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France's and Europe's Electricity Supply Security is at Risk

As decarbonized electricity emerges ever more strongly as the most efficient and economical energy vector for the massive decarbonization of the rest of the economy (industry, housing, mobility, etc.), the technological option that the European Commission is putting forward to produce this decarbonized electricity, a course that many member countries are following, relies quasi-exclusively on wind and photovoltaic power generation. This, combined with the governance associated to this policy's implementation, induces strongly increasing hazards for electricity supply security for all the European countries in the years and decades to come.

Yet, electricity, which is already a staple commodity essential to the proper operation of our modern societies in terms of health, individual and collective safety, telecommunications, economic efficiency, mobility, housing, etc., will be all the more so in the years and decades to come given the growing role it will be called upon to play. Technological transformations such as the increasing digitization of society and the economy will further increase the irreplaceable role of electricity. Note, moreover, that France places the electric grid among its critical infrastructures and that RTE [1] has been designated as an operator that is vitally important for national security, including military security.

In this context, the electricity supply security can only become increasingly essential in the future. Two other equally essential objectives for the electricity system must be noted: achieving carbon neutrality by 2050 for the entire economy, which implies cutting our current CO_2 emissions by a factor close to six, an extremely ambitious target; keeping the price of electricity at a sustainable level for the population and for the economy. These three closely related objectives will have to be pursued simultaneously. Indeed, it would be inconsistent to develop new means of production aimed at reducing CO_2 emissions (the second objective) that undermine the other two objectives.

Yet this is where Europe's current energy policy and that of many European countries that follow suit are headed. We analyze below the technical as well as the organizational and governance aspects that lead to increasing risks for the supply security.

1 - Projected technological developments are likely to induce increased dangers

A too rapid or too intense development of intermittent wind and photovoltaic productions would entail several unprecedented dangers:

- **Systemic dangers resulting from the general absence or weakening of wind or photovoltaic primary energy flows:**

* The absence of solar flux is obvious at night due to the daytime rhythm. Even during the day, however, this flux can be significantly reduced or even dwindle to nothing in the event of unfavorable weather conditions such as rain, fog, uniformly leaden sky, or numerous dark cloud passages, which prevent or strongly reduce photovoltaic production. With the progress in the quality of weather forecasts these production deficits are better predictable but they still happen. More importantly, in our latitudes, photovoltaic panels produce very little in winter when demand is at its highest: 4 to 5 times less than in summer on a daily average.

1 RTE - Gestionaire du Réseau de Transport d'Éléctricité - France's Transmission System Operator

* The near absence of wind at certain periods on the scale of France or even of a large part of Western Europe is a widely observed reality that is validated by experience and numerous undisputed scientific studies, definitively contradicting the slogan "There is always some wind somewhere" which belongs to the Coué method or to promotional material. Here again, increasingly accurate weather forecasts allow a better prediction of wind turbine production, but the production deficits will obviously remain.

* The combination of these primary energy flow insufficiencies is particularly critical during winter demand peaks at 7 p.m. in the event of absent or weak wind, the sun having long since disappeared. In these circumstances, whatever the installed capacity of wind farms and photovoltaic panels, even if it is exceedingly large, their overall cumulative production is at best paltry for the former and nil for the latter. Now, the security of electricity supply criteria currently applied in France were devised before the introduction of intermittent sources into the networks, they are based on a power outage probability of less than 3 hours per year. They are not adapted to large production deficiency management leading to outage risks that are much "deeper", if with the same probability.

In these circumstances, and in the absence of very large-scale energy storage solutions (see below), the supply security relies essentially on the main dispatchable means of production (hydropower, nuclear, fossil-fuel thermal: coal, oil, or gas). The complementary production-demand balancing measures such as voluntary demand deferment, although useful, are far from being on a sufficient scale. As for imports, they are certainly useful, but the production in neighboring countries resting also mainly on wind and photovoltaic, simultaneous shortages can occur, defeating any exchange possibilities.

* Germany, the country with the largest wind and photovoltaic capacity in Europe, with an installed capacity of more than 110 GW (more than four times the French park), is thus a good testing ground. Its four transmission system operators (counterparts of RTE in France), informed as they are by years of experience, have a deterministic approach and rightly consider that the guaranteed power of onshore and offshore wind turbines does not exceed 1% of the installed capacity. Some studies could raise this value up to 3% depending on the season, but this would not change the order of magnitude. As a result, to guarantee its supply security, Germany has retained a fleet of dispatchable means with a capacity of around 100 GW. In other words, it has developed a double production park. It is a luxury, but it is not sustainable because the current dispatchable fleet will lose its residual nuclear power (8.1 GW) by the end of 2022 and gradually its coal/lignite power plants with more than 40 GW by 2038, which, in passing, seems very late. Its strategy, as currently announced, seems to rely massively on the hydrogen vector, a large part of which, it seems, would be imported (from where?). This raises major questions, as transporting this gas is difficult and expensive. Its only remaining option to ensure supply security, in case of too great difficulties, is then a massive recourse to fossil gas, imported in particular from Russia. How will Germany achieve carbon neutrality in 2050 under such circumstances?

* What about France? It has a major strategic asset: its nuclear fleet, which produces 70 to 75% of the country's electricity without emitting CO_2, which is dispatchable, extremely competitive, and will soon regain its 63 GW of installed capacity. Despite the very valuable contribution of hydropower, however, this capacity already is not sufficient to get through the highest expected demand peaks without resorting to dispatchable gas-fired production means. In this context, it would be irresponsible to reduce the nuclear capacity by 2035 as planned, for two reasons. Wind power and photovoltaics do not offer any more guarantees in France than in Germany: as already stated multiplying wind turbines and photovoltaic panels will not guarantee production during these demand peaks. Only the development of large-scale energy storage / destocking capacities would offer a solution. However, according to RTE, in 2035 there will not be significantly more energy storage capacity than there is at present except for a possible increase by 1 to 2 GW of pumped hydroelectric energy storage (PHES) subject to uncertainties and which is, anyway, nowhere near the scale needed.

- **<u>Can energy storage / destocking eliminate the risks associated to deficient production from wind power and photovoltaic farms?</u>**

On paper, the storage / destocking of energy from decarbonized electricity seems to be a natural complement to intermittent wind and photovoltaic sources. However, the reality comes up against several determining parameters, in particular the overall efficiency of successive energy conversions, which impacts the storage capacities needed in terms of both power and energy and consequently the cost of the electricity destocking.

There are many ways to store energy but in the field of electricity storage, three technologies stand out:

* Two methods are noteworthy for their remarkably high storage / destocking efficiency: pumped hydroelectric energy storage (PHES) with a 75 to 80% conversion efficiency and electrochemical battery storage with a conversion efficiency of up to 85%. Accordingly, these two methods are extremely useful, but both have limited power and/or capacity:

- PHES in France represents 5 GW installed capacity and 0.1 TWh energy capacity, which limits it to intraday or intraweek use. Residual extensions are possible that would make it reach 6 to 7 GW installed capacity and 0.12 to 0.14 TWh energy storage at the most: particularly useful, but it would not change the face of the earth...

- Harnessing the batteries of a large fleet of EVs would allow to reach destocking power capacities much larger that with PHES, but the improvement in terms of energy storage would not be so large, since the optimal use of batteries remains strictly intraday.

These two methods are thus technically and economically very well adapted to compensate for an average sized lack of wind or sun during a limited time period of a few hours. Typically, to clear the noon demand peak which lasts about 3 hours or the 7pm evening peak which lasts less than 2 hours.

But under no circumstances would they be able to compensate a major and lasting lack of wind and sun, especially on very cold winter days when demand can reach 2 TWh in 24 hours, while hydropower and biomass provide at best 0.3 TWh. It is then 1.7 TWh per day that would have to be destocked. Yet, statistically, periods with absent or slack winds can last up to ten or so consecutive days.

In order to guarantee supply security during such a winter situation in an electrical system mainly powered by wind farms and photovoltaic panels, an energy stock capable of delivering up to 17 TWh of electricity would therefore have to be available at the beginning of winter. Assuming a conversion to electricity efficiency around 60%, this means an almost 30 TWh energy stock!

This is a considerable amount, that synthetic gas fuels alone (electrolytic hydrogen or methane obtained by CO_2 methanation with this hydrogen) could have sufficient potential to store. Technically, this is indeed possible. However, the extremely large global energy losses of the energy conversion chain from electricity to gas fuel then to electricity implies production means escalation to compensate for these losses, wherefore increased impacts on space occupation and needs for rare materials. In addition, the price of the electricity thus destocked raises doubts on the economic viability of such solutions.

- **<u>The hazard resulting from the massive introduction of digital technologies necessary for the operation of large-scale wind and photovoltaic means of production.</u>**

What is the current situation? Today's three-phase power grids which were invented by Nikola Tesla almost 130 years ago, have reached an extremely high level of operational security, so much so that the supply security is no longer questioned except in the event of a major production shortage, where it is the means of production that are at fault, not the technology of the network. This security is due to the properties of three-phase alternators which, once coupled to the grid:

* Remain naturally "hooked" in a very robust way via the electromagnetic torque between the alternator rotor (simultaneously conveying the combined mechanical inertia of the turbine + the inductor magnetic flux) and the alternator stator (carrying the electromagnetic wave of the induced magnetic flux, image of the frequency and the power through the internal angle of the alternator). These bonds are established via the strong currents produced therefore at very high energy, making them quasi-insensitive to electromagnetic perturbations,

* Are capable, thanks to the mechanical inertia of their rotors which also store kinetic energy, of damping rapid frequency variations, leaving time for their local power-frequency controls to re-establish the supply-demand balance, in conjunction with all the other alternators that participate in the adjustment, all this with no human intervention.

In this domain, then, the physical laws of electromechanics govern events, without the intervention of a digitized layer. Resting on this very robust physical balance, additional adjustments allow us to fine-tune the frequency and, through human intervention, to implement the power variations required to follow the load on the network according to demand as well as to compensate the fluctuations of increasing wind and photovoltaic production.

On the scale of France, around a hundred large alternators distributed across the country are sufficient to "shape" the frequency and voltage of the electrical system. This reduces the number of remote links needed for the overall network control so that it is easier to ensure their cyber-security.

* The introduction of wind and photovoltaic sources is a twofold game-changer:

- Their power variations combine with those of the demand. Sometimes the two will compensate one another partially but, more often than not, the variations will be increased significantly, requiring a significant power modulation increase on the part of the dispatchable means in order to restore the overall balance of the electrical system,

- These sources are coupled to the grid via electronic power inverters that bring no mechanical inertia to the electrical system. This can be partly remedied by using synchronous compensators, but this is not sufficient because electronic inverters powered by variable sources cannot provide the same power adjustment guarantees as alternators.

In the current state of technology, these two effects put together limit the permissible penetration ratio of wind and photovoltaic sources into a network, a limit that depends on the nature and size of the network. As of now, it is still the alternators that "form" the networks in frequency and voltage.

* New types of electronic inverters capable, like alternators, of "forming" the frequency and the voltage of the grid will become essential to increase the penetration ratio of variable sources, a function that the "grid following" type of inverters currently in use are not capable of assuming. The new type "grid forming" inverters will have to digitally "mimic" the physics laws characteristic of the alternators. This will mean replacing strong electromagnetic couplings with digitally controlled couplings.

These new inverters are being tested on mini-grids. However, moving from mini-grids with a very small number of inverters to full-scale grids raises major issues that are far from being resolved to date, in particular (non-exhaustive list):

- **The multitude challeng**e: on average wind and photovoltaic sources have much lower unit capacity than large alternators. They will therefore be much more numerous in the networks, probably on the order of several thousand to tens of thousands on the scale of France and ten times more on the scale of interconnected Europe. Yet, no one, today, can guarantee that such a large number of inverters will be able to operate together in parallel in a stable manner. Only experimentation and validation on full-scale operating grids can provide an answer to this question, but that test is extraordinarily difficult insofar as it must not jeopardize the supply security: the grid must continue to perform its function while the tests are being carried out,

- **The indispensable digitization of the electrical system:** the digitization will start at the level of each inverter taking part in "forming" the grid as they will operate and be connected to the grid thanks to low energy digital controllers, by nature vulnerable to electromagnetic disturbances despite built-in protections. Moreover, the real-time control of a very large number of inverters will imply a great deal of computer power, probably including AI (artificial intelligence). The set of inverters, then, will have to be interconnected via a spatially extensive digital telecommunications layer which adds on to the existing grid layer.

Such a system will be an ideal target for cyber-attacks, given its scope and the very large number of entry points. Will we be able to protect it, knowing that it is probably impossible to guarantee absolute cyber-security? Only in the case of control and command systems that are totally isolated from external networks such as those used in nuclear power plants, for example, can such a guarantee be reached.

- **A dangerous informational hyper-complexity**: As recent history shows, we cannot ignore the danger that informational hyper-complexity represents. Indeed, there are several instances in which mega computer programs did not succeed because of a hyper-complexity that could not be controlled. Moreover, the programs considered here will not just produce "simple" information that can be corrected before any consequences are felt, they will directly drive an extremely complex system of vital importance for the country and for Europe. Development bugs must be totally excluded from such programs considering their potential consequences. Who can guarantee that this will be the case?

- **Additional weak points of power electronics**: inverters have a very low tolerance to over-currents, as low as 1.2 to 1.5 times their nominal current, while alternators can transiently withstand up to 5 or even 6 times their nominal current without damage. Thanks to this particularly useful property, they can remain coupled to the grid during fugitive short circuits, by far the most frequent, so that it is possible to resume production immediately after the failure has been rapidly corrected. This property is a major advantage for supply security whereas with disconnection, power would be lost for several minutes or even tens of minutes, the time it would take to reconnect to the grid.

Many other difficulties could be mentioned that it would be too lengthy to detail here, even if solutions to resolve or mitigate them are on the horizon. The examples given above are the most critical and they suffice to show that this is, indeed, a real technological shift.

- **<u>Summary of the dangers for supply security due to the technologies considered.</u>**

Summing up the discussion:

* With today's technology (network "formed" by alternators), the massive and uncontrolled development of wind and photovoltaic electricity, accompanied by a capacity reduction of dispatchable means at the European level, leads to two types of hazards:

- An inability to supply the continent with electricity during winter demand peaks in the event of a massive simultaneous lack of wind and sun potentially affecting several countries at the same time, rendering mutual assistance impossible. Such a situation will inevitably lead to widespread power outages as long as very large energy storage capacities are not available, whose currently estimated cost is very high,

- An increased instability of the European network due to insufficient dispatchable means, no longer able to provide sufficient inertia and power-frequency control to stabilize the grid. The sanction could be severe, such as more or less extensive blackouts.

* The new technologies being considered (grid "formed" by inverters equipped with this capability) to accommodate more variable electricity input do not improve the intrinsic security of supply compared to the current situation; on the contrary, they introduce many new weaknesses, not the least of which is cyber-vulnerability.

In-depth risk assessments to clarify the situation would be imperative before considering taking this route, given that the overall risk of a deterioration in supply security cannot be excluded in view of our current knowledge. Will citizens-consumers who have been accustomed to a very high level of supply security for a very long time be ready to accept power outages when the availability of electricity will be even more critical than it is today for our societies?

2 - An overall governance of the European electrical system without a true leader?

Given the growing interdependence of the electricity systems of European countries, whose grids are and will be increasingly interconnected, the continent's security of supply and therefore that of each member country will depend more and more on decisions made at the European level and not just by each country. This leads to a necessarily complex global governance. But is this realistic and rational today?

- **European organization and governance of the electricity sector: who does what?**

In succession, we find:

  - **The member countries**

They are responsible for their national power systems and can, in particular, choose their power mix, which falls under their sovereignty. Is this prerogative detrimental while some benevolent minds advocate an "electricity airbus"? The answer is clearly no, for two main reasons:

* An electricity mix is necessarily linked to the geographical specificities of each country and the diversity of its natural resources: hydraulicity and relief which have a major impact on hydropower production, fossil resources, wind regimes largely conditioned by Atlantic or continental influences, the latitude which conditions the amount of sunshine, the size of the country and of its population, etc. But it is also dependent on its human and cultural particularities which condition the greater or lesser acceptance of possible solutions. And from the perspective of electricity supply security, the diversity of mixes is not in itself a disadvantage but an asset. Provided it is organized in a rational and realistic way.

* The other reason is political: who can believe that all countries could agree on the same choice of electricity mix? Just consider the Franco-German pair example.

This is, however, what the European Commission and countries that inspire it (and others that blindly follow in imitation) are unfortunately trying to impose with the almost exclusive promotion of wind and photovoltaic power as a quasi-magical remedy to global warming.

- **The transmission system operators (TSOs)**

Transmission systems are the "backbone" of each country's power systems. They also ensure interconnections with neighboring countries. In each country, they are managed by one transmission system operator (TSO), exceptionally several, as in Germany, which has four for historical reasons, but one of which, Amprion, is responsible for balancing the entire German network by coordinating with the three other German TSOs and also with the TSOs of other European countries.

In France, the “Energy Code” (equivalent to a law) entrusts RTE with the responsibility of ensuring the safety, security and efficiency of the transmission system on all time scales, which includes:

* At all times balancing electricity flows on the national grid, and on exchanges with neighboring countries,

* Maintaining the transmission system, ensuring the connection of new producers and of new consumers as well as establishing new interconnections with neighboring countries,

* Regarding projections, studying and planning extensions to the national grid and its interconnections with neighboring countries so as to meet anticipated demand while taking in consideration the production means and electricity mix as they are defined by the public authorities.

The role of the TSOs, is central in terms of short- medium- and long- term security planning. But they are not the decision-makers, the States are. Security of supply can be ensured, then, only if the States fully build on the expertise of the TSOs.

- **The ENTSO-E (European Network of Transmission System Operators for Electricity)**

This organization was created in 2008 at the initiative of several European TSOs, notably RTE. It brings together 43 TSOs from 35 countries across Europe. Its mission is to harmonize the technical management rules of the European networks to improve their efficiency and the supply security. It is also charged with facilitating trade between countries via electricity market exchanges.

ENTSO-E thus gathers together the competence of all the member TSOs and provides an overall vision of the European grid and its observed evolutions. As such, it carries out cross-cutting security forecast studies for each member country, that it publishes every two years. In addition, it produces technical rules and standards to unify the best practices of member TSOs. However, like the TSOs, it has no decisional power regarding investments.

Finally, add to this the CORESO[2] Center established in Brussels, also created by several network operators, including RTE. Its mission is to continuously monitor the European network in real-time and to alert the various network operators to potential incidents or drifts.

All in all, this coherent organizational set-up at the level of the European continent has all the technical expertise needed to manage Europe's supply security in real time and to elaborate the necessary projections for the future. Its overall expertise is undoubtedly at the best world level. That said, things depend on how well the decision-makers put this expertise to use.

- **The institutions of the European Union**

As a reminder, they comprise three entities: the Council of the leaders of the different countries, which represents the Member States, the Parliament, which represents the European citizens, and the Commission, which represents the European interests: as the guardian of the treaties, it verifies the compliance of decisions with theses treaties.

2 CORESO - COoRdination of Electricity System Operators

It is at this tripartite level that the common policies of the different States are decided, in particular in terms of limiting GHG (Greenhouse Gas) emissions to mitigate global warming.

This is how the so-called "three twenty targets" for 2020 were adopted. They will not all be met by December 31, 2020...

More recently, the "Green Deal" proposed by the new Commission in late 2019 was adopted in January 2020 by the Parliament. The EU countries ratified it, except Poland.

This European governance, which holds power without always having the necessary expertise, remains strongly marked by ideology and consequently by irrationality. The outcome is, in particular, that the electricity supply security does not seem to be given the priority it deserves.

- **A global governance of the European power system that seems to be based more on "post-truth" and "magical thinking" than on rationality and facts.**

The current governance is producing a succession of perverse effects as follows:

* Though they are supposedly responsible for, hence free to choose, their own electricity mix, the member countries are being rashly pushed into developing almost exclusively wind and photovoltaic energy by the Commission, inspired as it is by the "green doxa" and anti-nuclear countries,

* The subsidies allocated to these energy sources, guaranteeing very comfortable and risk-free income for 15 to 20 years to their promoters along with other advantages such as priority access to the grid, attract investors massively while they get rid of dispatchable production means, which are however essential to ensure supply security but whose expenses for intermittency offsetting are not compensated,

* These advantages granted to wind and photovoltaic power in exemption of the common law, seriously destabilize the electricity markets so that any investments in dispatchable means of production, including hydropower, are now economically unprofitable. Yet, hydropower, because it is controllable, is the most valuable and useful source of renewable electricity,

* The logical consequence of this policy is an anticipated attrition of dispatchable means of any kind, including means such as nuclear power which do not emit any CO_2. This will eventually lead to an electricity deficit during episodes of lacking wind and sun, as already pointed out above, as long as Europe does not have sufficiently massive energy storage capacities.

The “vicious circle” is thus closed, but the institutions that exercise the power do not seem to be worried:

* The Commission locked as it is in its fundamentalist ideology of the perfect competition market (except for wind and photovoltaic: why, when these technologies have become mature?) has a purely legal approach. The currently dominant market, the "electricity energy" market, having shown its limits and myopia insofar as it is unable to provide the right signals essential to stimulate medium and long-term investments in dispatchable means, the Commission has had to settle for accepting palliative means. These range from reserve installed capacities which, in normal circumstances, are banned from the "electricity energy" market, as in Germany, to "power capacity" markets, as in France and other countries. But this is not enough; we must also add the "demand deferment" market, pending the "energy storage" market.

All these markets certainly multiply the number of supervisory Brussels civil servants, but not necessarily the availability of the GWs that will be needed to balance demand at all times, the crucial criterion in the presence of variable production. Indeed, these new markets are based on contractual commitments that are supposed to be implemented during critical periods. But, in France at least, they have so far proved unreliable since a large share of the commitments made have not been kept when needed... In any case, these measures are useful, but their contribution remains and should remain modest in the light of balancing needs.

* The Parliament has many inexperienced politicians, most of whom seem to be superbly ignorant of the laws of physics and to be massively fed with "green" illusions. Of course, they cannot be expected to be competent in all things. But as legislators they must be able to choose to listen to the holders of expertise (the IPCC[3], the Academies, etc. and primarily the TSOs and ENTSO-E) capable of providing them with validated scientific and technical information, as opposed to the fashionable gurus and merchants of illusions... or of fossil gas, to whom they seem to lend a complacent ear. Are all these Members of Parliament aware of the dangers that their policies represent for Europe's electricity supply security?

* The members of the Council are deeply divided between countries that do not want or no longer want nuclear power and are lobbying the Commission intensely to force their views on all the others, and countries that have nuclear power or want it because they rightly consider it to be an unavoidable means of decarbonizing their electricity production (such as Eastern European countries in particular) but are generally in the minority and have great difficulty in making their case, a quasi-taboo.

Is the meeting of the European Council of Member States held on December 11, 2020 a step forward? Certainly, it reaffirmed the right of each country to choose the technologies it considers the most appropriate to achieve its climate objectives, including nuclear power, while adding... gas, which has great chances to be predominantly fossil for a long time!

In summary, a shared overall view consistent with the climate objectives that, in a rational and realistic way, stays open to all available decarbonized electricity production means, does seem to emerge with great difficulty, nuclear power still being excluded from the “taxonomy” today. Yet, were these differences of opinion overcome, supply security could receive the attention it deserves.

- **The expertise is excellent but is not sufficiently taken into account by the decision-makers.**

As highlighted above, the TSOs and their joint organizations, ENTSO-E and the CORESO Center hold excellent expertise. But do the decision-makers take heed? One can doubt it when the alerts issued by some TSOs or utilities organizations have no effect on the orientations and decisions of the European institutions which, far from being reoriented, continue on the contrary to accelerate invariably in the same direction.

* We mention below several of these alerts (non-exhaustive list):

- In October 2018, 10 European electricity sector national associations from 10 European countries: Union Française de l'Electricité (France); Energy-UK (United Kingdom); Energie-Nederland (Netherlands); BDEW (Germany); VSE (Switzerland); E-Wirtschaft (Austria); FEBEG (Belgium) and similar organizations from the Czech Republic, Norway, Luxembourg, signed a joint declaration stating in particular:

The increasing share of electricity production from wind farms and solar panels with their random variations, has a growing influence on the means of production available and on the grid, which must be balanced at all times [...] It is already clear that in the changes underway among the Member States, special attention must be paid to the development of "firm" capacities, i.e. capacities that are ready for use and can produce on demand according to need [...] In the past, this compensation was ensured by largely sufficient dispatchable capacities. In several countries, the situation has changed, or is changing. There are also countries whose production will not be sufficient in the future.

3 IPCC - Intergovernmental Panel on Climate Change

- In April 2019, in a public declaration, RTE stated that *decisions by European governments to shut down power generation capacity without broader coordination with other European States could put the European power system at risk* because of the increasing dependence of the continent's countries *"on electricity imports from other European countries to meet shortfalls, especially during periods of high demand"*.

* These successive alerts are not the only ones and they are unambiguous. Have they been heard and taken into account by the Commission, the Parliament and the Member States? One can doubt it: there has been no inflection in the policy advocated by the Commission, which has not deviated an inch from the "all wind and photovoltaic" mantra. The new Commission put in place in 2019 has even given it an additional push, as if this option were the magic solution. Only very recently, in November 2020, the Commission announced a new ambition continuing along the same lines: to multiply the offshore wind capacity by 5 by 2030 to reach 60 GW and by... 25 by 2050 to reach 300 GW. At the same time, this same Commission is doing everything it can to exclude nuclear power from the “taxonomy”, thus placing a handicap on equitable financing opportunities for nuclear power.

- **Assessment: incoherence and magical thinking**

The global governance of the European electricity sector, then, is at stake given that three major objectives have to be addressed together: decarbonizing electricity; ensuring Europe's supply security at all times; providing electricity at a competitive cost. However, there is a fundamental inconsistency in seeking to decarbonize the electricity sector while doing without the most efficient means to do so, nuclear power. In addition, nuclear also plays a major role in the security of supply because it is dispatchable. It seems clear that the real intent is to exclude nuclear, despite official declarations.

Moreover, the current escalation in ever more ambitious targets for the reduction of global CO_2 emissions by 2030 (the Commission has raised the already ambitious 40% reduction target to 55%, a value endorsed by the Council on December 11, 2020, even if it is subject to a few conditions, while the Parliament wants to raise it to 60%, all this without any somewhat serious impact study) is an instance of magical thinking, not of responsible governance: how can we believe that just making the announcement would make it happen? This will result in announced failure, while running the risk of wasting large amounts of money for want of rational and realistic governance.

- **The case of France**

Unfortunately, France is tagging along behind this "green" doxa and its impractical illusions, clearly oriented towards eliminating nuclear power. The authorities in control since the presidential election of 2012 have pursued this orientation with the absurd shutdown of the Fessenheim power plant: 1,800 MW were shut off with the stroke of a pen in June 2020. There was little delay before the consequences on CO_2 emissions were felt (coal-fired power plants had to be re-ignited in July and even more so in September, an unprecedented situation). The Fessenheim shutdown will undermine the supply security during the 2020-2021 winter, and any later critical periods of high demand. All this to glean a few "green" votes.

Another absurdity: the imperious decision to reduce to 50% the contribution of nuclear power to the national production, with a justification so flimsy that it can be summed up with the popular phrase "*you don't put all your eggs in one basket*". Successive secretaries of the energy transition have used variations on this theme:

Yet it's common sense to consider that it's reasonable not to have such an unbalanced mix - 72% of our electricity comes from nuclear power. After Fukushima, it is obvious that we cannot totally depend on this technology (E. Borne, January 2020) and more recently *We must turn to other sources of electricity* (B. Pompili, November 2020).

- **A reduction to 50% of the contribution of nuclear power without rational justification, inconsistent with the reduction of CO_2 emissions and which de facto reduces the country's electricity supply security in the absence of storage capacity on a sufficient scale.**

* **No rational justification**: in truth, the ministerial declarations quoted above are a cover for the vacuity of the reflection on the subject and the absence of serious impact studies.

Even at the trivial level of "*eggs in one basket*", the comparison is irrelevant: there is not a single basket, but 18 different baskets (reactor sites) distributed over the entire national territory thus diversifying possible causes of shutdowns due to natural risks such as earthquakes and other events. In addition, three different power "tiers", built at different times, bring a complementary technical and construction diversity, even if their root design and operation is based on the same technologies.

In addition, more sophisticated arguments can be put forward. For example, as the economist Dominique Finon points out in a recent article [1]:

The case for diversifying the mix in order to limit the technological risks of nuclear power is questionable as there is no reference to probabilistic risk, nor to the increasingly rigorous precautions taken by the ASN[4], recognized as one of the most stringent in the world. No probabilistic reasoning will prove that an accident would be more likely with 70% nuclear in the mix than with 50%, or with 10%, for that matter.

Apart from an accident, could a generic anomaly bring the ASN to mandate the shutdown of a large number of reactors as a precautionary measure? Feedback from 40 years of operation accumulating more than 2,000 reactor-years shows that this possibility is extremely unlikely, since the rare technical problems of a generic nature encountered have never led to the shutdown of more than a few reactors at a time. Thanks to in-depth knowledge of the installations, it has been possible to schedule corrective actions without taking safety risks, with the full agreement of ASN.

Of course, the past is no absolute guarantee for the future, but the continuous progress of knowledge and the extremely thorough inspections carried out every 10 years give us an accurate picture of the state of the installations. Constant vigilance during operation complements these measures.

Finally, a major case in point, retaining a large number of reactors is the best way to have power reserves in case some reactors become unavailable.

* **Inconsistency with the climate objectives**: reducing nuclear production to replace it by intermittent means is totally irrelevant to achieving the CO_2 emissions reduction objectives that are otherwise highly touted. Indeed, while nuclear power operates continuously, onshore wind operates only 24% of the time and photovoltaic 13% of the time in full power equivalents and on national average. When there is neither wind nor sun, how are these intermittent sources offset? In Germany, mainly by fossil fuels with high CO_2 emissions (coal, lignite, gas). In France, by hydropower, a little by gas (but as it emits CO_2, it is destined to eventually disappear) and a lot by... nuclear, as soon as the variations to be offset are massive, because it is the only production means able to do so, as occurred at the end of April 2020. Reducing the contribution of nuclear, then, comes to not only keeping gas-fired plants in the mix but also to lastingly increasing their share thus damaging today's excellent CO_2 performance of French electricity production: this would be inconsistent with the SNBC[5] targets and the stated ambition to reach carbon neutrality in 2050.

4 ASN - Autorité de sûreté nucléaire - French Nuclear Safety Authority

5 SNBC - Stratégie nationale bas carbone - The National Low Carbon Strategy which delineates a road map for CO_2 emissions reduction.

* **A severe reduction of power supply security**: prematurely decommissioning by 2035, as planned in the PPE[6], twelve other 900 MW reactors in perfect working order, representing a total of nearly 11 GW, is the best way to seriously degrade the country's power supply security, e.g., on a cold winter day with no wind or sun, the cold making for large demand. As already pointed out based on RTE forecasts, there will be no significant additional energy storage capacity at that time. And this 11 GW reduction will be all the more critical that neighboring countries will be likely to experience the same weather conditions at the same time and can be relied on all the less since they are also preparing to gradually reduce their dispatchable capacities at that time (about 25 GW of nuclear power cumulated between Germany, Belgium, Spain and Switzerland and about 40 GW of coal and lignite in Germany alone). The risks of massive outages will therefore increase every winter as our reactors are shut down. Hence, they will probably not be shut down. Keeping them in operation will not be an option but an imperative necessity, unless they are massively replaced with gas-fired power plants, an absurdity for the climate.

* **In short**: replacing a significant part of nuclear capacity with a view to diversification would make sense if and only if it were done with means of production having the same overall qualities: no CO_2 emissions; dispatchable; flexible; not limited in power to ensure supply security during peak demand; economically competitive.

The fact is that there are, to date, no means that combine all of these essential qualities: the dispatchable renewable production means, namely hydropower and biomass, are limited: hydropower to small-scale extensions; biomass by its annual natural reconstitution. Additionally, using biomass in mobility and/or housing is much more relevant than for electricity generation where a significant loss of yield associated to the Carnot cycle is incurred.

Moreover, professing to diversify by building wind farms and photovoltaic panels, which occupy a lot of space, require rare materials, destroy landscapes, and provide intermittent electricity subject to weather conditions, is absurd as Dominique Finon points out in the aforementioned article [1]:

If there is a problem with security of supply, it is primarily because intermittent renewable energies are gaining a larger share in the electricity mix inducing the risk of a "black hole" during peak demand.

- **When RTE's forecasting studies are curtailed by the ministry**

As indicated above, the “Energy Code” legally entrusts RTE with the responsibility of ensuring the safety, security, and efficiency of the transmission system at all times. This includes drawing up short-, medium- and long- term forecasts. Since forecasting is by nature an uncertain art, it must be systematically supplemented with sensitivity studies to variants in the hypotheses made so as to identify the range of possibilities and the corresponding potential risks, that in turn, could inform more in-depth risk studies.

Yet, RTE is not free to formulate all the hypotheses that would be appropriate in its prospective studies: the Ministry of Energy Transition de facto forbids it to do so. Two examples:

* Electricity demand hypotheses in excess of the SNBC projections are limited to small amounts. It is apparently inconceivable to consider the consequences of a much larger demand! Likely reason: electricity production mixes with a very large proportion of wind farms and photovoltaic panels are economically viable only for limited production levels. Beyond that, indeed, the difficulties and costs explode. To avoid bringing this to light, the demand considered must remain below certain limits...

* Changing the hypotheses put forward in the PPE to assess their consequences also seems to be taboo. Yet, here, the risk is not small that a rapidly growing societal opposition to wind farms and

6 PPE - Programmations pluriannuelles de l'énergie - Multi-annual Energy Plan

ground-mounted photovoltaic panels will challenge the objectives. But any allusion to this possibility seems to be forbidden.

This attitude on the part of the ministry has a name: censorship - of best practices recognized and validated as scientifically mandatory in prospective studies. Back to the obscurantism of another age... in the 21st century?

- **A dramatically erroneous assessment of the relative risks**

Who hasn't heard, including from ministers, the statement: *We can't continue to leave nuclear waste for future generations*. This type of declaration, though meant as responsible and altruistic, is in fact an easy show of "good will".

* Indeed, this misrepresents the reality of the issue: nuclear waste is being produced since more than half a century in France, and not only by nuclear power plants, which are responsible for only 60% of the most active or very long-lived waste. Research, industry, the military and nuclear medicine produce the rest. So, in any case, there is a stockpile that must be treated and shutting down nuclear power plants tomorrow would not solve the problem. It would also be necessary to stop all other nuclear activities, including those that produce radioelements for nuclear medicine. A half-century's step backward. And send all nuclear physics books to be burned at the stake? Absurd and childish.

The more so as, contrary to what the "green" doxa would have us believe, there are rigorous and safe solutions for the disposal of all types of nuclear waste. For the most dangerous and/or long-lasting, deep geological disposal is already implemented in several countries whose sense of responsibility cannot be questioned. As Dominique Finon reminds us [1]:

On the issue of nuclear waste and its geological disposal, any informed observer cannot but note that, in some democratic countries (Sweden, Finland, Canada), definitive disposal solutions have been identified and recognized as safe and have been adopted after a peaceful debate.

In France, the CIGEO[7] project meets these criteria: it has been and continues to be the subject of extremely in-depth geological and safety studies, which are and will be validated by the ASN after advice from the IRSN[8] and other organizations. Its safety will thus be established beyond doubt.

* Those who want to stop nuclear power on the grounds that it produces waste ignore or pretend to ignore the fact that nuclear power, identified by the IPCC as one of the new technologies with a "*long-term massive emissions reduction potential*", is an indispensable component of the solution to global warming. Depriving ourselves of this potential clearly increases the risk of amplifying global warming. The real issue is thus to opt for one of two risks:

- Intensify the dramatic consequences of uncontrollable global warming: populations driven out of their territories by rising sea levels, elsewhere by worsening droughts and famines, leading to conflicts for access to space and water, massive migrations to the less affected countries that will profoundly destabilize their societies, etc., causing deaths and human tragedies in large numbers. This is likely to happen before the end of the century.

- The imaginary risk due to nuclear waste which are managed in compliance with strict standards but that, according to professional agitators spreading irrational fears, could be "rediscovered" in 1,000, 10,000 or 100,000 years 500 meters underground by our descendants, presumed to have returned to the Stone Age.

7 CIGEO - Centre industriel de stockage géologique - Industrial deep geological waste disposal facility - located in eastern France, a thick layer of clay where the plan is to store the waste 500m below the surface.

8 IRSN - Institut de radioprotection et de sûreté nucléaire - France's public service expert in nuclear and radiation risks.

Refusing to take this so-called risk, that will never cause casualties, is irresponsible, stupid or pertains to ideological manipulation; it does not protect future generations, who, sadly, have far more to fear from global warming.

3 - Risks of energy deprivation that go beyond occasional rolling power outages...

Exposure to rolling outages (with their limited consequences) and to a higher probability of generalized blackouts, whose consequences will be all the more devastating that decarbonized electricity should massively replace fossil fuels in all of our activities (housing, mobility, industry, etc.), is not the only risk. Another prospect associated to the "all-wind and photovoltaic" policy is a general and structural deprivation of energy for the entire economy since electricity will be its main vector.

Jean-Marc Jancovici, in particular, has abundantly demonstrated in his writings and lectures the major role that energy plays in our developed societies: it is the "lifeblood" of our economies without which we will be confronted to GDP downturns leading to societal upheavals that the average citizen cannot begin to imagine. Of course, we will have to improve the efficiency of our processes and to limit the use of energy through reasoned and reasonable sobriety efforts. But this will be far from sufficient, the need for adequate energy supply will remain as a strong requirement.

To limit this reduced access to energy without impacting the climate, the most efficient solution is, by far, to resort to nuclear power. European countries not imbued with the "green" doxa are well aware of this, for example:

* The Czech Republic. It produces 50% of its electricity from local lignite (a pollutant and high CO_2 emitter), 34% from nuclear power (6 reactors in operation) and the rest from renewable sources predominantly biomass and hydropower. This Central European country has little wind and sun so that the deployment of wind farms and photovoltaic panels (currently 3% of production) is not an option for the future. Moreover, it is much less wealthy than its German neighbor, it cannot afford the latter's extremely costly strategy. The only realistic and sustainable solution it has to decarbonize its electricity therefore lies in the development of more nuclear power, proposed by the government and supported by public opinion. But it is rightly concerned with the limitations on nuclear financing set up by Europe, notably by excluding nuclear power from the “taxonomy”,

* The Netherlands. They produce 78% of their electricity from fossil fuels (51% gas, 27% coal and some oil), 19% from renewable energies (13% wind and photovoltaic, 6% waste and biomass) and 3% from nuclear power (a single 510 MW reactor). But this densely populated country with a small surface area (more than 500 people/km^2 compared to less than 120 in France) is limited in the development of onshore wind power and photovoltaic electricity, which are extremely land intensive. Its seafront on which offshore wind development is possible will not be sufficient to decarbonize all its electricity without resorting to nuclear power, an option put forward by the government. In 2018, the party currently in charge proposed to build new nuclear power plants. A poll carried out at that time showed that 54% of the Dutch agreed, while only 35% were against.

* As for France, it seems to have forgotten the major advantages due to its nuclear power, the result of insightful strategic decisions made in the early 1970s to loosen its dependence on oil and increase the country's energy independence. This major advantage is still fully relevant today, since the strategic stocks of uranium present on the territory offer two years of autonomy (compared to three months for oil stocks...) which can be increased if necessary, to 7 to 8 years by reprocessing depleted uranium stocks at constant technology! And up to 500 times more with Generation IV reactors.

Subsequently, the climate imperative gave new and essential legitimacy to the nuclear option, making France the major electricity-intensive country whose electricity sector is by far the world's lowest CO_2 emitter. This has averted huge CO_2 emissions for the past 40 years.

It is these two major assets that irresponsible or unconscionable ideologues want to ruin or weaken. Yet, they do not have alternative reliable decarbonized solutions that guarantee the supply security and are economically sustainable. This for the sake of the "all-renewable" and the "all-market" deemed to magically solve all problems. This folly was condemned by Hervé Machenaud in his book *La France dans le noir* [2]:

Should we dismantle the tracks behind the train when we do not know where it leads?

How can a country's energy future be planned so lightly? Everything suggests that this consists in a massive degrowth project that does not say its name, is deadly and is of totalitarian nature (the citizens are carefully kept uninformed). Insufficient electricity supply leading to rationing and recurrent outages is incompatible with a developed economy and would result in human, societal and social disasters if it were implemented, with massive job destruction, health care regression for lack of funding capabilities, etc. ending up in population uprisings. The only way out of such a situation would then be the urgent and massive construction of gas-powered facilities, as this would be the cheapest and fastest option. The climate urgency would then be nothing more than a vain remembrance...

Moreover, in the current PPE, the plan is to decommission twelve perfectly operational 900 MW reactors which ensure supply security for the electricity system and produce the most competitive electricity on the market. Some of them could continue to operate 10, 20 or 30 years longer (similarly to the US reactors akin to ours, most of which have obtained the extension of their operating life up to 60 years while several are now being extended up to 80 years). These reactor shutdowns would represent a waste of several tens of billions of euros based on the loss of income accumulated over 20 years following the political shutdown of the Fessenheim power plant. A waste so shameless that it should not even be considered in a country that will be drowning in debt as a result of the health crisis: more than 122% of the GDP forecast to date in 2021, i.e., nearly 3,000 billion euros.

All the more so since, according to a very serious estimate by the Energy Pool company [3], if fully implemented, the PPE would cost the country an additional 127 billion euros with no significant benefit on CO_2 emissions whereas this sum would enable the renovation of 3.6 million older homes at a rate of 35,000 euros per home! With a major effect on CO_2 emissions reduction.

This waste based on ineffective and ruinous ideological decisions must cease urgently, as the country's citizens-tax-payers-consumers can less than ever afford it. Nothing less than the energy future, hence the very future of the country, depends on it.

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