW</th>
<th>Share of total capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nuclear</td>
<td>63,130</td>
<td>0.0%</td>
<td>0</td>
<td>48.3%</td>
</tr>
<tr>
<td>Fossil-fired thermal</td>
<td>18,947</td>
<td>-13.1%</td>
<td>-2,857</td>
<td>14.5%</td>
</tr>
<tr>
<td>of which coal</td>
<td>2,997</td>
<td>0.0%</td>
<td>0</td>
<td>2.3%</td>
</tr>
<tr>
<td>of which oil</td>
<td>4,098</td>
<td>-42.6%</td>
<td>-3,039</td>
<td>3.1%</td>
</tr>
<tr>
<td>of which gas</td>
<td>11,851</td>
<td>1.6%</td>
<td>183</td>
<td>9.1%</td>
</tr>
<tr>
<td>Hydropower</td>
<td>25,517</td>
<td>0.2%</td>
<td>48</td>
<td>19.5%</td>
</tr>
<tr>
<td>Wind power</td>
<td>13,559</td>
<td>15.3%</td>
<td>1,797</td>
<td>10.4%</td>
</tr>
<tr>
<td>Solar power</td>
<td>7,660</td>
<td>13.1%</td>
<td>887</td>
<td>5.9%</td>
</tr>
<tr>
<td>Bioenergy</td>
<td>1,949</td>
<td>1.6%</td>
<td>31</td>
<td>1.5%</td>
</tr>
<tr>
<td>Total</td>
<td>130,761</td>
<td>-0.1%</td>
<td>-94</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

The sharp decline in conventional fossil-fired thermal capacity, following the closure of the four Porcheville plants and one in Cordemais, was offset by a surge in renewable energy capacity (+2,763 MW).
(Encadré) View the national registry of power generation and storage facilities

Since 2017, RTE has been listing the main characteristics of French power generation and storage facilities on OpenData, which is updated every month. Information provided includes the location of facilities, the technology and fuel used, capacity, annual output, etc.
The data comes from all system operators in mainland France and the overseas territories.

Encadré (Energie et puissance)
Energy and power
Understanding the difference between power and energy

Power (measured in watts, symbol W) represents a generation resource’s ability to deliver a quantity of energy per unit of time. A watt-hour (Wh) quantifies the energy delivered: 1 Wh is the energy produced by a 1W generation facility over a one-hour period (1W x 1h).

In addition to kilowatt-hours (kWh = 10^3 Wh), larger multiples of watt-hours are often used to describe electricity generation: megawatt-hours (MWh = 10^6 Wh), gigawatt-hours (GWh = 10^9 Wh) and terawatt-hours (TWh = 10^12 Wh). The energy consumed in one hour corresponds to power delivered to meet demand during that hour.
Total output down 0.4%

Total power generation in France reached 529.4 TWh in 2017, which was 0.4% less than in 2016. Several periods of drought caused hydropower generation to fall sharply (-16.3% relative to 2016). Numerous episodes of power plant unavailability, together with the decline in hydropower output, resulted in greater use of fossil-fired thermal power plants.

<table>
<thead>
<tr>
<th>Energy produced</th>
<th>TWh</th>
<th>Change 2017/2016</th>
<th>Share of generation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net generation</td>
<td>529.4</td>
<td>-0.4%</td>
<td>100.0%</td>
</tr>
<tr>
<td>Nuclear</td>
<td>379.1</td>
<td>-1.3%</td>
<td>71.6%</td>
</tr>
<tr>
<td>Fossil-fired thermal</td>
<td>54.4</td>
<td>+20.0%</td>
<td>10.3%</td>
</tr>
<tr>
<td>of which coal</td>
<td>9.7</td>
<td>+33.1%</td>
<td>1.8%</td>
</tr>
<tr>
<td>of which oil</td>
<td>3.8</td>
<td>+45.3%</td>
<td>0.7%</td>
</tr>
<tr>
<td>of which gas</td>
<td>40.9</td>
<td>+15.4%</td>
<td>7.7%</td>
</tr>
<tr>
<td>Hydropower</td>
<td>53.6</td>
<td>-16.3%</td>
<td>10.1%</td>
</tr>
<tr>
<td>of which renewable</td>
<td>48.6</td>
<td>-18.0%</td>
<td>9.2%</td>
</tr>
<tr>
<td>Wind power</td>
<td>24.0</td>
<td>+14.8%</td>
<td>4.5%</td>
</tr>
<tr>
<td>Solar power</td>
<td>9.2</td>
<td>+9.2%</td>
<td>1.7%</td>
</tr>
<tr>
<td>Bioenergy</td>
<td>9.1</td>
<td>+4.1%</td>
<td>1.7%</td>
</tr>
<tr>
<td>of which renewable</td>
<td>7.0</td>
<td>+5.4%</td>
<td>1.3%</td>
</tr>
</tbody>
</table>

It should be noted that nuclear represented 71.6% of total generation, the smallest share since 1992. The breakdown between sources was broadly the same as in 2016.
Variability of generation from different sources

France’s generation mix comprises resources that are sensitive to various parameters: cloud cover and sunlight for solar power, wind conditions for wind power, rainfall and temperatures for hydropower. For example, coverage of demand with hydropower output is at its highest in May, when snow is melting. But this output can be modulated and, to a degree, used to help offset fluctuations in wind and solar power output. Facilities that run on fossil fuels (coal, oil and gas) are powered up more often in the winter. Their coverage of total demand ranged between 1% and 20% in 2017.

The extremities represent the maximum and minimum and the white line the median.

Variability means adaptability
When the wind blows, it can be a breeze, a gust or a squall. Wind turbines thus have different ways to generate power. Depending on the wind, their output can vary greatly from hour to hour, day to day and region to region. Adapting the grid to accommodate the development of renewable energy sources has become a top priority for power sector players. Venteea, the goal of which is to facilitate the integration of wind power into the grid, is directly contributing to the drive to promote renewable energy and demand-side management via smart grids. VENTEEA: Harnessing the power of the wind to make grids smarter!

The future of the energy mix
Wind power, tidal and wave energy… marine energy sources hold real potential. Their integration into the power system will contribute to a successful energy transition and the development of a new industry. MAG RTE&Vous describes how RTE and its partners are meeting the challenges involved in connecting these new power sources to the grid.

Wind power

Panorama of Renewable Electricity
RTE, Syndicat des Energies Renouvelables (Renewable Energy Association), Enedis and ADEeF jointly publish a detailed analysis of developments in renewable energies.
http://www.rte-france.com/fr/article/panorama-de-l-electricite-renouvelable
1,797 MW of capacity added

Installed wind power capacity ended 2017 at 13,559 MW, after 1,797 MW of new capacity was added during the year. Of this total, 950 MW was connected to the RTE network and 12,609 MW to the grids of Enedis, LDCs and EDF-SEI for Corsica. Connection rates continued to trend higher and the pace accelerated in the first and third quarters, with 894 MW connected compared with 404 MW in the same period of 2016. Increased connection rates and growth in the connection queue reflect market players’ confidence in the wind power industry’s development prospects. It should be recalled that the Multiannual Energy Programme calls for installed capacity to reach 15,000 MW in 2018.

Multiannual Energy Programme objectives

The objectives set forth in the Multiannual Energy Programme are split between technologies as follows:

<table>
<thead>
<tr>
<th>Technology</th>
<th>Targets for 2018 (MW)</th>
<th>Targets for 2023 (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low option</td>
<td>High option</td>
</tr>
<tr>
<td>Wind power</td>
<td>15,000</td>
<td>21,800</td>
</tr>
<tr>
<td>Solar power</td>
<td>10,200</td>
<td>18,200</td>
</tr>
<tr>
<td>Hydropower</td>
<td>25,300</td>
<td>25,800</td>
</tr>
<tr>
<td>Bioenergy</td>
<td>677</td>
<td>790</td>
</tr>
</tbody>
</table>
Increase in wind power output

Wind power output surged by 14.8% relative to 2016. Boosted by an increase in installed capacity, production also benefited from favourable weather conditions in late summer and especially in December.

Wind power generation

Breakdown of wind power generation

Wind power output at half-hourly intervals

The first decile increased sharply (+19.6%) as did the last decile (+16.9%), reflecting generally good weather conditions over the year and especially in December. Given that there are several wind regimes in France, the wide spread of geographic sites tends to compensate for the variability of wind power generation resulting from changes in wind conditions.
Demand covered by wind power

On average, wind power covered 5.0% of demand compared with 4.3% in 2016. Significant records were set in the summer of 2017 with half-hourly coverage rates approaching 25%.

Monthly wind power output

A new output record was set on 30 December at 1:30 pm with 11,075 MW generated. The related capacity factor was 81.8%.

Monthly wind power generation

Monthly wind capacity factor

The monthly wind power capacity factor averaged 21.6% in 2017, down slightly from 22.0% in 2016.
887 MW of capacity added

In 2017, 887 MW of new solar power capacity was connected in mainland France, lifting installed solar capacity to 7,660 MW of which 7,017 MW is connected to the grids of Enedis, LDCs and EDF-SEI for Corsica and 643 MW to the transmission network.

Did you know? RTE publishes an Overview of Electrical Energy every month to provide insight into the major trends in the power market.

Output up by more than 9%

Solar power output was 9.2% higher than in 2016, reflecting the increase in capacity. With good sunlight conditions during the spring months, monthly solar power production exceeded 1 TWh for more than five months in a row, a new record.
Breakdown of solar power generation

Monthly solar capacity factor

The average solar capacity factor was 14.9% in 2017, up from 14.6% in 2016.

Solar power output at half-hourly intervals

Solar power covered an average 2.0% of demand in 2017, which was slightly higher than in 2016 (1.8%). The coverage rate peaked on 20 August 2017, at 3:00 pm, reaching 13.3%.
Monthly solar power output

On 20 April 2017, at 2:00 pm, solar power generation peaked at 5,646 MW, which corresponded to a capacity factor of 82.9%.

Bioenergy

Bioenergy capacity

Installed bioenergy capacity rose slightly in 2017 (+1.6%), ending the year at 1,949 MW. Another 303 MW of capacity was under development as of 31 December 2017.
Breakdown of bioenergy capacity

Municipal waste incineration plants still account for the lion’s share of bioenergy capacity. Installed biogas capacity rose by 39 MW during the year.

![Breakdown of bioenergy capacity](image)

Hydropower

Water reserves

Average water reserves declined by 16.9% year-on-year in 2017. In the month of February, reserves were nearly 45% below February 2016. Several periods of drought kept weekly reserves below the year-earlier levels throughout the year.

![Weekly water reserves in 2017 and 2016](image)
Hydropower generation

Annual hydropower generation declined by 16.3% from 2016, to one of the lowest levels ever recorded. This shortfall was attributable to a decrease in rainfall in France, which was down 40% year-on-year in January and down 50% in April 2017.

Decline in nuclear power generation offset in part by fossil-fired thermal

Decline in nuclear power generation

Installed nuclear capacity ended the year unchanged at 63.1 GW, which represents about half of total French capacity (130 GW). Availability was similar to 2016 but nuclear power generation declined slightly (-1.3%) and only accounted for 71.6% of total output.
Sharp increase in fossil-fired thermal generation

Generation from fossil-fired plants surged (+20.0% relative to 2016), notably because these facilities were called upon to make up for decreases in nuclear and hydropower generation. Coal- and oil-fired plants were fired up more often than in 2016 (+33.1% and +45.3%). Gas-fired generation also increased (+15.4%) in part thanks to the Bouchain plant commissioned at the end of 2016.
Map of fossil-fired plants in France

Gas-fired plants

- Combined-cycle gas turbines (CCGTs)
- Gas combustion turbines
Coal- and oil-fired plants

- Coal-fired plants
- Combustion turbines
- Oil-fired steam turbines

Locations:
- Le Havre (1)
- Vaires-sur-Marne (3)
- Arljhi (2)
- Emilio Huchot (1)
- Provence (1)
- Dirinon (2)
- Brennilis (3)
- Cordemais (2)
- Cordemais (1)
Fossil and renewable energies in 2017

The cold spell that swept through France in January made it necessary to rely heavily on fossil-fired thermal power plants. Though February was among the ten warmest months of February on record in 1900-2017, low hydropower generation also drove fossil-fired generation up during that month.

Monthly output from fossil-fired and renewable energy sources in 2017 (excluding hydropower)

Renewable coverage of power demand: 18.4%

Decrease in renewable energies’ coverage of gross consumption

The share of demand covered by renewable energy sources declined by 6.6% year-on-year. The coverage rate slipped to 18.4% from 19.7% in 2016, reflecting the sharp drop in hydropower generation.

Did you know? Renewable power covered 18% of demand in France in the first quarter of 2017.
**Method of calculating renewable generation**

The calculation method used is drawn from EU directive 2009/28/EC. 70% of consumption for pumping is deducted from production from pumped storage stations. Municipal waste incineration plant output is counted at 50%. The methodology used here does not make adjustments for weather conditions.

**Wind and solar output: 37.4% of total renewable generation**

Taken together, wind and solar resources produced 33.2 TWh and accounted for more than a third of total renewable energy generation in France (37.4%, up from 30.8% in 2016). This increase was attributable to a drop in hydropower generation combined with growth in solar and wind power output. Adding in the renewable share of hydropower and bioenergy, total renewable power generation in France ended the year at 88.9 TWh (down 6.8% from 2016).
**Uptick in CO₂ emissions**

CO₂ emissions increased for the third year in a row. Decreases in nuclear and hydropower generation, together with cold spells, made it necessary to rely heavily on fossil-fired thermal plants. In all, carbon emissions ended the year up 20.5%. Most of these emissions were due to a rise in coal- and gas-fired generation. Total CO₂ emissions resulting from own consumption were estimated at 4.25 million tonnes. These emissions are included in the carbon footprint assessments of the industrial sites in question.

<table>
<thead>
<tr>
<th>CO₂ emissions excluding own consumption (millions of tonnes)</th>
<th>2017</th>
<th>2016</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net production</td>
<td>27.9</td>
<td>23.1</td>
</tr>
<tr>
<td>Nuclear</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Fossil-fired thermal</td>
<td>26.3</td>
<td>21.5</td>
</tr>
<tr>
<td>of which coal</td>
<td>9.5</td>
<td>7.1</td>
</tr>
<tr>
<td>of which oil</td>
<td>1.3</td>
<td>1.2</td>
</tr>
<tr>
<td>of which gas</td>
<td>15.5</td>
<td>13.2</td>
</tr>
<tr>
<td>Hydropower</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Wind power</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Solar power</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Bioenergy</td>
<td>1.6</td>
<td>1.6</td>
</tr>
</tbody>
</table>

**Trend in CO₂ emission since 2008**

[Graph showing the trend in CO₂ emissions since 2008]
**CO₂ emissions vary over time**

More intensive use of fossil-fired plants, notably during the cold spell of January 2017, drove CO₂ emissions up from the 2016 level. Daily CO₂ emissions curves in winter show wide swings, caused by the use during the day of thermal power plants. Curves are flatter in summer.

![Monthly CO₂ emissions excluding own consumption](image)

**Calculating CO₂ emissions**

The CO₂ emission factors shown here only represent CO₂ emissions generated by the consumption of the primary fuel source. Different generation technologies contributed to total CO₂ emissions as follows:
- 0.986 t/MWh for coal-fired units
- 0.777 t/MWh for oil-fired units
- 0.486 t/MWh for newer gas combustion turbines
- 0.352 t/MWh for CCGT facilities
- 0.583 t/MWh for other gas facilities
- 0.988 t/MWh for municipal waste incineration facilities (only the non-renewable share, or 50% of generation, counts towards emissions).

These rates are calculated based on emission factors published by ADEME and plant efficiencies based on ENTSO-E recommendations.
Territories and regions
Consumption in the French regions

Gross consumption: Split between regions was stable on average

Gross consumption in the French regions was comparable to 2016, even though the average temperature was 0.6°C higher in 2017.

Regional electricity data with éco2mix
A regional version of the éco2mix app was introduced in April to provide real-time information about electricity in each region.

Adjusted consumption: Trends shaped in part by demographics

Trends in adjusted consumption in France were mixed in the 2010-2016 period due to a number of factors, one of which was demographics. This was the case in Occitanie, where electricity consumption rose 7.7% and the population grew by 5.7%. The population was stable in the Grand-Est region but it saw the sharpest decrease in consumption anywhere in France at -5.3% as a result of the region’s deindustrialisation.
Trend in adjusted consumption between 2010 and 2016

Population growth between 2010 and 2016
Consumption in heavy industry: Increases across the board

The Hauts-de-France and Auvergne-Rhône-Alpes regions are home to the largest number of industrial sites connected to the transmission grid. Consumption increased from 2016 in most regions with the exception of Occitanie (-1.2%). The biggest rise was seen in Provence-Alpes-Côte d’Azur (+16.6%).

Consumption by heavy industry excluding the energy sector in 2017
Breakdown of consumption in heavy industry

Key heavy industry areas

Main heavy industry areas connected to the transmission grid

Less than 1 TWh
1 to 2 TWh
2 to 4 TWh
4 to 6 TWh
More than 6 TWh
RTE partnership with CCi Hauts-de-France
RTE and CCi Hauts-de-France (the region’s chamber of commerce and industry) entered into a partnership on 18 September 2017 in the aim of boosting the local economy.
Solar power

Installed capacity

Three regions have more than 1,000 MW of installed solar capacity: Nouvelle-Aquitaine, Occitanie and Provence-Alpes-Côte d’Azur. These regions increased their installed capacity by 18%, 9% and 17% in 2017, respectively. Geographic positioning explains this increase: the regions are situated in the southernmost part of France, where conditions are favourable for solar power use and development.
Density of installed capacity by region

Regional density of solar capacity

Density is a calculation of installed capacity per square kilometre in each region. Provence-Alpes-Côte-d’Azur has the highest density even though it ranks third nationally in terms of capacity. Conversely, Auvergne-Rhône-Alpes ranks fourth in terms of capacity but its density is below the national average of 11.1 kW per square kilometre.

Did you know?

The PACA region has the highest concentration of Bonelli’s eagles nests!

Regional solar power development targets focus primarily on southern France. If the 2020 objectives are to be met, installed capacity will have to expand by a factor of 1.4 in Nouvelle-Aquitaine, 3.4 in Auvergne Rhône-Alpes and 1.9 in Occitanie.
Generation

Coverage of demand by solar power

Wind power

Installed capacity

Climate conditions (wind regimes), environmental constraints and local political priorities explain the differences between wind power development rates. Two regions have more than 3,000 MW of wind capacity installed: Grand-Est and Hauts-de-France. Significant year-on-year increases in installed capacity were seen in Bourgogne-Franche-Comté (+37%) and Nouvelle-Aquitaine (+27%).
Wind regimes and the density of installed capacity

Wind regimes

Wind energy has developed in the different regions thanks, among other factors, to favourable local conditions that guarantee certain wind speeds and thus a higher average capacity factor. Wind zones in mainland France as a whole can be divided into four homogeneous areas represented on the map below.

![Four homogeneous wind zones](image)

Average annual speed within each zone

- 5.2 to 9.1 m/s
- 2.5 to 6.6 m/s
- 6.3 to 8.9 m/s
- 4.5 to 7.0 m/s

This means that windy periods within a defined wind zone tend to occur at the same time and be of similar intensity. It also means that significant differences are observed between patterns in the different zones. It is this diversity across the country that makes it possible to have wind turbines operating virtually all the time in France.
Regional density of wind capacity

Density is a calculation of wind capacity per square kilometre in each region. The region with the highest density is Hauts-de-France, which ranks second in terms of installed capacity. Occitanie ranks third in terms of capacity but seventh in terms of density, slightly below the national average of 24.9 kW per square kilometre.

The map below shows the wind power targets set forth in France’s regional climate-air-energy plans, aggregated according to the new administrative regions and taking into account region-specific climate, environmental and policy considerations.

By 2019, the regional climate-air-energy plans will be integrated into the regional plans for land use, sustainable development and territorial equality (schémas régionaux d’aménagement, de développement durable et d’égalité des territoires - SRADDET) created by Law 2015-991, known as the NOTRe Act.
Generation

Coverage of demand by wind power

Other renewables in the French regions

Did you know?
Power lines can be difficult to access in mountainous areas. Full-scale rescue drills are conducted regularly with RTE teams.
**Bioenergy**

Bioenergy capacity is located throughout the French regions. Ile-de-France has the most capacity with a preponderance of household waste incinerations plants (75% of bioenergy capacity and 47% of renewable capacity in the region).

![Regional map of bioenergy capacity](image)

**Bioenergy generation**

![Coverage of demand by bioenergy](image)
Hydropower
France has 25 GW of installed capacity and generation is divided unevenly across France.

Regions with large mountainous areas (Auvergne-Rhône-Alpes, Occitanie and Provence-Alpes-Côte d’Azur) are home to more than 79% of total hydropower capacity in France. Most of the facilities are hydroelectric dams, notably water reservoir and poundage facilities. Hydropower plants in other regions are smaller and often use run-of-river or poundage systems.
Balancing generation and consumption

The electricity generated in the regions not only meets local needs but also helps cover demand in neighbouring regions. The Centre-Val de Loire and Grand-Est regions produce much more than they consume and thus make a great contribution to this interregional solidarity. As such, the regions that rely heavily on electricity imports, such as Ile-de-France, Bourgogne Franche-Comté and Brittany, know that they will have enough supply to keep up with demand. Most of these exchanges flow over the public transmission grid.
Physical exchanges between the regions

Breakdown of exchanges between regions

Effects of weather on generation and consumption

Consumption during very cold periods

In January of 2017, the average temperature recorded was 1.9°C below normal. It was the coldest month of January since 2010, and three cold snaps occurred. These low temperatures drove electricity consumption up due to the large share of electric heating in France. Power demand was nearly 15% higher on average than in January 2016.
Impact of heat waves on consumption

France experienced four heat waves in the summer of 2017. The one in June was noteworthy because it arrived so early and was so intense: 21 June 2017 was the hottest June day ever. Greater use of air conditioning is reflected in higher power consumption on such very hot days.

Impact of rainfall on hydropower output

Annual fluctuations in hydropower output are closely correlated to precipitation. The significant rainfall deficit of 2017 logically caused hydropower generation to decrease.

Electrical frequency: An indicator of balance on the grid

Frequency refers to the number of times a cycle is repeated over a period of time. When applied to electricity, it is measured in hertz (Hz). Electrical frequency corresponds to the number of times alternating current charges direction per second. This is a key indicator when it comes to managing the European power system. To find out more about the relationship between electrical frequency, supply and demand, go to RTE & Vous magazine (French only).
Europe
Consumption ended the year higher in Europe

Gross consumption in Europe was higher in the large majority of ENTSO-E countries, rising by 1.6% overall in 2016-2017 relative to 2015-2016 (data in this chapter calculated for the period from July 2016 to June 2017). Demand growth was especially strong in Central and Eastern Europe, particularly Germany (+4.4%) and Poland (+5.6%). On the other hand, consumption was flat in some countries (Italy, Belgium and Switzerland) and declined in others (United Kingdom).

Data calculated for the period from July 2016 to June 2017 versus the previous 12 months

Annual trend in power consumption
Temperature sensitivity in Europe

France is the most temperature sensitive country in Europe

A country’s electricity consumption is sensitive to temperatures. Demand increases with colder weather, notably due to the use of electric heating. Known as temperature sensitivity, this phenomenon is observed in all European countries, but it is by far the most noticeable in France.

The chart below helps illustrate the existence of this temperature sensitivity: on a daily basis, it traces consumption in a given country based on the average temperature in that country. Bank holidays, the Christmas holidays and the month of August are not represented since demand is so much lower than normal during these periods.

Below 15°C, consumption begins to increase as the temperature decreases. The curve is three to five times steeper in France than elsewhere. In some countries, temperature sensitivity is observed in summer when the temperature climbs above 20°C. Consumption notably increases with temperatures in Spain, and even more so in Italy, due in part to the use of air conditioning.
Germany and France are the biggest exporters

In the 2016-2017 period, Germany became the biggest exporter in Europe (+53 TWh) thanks to the expansion of its renewable generation capacity. France’s exchange balance contracted sharply (-45%) due to the low availability of its nuclear fleet during the winter months. It nonetheless ended the year with a high export balance (+36 TWh). Italy was once again Europe’s biggest importer (33 TWh), followed by Finland (20 TWh).

Data calculated for the July 2016 to June 2017 period relative to the previous 12 months
Electricity generation increased in Europe

European power generation reached 3,387 TWh in 2016-2017, up 1.2% from the year-earlier period. Germany and Italy both saw sharp increases (+4.4% and +5.4%, respectively). France and Germany still account for more than a third of total generation within ENTSO-E countries.

Data calculated for the July 2016 to June 2017 period relative to previous 12 months

Individual countries’ share of total ENTSO-E generation

Coverage rates across Europe

Breakdown of total generation in ENTSO-E countries by technology

Data calculated for the July 2016 to June 2017 period relative to previous 12 months
Demand covered by nuclear power

Of the 34 ENTSO-E countries, 15 have electricity mixes that include nuclear. Nuclear power generation rose sharply in Belgium and Sweden relative to the 2015-2016 period because of the increased availability of generation facilities in those countries. Total nuclear generation in all 15 countries nonetheless declined (-3.6%), and covered 24% of demand.

Data calculated for the July 2016 to June 2017 period relative to previous 12 months

Coverage of demand by nuclear power – 0%, 0 to 30%, 30 to 60%, More than 60%
Demand covered by fossil-fired generation

ENTSO-E member country demand covered by fossil-fired thermal plants averaged 43% in 2016-2017. The share exceeded 80% in the Netherlands (primarily gas) and Poland (mostly coal), and 60% in Germany (balanced mix of lignite, coal and gas). In France, declines in nuclear and hydropower output drove up fossil-fired generation, causing coverage to rise to above 11%.

*Data calculated for the July 2016 to June 2017 period relative to previous 12 months*
Demand covered by renewable energy

The share of demand covered by renewable energy sources varies greatly from one country to the next. Coverage exceeds 50% in countries like Sweden, Austria, Switzerland and Denmark. Norway’s renewable output exceeds its domestic consumption, though other types of generation are available if needed to ensure uninterrupted power supply throughout the year. Coverage rates exceeded 30% in Germany as well as in Italy (33%) and Spain (32%).

Average coverage of electricity demand with renewable energies in ENTSO-E countries was 32%, down from the previous period due to lower rainfall.

Data calculated for the July 2016 to June 2017 period relative to previous 12 months.
Demand covered by hydropower

Hydropower covered an average 15.7% of demand in ENTSO-E member countries in the 2016-2017 period, down from 17.7% in 2015-2016. This decrease reflects lower rainfall in Southern Europe during the period. Coverage exceeded 50% in countries geographically situated in such a way as to allow a large number of hydropower plants (Norway, Iceland, Switzerland, Austria). Coverage in Sweden declined to below 50% (40%).

*Data calculated for the July 2016 to June 2017 period relative to previous 12*
Demand covered by wind power

Five countries stood out with wind power generation covering more than 15% of annual consumption, especially Denmark, where the rate exceeded 40% with a third of production coming from offshore farms. Average coverage in ENTSO-E countries was comparable to the previous period, at 9.3%.

*Data calculated for the July 2016 to June 2017 period relative to previous 12 month*

**Coverage of demand by wind power**
Demand covered by solar power

Solar plants covered between 6% and 8% of demand in Germany, Italy and Greece, much higher than the average for ENTSO-E countries (3.3%). Coverage rose 8.5% relative to the previous period.

*Data calculated for the July 2016 to June 2017 period relative to the previous 12 months*

**Coverage of demand by solar power**
Markets
Market prices higher in Europe

Average spot prices on European power exchanges

Sources: European power exchanges (for Italy: Prezzo Unico Nazionale, or PUN)
Market prices in detail

Historical trend in European spot prices

Spot price trends over the past five years

Weekly trend in average spot prices
Prices rose across Europe in 2017, especially in Spain and Italy. Increases were more pronounced during the winter months in France, Belgium and Switzerland. Various factors contributed to this price growth. The availability of nuclear power plants in France was limited in January and February, and also in October and November, when it fell to a historic low for the season.

Fuel prices trended higher in the early part of the year, notably gas prices, which surged in Southern Europe in January. Particularly strong power demand during the cold spell in January also drove prices up. At the same time, water reserves decreased, especially in France and Spain. This reduced hydropower generation in the subsequent months, another factor that supported higher prices.

Prices nonetheless remained very volatile. Germany saw several episodes of negative prices as the share of domestic demand covered by wind power increased. Prices dipped below zero for 146 hours, a new record, and fell as low as –€83/MWh on Sunday 29 October. There were only four hours of negative prices in France during the year, and prices did not fall to such low levels.

On the other hand, prices were very high in January and November. Prices in France rose above €150/MWh on nine days in 2017.

Hourly price in Europe during the main price spikes in France

6 January 2017
Negative prices are rare, occurring mainly when demand is low (overnight, bank holidays, weekends, etc.) but generation capacity that is not easily modulated and non-dispatchable facilities (wind, solar) continue to produce power. Indeed, it can be more expensive for a producer to stop and then restart facilities that have little flexibility than to have prices be negative for a time.

The number of hours with negative prices in Germany increased sharply in 2015 and has remained high ever since. This is because wind power development has accelerated in the country. Every year since 2015, more than 5 GW of wind capacity has been added, notably following a surge in offshore farms.

Negative prices are primarily seen when non-dispatchable renewable sources (wind and solar) cover a large share of demand. This only happens when residual demand dips below 30 GW (less than half of average consumption in Germany).

Conversely, prices are at their highest when residual demand is strong (spikes in demand and/or when renewable generation is low).

Prices dipped below zero in France on 30 April and 20 August 2017, but during fewer hours, and they were not as low as in Germany.
Market coupling guarantees optimal use of cross-border capacities

Day-ahead market coupling makes the European power system more efficient. It enables the creation of a single trading area, and thus identical price zones when interconnection capacities do not limit cross-border exchanges. France has completed market coupling with most Western European markets over the past decade, and the coupled area will be expanded over the coming years to include Eastern Europe. Remarkable examples of convergence are now seen regularly. For instance, on 19 April 2017, between 3:00 am and 4:00 am, prices were identical from Portugal all the way to Finland.

Slight decline in price convergence within the CWE region

Cases of price convergence within the CWE region decreased slightly over the year to 34% from 35% in 2016. Convergence occurred across a wider range of prices (from €1.74/MWh in June to €151/MWh in January), depending on the marginal generation sources used in the region. However, more than 90% of cases of full convergence fell within the €20/MWh to €50/MWh range.

Average spreads between French and Spanish and Italian prices increased as prices rose more sharply in those countries than in France, limiting the number of cases of convergence.
Additional price convergence indicators

Distribution of spreads between France and its neighbours in 2017

Spread (€/MWh) = Price XX – Price France
“Spread moyen” = Average spread

* For GB-FR, losses on France-England interconnection (IFA) are deducted from spread

France still a net exporter

Overview of scheduled commercial exchanges

Great Britain
Exports: 11.8 TWh
Imports: 3.9 TWh

CWE
Exports: 8.7 TWh
Imports: 19.6 TWh

France
Exports: 74.2 TWh
Imports: 36.2 TWh
Balance: 38.0

Switzerland
Exports: 17.7 TWh
Imports: 7.4 TWh

Italy
Exports: 18.9 TWh
Imports: 0.7 TWh

Spain
Exports: 17.1 TWh
Imports: 4.6 TWh
France exported 74.2 TWh in 2017 and imported 36.2 TWh, for an exchange balance of 38 TWh. This was slightly below the 2016 level and the lowest on record since 2010.

In January, France showed a net import balance of 0.951 TWh, a new record. The country relied on imports because of the cold spell that occurred that month, illustrating the important role of interconnections between European countries in guaranteeing security of electricity supply. In January, France was a net importer from the CWE region, Spain and Great Britain. It also showed a net import balance of 0.826 TWh in November, when the availability of nuclear capacity was low and temperatures were unseasonably cold (-0.8°C on average).

France set new exchange records during the year:
- A net export of balance of 17 GW on Thursday 30 March between 6:00 pm and 7:00 pm, topping the previous record by more than 1 GW,
- A net import balance of 10.6 GW on Saturday 2 December between 11:00 pm and midnight.

This represents almost 28 GW of flexibility for the French power system, and reflects the volatility of these exchanges during the year.

### Annual contractual trades

### Difference between physical flows and scheduled commercial exchanges

Scheduled commercial exchanges between countries are the result of trades between market participants. Physical flows correspond to the electricity actually carried over interconnector lines directly linking countries.

For instance, a commercial programme for imports on the Franco-Swiss border may be “counterbalanced” by significant exports to Italy, though from a physical standpoint the power will partially go through Switzerland after it leaves France.

For a given country, the balance of physical flows across all borders and the balance of scheduled commercial exchanges with all neighbours are identical.

### Days with net imports

France was a net importer of energy on 52 days in 2017 (up from 46 in 2016), all during the period when the availability of nuclear power facilities was very low for the season, i.e. in January and during the last quarter.
CWE region

The flow-based coupling method

Flow-based coupling within the CWE region went live on 21 May 2015.

Previously, these four bidding zones were coupled on a Net Transfer Capacities (NTC) basis, meaning that limitations on exchanges were set bilaterally for each border (one constraint per border and per direction, implicitly taking into account the network situation).

Constraints now take the physical network infrastructure in the four countries into account explicitly. Cross-border exchanges are thus optimised to reflect the actual physical capacities of networks as closely as possible. This requires very close coordination between the TSOs in CWE countries.

In sum, it is no longer possible to consider borders separately, and indicators previously used for the France-Belgium and France-Germany borders have been replaced by France-CWE region indicators.

Imports from the CWE region were high

Since flow-based coupling began, maximum exchanges between France and the CWE region have exceeded by far the combined France-Belgium and France-Germany exchanges (exports and imports) observed in previous years with NTC. Imports from the CWE region set a record in 2017, reaching 9,222 MW on Saturday 25 November between 2:00 am and 3:00 am.
France was a net importer from the CWE region every month except April and May and it ended the year with an import balance of 10.9 TWh.

Imports were very high in the last quarter, and especially in December, when the import balance reached a record 2.9 TWh.
Spain

Increase in cross-border capacities

Average available capacity continued to increase in 2017, reaching 2,525 MW for exports and 2,300 MW for imports. Capacity notably increased in the Spain-to-France direction thanks to the installation of a new phase-shifting transformer in Arkale, on the Spanish side. This facility, which enables better flow regulation, has been taken into account operationally by RTE and its Spanish counterpart REE since July. To find out more, please see the article: “RTE et RÉE main dans la main” (French only).

It should also be noted that, unlike at other borders, exchange capacity between France and Spain is calculated on a weekly basis and not D-2, which tends to increase the number of constraints detected in real time. These constraints must be offset via a countertrading process – i.e. exchanges between the two TSOs in the opposite direction of the constraining commercial exchanges in order to diminish overall flows. This creates imbalances that must then be offset on the balancing mechanism. The capacity calculating method at this border is slated to be improved in the near future.

Despite increases in capacity, interconnections were saturated 75% of the time, which was more often than in 2016 (but less often than before the Baixas-Santa Llogaia line was commissioned). A new line planned in the Bay of Biscay will reduce saturation and help integrate the Iberian Peninsula into the European power system.
Use of the France-Spain interconnection for day-ahead exchanges

Use of the France-Spain interconnection for day-ahead trades over one year prior to commissioning of new line (05/10/2014-04/10/2015)

Use of the France-Spain interconnection for day-ahead exchanges in 2016

Use of the France-Spain interconnection for day-ahead exchanges in 2017
A record export balance

Except for the months of January and November, when France imported more than it exported, France was very much a net exporter for the year with the export balance reaching a record 12.5 TWh versus 7.8 TWh in 2016. This can be explained in part by low hydropower generation and higher gas prices in Spain.
Italy

Despite lower exports in January, the exchange balance with Italy increased in 2017, ending the year at 18.2 TWh. The interconnection was used less for imports during the year – just 452 hours, down from 815 in 2016. The line was saturated 74% of the time.

Monthly exchange balances with Italy
Great Britain

France was once again a net exporter to Great Britain, ending the year with a balance of 7.9 TWh, lower than in 2016 notably because of the situation early in the year (cold spell in January and low availability of French nuclear power plants). January and November showed net import balances of 0.4 TWh, the highest level since February 2012. Use of the link in the Great Britain-to-France direction increased to 22%.

It should be noted that exchange capacities were limited in January and February by the partial unavailability of the cross-channel interconnector (IFA) due to a storm.
RTE supporting the evolution of cross-border mechanisms

From the beginning, RTE has been working with market participants, in accordance with the principles set forth in the European network codes, to develop mechanisms encouraging the opening of the French electricity market and its integration within Europe:

- Several exchanges will be competing in France in the aim of making the French market more liquid. The EPEX Spot (already active in France) and Nord Pool have been selected through a call for applications. The European regulation on capacity allocation and congestion management (CACM) defines how market operators (electricity exchanges) are nominated to participate in day-ahead and intraday market coupling. These operators, called NEMOs (Nominated Electricity Market Operators), are selected in each country by regulators.

- The methodologies for calculating the commercial cross-border capacities offered to market participants are frequently improved on all borders, which enhances market fluidity. Coordinated calculation processes, complying with the objectives of the CACM regulation, will be set up on a D-2 basis on the France-Spain border in late 2018 at the earliest. In the meantime, France-Spain NTCs may be revised downward through D-2 security analyses, planned for early 2018.

- The overhaul of intraday exchange processes on the France-Spain border, which will be integrated in the spring of 2018 into the European cross-border intraday power platform Xbid, will make the use of this interconnection more fluid as it will be approaching real time.
Flexibility
Activities of the balance responsible parties

Markets are tools for optimising the power system

RTE works around the clock, seven days a week, directing electricity flows over its lines to ensure that generation and consumption are always balanced at the least possible cost to society. This balance is achieved through a series of decisions aimed at optimising the power system, from the long term down to real time. These decisions are taken by private actors, whose actions are coordinated thanks to the market mechanisms through which their activities are rewarded.

Increasing the flexibility of the power system is also clearly identified as key to a successful energy transition, notably to account for the intermittent nature of renewable energy sources. RTE’s market rules are well-suited to the participation of new, flexible capacities, and thus allow all operators to be rewarded for their capacity and energy through the market (demand response, storage, renewable sources, etc.).

Decisions about investment and planning of maintenance, mothballing Management of large hydroelectric dams

Decisions about generation/consumption planning over coming hours based on:
- Costs (variable, stoppage, start-up, value of water usage, etc.)
- Reserve allocations

Adjustment of generation programmes

Activation of flexible capacity that can be called up at very short notice (among available capacity, reserved and non-reserved)

Activities of the balance responsible parties

The system for balance responsible parties allows consumers, producers, suppliers and traders to conduct all types of commercial transactions in the electricity market, on timeframes ranging from several years ahead to almost real time. Thanks to the flexibility this system provides, market participants can respond to a wide variety of contingencies and uncertainties. Each balance responsible party creates an activity portfolio and agrees to settle the costs resulting from imbalances between generation and consumption within the portfolio, as recorded after the fact. The parties have a financial incentive to maintain a balance within their portfolios and thus contribute to the balance of the French power system.

As of 31 December 2017, there were 194 balance responsible parties with valid contracts. Of these, 134 were active during the year and 37 made significant physical injections or withdrawals.
Transactions conducted by balance responsible parties on markets

- BIP-BIP
- ARENH
- VPP
- Exchange

Purchases of PTS losses (outside the exchange)
Record ARENH purchase volumes

In 2017, ARENH purchases totalled 82 TWh, the highest level on record since the mechanism was launched (the ceiling, excluding the supply of losses, is set at 100 TWh). Indeed, the fixed ARENH price of €42/MWh (including capacity certificates) became competitive relative to market prices due to the price increase observed toward the end of 2016 and in the early months of 2017. To date, 94.6 TWh of ARENH power has been requested for 2018.

This increase explains in large part the decline relative to 2016 in transactions involving balance responsible parties, both OTC (Block Exchange Notifications, or NEB) and through the EPEX Spot exchange. Indeed, market players were able to secure the power they needed (at least in part) through the ARENH mechanism and thus needed to use other types of transactions less.

Intraday transactions continued to increase, notably cross-border ones. These mechanisms give balance responsible parties flexibility to operate as close as possible to real time.
Balancing mechanism

The balancing mechanism allows RTE to modulate generation, consumption and exchanges to ensure that electricity supply and demand are always balanced. The mechanism involves the selection of bids submitted by balancing service providers based on the merit order and identified needs.

Increase in upward balancing

Upward balancing totalled 3.22 TWh in 2017, the highest level since 2013. Cross-border balancing offers represented 36% of total upward balancing and 4% of downward balancing, or 1.15 TWh and 0.77 TWh, respectively. Total balancing volumes reached 7.7 TWh, which represented just over 1% of the whole activity of balance responsible parties.
The number of supply-demand imbalance situations increased between 2016 and 2017. This was mainly because of particularly low availability of thermal power plants, notably during the cold spell in January, when 18 of the 66 half-days for which a signal was sent to market participants about insufficient offers occurred. Though upward margins were quite thin during those periods, RTE did not have to take exceptional or emergency measures (interruptible loads, voltage drops, power cuts) thanks to increased use of interconnections. Still, on 25 January, when constraints were greatest, RTE came close to activating the interruptible load mechanism for industrial consumers.

Note: A supply-demand imbalance situation is considered to exist when RTE generates one or more messages about insufficient offers on the balancing mechanism (alerts or degraded modes) to encourage participants to submit additional offers.
Demand response

The Energy Code (art. L 271-1) defines demand response as an action intended to temporarily reduce, in response to a one-time request sent to one or more consumers by a demand response operator or electricity supplier, the electricity effectively withdrawn from the public transmission or distribution networks at one or more consumption sites, relative to a consumption plan or consumption estimate.

Market players can use demand response to optimise their own portfolio or to sell energy directly to other players or to RTE. There are two main categories of demand response that contribute to the supply-demand balance:

- Industrial demand response, when consumption is reduced at one or more industrial sites (either by shutting down processes or by switching over to own consumption). This type of demand response can be proposed either directly by the industrial user or through an aggregator or supplier.

- Distributed demand response, or the aggregation through an aggregator or supplier of individual demand response actions involving smaller demand volumes, all carried out at the same time by residential or professional customers.

Demand response is assigned a value through a number of mechanisms

France was the first country in Europe to open all parts of its national market to all consumers, including those connected to the distribution networks:

- Since 2003, it has been possible to offer industrial demand response on the balancing mechanism.
- Since 2008, RTE has been contracting demand response capacities with BSPs to guarantee the availability of this capacity to the balancing mechanism.
- Since 2011, RTE has been contracting demand response capacities that can be activated on very short notice for the mFRR (manual frequency restoration reserves) In 2017, demand response capacity made up more than half of the rapid reserve.
- Since January 2014, it has been possible to sell demand response energy directly on energy markets through the NEBEF mechanism.
- Since July 2014, industrial customers have been able to participate in frequency ancillary services by offering demand response (1 MW minimum). These reserves, which can be automatically activated in timeframes ranging from a few seconds to a few minutes, are critical to keeping supply and demand balanced. Previously, only generation facilities could participate. In 2017, demand response capacity could contribute up to 10% of the FCR (frequency containment reserve).
- Just over 1.9 GW of demand response capacity had been certified through the capacity mechanism for 2018 as of 16 January 2018.
- Starting in 2018, demand response tenders will help support the demand response sector. Organised by the Ministry of Energy, the public tenders will encourage the creation of demand response capacity to meet the targets set forth in the multiannual energy programme. The results of the tenders will be known mid-2018.
Tariff-based demand response

Traditional tariff-based demand response schemes
Special tariffs have been created to help maintain the supply-demand balance, notably during load peaks in winter, focusing on the demand side rather than supply to limit the load. “EJP” (Effacement Jour de Pointe – demand response during peak days) tariffs, introduced in the 1980s, involved raising supply prices in times of system stress but not for more than 22 days a year and only during the winter months. Users have not been able to sign up for these tariffs since 1998, and their effects have been diminishing ever since.

“Green” and “yellow” regulated tariffs were phased out on 1 January 2016, and the corresponding contracts have been terminated. Former customers had to sign new non-regulated contracts, with or without a demand response component. They have also been able to realise value on demand response through market mechanisms.

Other demand response tariffs for the mass market (professional and residential customers) were introduced in the 1990s thanks to the Tempo signal. RTE has been managing this signal since 1 November 2014 and providing information about it through the éCO2mix website to allow all suppliers to offer contracts that include demand response. Lastly, suppliers create and propose to their remote-read customers commercial offers that may include demand response clauses with specific conditions.

Suppliers have estimated the demand response capacity made available through these different tariff-based mechanisms in 2018 at close to 700 MW.

EcoWatt, a voluntary scheme available in the French regions
EcoWatt is a voluntary scheme introduced in Brittany in 2008 and then PACA (Provence-Alpes-Côte d’Azur) in 2010 - regions where local power systems faced specific problems. It aims to decrease the risk of outages by encouraging residents to reduce their power consumption during peak hours in winter. Organised in partnership with local stakeholders, the scheme has attracted more than 90,000 subscribers in the two regions.

At a time when “security nets” are being set up to help ensure security of supply to each region, and with smart grids being rolled out (SMILE in Brittany and the Pays de la Loire and FLEXGRID in PACA), EcoWatt remains an important tool for completing the energy transition and supporting the regions. It is gradually taking on a new identity regarding its traditional audiences (individuals, local authorities, etc.) but will remain primarily digital (website, social media). EcoWatt is still operating on the same principle: signals are generated when consumption is high in winter, both at the regional and city levels.
Demand response on the balancing mechanism
RTE had at least 340 MW available at all times in 2017, and the maximum offered was 1,898 MW. The average demand response volume made available to the balancing mechanism was 726 MW (+26% from 2016). This capacity enhances power system margins.

Demand response volumes activated on the balancing mechanism reached 27 GWh, up sharply from 16 GWh in 2016.

Trend in demand response capacity on the balancing mechanism

Minimum, average and maximum demand response capacity available on the balancing mechanism per week
RTE activated more than 100 MW of demand response over 28 days.

The NEBEF mechanism

The NEBEF mechanism (Demand Response Block Exchange Notification) allows market actors to realise value demand response directly through the energy market. Market actors inform RTE of the demand response planned for the next day and can re-declare schedules at the intraday scale. RTE verifies afterward that the volumes correspond to the schedules submitted by participants.

The number of parties having signed contracts with RTE to participate in the mechanism stabilised at 22 in 2017. Volumes on the NEBEF mechanism continued to rise, ending the year at 39 GWh, with most activity concentrated in winter. Significant volumes (more than 100 MW) was declared in January, November and December, on days when spot prices were particularly high.
Demand response volumes on the NEBEF mechanism

Note: Actual demand response figures for November and December are not yet available.

Demand response is mainly activated when prices are high. More than half of declared volumes on the NEBEF mechanism were offered during the 10% of hourly periods when prices were the highest of the year, and 14% when prices were above the last centile of spot prices for the year.
Additional NEBEF indicators

Detailed NEBEF indicators

Maximum demand response each day on NEBEF

Breakdown of declared volumes on NEBEF based on spot prices in 2017 –

€40/MWh is the annual median price in France, €71/MWh the last decile and €115/MWh the last centile.

Total demand response volumes for the year in half-hourly increments and average value at spot price
Capacity mechanism

Launch of the capacity mechanism in France

The goal in implementing a capacity mechanism in France is to guarantee security of supply over the medium term by covering risks during peak periods in winter. On 8 November 2016, the European Commission gave a green light for the French capacity mechanism to be implemented, with conditions. The mechanism rules were then approved by the Ministry of Energy and Energy Regulatory Commission on 29 November 2016.

There are two pillars to the capacity mechanism. First, it creates a requirement for obligated parties – mostly electricity suppliers – to obtain capacity certificates to contribute to the security of supply of their customers. Holding suppliers responsible in this way is notably a way to contain peak demand growth by creating an economic incentive to limit their customers’ consumption.

Second, RTE certifies the capacity of operators that agree to make their capacity available when demand peaks in winter. The capacity mechanism allows them to realise value on the availability of generation and demand response capacity by selling capacity certificates. Actors trade capacity certificates through auctions or OTC transactions. During the delivery year, RTE notifies them of the peak days when they have to uphold their individual commitments. After the delivery year, RTE informs suppliers of their final obligation level and calculates the actual availability of their capacity. Differences result in financial payments.
Forward indicators for the capacity obligation

The security factor is a key parameter of the capacity mechanism, the one that ensures consistency between certifications and obligations. As it stands, this factor makes it possible to implicitly account for the contribution to the security of supply in France of interconnections with neighbouring countries. As per the capacity mechanism rules (art. 2.2), a new way of accounting for the participation of cross-border capacity, following the European Commission’s approval decision of 8 November 2016, makes it necessary to modify the security factor for the 2019 delivery year.

RTE will propose, in accordance with article 6.1.4 of the capacity mechanism rules, that the factor be reset at 0.99 compared with 0.93 today. This value comes from the simulations conducted for the 2017 Generation Adequacy Report. The increase in value is the result of the cross-border contributions to security of supply in France being accounted for explicitly – rather than implicitly – with effect from the 2019 delivery year. Only the border with Switzerland will continue to be accounted for implicitly.

This proposed revision of the security factor will have to be validated by the Ministry of Energy, after consultation with the Energy Regulatory Commission.

Meanwhile, RTE has provided capacity obligation estimates for all of France for the 2019 delivery year. These estimates, made public on 11 December, take into account the proposed change in the security factor. One was prepared for each of the four demand variants in the 2017 Generation Adequacy Report:

<table>
<thead>
<tr>
<th>Demand variants in the 2017 Generation Adequacy Report</th>
<th>Forecast total capacity obligation for France in 2019 (GW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>High scenario</td>
<td>94.2</td>
</tr>
<tr>
<td>Intermediate scenario 3</td>
<td>93.7</td>
</tr>
<tr>
<td>Intermediate scenario 2</td>
<td>93</td>
</tr>
<tr>
<td>Low scenario</td>
<td>92.7</td>
</tr>
</tbody>
</table>

Suppliers can take measures to reduce their customers’ consumption. For the 2017 delivery year, 727 MW of demand response actions reduced the obligation of the suppliers in question by that same amount. For now, 695 MW are scheduled for 2018.

This data is published in the registry of consumption control measures.
Breakdown of certified capacity by production methods for delivery year 2018 (in MW)

Note: The figures for 2017 are different from those in the chart in the 2016 Annual Electricity Report since actors can re-declare their available certified capacity throughout the delivery year.

Certified entities and their production methods are defined at the site level.

Certified volumes are higher for 2018 than 2017, as producers are anticipating better availability of plants. For the purposes of transparency, exchange volumes and prices (€/certificate) are published on the EPEX SPOT website.

Most market players’ needs for the 2017 delivery year were covered after the first auction (15 December 2016): 22.6 GW were exchanged at that time, compared with 0.5 GW at the second auction on 27 April 2017, which was intended more to allow players to adjust their positions.

EPEX SPOT held two auctions for the 2018 delivery year, on 9 November and 14 December. The first auction for delivery in 2019 was also held on 14 December.

<table>
<thead>
<tr>
<th>Delivery year</th>
<th>Th. 15/12/2016</th>
<th>Th. 27/04/2017</th>
<th>Th. 09/11/2017</th>
<th>Th. 14/12/2017</th>
</tr>
</thead>
<tbody>
<tr>
<td>2017</td>
<td>Price (€/certificate)</td>
<td>999.98</td>
<td>1,041.94</td>
<td>–</td>
</tr>
<tr>
<td>2018</td>
<td>Price (€/certificate)</td>
<td>–</td>
<td>–</td>
<td>931.0</td>
</tr>
<tr>
<td>2019</td>
<td>Price (€/certificate)</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
</tbody>
</table>
Note: One capacity certificate is equal to 0.1 MW.

Details of these transactions can be found in the capacity certificates register.
Evolution of the capacity mechanism

At the request of the European Commission, and in accordance with the commitments made by French authorities (approval decision of 8 November 2016), changes to the capacity mechanism will focus on three areas:

– Strengthening competition and the oversight of parties participating in the mechanism (already covered in the market rules in late 2016),
– Explicit participation of cross-border capacities in the mechanism,
– Development of a framework that favours investment in new capacity.

In 2018, RTE will propose a new framework to take effect in 2019. It will include the explicit participation of cross-border capacities and introduce a mechanism for long-term tenders.
Transmission network
How the network evolved in 2017

Length of lines

With 105,961 km of lines in service, RTE continues to expand the transmission network to guarantee security of supply to the territories and regions and boost the system’s ability to accommodate more renewable generation.

Highlights of 2017 included the completion of the Brittany safety net, notably thanks to the creation of a 225 kV underground line between Lorient and Saint-Brieuc; the end of work on projects in the Rhône Valley; and the replacement of the 400 kV overhead lines between Lyon and Montélimar.

New underground lines (newly created or overhead lines newly undergrounded) totalled 545 km, while 520 km of overhead lines were taken down (permanently or to be replaced) during the year.

All in all, the network was expanded by 301 km in 2017.

<table>
<thead>
<tr>
<th>Length of lines in service (km)</th>
<th>Overhead</th>
<th>Underground</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>At 31 December 2016</td>
<td>100,203</td>
<td>5,457</td>
<td>105,660</td>
</tr>
<tr>
<td>New</td>
<td>462</td>
<td>571</td>
<td>1,033</td>
</tr>
<tr>
<td>Newly added</td>
<td>14</td>
<td>498</td>
<td>512</td>
</tr>
<tr>
<td>Replaced</td>
<td>448</td>
<td>26</td>
<td>474</td>
</tr>
<tr>
<td>Overhead lines buried</td>
<td>0</td>
<td>47</td>
<td>47</td>
</tr>
<tr>
<td>Scrapped</td>
<td>-520</td>
<td>-7</td>
<td>-527</td>
</tr>
<tr>
<td>Other modifications (placed in reserve, length adjustments, etc.)</td>
<td>-181</td>
<td>-24</td>
<td>-205</td>
</tr>
<tr>
<td>At 31 December 2017</td>
<td>99,964</td>
<td>5,997</td>
<td>105,961</td>
</tr>
<tr>
<td>Change 2017-2016</td>
<td>-239</td>
<td>540</td>
<td>301</td>
</tr>
</tbody>
</table>

Change in length of lines in service in 2017
For the first time since 2010, the total length of overhead lines was reduced to below 100,000 km, as shown in the chart below. The total length of underground lines came very close to 6,000 km.

Substation connections

A total of 22 new substations were connected to the public transmission system in 2017, including nine very high voltage substations. A 225 kV step was commissioned at the Mûr-de-Bretagne site in Côtes-d’Armor, as part of the plan to guarantee security of supply to Brittany.

A new 225 kV substation was connected at Gréoux-les-Bains, in Alpes-de-Haute-Provence, to help evacuate photovoltaic generation from the plant. Lastly, the addition of a new 225/63 kV substation at Villiers St-Sépulcre, in Oise, will enhance security of supply for Beauvais.
Overhead and underground lines: Complementary technologies

A variety of solutions are leveraged to expand the transmission grid, taking into account technical, economic, environmental and societal factors. Two techniques are used: overhead and underground.

RTE has committed to not increase the total length of overhead lines (removals offset additions) and to place at least 30% of new lines underground.

The difference in investment costs between overhead and underground lines depends on voltage levels: costs are the same for 63 and 90 kV, but underground lines cost about twice as much as overhead lines for 225 kV and eight times as much for 400 kV(*).

Underground lines currently represent:

- 7.7% of all 63/90 kV lines,
- 5.1% of all 225 kV lines,
- a negligible share of 400 kV lines.

(*) Underground cables for 400 kV AC are quite expensive and substations must be installed every 20 km to offset the capacitive effect of the cables. At this voltage level, buried DC lines can be an option. The cost is the same as an overhead AC line, but transmission capacity is three to five times lower.

Source: Ten-Year Network Development Plan

New and replaced lines

More and more of RTE’s lines are underground

More than 559 km of new lines were added to the public transmission network in 2017 (including overhead lines that were buried). Nearly all of the new lines built in 2017 used underground technology, as has been the case for the past ten years or so (with the exception of 2013, when the 340 km Contentin – Maine 400 kV line was commissioned, and 2016, when the 79 km Lonny – Vesle 400 kV line was completed).

RTE also replaced more than 474 km of overhead and underground lines on its network.
400 kV and 225 kV

Overhead

RTE replaced conductors along some 300 km of 400 kV and 225 kV overhead lines in 2017, a very large majority of them as part of two projects in the Occitanie and Auvergne-Rhône-Alpes regions: rehabilitation of the 225 kV Godin – St-Victor line in Aveyron, where conductors were reaching the end of their useful life, and the replacement of the 400 kV Le Chaffard – Pivoz-Cordier links in the Rhône Valley, as part of the plan to enhance security of supply between Lyon and Montélimar.

Underground

A total of 117 km of new 225 kV underground lines were brought into service in 2017, mostly as part of the Brittany safety net plan: the 225 kV Mûr-de-Bretagne – Plaine Haute line in Côtes d’Armor and the 225 kV Calan – Mûr-de-Bretagne link in Morbihan. The new 225 kV Fleurs – Volvon line was also commissioned in Auvergne-Rhône-Alpes to address constraints on the 63 kV network created by increased loads in the Forez plain area.

63 kV and 90 kV

Underground

The length of underground lines operated at voltages of 63 kV and 90 kV increased in 2017, with 428 km of new lines brought into service. RTE notably commissioned:

- The 90 kV Gavrelle – Moffalines link in Pas-de-Calais (enhancing security of supply to Arras),
- The 90 kV Challans – Soullans link in Vendée (partial undergrounding of the line),
- The 63 kV Frasnes – Melincols line in Doubs (undergrounded),
- The 63 kV Terradou – Vaison la Romaine link in Vaucluse (enhancing security of supply to the northern part of the department).

The undergrounding rate for new 63 kV and 90 kV lines was unchanged at 99.6% in 2017 and has averaged 99.5% over the past three years (2015-2017).

Undergrounding rate for 63 kV and 90 kV lines

Overhead

Conductors were replaced on 135 km of 63 kV and 90 kV overhead lines. Examples included:

Replacement of 90 kV lines: Eguzon – St Marcel in Indre and Juine – Les Loges in Essonne,
Replacement of 90 kV lines: Saintes – Piquage à Charron in Charente-Maritime,
The 63 kV Boege – Cornier link in Haute-Savoie,
The 63 kV Carrières – Villers Saint Paul line in Oise.

Fewer than 2 km of new lines were brought into service during the year.
Completion of the Brittany safety net

One highlight of 2017 was the completion of the project to secure supply to the northern and central parts of Brittany with the commissioning of the 225 kV Mûr-de-Bretagne substation and creation of a new 225 kV underground line between the substations at Calan, in Morbihan, and Plaine-Haute, in Côtes-d’Armor.

This project – which required seven years of studies, consultations and construction work – was wrapped up at the end of 2017. A core component of the Breton Electricity Pact, the safety net is vital to ensuring security of supply to Brittany. It notably guarantees supply to the northern and central parts of the region and will help accommodate renewable power from onshore and offshore sources while optimising transmission thereof.

Completion of the Lyon – Montélimar project

RTE has been doing maintenance on the 400 kV network between Lyon and Montélimar since 2011 to secure and optimise electricity supply between the two areas. This project is part of France’s national plan to physically secure the network, which RTE launched following the storms of 1999. All in all, more than 400 poles will have been strengthened or rebuilt to become more climate-resistant.

In addition to this physical work, RTE is doing maintenance to optimise the network. It has replaced nearly 3,600 km of cables with higher performance versions that can ensure continuity of supply.

There are two strategic links running between Lyon and Montélimar: a west axis and an east axis, both double-circuit lines that are almost 140 km long and cross through four departments (Isère, Drôme, Ardèche and Loire). Work on the 400 kV Le Chaffard – Beaumont – Coulange line (east axis) was completed in 2014. In 2017, conductors on the Le Chaffard – Pivoz Cordier line (west axis) were replaced.
Completion of the plan to physically secure the network

The storms of 1999 revealed the vulnerability of part of the transmission network:

- 8% of all 63 to 400 kV lines became unavailable (nearly 8,000 km of lines)
- 1,000 poles were destroyed or seriously damaged.
- Three and a half million homes were without power.
- Most of the delivery substations (90%) were back in service within four days.

All of this led to the launch in September 2001 of a plan to physically secure the network, with three key objectives:

- maintain supply to nearly all substations in the wake of significant climate events of an intensity not exceeding the storms of December 1999;
- restore basic services related to continuing of supply within five days of significant climate events caused by wind, ice or snow;
- control the risk of equipment falling on persons or property near residential areas or major transport routes even in the event of significant climate events.

Below are a few key figures for the programme, which was completed in 2017:

- 48,400 km of lines made secure
- 6,154 anti-cascading towers installed
- 2,897 substations made secure

These investments produced the following results:

- In 2016 and 2017, there were no interruptions to supply and the network secured did not incur any structural damage during a significant climate event;
- A large number of innovations were introduced over the 15-year plan implementation period.
Main projects brought into service in 2017
RTE invested €1.4 billion in 2017

RTE’s investments within the scope of businesses regulated by the CRE totalled €1,393 million in 2017, of which €1,166 million was spent on the network. Investments primarily focused on completing the reconstruction of the 225 kV line connecting the Rhône Valley and Massif Central (“2Loires” project), commissioning strengthened equipment in central Brittany (“Brittany safety net”), starting work on the new interconnection with England (“IFA2”), continuing work to build the DC line between France and Italy passing through the Frejus safety tunnel (“Savoy-Piedmont”), and restructuring the 225 kV network in Haute-Durance. A total of 66% of network investments targeted existing infrastructure.

Investments in information systems and property-logistics reached €144 million and €83 million, respectively.

RTE has submitted a €1,492 million investment programme for 2018 to the regulator. A portion of planned investment relates to customer connection needs, which are financed largely by requestors through investment subsidies. The proposed increase in investments from 2017 reflects a combination of factors: a decrease in investments intended to guarantee supply and facilitate assistance between territories (because consumption has been stable), an increase in spending on large projects (Savoy-Piedmont and IFA2 interconnections, continuation of other major development projects including Haute-Durance and Cergy-Persan, start of work to connect the offshore wind farm in Fécamp), and further significant investments in information systems.

RTE is planning its investments knowing sustained efforts will be required over the coming years for a successful energy transition. Indeed, the French transmission grid will play a key role in accommodating new generation sources, including offshore wind farms, and in integrating the European energy market by boosting cross-border exchange capacity. Moreover, RTE is responsible for ensuring the operational safety of the networks and continuity of supply to the different consumption areas and regions. RTE is adapting its investment strategy to the major changes the power system is undergoing, giving preference to solutions that preserve existing infrastructure in order to maintain or boost service levels, notably through flexibility solutions. To this end, RTE intends to develop the digital technologies that will allow it to optimise decisions about grid operations, maintenance and upgrades. The investment programme for the coming years aims to make RTE the leading European TSO in terms of power and digital.

A total of 51% of the projects planned for the 2017-2020 period are designed to improve security of supply and nearly 30% aim to prepare for the new energy mix. Developing new interconnections will capture 14% of investments and another 6% will go to projects that will make the power system safer.
To keep pace with these changes, RTE focuses in priority on existing infrastructure. Indeed, 66% of the investments planned involve upgrading or adapting the existing grid.

RTE also intends to develop the digital technologies that will allow it to optimise decisions about managing, maintaining and upgrading the grid. They must in all cases be rolled out with high voltage infrastructure.

**RTE standing up for the environment and biodiversity**

RTE is taking action to reduce the environmental impact of its activities by utilising resources and energy more efficiently. For instance, in 2004, RTE launched a proactive initiative to reduce leakage of SF6, a gas with a strong greenhouse gas effect. SF6 is currently indispensable to the electrical insulation of RTE equipment, including substations inside buildings (Gas-Insulated Substations, which society has come to expect). In 2017, SF6 emissions totalled 5.77 tonnes. A leak recovery solution will be implemented to reduce this amount. Compared with the 2008 level, emissions have been cut by almost 17.6%.

RTE is also forging partnerships to turn its power line corridors into corridors of biodiversity. Most of RTE’s infrastructure is located in agricultural areas (70%) or wooded regions (20%), and some 23,000 km of power line corridors cross through protected natural areas. Protecting and encouraging the development of biodiversity are cornerstones of RTE’s environmental policy. Its commitment is recognised as part of the “2011-2010 National Strategy for Biodiversity” by the Ministry for Ecology.

As of end-September 2017, RTE had developed a total surface area of 847 hectares as biodiversity-friendly areas (average +100 ha/year) through partnerships with local players, strengthening RTE’s roots in the regions.

Detailed sustainable development information can be found in RTE’s management report.

**Biodiversity: Building and preserving natural areas**

**Biodiversity**

Set apart from human activity, the open space near RTE’s infrastructure serves as a refuge for fauna and flora. Innovative land planning, research, partnerships, training... MAG RTE&Vous features stories that describe how RTE teams are mobilising throughout France to preserve and encourage the development of biodiversity under power lines.
Ten-Year Network Development Plan

For more information about network development, see the Ten-Year Network Development Plan

Main projects under way

Map of main projects under way
Bay of Biscay

The Bay of Biscay project involves creating a new interconnection between France and Spain. Scheduled to be brought into service in 2025, the interconnection will boost exchange capacity between France and Spain to almost 5,000 MW. This new 370 km link will run from the substation in Cubnezais (near Bordeaux) to the one in Gatika (near Bilbao). It will be the first France-Spain interconnection that is partially underwater.

Haute-Durance

Haute-Durance project

Power is supplied to this region primarily via a single 150 kV line built in 1936. The Haute-Durance now finds itself in a vulnerable position, particularly when power demand peaks in winter. RTE has thus designed a programme divided into six projects. It involves creating a 225 kV network to replace the existing 150 kV network and upgrading the 63 kV network (undergrounding, reconstruction or strengthening) all while protecting the local environment. The programme is being carried out through 18 work projects that will be staggered over time until the upgrades are completed in 2020.

Connecting offshore wind farms

Connecting offshore wind farms

France has set a target of having 6,000 MW of offshore wind capacity installed by 2020, which would cover 3.5% of power demand starting that year. Offshore wind development offers significant power generation potential given the country’s natural assets (11 million km$^2$ of water in its jurisdiction). The highest-potential areas are concentrated off the coasts of Normandy, Brittany and Pays de la Loire. The government has launched two tenders for the construction of six offshore wind farms in these areas. These projects aim to connect to the French power grid some 3,000 MW of offshore wind power generated by more than 400 offshore turbines. RTE is in charge of studies and the connection of these farms. The solution being considered involves creating 225 kV double-circuit lines, starting out underwater between the wind farm connected to the offshore substation and the landing point and then running underground between the landing point and the 225 kV substation where they are earthed.

The sites selected through the first call for tenders have already been the subject of a broad consultation with local stakeholders, government services and infrastructure operators to determine the best possible path for the lines from a technical, economic and environmental standpoint. Late in 2015, public inquiries were launched for the projects in the towns that will be affected by the future Fécamp, Courseulles-sur-Mer, Saint-Nazaire and Saint-Brieuc wind farms. Production is not scheduled to start at these sites until 2020.
Flexibility solutions

Network development and flexibility solutions

Technological and digital innovations are creating opportunities to develop the public transmission network in new ways and meet the new challenges posed by the energy transition. Trends in local consumption and generation are creating great uncertainty while the expansion of renewable energy production makes it necessary to manage variability.

RTE is taking these new developments into account by integrating flexible solutions into the grid, for instance via automated peak shaving/generation capping. It is also experimenting with next-generation substations (more information can be found at http://www.posteintelligent.com/).

Electricity quality

Equivalent outage time

Equivalent outage time (temps de coupure équivalent - TCE) is one of the indicators used to measure the quality of the electricity RTE supplies. In 2017, the equivalent outage time was 1 min 27 sec, excluding exceptional events. This result was much improved from previous years and within the 2 min 48 sec limit set forth in the incentive regulation.

The exceptional events recorded in 2017 related to the particularly violent storms that swept through France early in the year (equivalent outage time of 20 seconds).
Outage frequency

Since 2013, outage frequency has been factored into the incentive regulation set by CRE to encourage continuity of supply. In 2017, outage frequency excluding exceptional events was 0.35 outage/site, within the 0.46 limit set out in the incentive regulation and below the average for the past ten years.

Lightning density

Lightning density and short outage frequency

Among the factors shaping quality of supply, lightning density is a predominant cause of the short outages observed during the year. Usually, the regions that are hit by lightning the most show the highest frequency of short outages. Conversely, short outages are less frequent in regions that rarely see lightning. In 2017, lightning density was 0.8 strike per km² across France.

More information about electricity quality can be found in our magazine RTE & Vous.
Loss rate

The loss rate was stable in 2017

Line losses occur when electricity is moved from generation sites to consumption sites, and loss volumes depend on the power carried, the distance over which it is carried, weather conditions and the characteristics of the grid. Though most of these factors are external, RTE works to minimise losses by making decisions about grid development and operation that optimise the distance over which electricity travels as much as possible. Nearly 80% of losses are due to the Joule effect and Corona effect on high and very high voltage lines. Other factors contribute as well, notably when current passes into transformer substations. The environmental impact of losses corresponds to the power that must be generated to offset them.

In 2017, losses were stable at 11.2 TWh, which was 2.23% of total injections (generation and imports).