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From electricity capacity to production: a focus on load factor and the French electricity mix

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Electricity production and usage is a daily subject in the press in relation to the reduction of CO_2 emissions. The objective of this article is to present the French electricity production system and capacity in FY20, with a perspective of their evolution since 2012, detailing the different types of electricity production with their respective CO_2 emissions and practicality. We present the key feature of the load factor for a power plant, which is very different between thermal and renewable power plants and has material implications in terms of renewables' capacity to build and to replace thermal capacity.

Introduction to electrical grid, production and consumption

From a high-level point of view, an electrical grid is the network for the transportation of electricity from a relatively limited number of types of power plants (thermal, hydraulic, solar, wind, biomass) to the various and numerous consumers (individuals, municipalities, corporates). The electrical network has to connect producers and consumers and the electrical system to ensure that supply is sufficient to meet the need of consumers, from the baseload to the peak demand. The electrical grid is composed of high voltage, long distance, and low voltage powerlines (which are usually operated by different actors) to deliver electricity to each consumer; in that it is somewhat similar to the highway network and the road network for transportation by vehicle. In addition, it has to be resilient in its design in order to avoid low probability but high adverse impact situations of black-out in our modern society where access to electricity is essential.

Adding the carbon element to the equation

On top of the general features of the electrical system to put in place for a region or a country, the level of carbon emission has to be added into the equation. Indeed, according to Intergovernmental Panel on Climate Change, electricity and heat production represented around 25% of global greenhouse gas emissions in 2010, meaning the sector is central to efforts to decrease CO_2 emissions.

Until the advent of the industrial societies in the eighteenth century, the world had been using mostly renewable energy (water, wind, solar, wood and animal power). The rise of the intensive usage of coal, and then oil and gas, has allowed access to massive and easy-to-use quantities of energy (created through natural processes over tens or hundreds of millions of years) through their combustion, but with also with the negative side-effect of the generation of CO_2.

In order to reach the goal of reducing CO_2 emissions, one unavoidable path to be followed is therefore to significantly reduce - and one day ultimately stop (either because of exhaustion of the fossil reserves or too much CO_2 in the atmosphere) - the generation of CO_2 for electricity production. That goal is currently set despite the context of increasing worldwide electricity consumption due to economic growth. Balancing the two pressures will be challenging.

The majority of today's electricity is produced worldwide by electromechanical generators driven by heat engines. In thermal power plants, the heat is mainly generated through the combustion of fossil material such as coal, gas, oil, or wood, waste or biomass (all generating greenhouse gas) or with nuclear fission though the splitting of uranium or plutonium atoms (which does not generate greenhouse gas). The

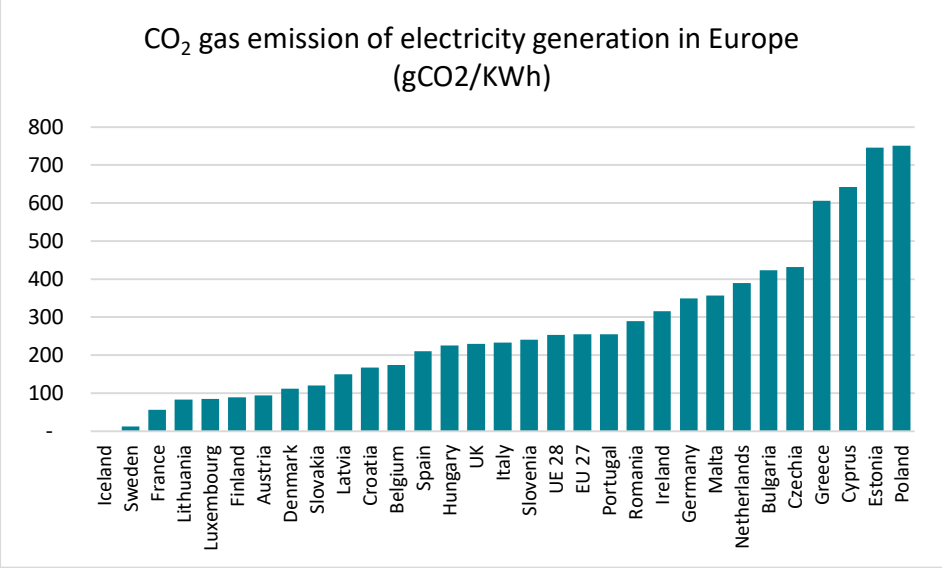
energy from the combustion or nuclear fission is used to heat water to become steam which drives an electromechanical generator. Thermal production has the advantage of the practicality of usage as it can be turned on at will (with a start time of 10 minutes for a gas power plant and from 2 hours to 2 days for a nuclear power plant, according to the OECD Nuclear Energy Agency) as long as the material used to produce the heat is available.

Other ways of producing electricity, in large quantity, are i) converting solar radiation during the day into electricity using the photoelectric effect, ii) hydraulic with dams or the run of the river, with the constraint of the quantity of water available, and iii) wind when there is more than 15km/hour of wind. Hydraulic and wind electricity production is based on kinetic energy. Solar, wind, and tidal waves are intermittent means of electricity production that can have intra-day variation (day/night), and/or seasonal variation (summer/winter), in addition to being dependent on short-term meteorological variations.

The load factor is the ratio of production divided by the installed capacity theoretical maximum production over a period of time (an hour, a day, a quarter, a year). The intermittent nature of hydraulic, solar or wind explains their typically low load factor. It is generally significantly lower than thermal plants, unless these thermal plants are used as back-up capacity.

One drawback of the lower load factor can be mitigated by building more capacity of renewables power plants compared to thermal plants (10GW of thermal plant with a load factor of 75% will produce the same amount of electricity as 50GW of solar plants with a load factor of 15%). Another drawback is that even if the volume of production is similar to thermal plants, storage capacity is needed in order to convert intermittent availability to at-will availability. The storage capacity can be either at a project level (a solar plant with storage technology), or at the electric system level (with dedicated large storage facilities).

Within Europe, in 2019 France was among the leading countries in terms of low CO_2 emissions for electricity production, as displayed through the European Environment Agency data. The CO_2 emissions presented are only for the operation, not for the complete lifecycle - which would include construction, operation, and decommissioning.



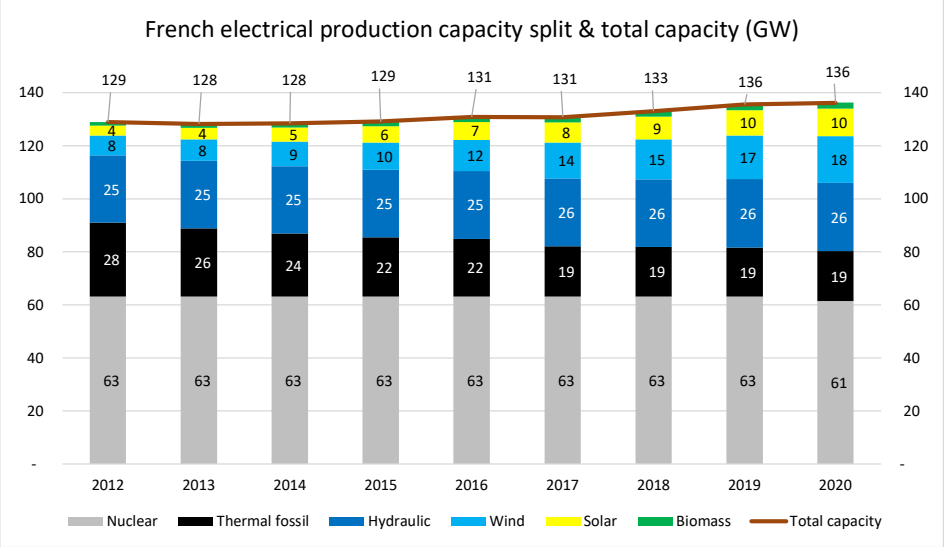
Source: Qivalio, European Environment Agency

Of the economically largest countries in Europe, France is the best-in-class. This is due to its large installed capacity in nuclear and large use of hydraulic electricity in the mountainous part of France.

Focus on the French case and its electricity production mix

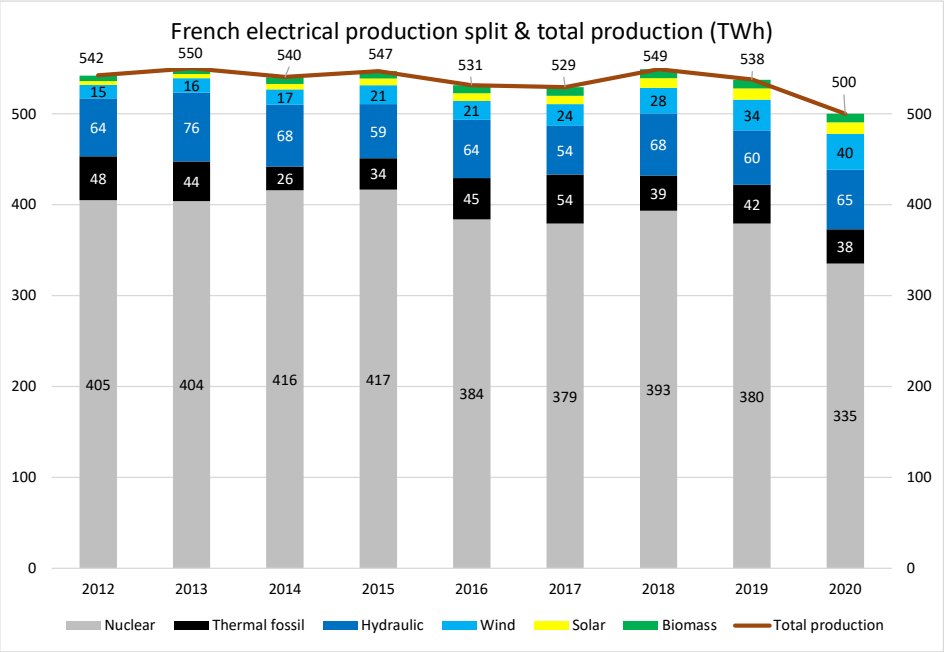
In order to have a better understanding of the French electricity production mix, we have taken data from the RTE 2020 report “bilan électrique 2020”.

Installed electricity capacity in France is split between nuclear, thermal fossil, hydraulic, wind, solar and biomass. It represented 136GW of installed capacity in 2020, with around 45% coming from EDF’s 56 nuclear reactors (with an individual reactor power of either 900MW, 1,300MW or 1,450MW), 19% from hydraulic, and 14% for thermal fossil. In 2020, nuclear capacity decreased to 61.4GW from 63.1GW as result of the closing of the two 900MW reactors of Fessenheim. Over the last 8 years there has been a steady growth of the capacity in wind and solar as a result of the incentive scheme put in place in France, with a fixed price offered for the electricity produced. Nevertheless, the proportion of the installed capacity remains rather low at 8% (3% in 2012) and 13% (6% in 2012) for solar and wind respectively.



Source: Qivalio, RTE

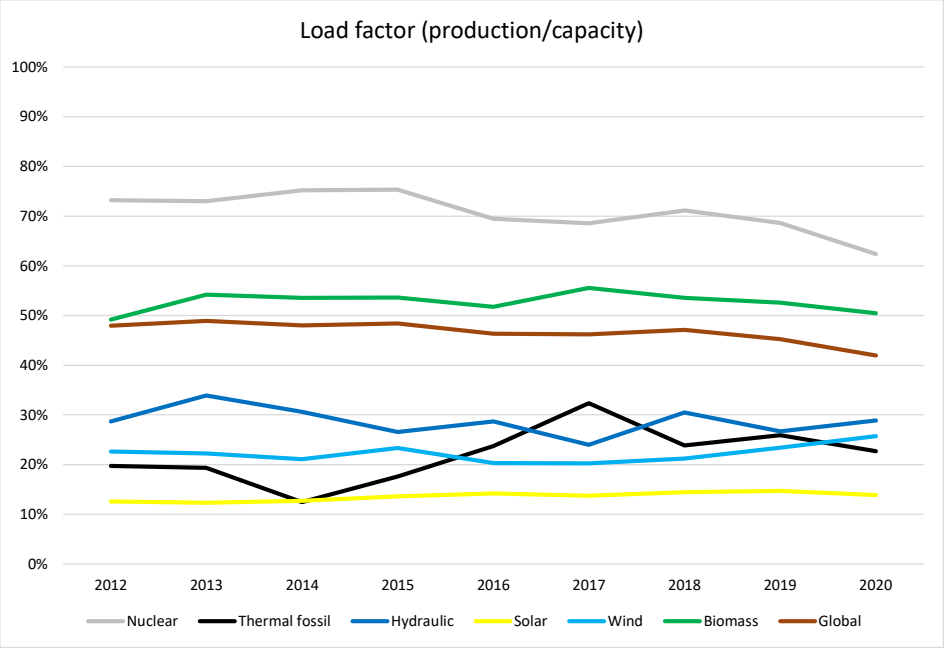
There are often articles in newspapers about power plants with confusion between installed capacity and production, therefore putting aside the load factor. It is, however, far different in real life between capacity and production, as a power plant can be intermittent, need periodic or unexpected technical maintenance, or have down times. These times can be the result of a lack of demand (and therefore no need to produce electricity unless it can be stored), or because of a lack of the electricity generating element for hydraulic, solar or wind.



Source: Qivalio, RTE

From actual electricity production since 2012, as per the graphic above, we can note the high proportion of nuclear, even if it has been declining over the period, from 75% to 67% of total electricity production. At the same time total production has also declined, by 8%, driven by 22% and 17% declines in thermal fossil and nuclear respectively partially compensated for by 207% and 166% increases in solar and wind. However, solar and wind electricity production are still only a small part of total production. It is to be noted that over the 2012-20 period, of the French electrical production presented above, net exportation to other European countries has always been in the 7-12% range.

From these data (yearly production and installed capacity) we derive the respective annual load factor of each means of electricity production (production during the year / average installed capacity between the beginning and the end of the year).



Source: Qivalio, RTE

Over the period we can see relative stability, at a low level, of solar (14% in FY20), wind (27%) and hydraulic (29%), which is not surprising as they are intermittent and reliant on the availability of sun, wind, or water. These load factors are below the 34% for wind and 18% for solar in 2020 for Neoen as a result of the French company's geographic presence outside of France. And slightly below the 28% and 16% for wind and solar for Falck Renewables in 2020, also with operations outside of France. In addition, with the guaranteed prices scheme for wind and solar, the electricity produced is always purchased even if the demand is lacking. Therefore, the load factor is not impacted by a potential lack of demand. Biomass was stable, and thermal fossil has experienced large swings as it can be used to balance the overall production if there is either a deficit or excess of production by the nuclear or intermittent energy sources. Nuclear load factor has trended down since 2018 as a result of a period of increasing maintenance. Overall, the global load factor has declined over the period and we expect the decline to continue as a result of the steady increase of solar and wind capacity with a structurally low load factor.

Conclusion

The electrical system for a region or a country is a complex system relied upon, in developed countries, to supply all the time the volume of electricity needed by the consumers. As the production of electricity through combustion generates CO_2 emissions, countries - and France in particular - have put in place various schemes in order to stimulate the construction of renewable energy power plants such as wind and solar plants. In 2020 in the wind and solar panel area, in France the main players were, according to Neoen, #1 Engie with 3.6GW of capacity, #2 EDF Renouvelables with 2.0GW, #3 Boralex with 1.0GW, #4 Total Qadran with 0.9GW, and #5 Neoen with 0.8GW.

In January 2019, the programmation pluriannuelle de l'énergie (PPE) in France for the 2019-28 period was released, with high ambition in terms of the development of wind and solar. Indeed, from an installed capacity of 23.7GW in 2018, the PPE plans in 2023 a low/high range of 41.9-46.1GW and in 2028 a low/high range of 73.5-84.9GW. While the targeted increase in installed capacity is significant, the related increase in production would be less impressive as a result of the low load factor compared to thermal power plants. At YE20, the PPE goals for installed capacity for 2023 appear to be achievable for wind (17.6GW at YE20, or 73% of the target according to RTE) but far away for solar (10.4GW at YE20, or 51% of the target according to RTE). We expect the incentives for wind and solar to continue to stimulate the volume of projects and capacity being built in the years ahead. This will probably therefore be beneficial in terms of potential for new projects for the sector of the companies building and operating solar and wind power plants. Wind and solar projects can currently obtain attractive financing conditions for the non-recourse debt of the projects and the corporate sponsors can also benefit from attractive financing conditions currently available on the corporate credit market. The capital expenditure cost per MW of capacity built has also decreased (with the most important effect on solar) over recent years, due to technical progress and higher production capacity. This year, however, the sharp increase in raw materials prices might reduce the steady decrease of the cost of building capacity.

Due to the intermittent nature of wind, solar and to a lesser extent for water power plants, their load factor is rather low compared to traditional heat power plants, which produce at will. France has a low CO_2 footprint thanks to its historically large installed nuclear and hydraulic capacity. It has also experienced a steady rise of solar and wind capacity even if it remains only a small fraction of overall electricity production in France (10.5% in 2020). Low load factor can be offset by proportionally higher installed capacity, but their intermittent nature will need to be mitigated by the development of large electricity storage capacity, which currently remains a challenge.

Overall, the French electricity mix is currently characterized by a very low CO_2 footprint on the back of nuclear and hydraulic power plants. A significant reduction of the proportion of nuclear electricity would imply a massive increase in the capacity of solar and wind renewables, as well as the investment and technology to manage their intermittent nature, which is currently only a relatively small constraint due to their low proportion of the French electricity mix.