IT CHANGES EVERYTHING
Issue no. 1 – July 2019

# IS LOW-CARBON ENERGY POSSIBLE?

EDF

# A magazine, podcasts and online documentaries

This is the way we decided to get involved in the conversation about the major challenges we are facing as part of the energy transition.

As a provider of 97% carbon-free electricity, we are playing a key role. Working closely with our customers, partners and employees, as well as elected officials, regional authorities, charities, NGOs and universities, we want to explore and challenge the shift — industrial, social, technological, economic and geopolitical — currently taking place due to the climate challenge. The fight against climate change is a fight against $CO_2$ that should be led by everyone, everywhere. We want to pool our efforts and start a widescale collective movement. We want to change everything — how we generate increasingly low-carbon electricity, but also how we consume energy.

Many people are using their expertise, engagement and creativity to “change everything”. Concrete solutions are emerging in regions, towns and people’s homes, as well as at generating facilities. A vast movement is underway, as reflected by the changing energy mix, digital innovations, technological progress, electric mobility, smart grids and new kinds of consumption. We want to accelerate this movement by innovating to contribute in any way possible, now and in the future, to a low-carbon world.

**In fact, low carbon is the theme of this first edition.** Is low-carbon energy possible? How can we achieve it? And how quickly?
It is these fundamental yet complex questions we wanted to address in our new issue,

**IT CHANGES EVERYTHING**

# Is low-carbon energy possible?

Thierry Guerrier and Yolaine de la Bigne spoke with Marie-Claire Aoun, an expert in the geopolitics of energy, and Jean-Louis Étienne, a doctor and explorer, about a wide range of issues including the energy mix, storage and acceptability in their podcast *"Ça change tout"* recorded on 21 June 2019.
**Here's a quick look back at the key moments of their conversation.**

**Why is it so difficult** to generate carbon-free energy?

**Time and money are a major factor.** It took 60 years for coal and 40 years for petrol to properly take hold in the energy mix.

... We can't wait that long to fully integrate **low-carbon energy.**

Renewable energy needs to become **competitive and profitable!**

**We need to start a conversation with people everywhere.** We have to put ideas forward, be prepared to adapt them, and start looking now to find the solutions that best meet the needs of each community.

If a person wants to be **energy self-sufficient** nowadays, they are able to with renewable energies. Getting individuals interested in making such investments is the best way to convince them.

We tend to underestimate just how dependent we are on electricity. **Education is key** if we want to encourage people to adopt the right behaviour.



We have to move towards a combination of low-carbon energies. In France, we are lucky that our electricity is already to a large extent carbon-free **thanks to nuclear energy.**

**We need to look at the whole picture** so as not to close any doors and weigh up the advantages and disadvantages of all our options.

Today, we are looking at a bright future in storage, we've made a lot of progress on the amount of electricity we can store and **optimising these batteries.**

You mentioned the problem of **intermittent energies.** What are the solutions?

The **storage market** is huge.

Engineers have already come up with solutions that work in theory, but putting them into practice is tough. Developing a **brand new energy system** is a colossal challenge.

But the **engineers** are on it!

ÇA CHANGE TOUT

**The podcast *"Ça change tout"* is available on all platforms and can be downloaded on Apple podcasts, Spotify, Deezer, Podcast Addict, Google Podcasts and many more, including edf.fr.**

## Interview

“The transition towards a society that consumes less energy is unavoidable. Companies and politicians should start working on a strategic vision now.”

**Jean Jouzel**

Climatologist, glaciologist, international expert member of the Intergovernmental Panel on Climate Change (IPCC), Director of Research (Emeritus) at the French Alternative Energies and Atomic Energy Commission (CEA) and member of the Economic, Social and Environmental Council (ESEC).

Jean Jouzel was one of the first scientists to establish a link between human activity and climate change. He has been bringing the urgency of the environmental situation to the attention of political and industrial decision-makers, as well as the general public, for over 30 years. He told us about his vision of the climate transition as something that is not only unavoidable and essential, but also a way to create value.

— Debates about climate change often seem too abstract for some, particularly due to the growing amount of technical data. How can we make it easier for people to understand the urgency of the current situation?

**Jean Jouzel.** We must limit global warming to 1.5 °C above pre-industrial levels, and we've already notched up a 1 °C increase. A 2 °C rise in temperatures would have serious repercussions on our environment and living conditions. This 0.5 °C difference is crucial. For example, an increase between 1.5 °C and 2 °C would put the coral reefs at risk. And, if we do not act today, future generations will be facing warming of 3-4 °C. So, there is no need to use really technical language to explain it – the figures say it all. Thirty years ago, the IPCC issued its first warning about climate change. What we predicted at the time then came to pass. So, we could talk about the different reports and the time we have to implement certain policies, but the reality is, unfortunately, clearer than ever — we must act now. If we want to limit global warming to 1.5 °C, we have to make decisions and act now. The transition towards a society that consumes less energy is unavoidable.

— But can we implement these essential decisions quickly enough? Can companies and industries change their economic organisation and adopt new strategies that abruptly?

**J. J.** To truly change course, we must know where we are going and how. Companies, like the world's political leaders, have to develop a medium- and long-term strategic vision so that they can take action immediately. People's mindsets are changing on this. More and more shareholders are asking listed companies to assess the specific climate risks related to their activities. Environmental responsibility is therefore becoming a key consideration for companies. This is a forerunner of the in-depth change in attitudes that society as a whole should adopt.

— How?

**J. J.** For example, I think we should completely do away with the idea that the energy transition and economic growth are incompatible. It doesn't make sense. Making society more mindful of climate issues would actually generate real momentum. A successful transition would effectively create 900,000 net jobs in France, and almost 6 million across Europe. That is why I disagree with the term "degrowth". I would prefer to talk about "alternative" or "different" growth — terms that take into account well-being, ethics and protection and are not necessarily synonyms for a recession! We have to get away from that mindset. A value creating economy would be able to further invest in solutions for the future — the two are clearly linked. The first continent to embrace the energy revolution will also be a winner in economic terms. And Europe — thanks to its industry, capacity for innovation and the awareness of its younger generations — is particularly well placed to deal with this major shift.

— Will future solutions be technology based, or depend on good practice and individuals' behaviour?

**J. J.** Again, I don't think there's any point setting the two against each other. We should obviously be investing in research, particularly to develop storage capacity for renewable energy and methods to capture $CO_2$, but this cannot just be seen as a technical challenge. It's something that also requires civic engagement across the whole of society. In France, for example, we should be able to halve our energy consumption by 2050.

— What do you think are the actions we need to take as a priority?

**J. J.** Fossil fuels are still our main source of energy. We must reduce the amount we use before giving them up completely. We should make an effort in the mobility sector by promoting solutions that have a lesser impact on the environment. We also have to aim for carbon-neutral buildings. These two approaches are important and should be pursued simultaneously.

— Given the climate challenge will create jobs and new professions and change our consumption habits, you could say it also represents a social challenge.

**J. J.** Exactly! That's actually a huge part of it, and one many people seem unaware of. The most significant risk of climate change is growing social inequality. Society's poorest are those who struggle the most to come back from extreme climate-related events — as proven by Hurricane Katrina, which devastated New Orleans in 2005. The wealthiest are able to bounce back, but it is much harder for everyone else. The stability of our societies is therefore at stake. Moreover, climate change will provoke huge levels of migration, which could lead to geopolitical unrest. The Nobel Peace Prize 2007(1) awarded to the IPCC made it clear that the fight against climate change has a key role to play in maintaining peace.

**"It is time to act. Making society more mindful of climate issues would actually generate real momentum in the economy."**

**Jean Jouzel**

*(1) Awarded jointly to Al Gore Jr. and the IPCC "for their efforts to build up and disseminate greater knowledge about man-made climate change, and to lay the foundations for the measures that are needed to counteract such change"*

# TOWARDS CARBON NEUTRALITY IN 2050



Revised at the end of 2018, the French national low-carbon strategy lays out the roadmap to achieving carbon neutrality by 2050, in line with the targets set in the **Paris Agreement**. Every sector of the economy is affected: transport, housing, agriculture and food, manufacturing, the circular economy and, of course, energy.

Although France already has one of the lowest levels of greenhouse gas emissions per inhabitant for a developed country thanks to EDF's nuclear fleet, it has chosen to pursue and implement an ambitious strategy for the energy transition. This led to the country adopting the Law on Energy Transition for Green Growth in 2015 and formalising the first national low-carbon strategy. It aims to cut France's greenhouse gas emissions by 75% by 2050 compared with 1990 levels. At the end of 2015, the Paris Agreement set the bar even higher, aiming to limit this century's global temperature rise to well below 2 °C. The second national low-carbon strategy is a roadmap for France that sets the objective of carbon neutrality by 2050 and calls for redefining emission caps every five years.

**Following the Climate Plan and the national low-carbon strategy,** the French government published a draft Multi-year Energy Programme (PPE) in January 2019, which will set out priority actions to be taken in the energy sector. This roadmap for France's energy policy specifies the operational measures that will set the country on the path to carbon neutrality. It will now be discussed by a number of bodies, who will make

SNBC* * French national low-carbon strategy

**The French national low-carbon strategy** lays out the roadmap for the country to reduce its greenhouse gas emissions. It includes 67 industry-specific and cross-disciplinary recommendations (carbon footprint, investments, land management, regional economies, R&D, education and training).

## Objectives by industry

**1.**
**30% of $CO_2$ emissions(1) in the transport industry,** which needs to reduce its emissions by 70% by 2050, in particular by promoting electric mobility and vehicle energy efficiency.

**2.**
**27% of $CO_2$ emissions(1) in the housing industry,** which needs to reduce its emissions by 86% by 2050 by making energy retrofitting a national priority.

**3.**
**20% of $CO_2$ emissions(1) in the agriculture and forestry industry,** which needs to reduce agricultural emissions by 48% by 2050 by increasing carbon sinks and stocks on agricultural land and sustainable forest management.

**4.**
**18% of $CO_2$ emissions(1) in the manufacturing industry,** which needs to reduce its emissions by 75% by 2050 by managing the demand for energy and materials and developing the circular economy.

**5.**
**10% of $CO_2$ emissions(1) in the energy industry,** which needs to keep its emissions below 2015 levels and reduce emissions from energy generation by 95% by 2050, compared with 1990, by increasing energy efficiency and developing renewable energy.

*(1) 2015 data*

IPPC* * Intergovernmental Panel on Climate Change

## The IPCC published its fifth report

**Every half a degree of warming counts in the fight against climate change.** Temperatures have already risen by 1 °C on average compared with pre-industrial levels. At current emissions rates, global warming will reach 1.5 °C between 2030 and 2052. In October 2018, the Intergovernmental Panel on Climate Change (IPCC) published a report on the impact of global warming of 1.5 °C compared with 2 °C in 2100 (2 °C being the objective set by the Paris Agreement). The report argues that the additional half a degree is far from insignificant.

At 1.5 °C, for example:
- Sea levels would rise by no more than 10 cm by 2100, affecting fewer people across the world;
- 1.5 to 2.5 million $km^2$ of permafrost would be preserved, which would have a major effect on $CO_2$ storage;
- Half as many people would be at risk of fresh water shortages;
- 30% of coral reefs would be protected through reduced ocean acidity.

Currently, **the only way of achieving this goal** is by reducing $CO_2$ emissions immediately in order to decrease by 45% by 2030 and reach carbon neutrality by 2050 — 25 years earlier than the 2 °C scenario. We will need to transform faster than ever before and make progress in large-scale $CO_2$ capture technology. We could also use natural methods such as trees, soils and natural carbon sinks such as the ocean, as well as chemical processes like underground carbon storage.

## All together for zero carbon

In 2018, EDF joined the Net Zero Initiative launched by the Carbone 4 consulting firm. The initiative brings together companies that want to help achieve carbon neutrality — including EDF, which aims to reach this goal in 2050. The nine partner companies involved in the initiative are drawing up a framework and methodology to bring the concept of carbon neutrality to life. As a provider of low-carbon electricity, EDF has a rightful place in this process.

their recommendations. The public will also be invited to have their say, once the environmental authority has issued its opinion. The PPE has five aims: reduce energy consumption, limit the use of fossil fuels, diversify the energy mix, create jobs and boost purchasing power. For the first time, it includes primary questions related to both energy and climate change. Most importantly, the PPE confronts these issues across two different time scales — essential for an industry that needs ample time to plan investments. Operational measures to put France on the path to carbon neutrality will be implemented by 2028, and the goal should be achieved in 2050.

**Decarbonising the economy through electricity.** The draft PPE reaffirms that, to reach its goals, France will need to reduce its energy consumption and realise the necessary decarbonisation of the economy, which will be made possible largely through electricity. There are two reasons for this. Firstly, electricity consumption will increase slightly — by 0-0.5% per year — driven by population growth and new uses (electric vehicles, heat pumps, connected devices and appliances, etc.).

To put France's current situation into context, Sweden has one of the most electrified economies, with consumption per capita of 13,700 kWh per year (versus 7,148 kWh per year in France), according to the most recent data from the International Energy Agency (IEA). As a result, Sweden has one of the lowest rates of $CO_2$ emissions — 3.8 tonnes per capita, compared with 4.8 tonnes in France and 8.9 tonnes in Germany.

Secondly, electricity in France is already highly decarbonised thanks to EDF, whose energy generation is already 97% carbon free.(1) According to electricity transmission network operator RTE, the French electricity sector emitted 20 million tonnes of $CO_2$ in 2018, of which EDF accounted for 9.3 tonnes. In terms of carbon performance, EDF generates just 17g per kWh compared with 37g per kWh for France as a country, which demonstrates the way in which EDF is playing a major role in driving the transition toward a decarbonised economy.

In contrast, despite huge investments in electricity generated from renewable sources, Germany generates over 500g per kWh, due to its use of coal and lignite. Moreover, low-carbon electricity exports from France — the largest exporter in Europe — help to decarbonise the entire continent by reducing other countries' reliance on gas- or coal-fired plants.

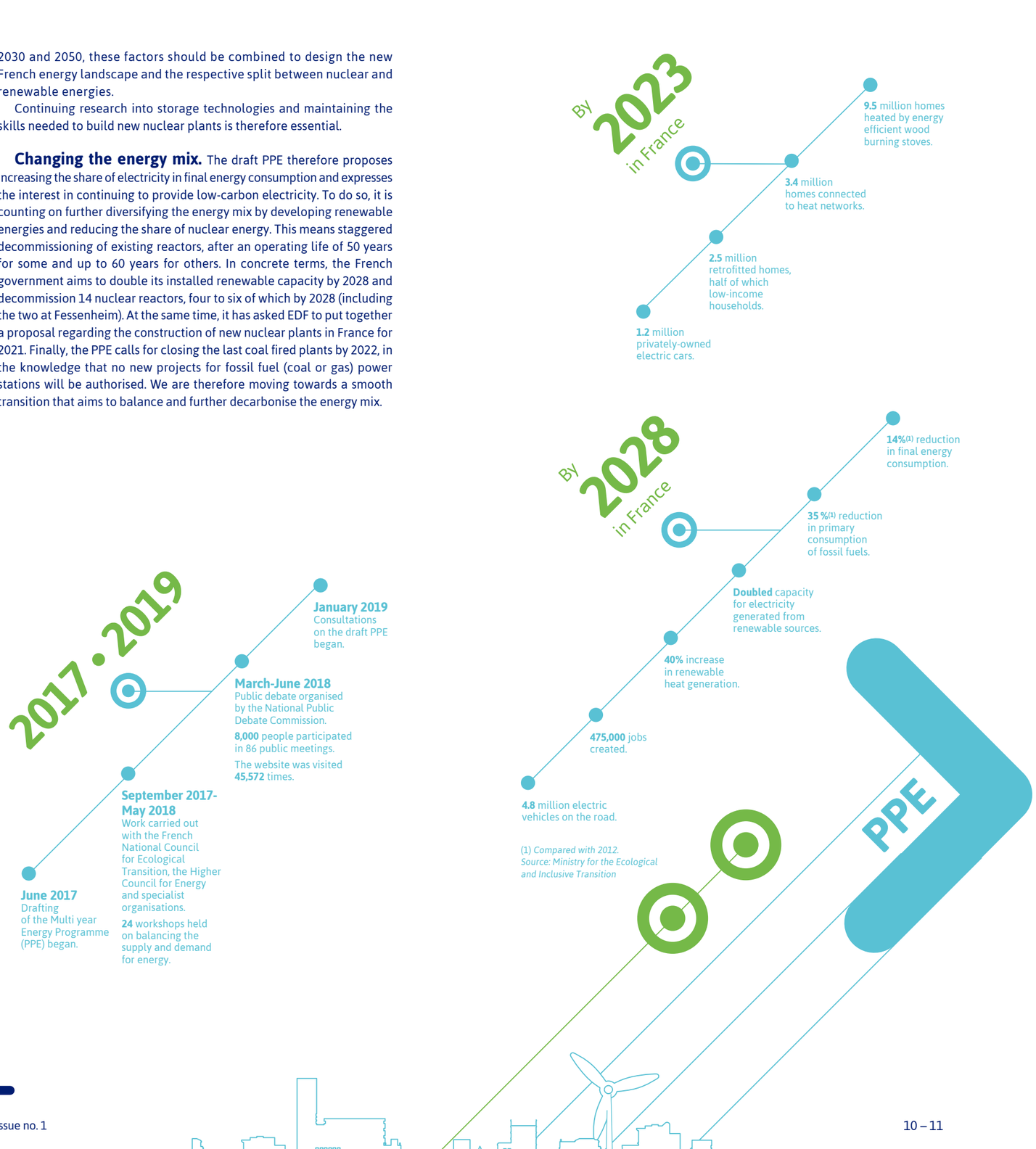
Energy generation will also change — increasingly renewable and decentralised, it will take place nearer people, and be increasingly environmentally friendly. The share of nuclear energy will be gradually reduced in order to diversify our sources of low-carbon electricity generation. Biomass should be produced sustainably to meet the needs of all bioeconomy value chains (food, materials, energy, etc.) and, in particular, used optimally to produce biofuels. Renewable energy will be generated everywhere and managed by local smart grids.

**Major decisions regarding the long-term electricity mix** will be prepared during the first stage of the PPE. Achieving carbon neutrality by 2050 is a priority for France in its efforts to combat climate change. In order for it to happen, the electricity mix must ultimately be completely decarbonised. It seems that new nuclear capacity will not be required for the electricity system before 2035. Beyond that date, we must focus on the issue of building new low-carbon electricity generating plants to maintain the balance between supply and demand as the current nuclear fleet is decommissioned.

With current technologies, it is not yet possible to determine exactly which electricity generating technology — nuclear power or renewable energy plus storage or other flexible solutions — will be the most suitable to replace the current nuclear fleet beyond 2035. Between 2030 and 2050, these factors should be combined to design the new French energy landscape and the respective split between nuclear and renewable energies.

Continuing research into storage technologies and maintaining the skills needed to build new nuclear plants is therefore essential.

**Changing the energy mix.** The draft PPE therefore proposes increasing the share of electricity in final energy consumption and expresses the interest in continuing to provide low-carbon electricity. To do so, it is counting on further diversifying the energy mix by developing renewable energies and reducing the share of nuclear energy. This means staggered decommissioning of existing reactors, after an operating life of 50 years for some and up to 60 years for others. In concrete terms, the French government aims to double its installed renewable capacity by 2028 and decommission 14 nuclear reactors, four to six of which by 2028 (including the two at Fessenheim). At the same time, it has asked EDF to put together a proposal regarding the construction of new nuclear plants in France for 2021. Finally, the PPE calls for closing the last coal fired plants by 2022, in the knowledge that no new projects for fossil fuel (coal or gas) power stations will be authorised. We are therefore moving towards a smooth transition that aims to balance and further decarbonise the energy mix.




(1) *Compared with 2012.*
*Source: Ministry for the Ecological and Inclusive Transition*

(1) *EDF generation in mainland France (excl. Corsica and overseas France)*

## How will EDF contribute to the Multi-year Energy Programme?

EDF, like all other energy providers in France, has contributed to drawing up the Multi-year Energy Programme. The Group is actively involved in further decarbonising the energy mix with nuclear and renewable energy, while closing its coal-fired plants. EDF is gradually bringing about the transition to protect the electricity network and limit any economic impact on communities. The participants guide submitted by the Group presents its vision for the energy transition, which can be broken down into four points:

**1.** Electricity consumption is forecast to increase slightly over the next 20 years, by 0-0.5% each year, due to the emergence of new habits and population growth.
**2.** Electricity that is increasingly generated from renewable sources. EDF is fully committed to achieving this, as demonstrated by its Solar Plan and Electricity Storage Plan.
**3.** The current fleet of nuclear facilities, which will shrink over time, supplemented by renewable energy to generate competitive, low-carbon electricity. EDF recommends gradually closing reactors from 2029 to maintain the balance within the national and regional electricity system.
**4.** The need to build new nuclear units to decarbonise electricity by 2050. If this decision is taken soon, the first plants could be commissioned in 2030 and provide the required number of gigawatts by 2050.

**Achieving carbon neutrality will require us to use all of the tools at our disposal: encouraging energy-saving behaviour, improving energy efficiency across all industries, increasing the use of renewable energy (such as biomass, geothermal and waste to energy), developing synthetic fuels and gases and, of course, electricity. These transformations must not neglect any social considerations — the transition must be fair and inclusive.**

# THE FUTURE OF NUCLEAR POWER IN FRANCE

It is an important moment for nuclear, France's third largest industry.


The PPE underlines the essential role of nuclear power, which is able to constantly provide manageable, low-carbon electricity, to face challenges related to climate change, the economy and societal issues in France. A long-term industrial and economic vision will be required to preserve this asset in the French energy mix for many years to come.

**On a global scale,** in most of the simulations analysed by the IPCC that maintain temperature rises below 1.5 °C, the share of nuclear increases. If current trends continue, a six-fold increase in worldwide nuclear capacity would be required in order to meet our climate objectives – from 59% to 106% by 2030 and from 98% to 501% by 2050, compared with 2010. The challenges concern several areas, including decommissioning, innovation and digitalisation. What is the outlook for French nuclear power in 2050?

**Nuclear power, the greatest ally to renewable energy.** By 2035, renewable energy and nuclear power will account in a lasting way for equal shares in the energy mix. The transition to this new equilibrium needs to be gradual to protect the electricity network and the balance between supply and demand, which is essential to guarantee the reliability of the electricity system. As electricity cannot be stored in large quantities, EDF adapts generation to consumption at all times in order to meet not only the needs of industries that operate 24 hours a day, but also emerging needs, such as electric mobility and connected devices and appliances.

Adapting a nuclear unit's generation according to the needs of the grid is called dispatchable generation or modulation. The development of renewable energy sources is increasingly influencing the balance between energy generation and consumption. Generation from intermittent energy sources such as solar and wind power fluctuates, as does energy consumption. To compensate and balance the electricity grid, nuclear and hydropower capacity also need to fluctuate more. Modulation is essential to successfully integrating renewable energy in the energy mix and the energy transition as a whole. EDF has extensive expertise in this area. The Group's nuclear reactors can increase or reduce output in just 30 minutes. This flexibility and responsiveness mean nuclear power is the greatest ally to renewable energy, enabling its large-scale integration.

### The *Grand carénage* programme progress report

2019 is a key year, with a number of operations planned, like at Tricastin, the first unit of the fleet to have its operating life extended beyond 40 years. Preparation for the next lot of 10-year inspections will also take place, as 70% of the inspection work is carried out pre-shutdown. The work for each inspection starts several years in advance in order to minimise shutdowns as much as possible and maintain the balance between supply and demand. Operators, engineers and a variety of suppliers come together to carry out this preparatory work, which provides a significant boost to the local economy. Bugey 2 will be inspected this year, as will Chooz 2, in the first of its second series of 10-year inspections.
Last but certainly not least, this year will see EDF's emergency diesel generator project go into operation — a key part of the Grand carénage programme. Over 30 of these generators have been deployed. Following the accident at the Fukushima power plant, and in line with a timeframe presented to the ASN, EDF defined and implemented the "post-Fukushima" programme. Nuclear power plants in France will be equipped with additional safety upgrades to increase their resilience in extreme situations.

**Maintaining safety standards within the existing fleet.** To meet this ambition, the PPE seeks to upgrade the French nuclear fleet and encourages companies to continue to make the investments needed to safely extend the operating life of most units to 50 or even 60 years, if approved by France's national nuclear safety authority (ASN). That is the purpose of Grand carénage, our nuclear power plant renovation and modernisation programme, which step by step will contribute to reaching a 50% share for nuclear in the energy mix by 2035. Modernising nuclear plants to extend their operating lives will give renewable energy the time it needs to gain traction. The Grand carénage programme represents a pillar of the energy transition. It makes the nuclear and renewable energy combination more competitive, which will be further reinforced by increasing demand for decarbonisation in Europe.

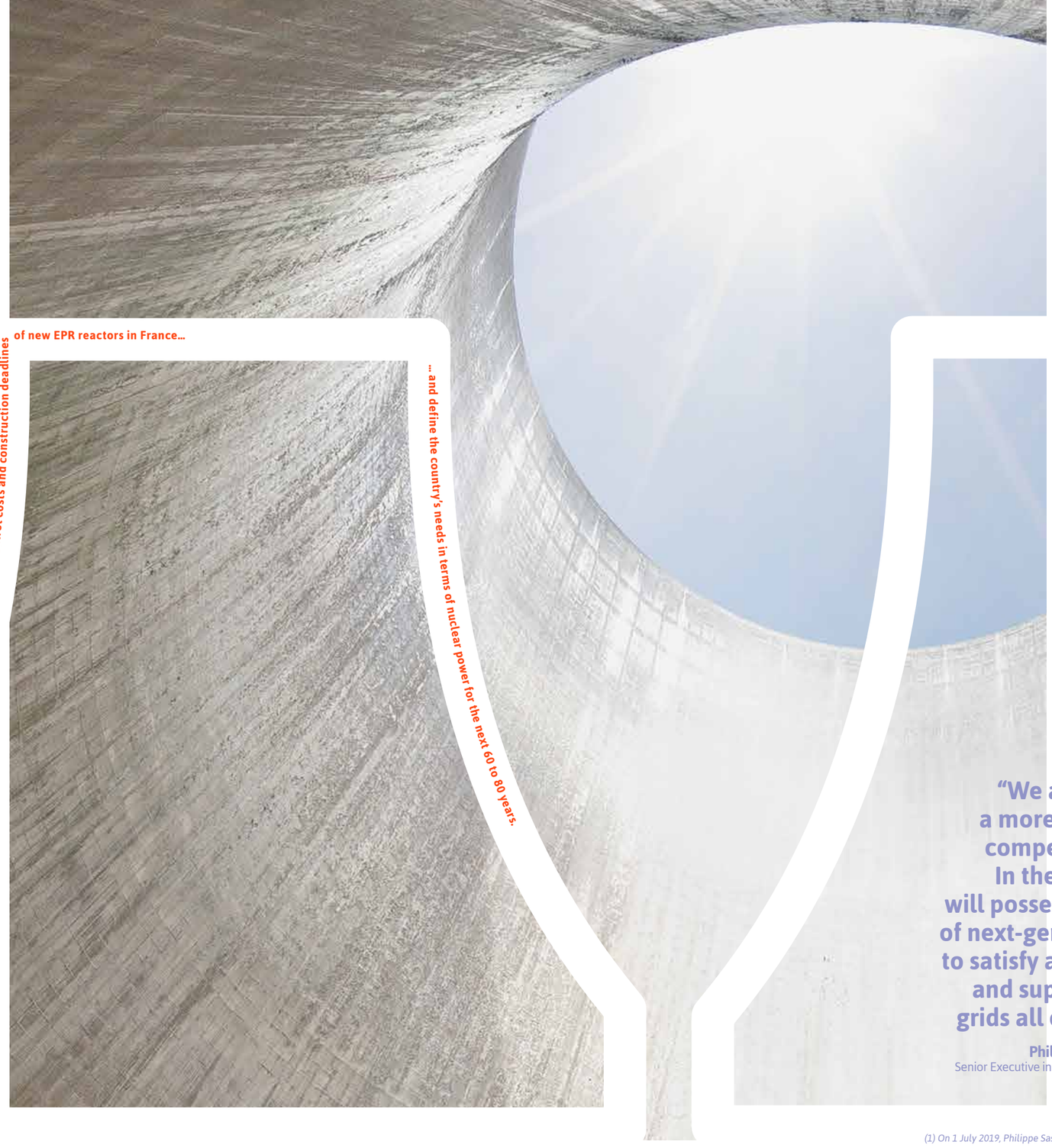
Investments as part of the Grand carénage programme added up to around €48 billion in 2014 and 2015.

Beyond that, Grand carénage aims to get the most out of existing facilities in order to spread over time the need to build new generating plants, including nuclear units.

France needs to be prepared to replace about 50 GW of its nuclear capacity by 2050.

Over this period, the French energy mix will rely on the complementarity between renewable and nuclear energy, with a marked increase in the share of renewables. Nuclear energy in 2050 will be a new kind of nuclear — it would not be appropriate to plan quantities right now. But if the country is to reach the nuclear gigawatt capacity it needs by 2050, work to build the first two units must start soon.

Renovating and renewing the fleet are two pillars of the same industrial strategy, which aims to preserve nuclear energy as a long-term asset for France.



**In this proposal, EDF will need to demonstrate its ability to control costs and construction deadlines of new EPR reactors in France…**

**… and define the country's needs in terms of nuclear power for the next 60 to 80 years.**

**50,000**
**employees and service providers working on the fleet in operation in France.**

**"We are building a more efficient and competitive sector. In the future, EDF will possess a whole range of next-generation reactors to satisfy a variety of needs and supply electricity grids all over the world."**

**Philippe Sasseigne**
Senior Executive in charge of Nuclear and Thermal(1)

*(1) On 1 July 2019, Philippe Sasseigne will be replaced by Cédric Lewandowski*

**Designing the nuclear energy of tomorrow.** Although EPR is just starting out, EDF and Framatome are already working on its optimisation. It may seem early but in fact we must start now, because industrial timescales are long. The project is key for the future of the nuclear industry as it will form the economic, financial and industrial approach to renewing existing nuclear power plants. With a 1,670-MW capacity, this enhanced EPR reactor — known as EPR 2 — will first renew the French nuclear fleet, then expand the French nuclear industry's offering on the export market. The goal is to reduce the time and cost of construction by simplifying and standardising equipment, integrating feedback from the first EPR construction projects around the world.

All these projects to build new reactors are part of the plan to restructure the French nuclear sector, with two Group subsidiaries taking part: Edvance, to design and build new nuclear islands, and Framatome, to provide their components.

**Supporting the development of nuclear power** to meet climate objectives on a global scale. The commissioning of the world's first EPR in Taishan, China, in 2018 was a major milestone for EDF. This technology, developed by the French nuclear sector and driven by EDF, aims to become the benchmark for Nuclear New Build; reactors produce low-carbon electricity with unparalleled levels of power and safety. The success of Taishan — the product of 40 years of collaboration between engineers in France and China — is expected to continue, with a second unit set for commissioning at the end of 2019.

**"EPR 2 is a reactor that has been created to be used in France. It is similar to the EPR, but its cost and production time have been optimised. The goal is to be able to build EPRs in France that generate electricity for a total cost of €65-70 per MWh — cheaper than any form of fossil-fuel energy generation — supplemented by carbon pricing, which we could develop over the same period."**

**Xavier Ursat**
Senior Executive Vice-President in charge of New Nuclear Projects and Engineering

The experience acquired by hundreds of engineers will be leveraged in the Flamanville 3 and Hinkley Point C projects in the UK. The technology is of interest to electricity companies in India, where low-carbon generating plants are required, both to meet the country's growing needs and tackle the high levels of air pollution in its cities. India has therefore planned to increase its nuclear generation capacity by 56 GW between now and 2040.

Elsewhere, EDF, TechnicAtome, Naval Group and the French Alternative Energies and Atomic Energy Commission (CEA) are working together on a development project, the Small Modular Reactor (SMR). The project seeks to address a high-growth market — that of vast countries like Australia, Brazil and Canada, whose isolated regions lack robust electricity networks. The SMR has a capacity of 340 MWe, which means it meets buyers' needs while generating low-carbon electricity. It can also be used to supply geographically isolated electricity-intensive industries. The reactors are mass produced in a factory to reduce costs and multiple units can be used on one site. The design and dimensions of the French SMRs comply with all safety requirements. They can also act as an external source of cooling for up to seven days in the event of an accident.

**Decommissioning expertise.** EDF believes decommissioning is a sector all by itself that goes towards its corporate social responsibility goals. It ensures that the company acts as part of a circular economy by reusing resources from various decommissioned sites. The changes implemented at EDF's fleet of generating plants have allowed it to develop first-class expertise in decommissioning, in particular for plants that were coal- or fuel-fired. This expertise has already been put to use dismantling nuclear power plants like Chooz 1, the first pressurised water reactor built in France. The experience acquired, particularly in nuclear islands, will be used to introduce standardisation, a key factor in the industrial process of decommissioning. The accumulation of this comprehensive expertise will strengthen public acceptance of nuclear power and open the way for the future construction of a new generation of reactors.

**58**
**reactors in operation.**

**France's nuclear industry involves 2,500 companies — 80% of which are SMEs — employing 220,000 people.**

## The nuclear industry – powering France and its economy

Nuclear is France's third largest industry after aerospace and the automotive industry. The sector's buoyant exports and workforce renewal allow it to recruit every year and offer long-term, qualified and non-relocatable jobs. The industrial landscape of these companies, concentrated in the areas surrounding long-standing nuclear facilities, covers the whole of France, creating jobs for the entire country. France controls the entire value chain for nuclear generation, which means it is able to retain a greater proportion of the jobs created. One euro invested in the nuclear industry creates up to three times as many jobs as in other electricity generation sectors.

**New skills to prepare for the future**
Maintaining and renewing skills in the sector, for both major contractors and manufacturing subcontractors, is essential for its sustainability, its ability to operate industrial facilities in the right conditions (particularly as regards safety) and its capacity for innovation and future development. The number of specialised training courses has increased dramatically in recent years – almost 70 are currently offered in France. The number of specialist engineers graduating each year has tripled in four years. More and more foreign students are taking these courses, and many come from countries that aim to increase or start their nuclear electricity generation. People working in this industry attend over 10 days of training per year on average. This figure can go up to eight weeks per year for nuclear operators. The nuclear industry is capable of renewing itself by stabilising and increasing its range of expertise. Alongside the major energy providers, the French nuclear industry includes bodies whose role is to check that regulations are being observed, deliver certifications, qualifications and accreditations to companies and other stakeholders, and offer training to acquire the skills required to work on nuclear facilities.

**On the road to nuclear 4.0.** Like the aerospace and the automotive industry, it is time for the nuclear industry to make the jump to digital. This involves assembling plants made up of different systems — such as I&C systems, turbine islands, coolants, reactors and electrical output — that are integrated to interact together. One of the pillars of digitalisation is the digital twin, which enables working as part of an extended enterprise, i.e. in collaboration with other nuclear power suppliers. Product Lifecycle Management (PLM) creates a virtual plant for every physical one, which collects and archives operations in real time, from design to the dismantling of the site. PLM is being implemented in the existing fleet and Nuclear New Build to enable standardised, real-time and cross-disciplinary work. This is essential to safeguard industrial programmes such as Grand carénage, decommissioning and EPRs, improve facilities' performance and make sure the whole sector functions as an extended enterprise. Nuclear New Build has therefore launched the SWITCH programme to shift from paper archives to digital databases, standardise and digitalise all of its processes and implement system engineering.

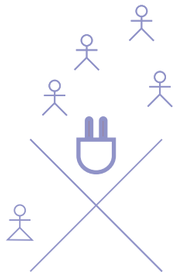
With an existing presence in India operating wind and solar power, EDF is in a strong position to build six 10-GW EPRs in Jaitapur. By developing these three forms of energy, India is making a clear commitment to low-carbon electricity generation.

# JAITAPUR

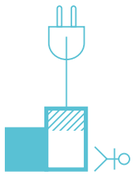
## Guiding India through the energy transition


**3.287 MILLION KM²**

**1.3 BILLION INHABITANTS**



**240 MILLION PEOPLE IN INDIA**
do not have access to electricity.



**X3**
Electricity access has tripled since 1990.

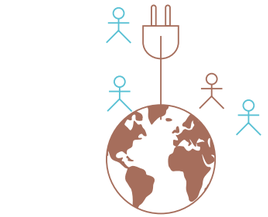
**India** is the world's third largest consumer of electricity and its usage has tripled since 1990, even though over 240 million of its inhabitants still do not have access to this form of energy. The electricity needs of this country of over 1.3 billion people are therefore significant. With cities facing serious problems related to air pollution, Indian authorities have decided to gradually replace their coal-fired plants with low-carbon electricity generation. Today, the country is shifting up a gear, aiming for a 40% low-carbon electricity mix by 2030, even though it requires huge amounts of energy as quickly as possible. With this goal in mind, the authorities are counting on renewable energies and nuclear — two forms of energy generation in which EDF has extensive expertise.

### Building the most powerful nuclear facility in the world.

By 2035, India is aiming for an installed nuclear capacity of 63,000 MW — the equivalent of the French fleet — compared with the current capacity of 5,780 MW. On 14 December 2018, EDF, as a leading nuclear energy provider, submitted a proposal to the Indian energy company NPCIL to install six EPRs at the Jaitapur site.
If the bid is accepted, the plant will provide electricity to 14 million households in India. With six EPRs and a total capacity of 10 GW, it would be the most powerful nuclear facility in the world. It would also be the fourth successful export of French EPRs, coming after the installation of one in Olkiluoto, two at Taishan and two at Hinkley Point C. EDF would also carry out engineering studies and the future operator would benefit from its expertise in public acceptance and local procurement policies.


**"This agreement is an initial victory that proves we are stronger together overseas, as a sector. India already operates 22 nuclear reactors and has a dynamic and robust industrial landscape. EDF can offer guidance to ensure that the country meets the highest industrial and safety standards for EPRs."**

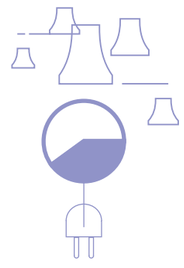
**Xavier Ursat,**
Senior Executive Vice-President in charge of New Nuclear Projects and Engineering



THE WORLD'S THIRD LARGEST PRODUCER OF ELECTRICITY.

**65%** fossil-fuel energy mix in

2018



**40%** low-carbon energy in the electricity mix in

2030

**"India is at the heart of EDF Renewables' international strategy due to the size of its market, its abundant natural resources and its elective policies to support renewable energy. In February 2019, we held a portfolio of 800 MW of gross wind and solar capacity in operation, under construction or in development in India."**

**Frédéric Belloy,**
Executive Vice President of International Operations at EDF Renewables

**Gradually replacing coal with renewable energy.** The significant drop in the price of photovoltaic electricity has made solar energy more competitive than coal. There is huge potential to develop solar and wind energy in India, which is aiming for installed capacity of 100 GWp and 60 GW, respectively, by 2022. EDF already provides renewable energy in India, operating 207 MWp in gross solar capacity (primarily in the states of Uttarakhand and Madhya Pradesh) and 164 MW in total gross installed wind capacity at the end of 2018.

At the start of 2019, the Group was awarded a significant portfolio of 300 MW of wind projects in a government call for tender. Consequently, it will meet the annual electricity needs of 1.3 million people in India.

## Interview

“For all such races against the clock, the central issue is always the same: can we work together to make it in time?”

**Jeffrey Sachs**
Economist and Director of the UN Sustainable Development Solutions Network under the auspices of the Secretary-General of the United Nations.

Economist and special adviser to the Secretary-General of the United Nations, Jeffrey Sachs has also worked as a consultant for many governments in South America and Europe. His work with political leaders provides him with an overview of climate change. “We can solve all the problems facing us,” he explains, to encourage governments and companies to take action as fast as possible.

— For the past few years, worldwide, we have all heard constant talk of agreements, measures, commitments and targets around climate change. And yet the degree of emergency remains, and is even intensifying. How do you explain this paradox?
**Jeffrey Sachs.** Several significant initiatives have actually been introduced to reduce the use of fossil fuel energy and move towards a world free of carbon emissions. It would therefore be wrong to say that nothing has been done, or that the international community has remained passive. The cost of carbon-free energy continues to fall and technology is improving, but our progress is too slow. Our current rate is simply not fast enough and we are going to exceed the limits set in the Paris Agreement. This means that the world will become increasingly unstable.

— Were the targets too ambitious?
**J. S.** No. And it’s impossible to think like that. We absolutely have to achieve the thresholds set. We must and we can. The “zero emission” target for 2050 is not a utopia or an abstract ideal. Technologically, economically and financially, we have the means to achieve it. But as I said, for all such races against the clock, the central issue is always the same: can we work together to make it in time? Today, we’re not going fast enough.

— While everybody agrees about the urgency, opinions diverge at times regarding the necessary means and scenarios.
**J. S.** We are aware of the main principles of action to guide us towards a carbon-free world and a life without $CO_2$ emissions. For example, we know that the energy mix in the future must combine renewables, such as wind, hydro, solar and nuclear, with considerable efforts to improve the energy efficiency of buildings. For transport, we have to get beyond a system focused on the internal combustion engine and switch to clean energy, namely, electricity and hydrogen. We need precise road maps. There will of course be obstacles and difficulties to overcome,

but the path ahead is clear. Governments worldwide must take this path and define medium- and long-term energy plans without letting themselves be influenced by the lobbies. And they also have to bring along an entire ecosystem in their wake.

— What could really change the situation?
**J. S.** Engineers. There are many experts, in both the financial and economic sectors, who are useful and of course necessary. But, above all else, we need engineers who are aware of the issues, and able to invent and implement effective solutions. Only engineers can tell us how to duplicate certain solutions and where to introduce them depending on local contexts. Economists like myself have a role to play in costing, defining budgets and promoting two key arguments: one, explain that climate transition is not necessarily expensive; and two, convince everyone that today’s investments – even if they may at times appear costly – are not high compared to the amounts that will be needed to repair the ravages of climate change. This is how we will be able to roll out the industrial solutions developed. So engineers are on the front line, together with another central figure...

— Who?
**J. S.** Citizens! You and me! Awareness of the climate emergency needs to be foremost in everyone’s mind. The solutions exist and each person’s energy can really get things moving. It’s up to us to express our collective will and our desire to see solutions take shape. The driving force comes from our engagement and individual conviction, which will eventually form a collective conviction.

— Are you confident given the urgency?
**J. S.** Be it climate change, global poverty or the risk of epidemics, we have the technological and economic solutions. I have spoken with many experts, I have seen initiatives first-hand and analysed their concrete results. The solutions exist and they work. Optimism and belief are within our power. We have the possibility and the desire to make the right choice. No one wants to slide into climate chaos. For that reason, yes, I am confident.

**“It’s up to us to express our collective will and our desire to see solutions take shape.”**

**Jeffrey Sachs**

Hydropower

# AN ELDORADO FOR ENERGY?

The leading producer of hydropower in France and the European Union, EDF is also an international benchmark, with hydropower plants in operation, planning and under construction on every continent, from mega-dams to micro-plants.

Hydropower, the world's most widely used renewable electric energy, has a number of advantages. It is flexible, responsive, competitive, renewable and does not produce $CO_2$ emissions. Moreover, reservoirs make hydropower the only energy that can currently store electricity on a large scale. Within minutes, hydropower plants can reach their maximum power and inject large amounts of electricity into the grid when needed to safeguard and maintain continual supply. This makes hydropower the perfect partner to intermittent renewable energy sources such as solar and wind power. EDF leads a high-performance industry, operating 433 hydropower plants and managing 75% of the surface water storage reserves in continental France. The Group therefore manages water collectively to meet the needs of cities, manufacturers, farmers and the tourism industry. Making sure that hydroelectric facilities are safe is a priority for hydropower operators.

**The future of hydropower in France is still being written.** Although 95% of potential hydropower is already exploited in France, it is still an energy of the future and set to play a key role in the energy transition. EDF must improve the efficiency of its fleet to gain in capacity and availability, like the **Romanche Gavet** power station in the Isère region. In the Romanche valley near Grenoble, the Romanche Gavet project is the largest of its kind in Europe. It intends to replace six power plants with a single more efficient underground hydroelectric facility that will have a capacity of 92 MW and be better integrated within its environment. The new plant will eventually generate 560 GWh per year, 30% more than the six existing plants. An enormous tunnel boring machine was used to dig a 10-kilometre tunnel under the Belledonne mountains to channel the water. When it is complete, the new Romanche Gavet power station will produce enough electricity to power the equivalent of

- **30%** increase in hydropower generation.
- **560** million kWh per year.
- **230,000** households supplied with electricity.
- **12**-m high dam.
- **10**-km long tunnel.

- **20%** increase in site capacity with the new generator unit.
- **270,000** people supplied with electricity.
- **240**-MW capacity Pelton wheel.

230,000 households. Further north in Savoie, another hydropower station, **La Coche**, has also been renovated. The pumped storage plant (PSP), located in the Tarentaise Valley, has been completely upgraded. EDF is building a new generator unit to boost capacity by 20%. A 240-MW Pelton wheel, the biggest in France, was delivered at the end of 2018. The new facility will produce a total of 650 GWh per year for 270,000 people, i.e. 40,000 more than currently. As all large sites in France are already in operation, the future of hydropower also lies in small hydro, an area in which EDF intends to exploit the potential and leverage its experience as well as its desire to integrate facilities seamlessly into their surroundings by involving local stakeholders. The capacity of such plants does not exceed 12 MW and they can be used to further develop installed capacity in France. They are placed along rivers or streams and often used in isolated areas.

**The saga of large scale hydropower continues on other continents.** The Hydro Engineering Centre supports the Group's large-scale international projects. The **Sinop Dam** project in Brazil has now entered its final stages. Work began in 2014 and was completed at the end of 2018. The dam began filling in January 2019 so that technical tests could take place before commissioning. It is the largest dam built and operated by EDF and will supply water to a series of hydropower facilities with a total installed capacity of 408 MW. Sinop includes a plant running two Kaplan generators, each with a capacity of 200 MW — the largest in the world using this technology — as well as a 500-kV transmission line.

Focus is now turning to Africa. At the end of 2018, EDF, Cameroon and the World Bank Group signed agreements to build the **Nachtigal** hydroelectric dam. With a capacity of 420 MW, the power station is a national priority to safeguard Cameroon's electricity system by covering 30% of its energy needs, generating almost 3 TWh per year. In addition to the construction of the dam, there will also be a socio-economic development programme for the region, harnessing EDF's experience with the Nam Theun 2 dam project in Laos.

- Installed capacity of 420 MW.
- Covering 30% of energy needs in Cameroon.
- Annual generation of nearly 3 TWh.

- A plant fitted with two Kaplan generators, each with a capacity of 200 MW.
- A 500-kV transmission line.
- Installed capacity of 408 MW.

**HYDROPOWER IN 2018**

- **25.4%** increase in 2018. EDF recorded a 15-year high in hydropower generation in France (46.5 TWh).
- **433** hydropower plants.

# THE SEA

## A source of renewable energy?

Although there are many forms of renewable marine energy, they are not at the same level of technological maturity and do not have the same potential for industrialisation. Of them, offshore wind energy is unquestionably the most suitable for generating low-carbon electricity on a large scale. Other solutions, apart from perhaps tidal energy at a few sites, are still at the experimental stage.

360 million km² of seas and oceans

71% of the Earth's surface is covered in oceans

**1. Offshore wind energy**

Offshore wind energy involves installing up to 10-MW turbines out at sea off the coast, where wind is strong and regular. A generation of floating wind turbines – which are not subject to depth restrictions and can therefore be installed further from the shore – are able to harness even stronger winds.

An example of this is the Provence Grand Large experimental project, which has three floating wind turbines with a capacity of 8.4 MW. The project will also measure its potential impact on birdlife, because their migrations over the Mediterranean are little understood. Commissioning is planned for 2021.

**2. Tidal energy**

Tidal energy uses the difference in height between tides to generate electricity. The Rance tidal power station in Brittany is the world's first plant of this type.

**3. Marine current power**

Marine current power exploits the kinetic energy of tidal currents.

**4. Wave energy**

Wave energy harnesses the energy of waves and ocean swells.

**5. Ocean thermal energy conversion**

Ocean thermal energy conversion uses the temperature difference between the sea's shallow and deeper waters. A temperature difference of at least 20 °C is required to vaporise a working fluid and spin a turbine coupled to a generator.

**6. Osmotic energy**

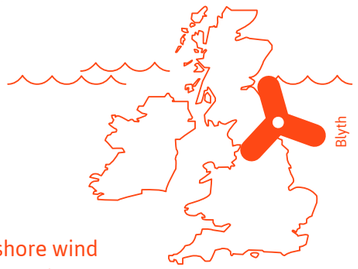
Osmotic energy uses the difference in salinity between freshwater and seawater at estuaries, for example, where these two types of water meet.

**Brittany, the land of marine energy experimentation**

With 2,700 km of shoreline, Brittany is the ideal location to test the suitability of marine energies. Moreover, the peninsula region can currently only cover around 15% of the electricity needed for its own consumption due to a lack of generating plants. Brittany is a large scale laboratory where tidal plants, floating and fixed wind turbines, marine current generators and wave farms are all being tested. It all began at the Rance tidal power station, operated by EDF. Inaugurated in 1966, this pioneering plant, with a total installed capacity of 240 MW, supplies enough electricity for 225,000 people every year — equivalent to the population of the city of Rennes.
In Audierne Bay, a demonstrator project for a marine current farm is under consideration. Three panels that oscillate with the ocean swell will be tested to develop a capacity of 1.5 MW. None of the experiments have so far resulted in industrial operation.

- **6 GW** of offshore wind power in development or operation around the world.
- **Over 2 GW** of offshore wind farm projects in France.
- **10 GW** of offshore wind farm capacity by 2028 as part of the PPE.

*Source: FEE, the French wind power association*




The growing success of offshore wind turbines shows their current competitiveness, with low costs in France in particular. Out at sea, wind is stronger and more regular than on the land. Manufacturers claim that offshore wind turbines are more powerful than their onshore equivalents — they can reach a capacity of 12 MW, compared with 2-3 MW on land. How can we nurture the success of offshore wind?

# BLYTH

## A pioneering offshore wind farm

**In Blyth**, off the coast of Newcastle in the UK, the Group has inaugurated the first offshore wind farm with gravity based foundations floated into position — the first time that this method of transport has been used for this type of foundation. The impressive structures — the upper part of which is made of steel, with gravity bases made of concrete — are 60 metres tall and weigh 170 tonnes. They were floated into position seven kilometres off the coast by tugboat.
This technology means that structures can be built in ports, then installed more efficiently and cheaply, involving less transport. The Blyth Offshore Demonstrator (BOD) has five 8.3-MW turbines and a total capacity of 41.5 MW. In the UK, EDF Energy already operates the Teesside offshore wind farm, which has a capacity of 62 MW and is located around 80 km away from the new turbines at Blyth. The Group also acquired the offshore wind farm project "Neart na Gaoithe" in Scotland in 2018. The wind farm will have a capacity of 450 MW and supply over 375,000 households.

**The Group** has also established a foothold in the offshore wind market in the US, where it is already well positioned in renewable energy.
With Shell, EDF has invested in developing a number of projects off the coast of New Jersey, across a surface area of 74,000 hectares. This huge area, near major urban centres, has a potential capacity of 2,500 MW — the equivalent of a year's worth of energy for almost one million homes. In China, where EDF is already active in onshore wind, nuclear power and energy services, the Group is in the process of negotiating two 500-MW offshore projects off the coast of Dongtai, north of Shanghai.

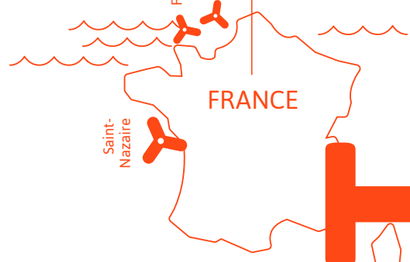
## FRANCE'S EXCEPTIONAL POTENTIAL

**2nd**
The world's second largest exclusive economic zone.

**11 million** km².

**20,000 km** of shoreline.

**3** coastlines.




# SAINT

# SAINT-NAZAIRE

## Acceptability and consultation

**France** has the second largest exclusive economic zone in the world. The country has strong ambitions for developing in offshore wind; hence the Fécamp, Courseulles-sur-Mer and Saint-Nazaire projects. With an aggregate capacity of almost 1.5 GW, these three projects will provide enough electricity for over two million people.
In 2012, the French government awarded the projects to a consortium led by EDF Renewables that includes Éolien Maritime France, an equally held joint venture between EDF Renewables and Enbridge. The appeals brought against these projects should not distract from the strong consensus on developing renewable energy that currently exists. These three projects are key for the success of the French offshore wind industrial sector and were supported by extensive consultation and work carried out on the ground for over 10 years with local stakeholders, the French government, industrial players, non-profit organisations and local residents.
In Saint-Nazaire, there has been a continuous dialogue with professionals from the fishing and tourism industries, nature and bird protection bodies and many others since 2008. This is the way in which we carried out an environmental consultation process.

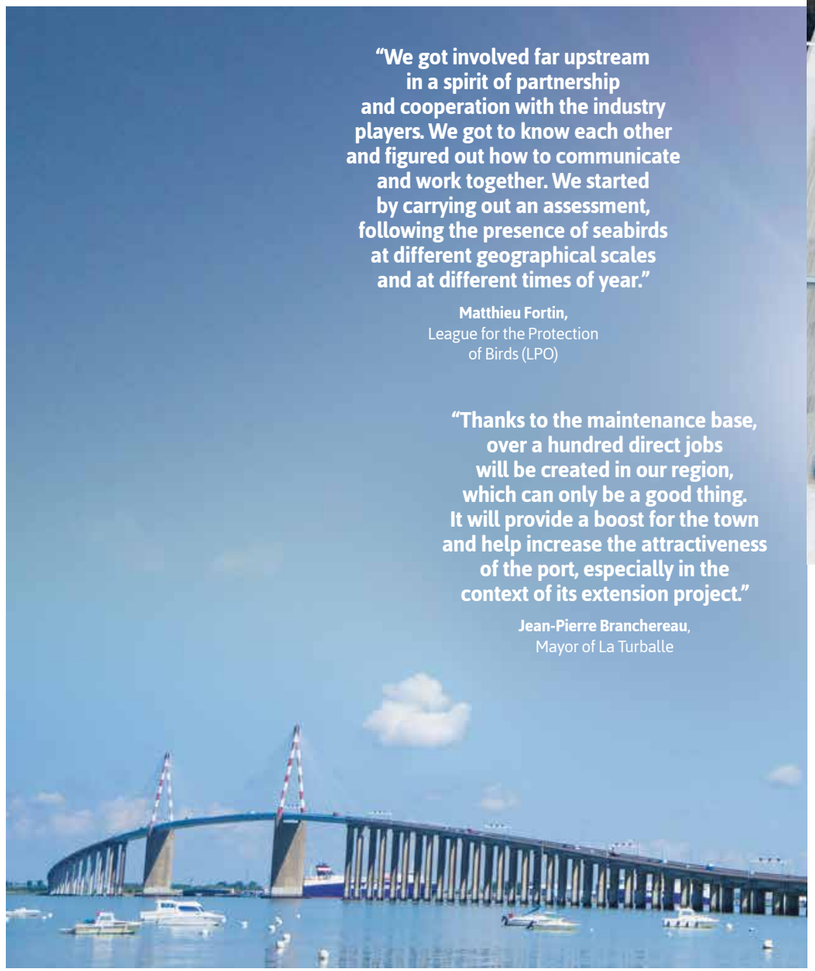
**80**
offshore wind turbines.

**480 MW**
total capacity.

**78 km²**
surface area.

**12-20 km**
of shoreline.

**2,000**
participants and **10 public debates**.



**"We got involved far upstream in a spirit of partnership and cooperation with the industry players. We got to know each other and figured out how to communicate and work together. We started by carrying out an assessment, following the presence of seabirds at different geographical scales and at different times of year."**

**Matthieu Fortin,**
League for the Protection of Birds (LPO)

**"Thanks to the maintenance base, over a hundred direct jobs will be created in our region, which can only be a good thing. It will provide a boost for the town and help increase the attractiveness of the port, especially in the context of its extension project."**

**Jean-Pierre Branchereau,**
Mayor of La Turballe

**Some of the work** has focused on the impact of wind turbines on seabirds and bats — the only flying mammals in the world. It was carried out across a 100-km zone on and around the site. Over 60 different bird species like cormorants, great black-backed gulls, little gulls, terns, divers, northern gannets and common scoters have all been observed there over the year.
All involved have also focused on protecting marine mammals' habitats, fishing resources and species living on the seabed that could be affected by the offshore wind project. The turbines will each be spaced so as to not disturb animal locomotion or fishing activity.

### TIMETABLE FOR THE SAINT-NAZAIRE WIND FARM

**2007**
Start of the consultation.

**2008**
Start of the technical and environmental studies.

**2012**
Award of the project following government call for tender.

**From 2013**
Public debate and continued environmental studies.

**2015-2016**
Authorisation given for the wind farm and its connection to the grid.

**2016**
Selection process for subcontractors for foundations, cables and installing the wind turbines.

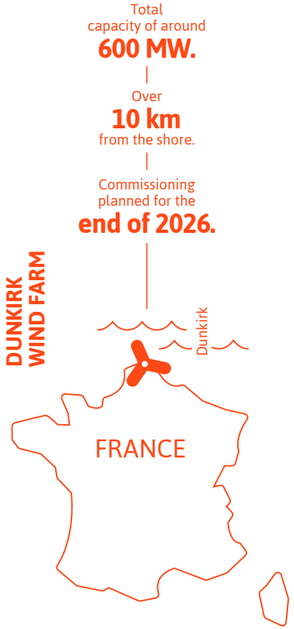
**2019**
Project free from appeals.

**2022**
Commissioning planned.

# NAZAIRE

# DUNKIRK

## Offshore wind demonstrates its competitiveness




**“With the Dunkirk project, EDF group has become a leading provider of offshore wind power in Europe. It shows EDF’s deep rooted regional presence and confirms the consolidation of the industrial offshore wind sector in France. Given the competitive nature of this project, the government has announced its intention to double the objectives for offshore wind in the Multi-year Energy Programme, presenting new development opportunities for EDF and all other offshore wind providers.”**

**Bruno Bensasson,**
Group Executive Vice President
in charge of renewable energies
and Chairman and Chief Executive Officer
of EDF Renewables

**In June 2018, following a call for tender** initiated by the public authorities, the Ministry for the Ecological and Inclusive Transition chose a consortium led by EDF group, through its subsidiary EDF Renewables, in partnership with Innogy and Enbridge, to design, build, operate and maintain the future wind farm off the coast of Dunkirk.

Located 10 km off the coast, the Dunkirk offshore wind farm will have an installed capacity of almost 600 MW and provide enough electricity to meet around 40% of the Nord department’s needs. The project is key to the development of the economy, industry, maritime and tourism industry in the city and will create jobs throughout the region.

This is another project where consultation was held with local stakeholders right from the tendering stage. It will now be undertaken even more actively, and the partners are planning to refer to the French Commission for Public Consultations.

Through this project, renewable energies are now showing their competitiveness, with prices close to the market price for electricity. The cost of offshore wind fell between 2012 and 2019 in particular due to technological progress, the structuring of the sector and improved regulation.

# ONSHORE WIND POWER GAINING TRACTION

# A POTENTIAL TO DEVE

Adopted in 2015, the Law on Energy Transition for Green Growth set ambitious goals for the development of renewable energy in France. Wind energy is expected to grow from 15 GW in 2018 to 34.1 GW in 2028.(1) The objective includes generation from onshore and offshore wind power.


**9,874.5 MW**
gross of onshore wind power in operation at end-2018.

Over **80** wind farms at end-2018.

## IN FRANCE

**Onshore wind farms commissioned in 2018**

- **Espiers** (18 MW)
- **Guilleville** (17.7 MW)
- **Clanlieu** (13.2 MW)
- **Demange-aux-Eaux** (19.8 MW)
- **Courant-Nachamps** (21 MW)

**Almost 100 MW of additional capacity went into service and 130 MW were under construction in France in 2018.**

A key player in onshore wind power worldwide, EDF Renewables is continuing to develop in France, operating over 1.5 GW of gross capacity at the end of 2018. The country enjoys the second highest levels of wind energy potential in Europe, with three complementary wind regimes that allow it to balance supply to the electricity grid. The Grand-Est, Hauts-de-France and Occitanie regions currently generate more than 60% of France's electricity from wind. EDF group brought six onshore wind farms into service in France in 2018, and a number of other farms are under construction.

Every project drives growth in the local area and yields tax revenue. Towns with a wind farm now receive 20% of the French flat-rate tax on network companies (IFER), which is one of the taxes imposed on wind farms regardless of the regional tax regime applicable. For example, a wind farm with four turbines (12 MW) generates over €130,000 of annual tax revenue for local communities. Although projects create value locally, they must be set up at appropriate sites and in close collaboration with all stakeholders and, in particular, the local authorities, agricultural sector, environmental protection associations and local residents. This is essential for current and future projects to be accepted.

*(1) PPE summary, Ministry for the Ecological and Inclusive Transition*






**The issue of recycling.** Recycling wind turbines is a key issue, along with renewing first-generation turbines. Today, over 97% of wind turbine components are reused or recycled, and their composite materials — in the blades, for example — are reused, through both energy and material recovery, as solid recovered fuel (SRF). The law stipulates that operators must dismantle their turbines and rehabilitate the land where they were installed. When turbines are being dismantled, the various components are dealt with by recycling teams, in particular to recycle different types of steel, composite materials and concrete foundations. Wind-generated electricity providers must offer financial guarantees of €50,000 per turbine to dismantle wind farms and rehabilitate the site from the project's development stage. In 2018, EDF renovated the entire Eckolstädt wind farm in Germany. Built in 1999, the farm and its 11 first-generation wind turbines were dismantled by the Group subsidiary REETEC.

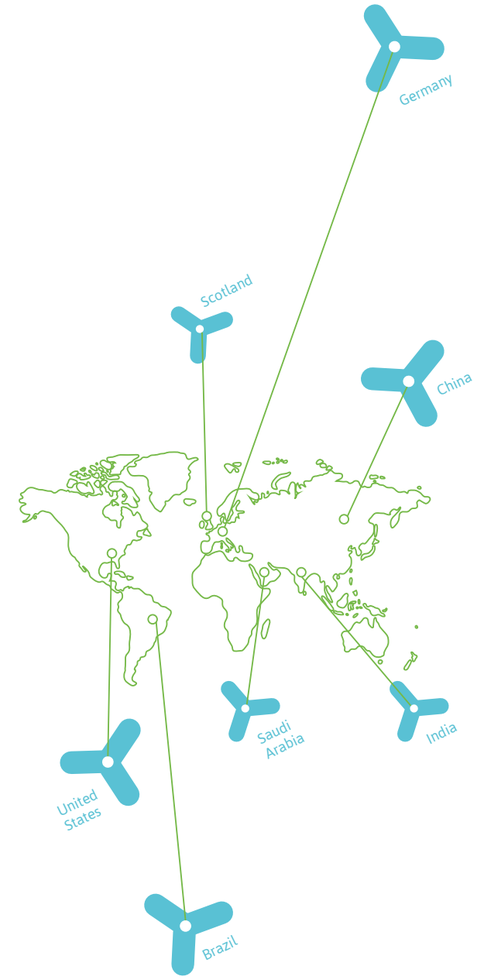
## INTERNATIONAL PROJECTS

### BRAZIL
• Signature of contracts to expand two wind farm projects in the state of Bahia (276 MW), Folha Larga and Ventos de Bahia. Commissioning due in 2024.
• Commissioning of phase two of the Ventos de Bahia wind farm (117 MW).
• Beginning of construction of Folha Larga project (344 MW).

### EUROPE
**Scotland.** Commissioning of the Dorenell wind farm (177 MW) in the north of Scotland.
**Germany.** Renovation of the Eckolstädt wind farm (34.5 MW).

### UNITED STATES
• Commissioning of the Stoneray wind farm in southwest Minnesota. It will generate the equivalent of a year's electricity consumption by 47,000 Minnesota households.
• Commissioning of the Copenhagen wind farm (80 MW) in upstate New York.
• Acquisition of the Milligan 1 wind project (300 MW) in southern Nebraska.

### MIDDLE EAST/ASIA
**Saudi Arabia.** Award of Dumat Al Jandal wind project (400 MW).
**China.** Commissioning of the Feicheng I wind farm in its entirety and construction of the Kangping II and III project.
**India.** Award of a 300-MW portfolio that will cover the annual electricity needs of over 1.3 million people in India.



# AN OVERVIEW OF RENEWABLE SOLUTIONS

Along with wind and solar power, other renewable energies — such as biomass, geothermal and ocean thermal energy conversion — are emerging to offer local authorities and companies a whole range of possible solutions.

## 1

**Capturing water from a mine shaft to provide heating and air conditioning to an eco-district**
In collaboration with Semag, Dalkia has designed, built and now operates a renewable energy network in Gardanne in the Bouches-du-Rhône department of France. This smart network was created to provide heating and air conditioning to existing and future buildings in the Puits Morandat business park, using a natural local resource — the groundwater in the largest mineshaft in Europe, located at a depth of 1,100 metres. A geothermal system will provide heating to the 14-hectare eco-district.

## 2

**Recycling waste biomass for heating**
The heat generation plant in Surville (Lyon) is the largest public biomass heating plant in France. Three 17-MW boilers use local biomass made from wood chip, sawmill offcuts and small pieces of wood that are not suitable for recycling, all of which come from the forestry industry. Operated by Dalkia, this heating system will avoid 44,000 tonnes of $CO_2$ emissions per year. The ash will be recycled in forests to fertilise the earth.

## 3

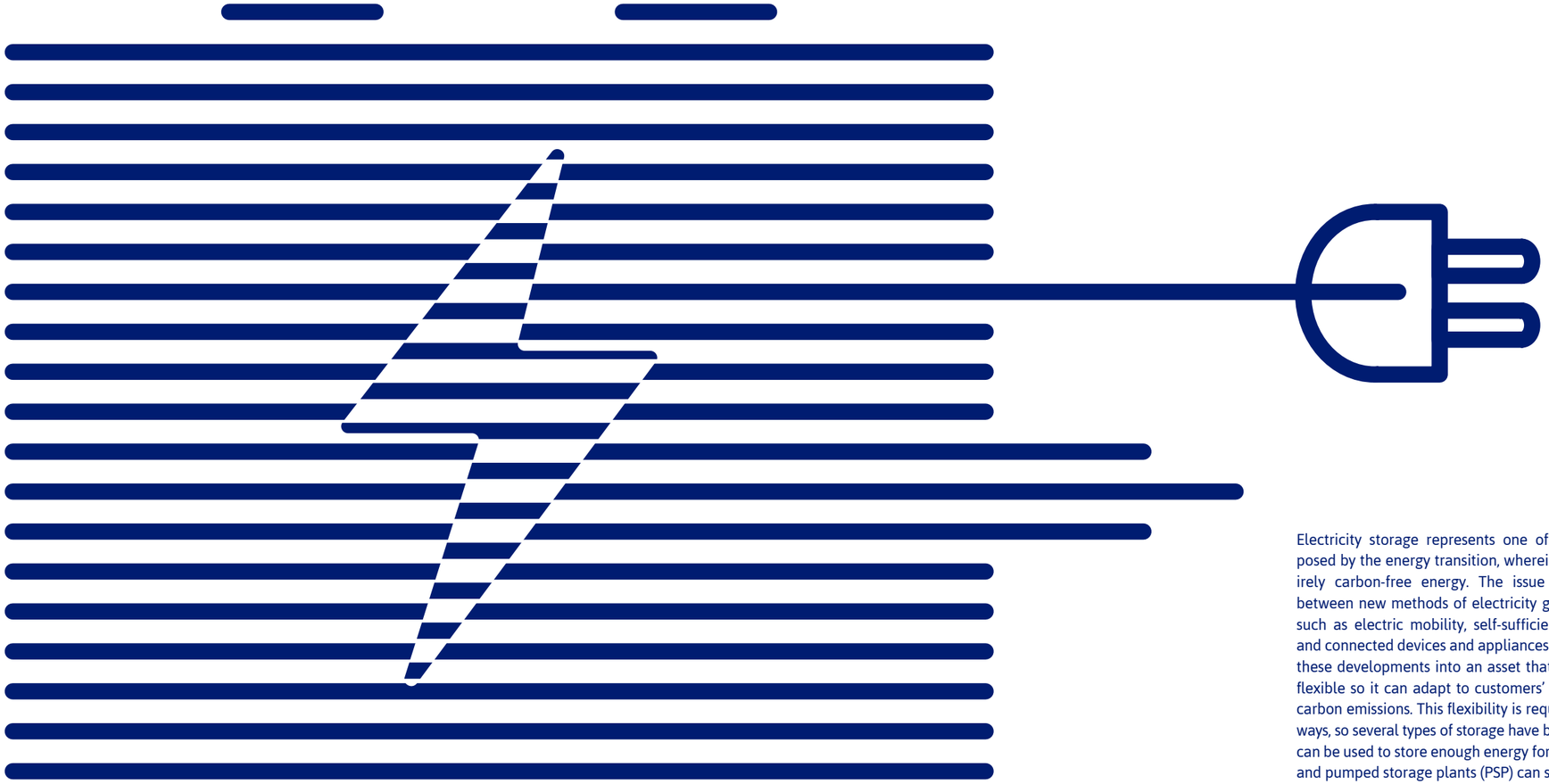
**Transferring heat from the Mediterranean to an urban heating network**
Dalkia operates the urban network for the town of La Seyne-sur-Mer and the conurbation of Toulon Provence Méditerranée. The network is 75% fuelled by a local renewable energy from the Mediterranean Sea and consists of a warm water loop that links a seawater heat exchanger to heat pumps installed in the connected buildings.

## 4

**Designing a digital boiler to heat a hospital**
Dalkia and startup Tresorio have inaugurated their first experimental digital boiler at a hospital in Metz. Dalkia designed and developed the thermal module, which recovers the heat produced by Tresorio's computer servers. The boiler is a key innovation for the digital and energy revolution. Smart and competitive, it constantly generates clean energy.

## 5

**Using clean hydrogen to get about**
EDF has launched Hynamics, a new subsidiary that offers high-performance, low-carbon hydrogen for industry and mobility. This is an energy of the future that will account for 18% of global energy demand in 2050. Hynamics has chosen to produce hydrogen through water electrolysis, a technique with very low $CO_2$ emissions. Hydrogen is particularly suitable for industrial facilities and vehicle fleets.



# Realising the considerable potential OF STORAGE to boost the energy transition

Electricity storage enables us to develop an electricity market that is increasingly free from fossil fuels. In the future, new storage methods — linked to electric mobility, for example — will give it an even wider scope.

Electricity storage represents one of the pivotal challenges posed by the energy transition, wherein we must generate entirely carbon-free energy. The issue lies at the crossroads between new methods of electricity generation and new uses such as electric mobility, self-sufficient photovoltaic systems and connected devices and appliances. Electricity storage turns these developments into an asset that makes electricity more flexible so it can adapt to customers' needs without releasing carbon emissions. This flexibility is required in various different ways, so several types of storage have been developed. Batteries can be used to store enough energy for one day, but large dams and pumped storage plants (PSP) can store energy on a greater scale — for a week or even a month (the large reservoirs at Serre-Ponçon, for example, are used for seasonal storage). For even greater flexibility, they can be combined with other measures, such as nuclear reactors, which can be used to mitigate the troughs in intermittent energy generation from wind and solar power. Renewables, nuclear and storage are genuinely complementary in the effort to meet the demand for inexpensive, low-carbon electricity.

## Increasingly competitive storage

With wind and solar energy on the rise, developing storage is an increasingly interesting prospect. Above all, it is becoming accessible both technologically and financially. The cost of lithium-ion batteries, for example, has been divided by six in less than 10-years. EDF already holds a strong position in electricity storage, with 5 GW of PSPs in France, 12 GW of dispatchable hydropower and 100 MW of batteries in service worldwide, in French island communities but also the UK and US. The Group also operates in all mature electricity storage technologies; in addition to PSPs and batteries, EDF also leads the way internationally in R&D and is a pioneer in the most promising technologies, like zinc-air batteries. In 2018, EDF's R&D launched a programme to research recycling batteries in Europe, a major challenge for the future. Things are also changing on a European scale. At the start of 2019, France and Germany announced the introduction of a mega consortium known as "the Airbus of batteries". With €4-6 billion at its disposal, and partly financed by European subsidies, the consortium aims to forge a place for itself in the automotive battery market, which up to now has been largely dominated by Asia.

## International ambition

In 2018, EDF group announced that it would develop 10 GW of new storage capacity over the 2018-2035 period, representing a total investment of €8 billion. This unprecedented plan meets four different requirements. Large capacity storage is used to optimise performance and balance electricity systems. EDF's largest operational battery storage project of this type has been operating at West Burton in the UK since 2018. With a capacity of 49 MW, it is able to stabilise demand for electricity and adjust frequency across the network, at a time when renewable energy generation is undergoing significant expansion and ageing generating plants are being closed down in the UK. To supply electricity to isolated regions and islands, EDF is developing innovative micro networks that combine renewable energy generation and electricity storage and can be controlled remotely. That is why, at the end of 2018, EDF group commissioned the MASERA demonstrator project with Nanyang Technological University, designed for people living on islands in Southeast Asia.

Electricity storage also satisfies the needs of individuals, companies and local authorities. An example of this is the self-sufficiency contracts like *Mon Soleil et Moi,* combining photovoltaic panels and batteries, that EDF offers in France. In developing countries without an electricity grid (over a billion people in the world do not have access to electricity, 50% of whom live in Sub-Saharan Africa), storage makes it easier to access electricity through off-grid solutions. In Africa, EDF group and its partners install and maintain solar kits (solar panels equipped with batteries) for rural and suburban households.

**10 GW**
of new storage capacity by 2035.

Almost
**100 MW**
of additional capacity went into service in France in 2018.

> “We must pass on a genuine energy culture, reduce our use of carbon as much as possible and move towards other kinds of lower-carbon energy.”

**Jean-Louis Étienne**

Machinist, doctor, explorer and the first man to reach the North Pole alone.

## Interview

Jean-Louis Étienne has had several careers, all of which have been driven by his commitment to protect the planet. Today, as he launches his new project, he continues to combine thought and action with effusive energy. In fact, during this interview, he was the one who asked the first question.

**Jean-Louis Étienne.** Do you know why people are unaware of the importance of climate change?
— No.
**J.-L. É.** Because we have made it a topic of conversation like any other. What do two people say to each other when they bump into each other on the street? "Hi, how are you? The weather is nice today," or, "What terrible weather we're having this morning." Those are the two pillars of our society: health and the weather. Now, we add: "The climate is heating up, isn't it awful?" It's an invisible enemy — the naked eye cannot see $CO_2$ in the air. Climate change has therefore become an almost everyday topic of conversation. But we are now entering into the really problematic stage. The planet has warmed by 1 °C over the last century. It's like a patient with a chronic fever; we have to treat it, cure it.

— How can we underline this urgency and make people more aware?
**J.-L. É.** I think it's essential that we create and pass on a genuine energy culture. We take the different energy sources as a given, which magically spring into action when you click a button. And yet, they come from somewhere, requiring expertise and technical knowledge. Energy is a precious resource and we need to bear that in mind to properly identify the issues we currently need to address. It is even more important because, since we discovered the hole in the ozone layer, we have known our behaviour affect the atmosphere and therefore that we can change the climate. Ice core samples from the South Pole show that the planet has a life of its own, it gets hotter then cools down again. However, for the last 150 years, with the beginning of the industrial era and intensive use of coal, temperatures have been gradually increasing. It is a huge responsibility for humankind, one we have to accept in order to start taking action. A better understanding and genuine energy culture would help. My latest project, Polar Pod, is built around this idea of education. It's about collecting as much information as possible on the Southern Ocean surrounding Antarctica – the Earth's largest ocean carbon sink. We want to understand how it works and learn about its distinctive features.

— What do you think we need to do as a priority?
**J.-L. É.** First of all, we need to reduce our use of coal as much as possible. This is absolutely essential. At the same time, we must start using other energy sources that emit less $CO_2$, like renewables.

— But isn't that a vision that can only apply to "rich" countries? Don't emerging countries need coal in order to continue to develop?
**J.-L. É.** This argument seems increasingly false to me. China, for example, is aware of what's at stake, and is changing quickly when it comes to environmental issues. Instead of setting two models against each other, we could take a cooperative approach and share our expertise, such as our nuclear experience, with developing countries.

— Renewable energy is a source of hope, but also debate. How do you see them developing in the future?
**J.-L. É.** It is an essential part of the energy of the future but certain words and slogans have, to my mind, influenced public opinion. For example, saying things like, "In 2050, we will only use renewable energy" is false and counterproductive. The wind and the sun are not constant or regular and their energy density is too low. To keep the Paris metro system running, for instance, you would need 400 2-MW turbines and constant 20-km/h winds. It's just not realistic. But it also wouldn't be realistic to go to the other extreme and say that there's no point in renewables. On the contrary, this type of energy is a very effective solution on a smaller scale — for personal consumption or that of a town or small community. By leveraging photovoltaic or thermal energy — which is currently underused — and wind power, we could get real results. But again, I want to underline the importance of creating an energy culture. Everyone talks about the benefits of renewable energy, but no one wants a wind turbine in their back yard. Again, I think it is really important that we present general energy issues properly, to get people to buy in to them. That is essential, especially for renewable energy. Everyone needs to get involved and take an interest. Individuals need to make their own decisions about insulating their homes or installing photovoltaic panels. We have to remind people of the importance and impact of these measures so that they take action. I actually think this is one of the most important messages at the moment.

— Why?
**J.-L. É.** Because everyone needs to be effective in their personal and professional spheres of influence in order for these solutions to have the desired effect. We must all take action, pass on the message and win over our friends and family.

**"It is really important that we present general energy issues properly, to get people to buy in to them. Renewable energy needs everyone to get involved and take an interest."**

**Jean-Louis Étienne**

# THE SUN
# AN UNDER EXPLOITED POTENTIAL

Solar energy is developing rapidly and its potential remains underexploited around the world. For many years, large solar parks were confined to isolated areas, but they are now becoming more widespread.

**An international ambition.** Like wind, the sun is a source of renewable energy. It can be connected to the electricity grid or used on site. Like all renewable energies, solar is developing rapidly as a result of the considerable reduction in the cost of photovoltaic panels. Additional potential savings can be made by improving industrial processes and designing innovations. Solar is currently EDF's second priority focus for growth in renewable energy. For the first time ever, commissioning in solar exceeded that of wind power in 2018. With a capacity of 880.5 MW, solar represented 54% of all commissioning. Internationally, the Group has developed a number of large-scale projects including the commissioning of Pirapora II in Brazil and Santiago Solar near the Chilean capital, and the construction of the Valentine Solar and Maverick 2 & 3 solar power plants in the US, as well as five solar projects with a capacity of 310 MWp in Florida. In Israel, EDF Renewables reached a major milestone when five photovoltaic solar farms started operating in the Negev desert with a total installed capacity of 101 MWp. These new plants mean the Group now operates more than 25% of the country's installed capacity in renewable energy. As an integrated operator, EDF operates and maintains most of its own solar installations, as well as those of third parties.

**20,000 HECTARES** of real estate must be secured to ensure the Solar Plan's success.

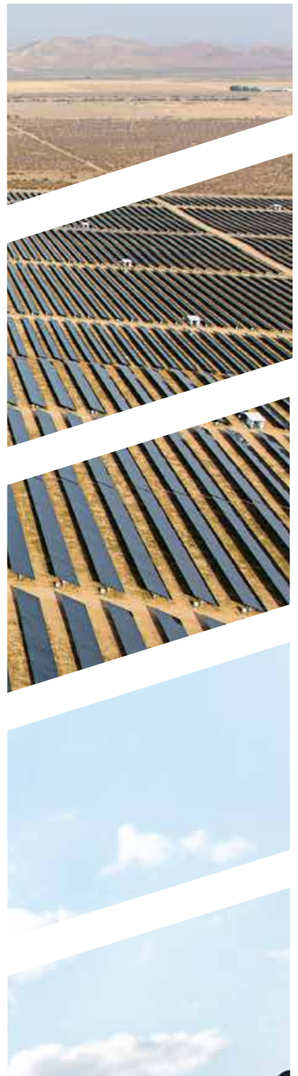
EDF is aiming for **30%** of the French photovoltaic industry market share by 2035.

**8 GW** of French solar capacity in 2018.

Over **19,000** photovoltaic installations for self sufficiency were connected in 2018.

**230.4 MW** of gross installed solar capacity in France at the end of 2018.

The PPE set a goal of **35.6-44.5 GW** of installed solar capacity in 2028.



## A mega farm in the land of black gold

The authorities in Saudi Arabia are investing in the post-oil future. EDF has completed the first of three phases of the project to build a mega solar farm, developed by the Masdar consortium. In 2020, the Mohammed bin Rashid Al Maktoum solar farm — the world's largest — will have a capacity of 800 MW (1 GWp). The mega farm will consist of more than three million solar panels across 16 km². It will resemble Catalina Solar, an enormous solar farm in Rosamond, California (see left).



**The Solar Plan.** Although France is behind its European neighbours when it comes to solar energy, things are starting to change. Thanks to the significant decline in photovoltaic panel prices, EDF's Solar Plan and the draft PPE, photovoltaic energy is expected to rise four- or five-fold between now and 2028. Between 2020 and 2024, the draft PPE anticipates launching around 10-calls for tender for 2 GWp for ground-based solar and 900 MWp for rooftop solar per year. For EDF, this elective initiative is an opportunity to give solar power the position it deserves in a country with the fifth greatest solar potential in Europe. Launched in 2018, EDF's Solar Plan aims to earn the Group 30% of France's market share between 2020 and 2035, which will then equate to 30 GW. To rise to the challenge, EDF is drawing on its recognised expertise in development, construction, operation and maintenance of large solar power plants, as well as its commitment to dialogue and consultation, as the Solar Plan will be carried out with regional stakeholders. One year after being launched, the Solar Plan is in full swing, with 100 MWp of new capacity last year, over 400 MW at an advanced stage of development and several thousands of hectares of real estate secured.

Several plants built by EDF have gone into service, such as the Fouilloux power station in the Charente-Maritime department in September 2018 and Saint-Pargoire in Hérault. Construction has begun on other projects, such as the Aramon plant in the Gard department and Toucan 2 in French Guiana. To accelerate its development, EDF Renewables acquired the Luxel group, bringing to the table 1 GW of capacity in France, including projects that are ready to be built or are already in development and 90 MWp in operation.

**"In France, the introduction of a €3 bonus per megawatt hour in the CRE(1)'s calls for tender for solar projects that are partially crowdfunded has contributed to the success of the renewable market."**

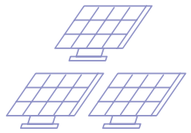
**Alexandre Lévy,**
head of investment projects
at EDF Renewables

*(1) The French Energy Regulatory Commission (CRE)*

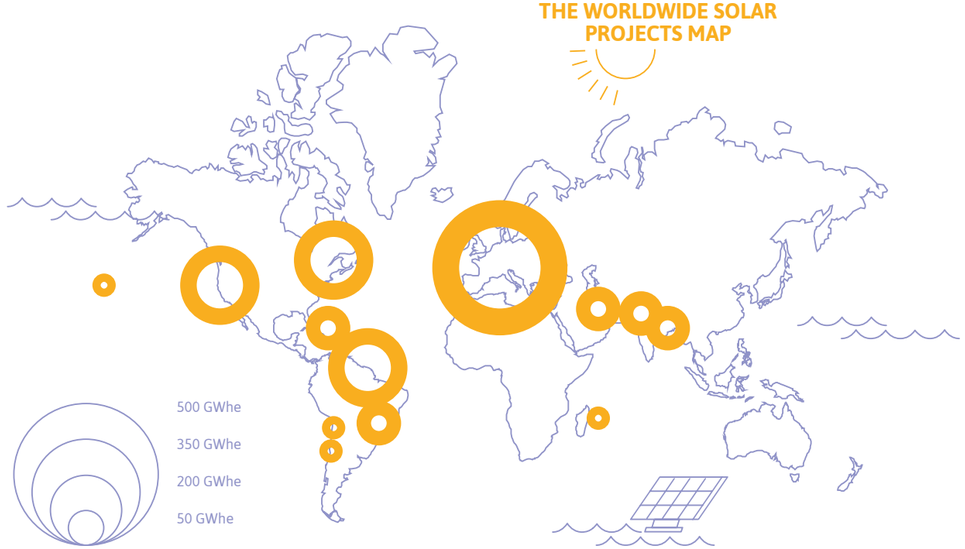
**Real estate at the heart of projects.** Given the current high demand for land and the need to preserve soils in their natural states, EDF prefers to redevelop brownfield sites, former quarries and polluted areas, and install solar panels on rooftops and bodies of water. To inject momentum in the movement, the Group also uses certain technological innovations such as bifacial solar panels and floating photovoltaic installations. In 2018, EDF won the bid for its first floating photovoltaic project (19.1 MWp) on the Lazer reservoir in Hautes-Alpes, France. Solar panels will be installed across 24 hectares, covering three quarters of the reservoir's surface — which itself is used to power a hydroelectric power plant. Positioned at less of an angle to avoid wind exposure, the panels are fixed to a floating structure. The disadvantage of this angle is offset by the proximity of the panels to the water, which cools them down and boosts their performance.

**Financing to developing solar energy.** The budget for the Solar Plan is estimated at €25 billion. It will largely be funded by equity, partnerships and banks. Crowdfunding represents another source of funding. In 2018, EDF successfully completed two crowdfunding campaigns for the Saint-Pargoire (Hérault) and Aramon (Gard) solar projects. For Aramon, built on the site of a former fossil-fired power plant, €200,000 was raised from 78 local backers, but this covers just a small part of the total cost of these projects. Limited to residents within a restricted area, they make it easier for people to get involved in environmentally friendly behaviour and boost the local economy, while benefiting from a favourable tax structure and high performance. On the back of this success, the Group will roll out six new campaigns between now and 2020.

**0.9 GW**
of solar capacity
was commissioned
worldwide in 2018.



**THE WORLDWIDE SOLAR PROJECTS MAP**





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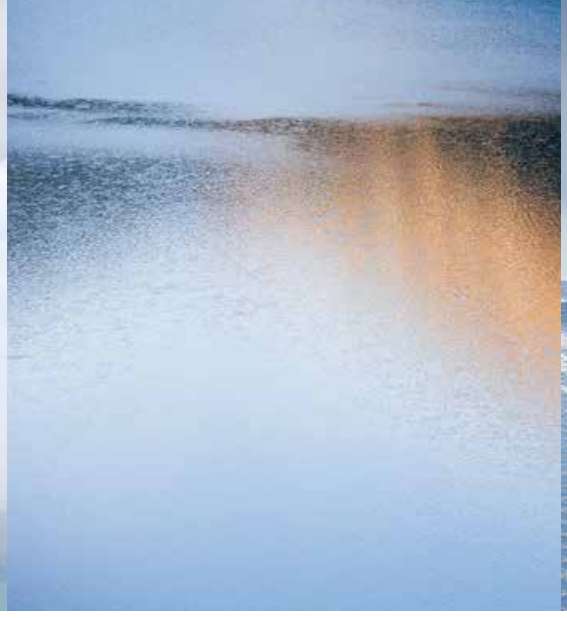


## Is the climate challenge compatible with long industrial timescales?

Jean Jouzel, climatologist and winner of the Nobel peace prize for his work with the IPCC, believes the transition towards a society that consumes less energy is both unavoidable and urgent: “We have to do everything we can to limit global warming to 1.5 °C.” To achieve this, the Multi-year Energy Programme sets 2050 as the target to reach carbon neutrality. EDF’s Nuclear New Build programme has a major role to play and offers a solution for the future to safeguard the country’s electricity supply.

P. 04

## The climate emergency needs everyone to act.

Economist and Director of the UN Sustainable Development Solutions Network under the auspices of the Secretary-General of the United Nations, Jeffrey Sachs, said, “For all such races against the clock, the central issue is always the same: can we work together to make it in time?”. Effective technological and financially viable solutions already exist, and the rise of renewable energy — such as hydropower, marine energy, onshore and offshore wind power, biomass and hydrogen — demonstrates this every day. However, to fully exploit the potential of these energies, we need to make progress in two key areas: effective storage solutions and acceptability.

P. 24

## Passing on a genuine energy culture.

In order to bring about real change, we need to pass on a genuine energy culture to make sure everyone understands they are all able to take tangible action. That is the position of Jean-Louis Étienne, doctor, explorer and a renowned specialist on the Poles; “Renewable energy needs everyone to get involved and take an interest.” Solar photovoltaic or thermal energy — which is currently underused — are part of the solutions for the future that will help us to achieve concrete results. This is a vision EDF shares and is translated in its Solar Plan.

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The Group is ISO 14001 certified – **July 2019.**