
eDF
MARINE
ENERGY
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





Aerial view of the
Rance tidal plant.
© EDF/Julien Goldstein

Cover photo:
Tests being performed on a marine turbine, moored to a barge, in Douarnenez Bay (Brittany).
© EDF/Philippe Dureuil

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MARINE ENERGY, INSPIRING INNOVATION

The ocean is a natural source of renewable energy. Its forces are harnessed in order to generate electricity by using the mechanical energy of the currents and tides, as well as the thermal energy stored at the ocean surface.
Water covers a large proportion of the globe. It is therefore a large and promising energy resource. Marine energy does not emit greenhouse gases and is available in many countries around the world. In France, EDF spearheaded the use of marine power, commissioning the Rance tidal power plant in 1966. This innovative spirit continues to thrive with projects like the Paimpol-Bréhat marine turbine.

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Designed and produced by: makheia sequoia
Translation: Concept & langage
Printed by: La Galiote-Prenant
Printed on environmentally friendly paper

OCEAN TIDES: A SOURCE OF RENEWABLE ENERGY

Tides are created by the rise and fall of sea levels caused by the gravitational forces of the moon and the sun. These two bodies exert their forces of attraction on the mass of water at the Earth's surface, the movements of which can be accurately calculated over periods spanning hundreds or even thousands of years. When these forces combine, the tidal range is high (spring tide). However, when these forces act against each other, the tidal range is lower (neap tide). As tides are a predictable phenomenon, they are a reliable source of renewable energy. There are two techniques for converting tidal energy into electrical power: harnessing the water's potential energy through fluctuations in water levels at high and low tide (this is known as tidal energy); harnessing the kinetic energy of water in motion (tidal currents) – this is known as marine current energy. Natural conditions in France are conducive to tidal power and marine current energy, both of which are marine forms of hydropower, the world's leading source of renewable energy.

Bulb turbine set at the Rance tidal plant.
© EDF/Éric Cattin

20%

In Europe, the theoretical amount of harnessable marine energy stands at around 15,000 MW with potential generation capacity ranging from 20 to 30 TWh a year, enough to supply 6 to 8 million inhabitants. 60% of this theoretical potential is concentrated in the United Kingdom while 20% is concentrated in France, giving the latter an estimated potential of 3,000 MW.

Foremost tidal power producer

EDF was the global pioneer of tidal power generation, with the construction of the Rance tidal plant in 1966 (Ille-et-Vilaine, Brittany). This was the only commercial facility of its kind until the Sihwa plant was commissioned in South Korea.
The Rance power plant has an installed capacity of 240 MW, spread across twenty-four 10-MW bulb turbine-generator sets. For the past 40 years, the plant has generated about 500 GWh/year, equivalent to the amount of electricity used by the city of Rennes.
Drawing on the experience acquired from the Rance project, EDF is now embarking on the construction of a pilot marine-turbine facility at Paimpol-Bréhat (Côtes-d'Armor). The plant will be connected to the electrical grid as soon as it is commissioned.

Renewable energy sources

These primary energy sources are inexhaustible over very long timescales as they are derived from the energy of the sun, the Earth or gravity. Renewable energy sources include hydroelectric power (derived from the force of water), solar power, wind power, biomass (organic matter that generates energy, such as burning wood) and geothermal energy tapped from the depths of the earth, as well as marine energy, generated by tidal forces. These energy sources cannot be depleted and do not produce CO_2 emissions.

540 MW of installed tidal capacity worldwide.
1 billion KWh generated per year, including the power generated by the Rance tidal plant in France.

DID YOU KNOW?

The turbine hall at the Rance tidal plant measures 300 metres in length.

Technicians use bicycles to get around. The Rance tidal plant generates close to 40% of electrical power in Brittany (France).

FROM TIDAL FORCES TO ELECTRICAL POWER, HOW IT WORKS?

FROM MOON TO EARTH

The power of water has always fascinated mankind, and its secrets have been known since ancient times: harnessing of water, aqueducts, waterfalls, water wheels, mills – including tidal mills in Brittany. In the Middle Ages, the use of this driving force helped industry to boom. Once the turbine was invented, followed by the generator in the nineteenth century, electricity could be generated from hydropower.
A spearhead in the use of marine energy, EDF has been operating the Rance tidal power plant (Ille-et-Vilaine) for the past 40 years, thus generating clean energy in constant and predictable amounts.
Spurred on by its experience, EDF decided – in July 2008 – to build a pilot marine-turbine plant at Paimpol-Bréhat (Côtes-d'Armor), also harnessing tidal power. Using tidal currents, this mode of generation has numerous advantages: predictable, invisible (provided that the structure is completely submerged), environmentally sound, compact (owing to water density) and thus acceptable to other users of the marine environment.

Christening of the marine turbine, ARCOUEST 19 October 2011.
© EDF/Rémy Artiges

THE PAIMPOL-BREHAT PILOT MARINE-TURBINE PLANT

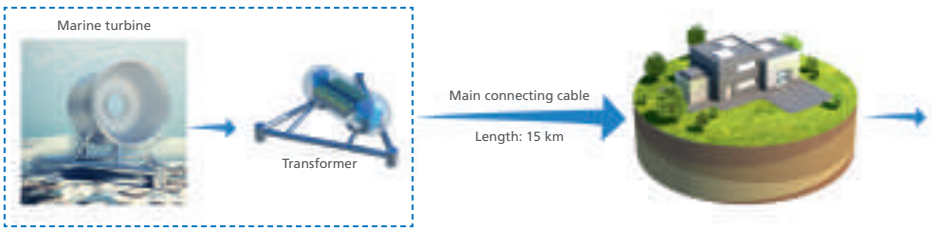
The principle of marine current energy is a quite straightforward: marine turbines are driven by tidal currents.

Their rotational movement drives a generator, which generates variable electrical current, which is rectified by an offshore transformer and transmitted to the power grid by means of a main connecting cable. Turbine speed varies according to tidal current, with maximum rotation speed reaching about seven rpm (for the strongest currents observed in the area, i.e. 3 m/s). A marine turbine consists of a turbine resting on a three-legged support structure, heavy enough to be "simply" placed on the ocean floor, without involving any construction work, thereby minimising its impact. The turbines at Paimpol-Bréhat will have an outer diameter of 16 metres.

WORKING PRINCIPLE OF A TIDAL POWER PLANT

Tidal power plants are built in areas where sea levels are known to fluctuate significantly.
A tidal power plant consists of a man-made reservoir and a dam, built to accommodate turbines that can operate at rising and falling tide (bulb turbines).
The principle involves using the difference in level created by tidal range in order to fill the reservoir (riverside): when the tide rises (flood tide), the gates are opened in order to fill the reservoir.
At high tide, the gates are shut in order to impound the water riverside.
When the tide ebbs, the drop in sea level causes a difference in height. The potential energy of the impounded water can thus be converted into mechanical rotational energy using turbines.
The gates are reopened to channel the water from the reservoir towards the sea. The turbines' rotational movement converts this mechanical energy into electrical energy by means of a generator. The electrical current is rectified by means of a transformer before being transmitted to the grid via high-voltage power lines.

SCHEMATIC DIAGRAM OF THE MARINE-TURBINE FACILITY



Turbine components submerged at depths of 35 to 38 metres

DID YOU KNOW?

The capacity (kW) of a marine turbine depends on the turbine's diameter and on ocean current velocity.

PAIMPOL-BRÉHAT: AN ENVIRONMENTALLY SOUND PROJECT

Environmentally friendly

From the design phase onwards and with input from all project stakeholders, the project's main specifications were determined with a view to eliminating or minimising environmental impact. The design was thus adapted to the sensitivity of the plant's environment (fully submerged turbine, rotating slowly and fitted with a central orifice). The same considerations were applied to the techniques employed to install machines on the ocean floor, as well as to subsequent maintenance work, which will not use drilling or anchoring techniques, as the machines are heavy enough to remain stable. The connecting cable was laid using burial and installation techniques suited to the different zones along its route (open sea, foreshore, coast), depending on the type of ocean floor (hard, soft).

Ongoing communication and dialogue

In 2004, EDF started holding talks with key stakeholders. In July 2008, EDF took the decision to build the Paimpol-Bréhat marine-turbine plant. In September 2008, a contact group was set up to facilitate these discussions. On the whole, marine turbines are positively perceived and are well accepted. This is due to ongoing efforts at engaging in systematic communication and dialogue with stakeholders, which include the public services, local and regional authorities, elected representatives, maritime users (professional fishermen, amateur sailors, divers, etc.), and environmental protection groups.

The project is being sponsored by the Region of Brittany, the ADEME and the European Community, which – via the European Regional Development Fund – has pledged to promote the public's knowledge of the marine environment, and to develop regional competitiveness and employment.



View of Launay bay at Ploubazlanec.
© EDF/Marc Didier

KNOCK-ON EFFECTS FOR THE REGIONAL ECONOMY

Positive knock-on effects are expected to benefit the local economy with the need for environmental monitoring of the new facility. In liaison with regional development structures, EDF is acting as facilitator between local businesses and its key project suppliers. The construction and installation of marine-turbine components (barges, turbine support structures, assembly) are taking place in Brittany (Lorient, Brest, Lézardrieux, Paimpol).

An innovative project in a dynamic region

In the surrounding area (Ploubazlanec, Bréhat and Paimpol, Paimpol-Goëlo), economic activities are varied, ranging from agriculture and manufacturing to the craft industry and tourism, not forgetting the maritime sector. Only maritime users are really affected by the project (sea routes and trading ports, other ports and moorings, maritime businesses, recreational activities).

Minimal impact on the environment

The impact study has shown that the effects of the marine-turbine plant on the environment will be minimal during plant operations: localised reduction of current velocity, barely perceptible electromagnetic current (from the cable), minimal risk of fish, cetaceans and birds colliding with the machines and finally, no risk of collision with ships. Compensatory measures have been taken to mitigate a handful of minor impacts.

DID YOU KNOW?

In the spring of 2011, EDF obtained all its administrative licences after a processing period of two and a half years. A key step in the process was the joint public enquiry (four procedures) in the summer of 2010. The commission of enquiry finally granted its unmitigated approval, accompanied by a few recommendations.

CONCERTED EFFORTS TO ELIMINATE, REDUCE AND MITIGATE ENVIRONMENTAL IMPACT

The report issued by the commission of enquiry mentions the minimal impact generated by the project and highlights the adequacy of compensatory measures being taken to minimise effects resulting from the presence of the facility and from work being carried out there. The purpose of these measures is to address potential inconveniences and to mitigate any effects on the natural environment.
Support initiatives are also being taken in conjunction with the project. An agreement was signed with the local fishing committee in order to support the productivity of certain major resources in the local economy, such as lobster. A lobster-marking programme has been implemented in liaison with the French Recreational Fishing Federation.

A PROMISING FUTURE FOR A RENEWABLE ENERGY SOURCE

Faced with the dual challenge of growing energy demand throughout the world and an exacerbated greenhouse effect over the coming decades, renewable energies, 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. Renewable energy sources will therefore be part of the solution. Foremost among these is hydropower, which, because it is well established and costs less to produce, has real potential in numerous countries. Renewable marine energy forms, which are lesser known, also have significant potential: 3,600 TWh/year could be technically harnessed by 2030 across the globe. France aims to have 6,000 MW of installed capacity by 2020, primarily comprising off-shore wind farms, as well as energy harnessed from tides in the form of tidal power and marine capacity, which could amount to hundreds of megawatts.



Venturi marine turbine before being transferred to a barge at Brest (Brittany).

SPOTLIGHT ON EDF'S MARINE TURBINE FACILITY AT PAIMPOL BRÉHAT

Initiated in 2004 and unequalled anywhere in the world, this project will consolidate EDF's position as marine energy leader. This marine turbine prototype measures 16 metres in length and weighs 850 tons! Once it is up and running, the Paimpol Bréhat marine turbine facility is expected to generate enough electricity for 2,000 to 3,000 households.



The marine turbine prototype during its first immersion test in 2011.

Other sources of marine energy

Other modes of power generation harnessing the ocean's resources are currently being researched or trialled at variously advanced stages of development. These methods include:

- **offshore wind energy,** which is not directly harnessed from the ocean, but could drive expansion of the industry both in France and abroad;
- **potential or kinetic wave energy** generated by the movement of the ocean surface through the effect of the swell (oscillating movement of surface water due to wind friction on the ocean surface);
- **ocean thermal energy,** which harnesses temperature differences between surface water and deep water;
- **osmotic energy,** which uses the difference in salt concentration between seawater and river water, for instance near estuaries where these two types of water combine;
- **marine biomass,** through the gasification, fermentation and combustion of algae and phytoplankton.



FOR MORE INFORMATION

Visit http://paimpol-brehat.edf.com



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

Ref:ENE013-2013

The Rance dam:
View of the basin at high tide. Swirling masses of water as the sluice gates open.

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EDF Generation The EDF group carries ISO 14001 certification October 2013