

HYDROELECTRIC POWER

SERIES | THE FUTURE OF OUR ENERGY

EDF, EUROPEAN LEADER IN POWER GENERATION

The EDF group has a stake in the leading European energy markets:
In the United Kingdom with EDF Energy, in Italy with Edison and in France where EDF is market leader.
With its mix of nuclear, hydroelectric and fossil-fired generation capacity, combined with other renewable energies, EDF operates a highly efficient, diversified and comprehensive power generation fleet.

POWER GENERATED BY EDF IN MAINLAND FRANCE, 2012



Nuclear
404.9 TWh
89.1%



Hydroelectric*
34.5 TWh
7.64%
(10% in years when water conditions are normal)



Fossil-fired
14.9 TWh
3.3%

* 34.5 TWh is the net output figure. This is calculated by taking the gross output figure of 41.2 TWh and subtracting the amount of electricity needed to run pumped-storage facilities (6.7 TWh in 2012).

INSTALLED CAPACITY

97.9 GW

in France as at 31 december 2012
(excluding Corsica and French Overseas Departments and Territories).

NATIONAL POWER OUTPUT **

454.3 TWh

of electricity were generated in France by EDF in 2012.

** These figures are rounded off to one decimal point.

95%

of the electricity generated by EDF does not produce greenhouse gas emissions.

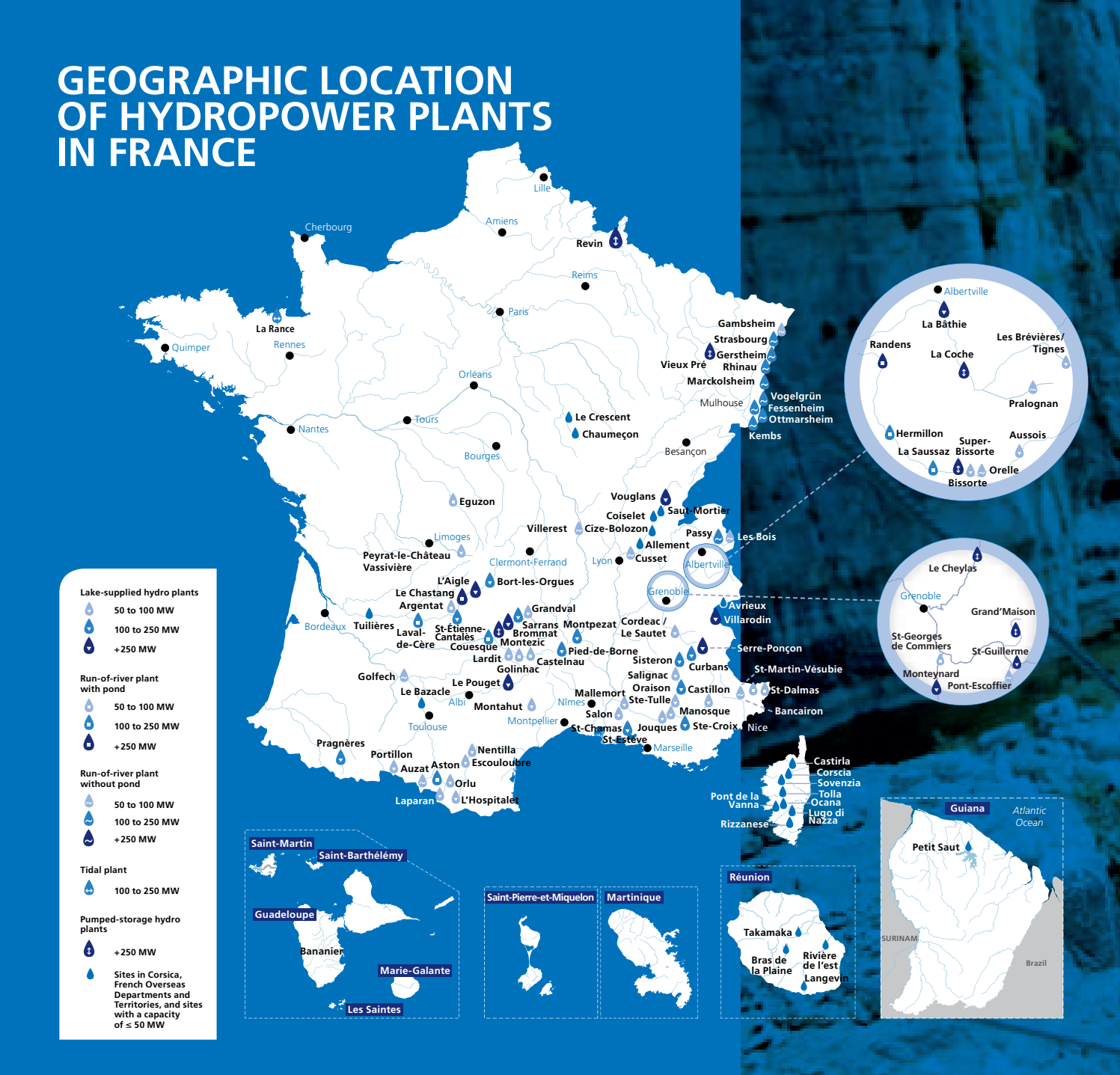
UNITS OF MEASURE

- The watt (W) is used as a measure of mechanical and electrical power.
- The megawatt/hour (MWh) is used to measure the amount of electricity generated by a 1-MW facility within a 1-hour period.
- 1 MW = 1,000 kilowatts (kW) = 1 million watts.
- 1 terawatt/hour (TWh) is equal to 1 billion kWh.

FRENCH FLEET

- **19** nuclear power plants
- **435** hydroelectric power plants
- **19** fossil-fired power plants
- **13** gas turbines
- **3** combined-cycle power plants

GEOGRAPHIC LOCATION OF HYDROPOWER PLANTS IN FRANCE



Lake-supplied hydro plants

- 50 to 100 MW
- 100 to 250 MW
- +250 MW

Run-of-river plant with pond

- 50 to 100 MW
- 100 to 250 MW
- +250 MW

Run-of-river plant without pond

- 50 to 100 MW
- 100 to 250 MW
- +250 MW

Tidal plant

- 100 to 250 MW

Pumped-storage hydro plants

- +250 MW
- Sites in Corsica, French Overseas Departments and Territories, and sites with a capacity of ≤ 50 MW



Visual inspection
at Quinson dam
on the Verdon River.
© EDF/Stéphane Lavoue

Cover photo:
Aerial view of Tignes dam.
© EDF/F. Oddoux

HYDROPOWER: THE ENERGY OF CHOICE

By 2020, renewable energy sources will have to account for 20% of European electricity supply if greenhouse gas emissions are to be reduced. In France, hydropower already accounts for 10% of the electricity generated by EDF. As the world's foremost renewable energy, hydroelectric power is a sustainable, flexible and competitive source of electricity. As it does not emit greenhouse gas, it is also of great benefit to the environment. Furthermore, it provides an inexpensive solution to sharp fluctuations in electricity demand.
As water is a public commodity, sufficient supplies of it must be made available to cater for all needs: electricity, drinking water, farming, industry and tourism. Every effort is made to maintain the highest safety standards.

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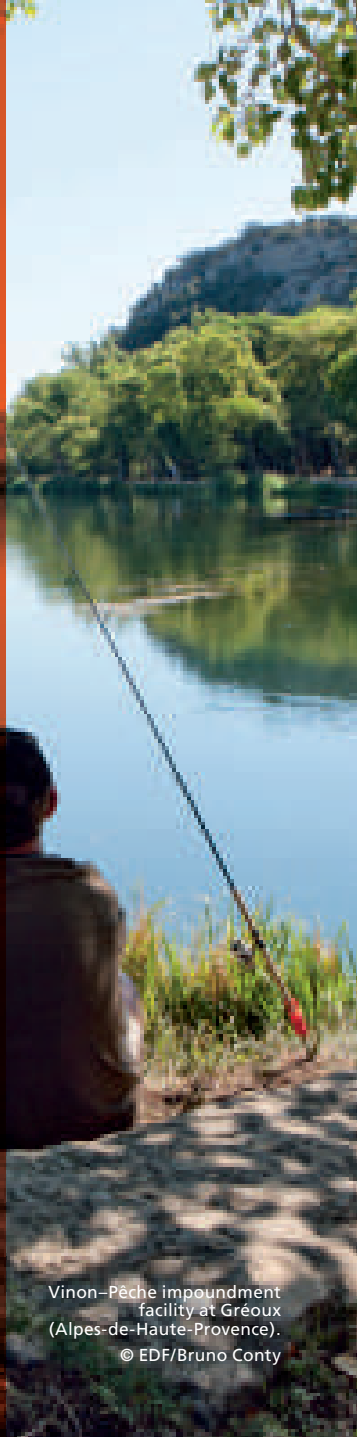
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Hydropower, energy of the future
Hydropower: a solution to present and future economic challenges

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WATER: THE WORLD'S FOREMOST RENEWABLE ENERGY

Hydropower is an essential source of electrical energy worldwide. It ranks foremost among all renewable energy forms. This environmentally friendly energy form does not contribute to the increase in greenhouse gases* or to air pollution, as it does not emit carbon dioxide or any polluting gases. Hydroelectric power has its own place within the natural water cycle (rainfall, snow melt, mountain streams and rivers): water is impounded in dams and is used to drive turbines and generate electrical current. It is not so much the hydraulic head as the amount of impounded water that determines a hydro plant's capacity. Indeed, the world's four leading hydropower producers are flat countries with large catchment areas: United States, Russia, Canada and Brazil. France's natural landscape provides ideal conditions for hydroelectric power generation: regular rainfall, contrasting terrain, long waterways and a dense hydrographical network.

* Greenhouse effect
This natural phenomenon leads to the warming of the atmosphere and surface of a planet that is exposed to solar rays.



Vinon–Pêche impoundment facility at Gréoux (Alpes-de-Haute-Provence).
© EDF/Bruno Conty

Renewable energy sources

These are very long-term, inexhaustible sources of primary energy, as they are directly or indirectly derived from solar energy, the earth's energy or gravity. Renewable energy sources include solar power, wind power, hydro energy (dams), the biomass (organic matter that releases energy, such as burning wood), geothermal energy that uses heat from the depths of the earth, and tidal power. These energy forms do not become depleted and most of them do not produce CO_2 emissions.

DID YOU KNOW?

FLEXIBLE AND RESPONSIVE
Lake-supplied hydro plants (which impound water in dams) are the most commonly used response to peaks in demand.

7.5 BILLION CUBIC METRES
The volume of water impounded in all EDF dams.



Leading hydropower producer

EDF is the European Union's leading hydropower producer, with more than 20,000 MW of installed capacity spread across 435 hydropower sites, ranging from about 10 kilowatts to several hundred megawatts. 70% of France's hydroelectric energy potential, estimated at 98TWh/year, is currently being used. Hydro energy plays an instrumental role in France's energy independence, saving the country 13 million tons of oil every year.

TOTAL WORLDWIDE POWER OUTPUT IN 2009



67.2%
Fossil-fired (coal, oil, gas)

13.5%
Nuclear

16.1%
Hydro

3.2%
Other renewables

THE INCREDIBLE FLEXIBILITY OF WATER

ADJUSTING LOAD ON THE FRENCH ELECTRICAL GRID

With water reserves amounting to 7.5 billion cubic meters, and 20 GW of installed capacity, impoundment facilities and hydroelectric plants are able to constantly adjust power output to respond to fluctuations in electricity demand (in very cold weather or during peak periods, or as a result of incidents occurring on the grid or at other plants), thereby supplementing the power generated by nuclear and fossil-fired facilities. The hundred biggest hydro plants are controlled by four hydroelectric control centres located in Lyon, Toulouse, Sainte-Tulle and Kembs.

ENERGY ON TAP

While energy cannot be stored on a large scale, water can nevertheless be impounded in large reservoirs by using dam walls or dikes to store potential energy. The release of this water unleashes energy, the magnitude of which increases or decreases in proportion to hydraulic head and flow rate.
The channelled water drives turbines, which immediately generate electricity. A hydroelectric plant can reach its maximum capacity within a few minutes, as opposed to about 10 hours for a conventional fossil-fired plant and about forty hours for a nuclear reactor. Its flexibility and countrywide water reserves make hydroelectric energy the ideal means for adjusting electrical power during periods of peak demand.

Maintenance being performed at Lafigère hydro plant (Ardèche).
© EDF/Patrice Dhumes

20 GW
OF INSTALLED CAPACITY

43.5 billion kWh
generated each year

435 hydro plants
ranging in capacity from a few dozen kilowatts to 1,800 megawatts

622 dams
including 150 with a head of more than 20 metres

INSTALLED CAPACITY DISTRIBUTION IN MAINLAND FRANCE (EDF FLEET)



1,800 MW within the space of 2 minutes


© EDF/Franck Oddoux

Commissioned in 1985, the Grand'Maison power plant in the Isère is the most powerful hydroelectric facility in France. Within the space of two minutes, it is able to generate 1,800 MW of electrical power, tantamount to the power generated by two nuclear reactors. Grand'Maison is a pumped-storage facility that uses two reservoirs located at different altitudes. During periods of peak demand, water in the upper reservoir is pumped down to the lower reservoir. When the demand for electrical power drops, the water is pumped back to the upper reservoir.

Operating around the clock

and 365 days a year,
control centres cater to the needs of the national grid and remotely control the country's hydro generation facilities, promptly responding to peaks in demand.

FROM WATER TO ELECTRICITY: HOW IT WORKS

FROM WATER SOURCE TO POWER PLANT

From time immemorial, the force of water has always fascinated man, while its secrets have been known since ancient times: harnessing of water, aqueducts, hydraulic head, wheels and mills. Mediaeval industry expanded through the harnessing of this driving force. The invention of the turbine, followed by that of the generator in the 19th century, made it possible to generate electricity from hydroelectric power. A precursor in the use of energies harnessed from the sea, EDF has been operating the tidal plant at La Rance (Ille-et-Vilaine) for the past 40 years. In July 2008, EDF decided to build a pilot marine turbine farm in order to harness energy from sea currents to generate electricity.



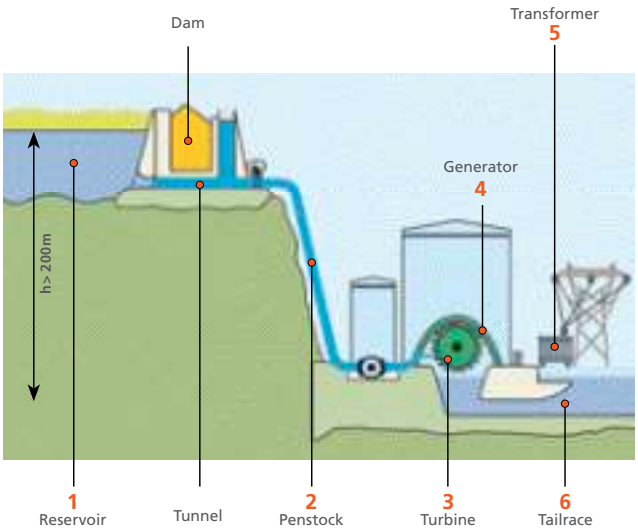
Turbine hall and control room at Serre-Ponçon in the Alps.

© EDF/Julien Goldstein

HOW A HYDRO PLANT WORKS

The principle is straightforward and relies on the force of gravity: potential energy from water impounded in dams is converted into mechanical energy by means of a turbine. This energy is then converted into electrical energy using a generator.

The dam is used to store up large quantities of water by forming a lake **(1)**. When the sluice gates are opened, water flows into a penstock or channel **(2)**, which directs it towards the power plant. The water causes the turbine **(3)** to spin. The turbine drives the generator **(4)**, which produces electrical current. This current is rectified by a transformer **(5)** before being transmitted along high-voltage power lines. Outside the power plant, the water returns to the river via a tailrace **(6)**.



DID YOU KNOW?

AVAILABLE CAPACITY

Available capacity (kW) is a combination of two factors: **hydraulic head (m) and derived flow (m^3/s).**

Different plants for different landscapes

Hydro plants come in a variety of forms, depending on the layout of the waterway, the terrain or the hydraulic head:

- Mountain sites with a steep gradient, like the Portillon plant in the Pyrenees (1,420 m head in a penstock), but with a low flow rate
- Medium-head plants with a higher flow rate
- Run-of-river plants, with a slight gradient (10-15 m) but a very high flow rate, as found in large rivers (Rhine, Rhône, Isère, Durance, etc.)
- Pumped-storage plants, pumping water downhill during peak periods and pumping water uphill during quiet periods
- Tidal plants, such as La Rance in Ille-et-Vilaine

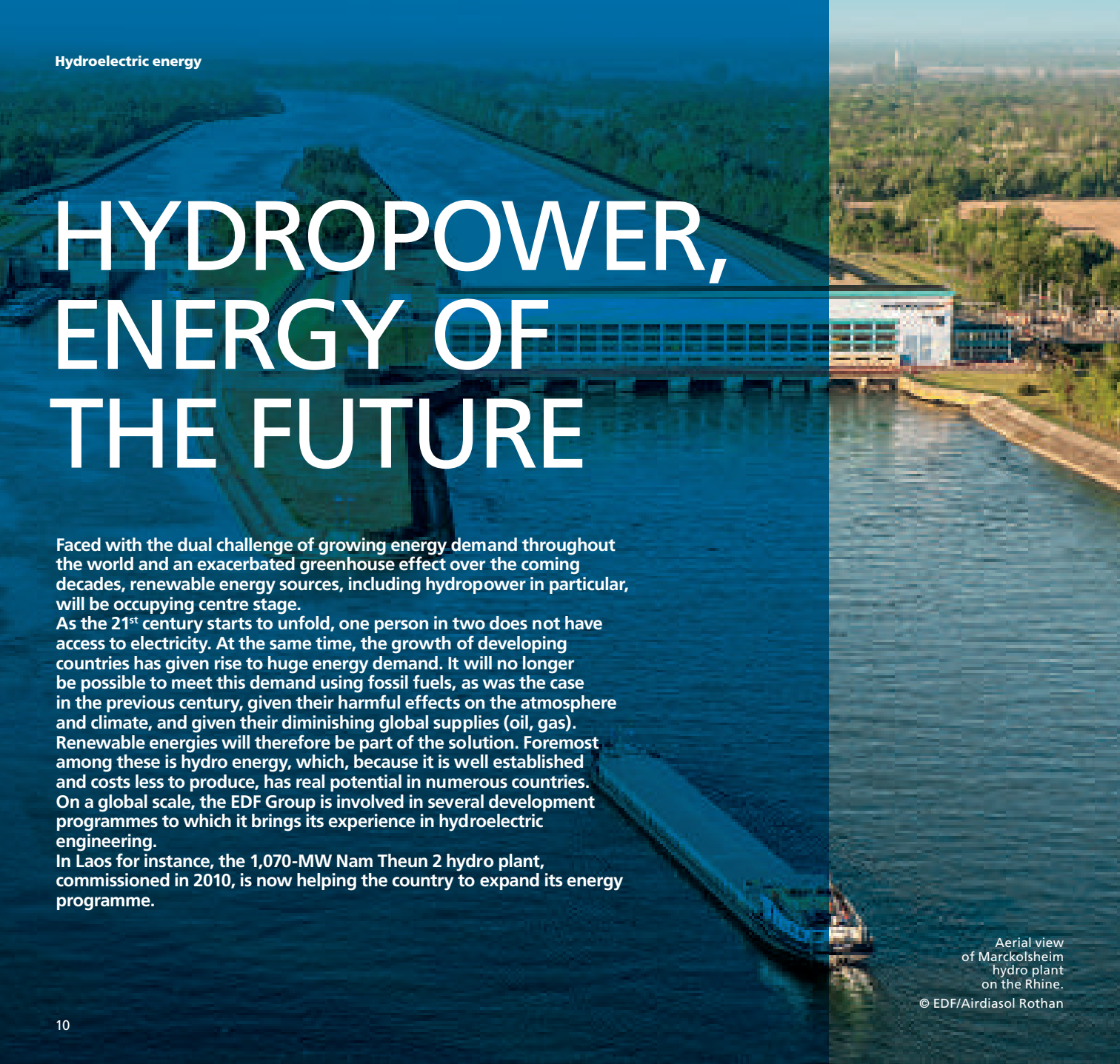
Depending on the type of dam (arch dam, weight, abutments, rock fill or earth dam, moveable dam) and hydraulic head (high, medium or low), three main types of turbine are respectively used: Pelton, Francis or Kaplan

HYDROPOWER, ENERGY OF THE FUTURE

Faced with the dual challenge of growing energy demand throughout the world and an exacerbated greenhouse effect over the coming decades, renewable energy sources, including hydropower in particular, will be occupying centre stage.

As the 21st century starts to unfold, one person in two does not have access to electricity. At the same time, the growth of developing countries has given rise to huge energy demand. It will no longer be possible to meet this demand using fossil fuels, as was the case in the previous century, given their harmful effects on the atmosphere and climate, and given their diminishing global supplies (oil, gas). Renewable energies will therefore be part of the solution. Foremost among these is hydro energy, which, because it is well established and costs less to produce, has real potential in numerous countries. On a global scale, the EDF Group is involved in several development programmes to which it brings its experience in hydroelectric engineering.

In Laos for instance, the 1,070-MW Nam Theun 2 hydro plant, commissioned in 2010, is now helping the country to expand its energy programme.



Aerial view of Marckolsheim hydro plant on the Rhine.

© EDF/Airdiasol Rothan

THE EDF GROUP: A KEY PLAYER IN THE FAIR DISTRIBUTION OF WATER RESOURCES



Regatta on Lake Serre-Ponçon.

EDF has always had a close relationship with water. In order to generate electricity, the utility harnesses water directly as a driving force for its hydroelectric plants, or indirectly as a heat sink for its fossil-fired and nuclear plants. However, water is also needed for other, equally important purposes such as public consumption, agriculture, industry and tourism. In order to do this, future water reserves have to be evaluated on the basis of hydro-climatic factors such as snowfall or rainfall in catchment areas. It is the duty of the public authorities, in conjunction with various other players including local authorities and water agencies, to ensure that water is equitably managed.



CLOSELY MONITORED STRUCTURES

Dams are affected by water mass and pressure, as well as by changes in temperature. The safety of hydroelectric plants therefore requires that each site and its facilities be kept under constant scrutiny. Dams are therefore constantly inspected and monitored. On the occasion of statutory ten-year outages, dams may be drained in order to check the condition of sections that are normally submerged. Robotic devices are sometimes used in order to avoid draining the dams.

HYDROELECTRIC POTENTIAL

In France, 70 TWh of electricity are generated each year from an available capacity of 98 TWh. This output could be expanded:
1) By enlarging the existing fleet of 10 to 50-MW hydro facilities (23 TWh) or by building new dams like the one at Romanche-Gavet in the Isère or on the Rizzanese in Corsica, commissioned in 2013
2) By enlarging small hydro facilities, i.e. 0.1 to 10-MW units (4 TWh) or by refurbishing old mills (pico hydro, a term referring to capacities ranging from 10 to 100 kW) already in existence (1 TWh).

DID YOU KNOW?

In order to generate electricity, water is released from hydroelectric plants. As a result, water flow and current increase downstream of the structure, potentially posing a risk to people in the vicinity or on the riverbed. However, water must be released in order to drive turbines during periods of peak demand, to satisfy the needs of farmers and manufacturers, to maintain a minimum flow that is compatible with downstream ecosystems, and to reduce high water levels. In order to mitigate this risk, information campaigns are run every year and 10,000 yellow danger signs are posted along the banks of rivers, lakes and canals.

EDF and the preservation of wildlife

EDF builds fish lifts and ladders to help migrating fish, such as salmon, across the dams.



EDF
Generation
Communication Department
Cap Ampère - 1, place Pleyel
93282 Saint-Denis cedex
Head office: 22-30 avenue de Wagram, 75008 Paris
Limited company with a registered capital
of 924 433 331 Euros
RCS Paris 552 081 317
www.edf.com

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Tunnel leading to the Montahut facility.

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EDF Generation The EDF group carries ISO 14001 certification October 2013