2.0 National Objectives and Progress

The directive 2009/28/CE set a 25% target for the contribution of renewables to final energy consumption by 2020. This objective was translated since 2009 into French law through the multiannual programming of investment, the “Programmation Pluriannuelle des Investissements” (PPI). The PPI defined targets for the capacity of power generation by primary energy source and, where appropriate, by production technology and geographic area. The PPI encompassed both the “Grenelle de l’environnement” and the adoption of the European Energy Climate of December 2008. The PPI defines the national objectives of energy policy (security of supply, competitiveness, and environmental protection) in terms of development of electricity production by 2020. It contributes to the implementation of non-CO2-emitting energy sources including renewable or nuclear.

The Energy Transition for Green Growth Act was adopted in its final version in August 2015. The Act defines long-term objectives in the framework for transitioning toward a low-carbon economy and energy system and it aims to define new policy tools. It addresses several aspects including energy efficiency, renewables deployment, and the future of nuclear energy. The Act defines several targets in terms of greenhouse gas emissions, primary energy consumption, share of renewables, and share of nuclear in electricity production. New targets for each renewable energy source will be defined in the PPE when finalized. Current trajectories for 2018 and 2023 scenarios were updated 24 April, 2016 as follows: By the end of 2018:

- 15 GW of land-based wind
- 0.5 GW of fixed offshore wind
- 10.2 GW of solar energy
- 25.3 GW of hydroelectricity

By the end of 2023:

- Between 21.8 and 26 GW of land-based wind
- 3 GW of fixed offshore wind, with between 0.5 and 6 GW of ongoing projects, depending on the outcome of the first projects and price levels
- Between 12 and 18.2 GW of solar energy
- Between 25.8 and 26.05 GW of hydroelectricity

For 2015, renewables represented 18.7% of the electricity demand, with wind being the second largest source after hydro. This number was lower than 2014 because consumption increased by approximately 2% while hydro decreased by 14% due very low rainfalls during the year. In order to set targets for 2018 and 2023 for each energy source, work to define the the Pluriannual Energy Program (Programmation pluri-annuelle de l’Energie (PPE)) started during the last quarter of 2015 and is ongoing.

2.1 National targets

For renewable energy, the PPI provides the following development targets by 2020:

- 25,000 MW of wind energy, specified as 19,000 MW land-based and 6,000 MW offshore
- 5,400 MW of solar energy
- 2,300 MW of biomass
- Additional 3 TWh/yr and 3,000 MW peak capacity for hydroelectricity
• 100 MW of installed wave, tidal, and floating wind, with between 200 and 2,000 MW of ongoing projects, depending on the outcome of the first pilot farm projects and price levels

2.2 Progress
In France, the rate of installation of wind turbines increased between 2007 and 2010, with yearly figures above 1,000 MW, followed by a significant decrease from 2011 to 2013 and a positive 2014 year. With nearly 1 GW of incremental capacity installed, 2015 was a good year in terms of installation rate, leading to a total land-based wind capacity of approximately 10.3 GW (see Figure 1).

The increase in the rate of installation reflects the impact of the recent regulatory changes such as the confirmation of the FIT after EU validation and the simplification of administrative procedures. This led to a total annual production of 20.4 TWh, a large portion of the 88.4 TWh that renewables produced in 2015. After hydroelectricity, which represents approximately 60% of renewables production, wind is the second largest contributor. In the meantime, coal electricity generation decreased by 1.5 GW and now representing 2.3% of the installed capacity.

In 2015, wind and all renewables accounted for 4.3% and 18.7% of electricity production respectively. According to the transmission system operator in France, the electricity consumption in France amounted to 476.3 TWh, which was 2% above the 2014 figure, but approximately at the same level as years 2011 to 2013. Except in 2014, which benefited from quite favorable meteorological conditions, electricity consumption has been fairly stable in France due to the evolution of the economic structure as well as consumption moderation policies. Despite the encouraging activities during year 2015, a more rapid increase of the installation rate is needed to reach the 2018 PPI target of 18 GW of land-based installed wind capacity.

2.3 National incentive programs
In 2014, the French government confirmed the support mechanism for land-based wind, which was also validated by the European Commission. As a result, 2015 gave a more precise view on the future of support mechanisms for wind and other renewables. The Energy Transition for Green Growth Act introduced new funding mechanisms for renewables, introducing a so-called “Complément de rémunération” (Feed-in Premiums), which will be granted as a premium in addition to the market price at which generators sell their electricity directly in the market. However, the law does not apply to facilities that requested power purchase agreements prior to 1 January 2016. In addition, land-based wind turbines will benefit from a transition period that allows electricity producers to choose between the previous FIT system and the new Feed-in Premiums system. This transition period will extend at least to 2018, allowing both systems to exist in parallel. Stakeholders were consulted to finalize the Feed-in-Premiums support scheme and to provide the
European Commission with a French-shared position in the context of the publication of the new European state aids guidelines. The decree was published in May 2016.

The FIT that remains in place consists of a fixed amount of 82 EUR/MWh (89 USD/ MWh) for the first ten years of operation, followed by an additional five years of purchase at a level dependent on the average production hours during the first ten years. Specific regulations (FIT level and conditions) were also defined for wind turbines installed in cyclonic areas in French overseas territories.

Offshore wind development has been directed through two calls to tender for the development of projects in predefined dedicated areas for a predetermined capacity. Grid connection was systematically guaranteed for each tender area. The selection of winning consortia was made on the basis of several criteria, including a proposed level of electricity FIT. A third round of tenders is being prepared by the French administration, in consultation with all stakeholders, and may include a possible evolution of the FIT for such future projects. Stakeholder engagement aims to improve the tender process, along with reducing the levelized cost of energy of such projects.

Along with this preparation work, a call for pilot farms of floating wind turbines was launched in 2015. It targets the development of pilot farms with 3 to 6 wind turbines and power equal to, or larger than, 5 MW in four designated areas (one in Brittany and three in the Mediterranean Sea). Pilot farms are expected to run for up to 20 years and will benefit from a double funding mechanism combining both a FIT and a direct partial funding of capital expenditures. This call closed in April 2016 with results expected after the summer.

2.4 Issues affecting growth

The Energy Transition for Green Growth Act confirmed an ongoing trend for simplification of the permitting and licensing process and introduced new measures:

- Suppression of the “Wind Development Areas” (Zones de Développement de l’Éolien ou ZDE) and of the so-called rule of the five turbines (defining a minimum number of wind turbines per installation), as part of the French law for energy transition voted April 2013;
- Creation of specific support mechanisms and regulations were also adopted to foster the installation of wind turbines in the French overseas territories by the publication of a dedicated FIT,

A revision of several technical constraints was adopted to facilitate the coexistence of wind turbines with radar, leading to updated administrative rules for the installation of wind turbines near meteorological radars. Furthermore, exchanges with the Defense and Administration for Civil Aviation (DGAC) could lead to improvements during 2016.

3.0 Implementation

3.1 Economic impact

According to the Syndicat des Énergies Renouvelables (SER), the French industry employs approximately 10,000 people. Industrial players located in France are represented along most of the value chain of the wind sector, ranging from development and studies, component manufacture and delivery, engineering and construction, and operation and maintenance. This represents approximately 100 small-to-medium enterprises and 15 larger players.

The only wind turbine manufacturing facility in France was Vergnet, which produces “far-wind” wind turbines for cyclonic areas. Now, a French company, DDIS, is developing a patented technology for innovative direct-drive electrical machines. A large range of suppliers already exist such as Nexans for electric cables, Leroy Somer for generators, Rollix for blade and yaw bearings, etc. Several small-to-medium enterprises are also providing advanced technologies such as LeoSphère, a leading lidar provider, METEODYN, METEOPOLE, providing service and software for wind resource assessment. This situation is currently evolving very fast, along with the development of a local offshore industry.

Within the PPE exercise, several forecasts are being made to assess possible job creation according to the various scenarios. Tentative figures show a potential ranging from 340,000 to 415,000 full-time equivalent jobs created by 2023 as the estimate of cumulative employment over 20 years.

3.2 Industry status

During 2015, a major evolution occurred in the French landscape of wind turbine manufacturers. In March, AREVA and GAMESA officially created ADWEN, a joint venture dedicated to designing and manufacturing large-scale offshore wind turbines. Alstom activities in wind were acquired by General Electric, which later confirmed that France would remain the headquarters for offshore wind.
Offshore farms tendered in 2011 and 2013 led both Alstom (now GE) and AREVA Wind (now ADWEN) to announce the installation of major industrial facilities in France. In 2014, Alstom inaugurated a new nacelle assembly factory near Saint-Nazaire, with plans for two new factories near Cherbourg (Normandy) for wind turbine towers and blades. The first commercial wind turbines to be produced are planned to be used for the Block Island project in the United States. ADWEN also confirmed plans to install several facilities near le Havre (Normandy). These important developments are expected to attract a strong network of local and European industry suppliers.

Other players are active in the development of foundations for offshore wind, such as STX France, which in 2014 delivered a substation for DONG and actively works to promote jacket solutions for offshore wind turbines. STX also launched an investment for new facilities for future substations and foundations in their Saint-Nazaire premises. The development of the floating wind projects has fostered the creation of French start-ups like Nenuphar, which is developing a vertical axis wind turbine for floating applications, and IDEOL, which is developing a concrete floater solution (see section 4.1).

In order to encourage the development of a local industry, a dedicated initiative called Windustry was launched with governmental support to encourage industrial development in the wind market, by strengthening the supply chain. It provides guidance and advice for companies seeking to enter the wind industry and diversify their activities. About 50 companies have been involved in the Windustry initiative so far and the initiative aims at creating 50,000 jobs by 2020.

3.3 Operational details

France was divided into 22 administrative regions until 2015 when a merger of these administrative regions led to a creation to 13 regions. From these 13 regions, two represent almost the half of the installed wind power. The leading regions, in terms of installed power, are the Hauts de France (ex Nord-Pas de Calais and Picardie) and Alsace-Lorraine-Champagne-Ardenne—with approximately 2,500 MW installed by the end of 2015. These two regions are located in the northern part of the country. In 2015, the same two regions represented more than 50% of the newly installed capacity, 276 MW and 216 MW respectively (see Figures 2 and 3). Other regions with good installed capacities are Languedoc-Roussillon-Midi-Pyrénées in the southwest and Brittany, illustrating the different wind dynamics in France.

France benefits from three different wind regimes, corresponding to the Mediterranean, the Atlantic Coast, and the North Sea/Channel (“Manche” area). This situation therefore leads to a non-homogeneous installation density of wind turbines, with very strong activity in the north and west. This translates into higher capacity factors in the north and south (Figure 4).

In terms of wind turbine suppliers, more than 75% of turbines installed in 2015 were from Enercon, Senvion, and Vestas. Looking at the whole installed capacity, Enercon, Nordex, Senvion, and Vestas hold approximately 75% cumulative market share.

Though the current wind turbine installations are located on land, offshore wind is considered to be a strategic sector and has been highly supported in the recent years. More precisely, two tenders were initiated in July 2011 and March 2013 to develop offshore wind farms. Four areas were defined for a total of approximately 2,000 MW in the first round and two others for a total of 1,000 MW in the second round (see Figure 5).

Eolien Maritime France, a consortium led by EDF EN and Dong Energy, was awarded the Fécamp, Courseulles-sur-Mer and Saint-Nazaire wind farms where the 6-MW GE-Alstom Haliade wind turbines will be installed, for a total of approximately 1,500 MW. Ailes Marines SAS, a consortium led by Iberdrola and Eole-RES, was awarded the Saint-Brieuc wind farm where ADWEN 8-MW wind turbines are expected, for a capacity of 500 MW. A consortium led by ENGIE, EDP Renewables, and Neon Marine was awarded the Tréport and Iles d’Yeu-Noirmoutier areas, where ADWEN 8-MW turbines are expected totaling nearly 1,000 MW.
4.0 R, D&D Activities

4.1 National R, D&D efforts

The development of offshore wind and large wind turbine technology has been a priority in recent years. The French Agency for Environment and Energy Management (ADEME) has been the driving funding agency for applied R, D&D projects. ADEME funds and administers three kinds of projects: PhD thesis, R&D projects for intermediate TRL, and the Programme des Investissements d’Avenir, dedicated to industrial projects, and funded by subsidies, reimbursable aids, and possibly equity. Wind energy R&D projects funded by ADEME cover resources assessment, radar compatibility, materials, and the study of biodiversity.

In the area of industrial demonstration projects, after a call for proposals in 2009 on ocean energies which included floating wind technologies, another call was launched and four projects awarded by ADEME in 2013. These four projects are:

1. The EOLIFT project (2013–2017), led by Freyssinet, proposes the development of innovative pre-stressed wind turbine concrete towers for high power (more than 3 MW) and tall height (more than 100 m), incorporating lifting equipment to avoid the need for high capacity cranes. The objective is to increase the speed of construction of wind farms and to reduce costs related to the tower and foundation by 15%. A demonstration is planned for a 3-MW wind turbine with a 120-m tower.

2. The JEOLIS project (2013–2017), led by Jeumont Electric, aims to develop a new hybrid generator to optimize the electric conversion chain of wind turbines. It is composed of generator with a winding on the rotor, whose performance is enhanced by a significantly reduced number of permanent magnets. A demonstration is on-going on a coastal 750-kW turbine. The project also targets the design of a 5–6 MW generator.

3. The EFFIWIND project (2014–2019), coordinated by the Adera and Canoe platform, is focused on the development of new thermoplastic materials for blades and nacelle housings. It aims to demonstrate the use of acrylic resins for these applications on offshore wind turbines. A set of blades will be produced and tested on a land-based wind turbine.

4. The Alstom Offshore France (AOF) project, coordinated by Alstom Renewable Power, is dedicated to the creation of industrial facilities in France for the production of the Haliade 6-MW offshore wind turbines. The project includes the creation of three industrial facilities near Saint-Nazaire and Cherbourg, one for the assembly of nacelles, one for manufacturing permanent magnet generators, and the third to manufacture blades.

Among the selected topics, floating wind technology was identified as a strategic area because France has a favorable situation for floating wind: local harbor facilities, and a local naval and offshore oil and gas industry capable of supporting this market. More precisely, three projects are currently under development for floating wind.

- The Vertiwind (2011–2017) project aims at developing an innovative vertical axis wind turbine technology designed by the start-up Nénuphar, Oceanide, Bureau Veritas, and IFP Energies Nouvelles. This project is associated with the EC FP7 INFLOW project, led by IFP Energies nouvelles, and is planned to qualify the technology. The project will be a first milestone to demonstrate the Twinfloat concept using contra-rotative vertical axis wind turbines.

- The SeeReed project (2013–2017), led by the DCNS Group and GE Alstom, covers the qualification of a semi-submersible lightweight floating wind energy platform equipped with the 6-MW Haliade turbine.

- The OceaGen project (2014–2017), led by IDEOL (a startup located in the South of France) and Bouygues, aims at developing a concrete barge using the Damping Pool™ concept. A prototype was scheduled to be installed in 2015 on the SEMREV test site off the Atlantic coast at Le Croisic.

Phase 2 of the VALEF project was carried out in the framework of France Energies Marines (Institute for Energy Transition). This project aims to provide adequate methodologies and validation data to ensure the accuracy of the software modeling the dynamic behavior of floating wind turbines. It includes several partners: ADWEN, Ecole Centrale Nantes, DCNS, EDF, IFP Energies Nouvelles, and INNOSEA.

During 2015, the SmartEole project was selected by the French National Research Agency (ANR). Led by Prisme Orléans, the main objective is to improve the energy production efficiency and lifespan of wind turbines through the development of lidar-based innovative control solutions. The project started in January 2015 and is scheduled for 3.5 years. It aims at demonstrating control strategies at different scales of wind turbines: blade, wind turbines, and farm. A first test campaign was carried out on a Maia Eolis site to acquire nacelle based, vertical, and scanning lidar measurements. Several experiments have also been carried out at the lab scale to test air jet active control.

4.2 Collaborative research

Along with several national projects, France is also active in several European projects, such as:

![Figure 4. Capacity factors during 2015 per region (Source RTE)](image-url)
• The Spinfloat project, led by ASAH LM / EOLFI and Gusto MSC, which is based on a vertical axis wind turbine with pitched blades installed on a three-column, braceless, semi-submersible floater. This project also involves SSP Technology, a Danish blade manufacturer; Fraunhofer IWES the German Institute for Wind Energy, in charge of the drive train; GustoMSC, the Dutch designer of mobile offshore units; ECN the Dutch energy research Institute; and the Italian University Politecnico di Milano for wind tunnel testing.

• The INFLOW project, which is carried out in close relation with Vertivind, addresses the demonstration phase of the latter project. It is led by IFP Energies nouvelles and also involves numerous partners from six European countries, including the Nenuphar Startup, EDF Energies Nouvelles, DU CO Vicinay Cadenas, VryHof Anchors BV, Fraunhofer IWES, DTU, and Eiffage Constructions Métalliques.


During 2015, IFP Energies nouvelles hosted the 76th IEA Wind Executive Committee meeting at its premises in Rueil-Mamaison, and organized with LeoSphere, a demonstration of lidar technology, along with a workshop on floating wind initiatives in France.

5.0 The Next Term

After the adoption in 2015 of the Energy Transition for Green Growth Act, 2016 will see the definition of the future objectives for renewables through the PPE and adoption of a new scheme to support the development of renewables and wind for the coming years. The development of offshore wind is also expected to continue, with the announcement of a third round of tenders. The outcome of the call for pilot farms of floating wind turbines will also be known in 2016 and will undoubtedly strongly enhance the development and demonstration of this technology.

References:
Opening photo: Beau Regard (Photo credit: Maia Eolis)
Authors: Daniel Averbuch, IFPEN Energies nouvelles, France; and Victoire Lejzerzon, Ministère de l’Environnement, de l’Energie et de la Mer (DGEC), France.