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# Defining and quantifying intermittency in the power sector

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**Supplementary Materials_**

For the clarity of this paper, we discuss why current tools are unfit to measure intermittency in this section. We will argue using various examples from the French electric production and consumption over 2018. As in the previous sections, we use the data provided by RTE for the half-hour averaged productions in 2018 [20], and will display all four sectors following the same color-coding (blue: consumption; red: nuclear; green: wind; yellow: PV), as well as the hydroelectric power production (lock and run-of-the-river dams) in purple.

Load duration curves (Figure S1) show which power is available for any fraction of time. It corresponds simply to sorting time series from highest to lowest value: the highest value is happens only once a year, while the time series is above its lowest value 100% of the time. Load duration curves thus show the maximal and minimal production, and give a notion of how the series distributes between these extrema. For instance, the PV production is null approximately half of the time, as expected, while the nuclear sector notably never produces less than half of its maximal capacity. Still, this cannot reveal how quickly and strongly these sources vary over time. A source varying daily between 50 and 100% of its maximal capacity would surely be unstable and uneasy to use to meet the consumption, while yielding the same load duration curve as the nuclear sector. Alternatively, a source producing its maximal output on January 1st and decreasing almost linearly to no production mid-year would be very stable, loosing daily only about 0.5% of its maximal output; its load duration curve would mimic very closely the solar one. In fact, due to the lack of dynamical information, one cannot determine which production proves more stable and which one varies more importantly, whether within an hour, a week or a few months.

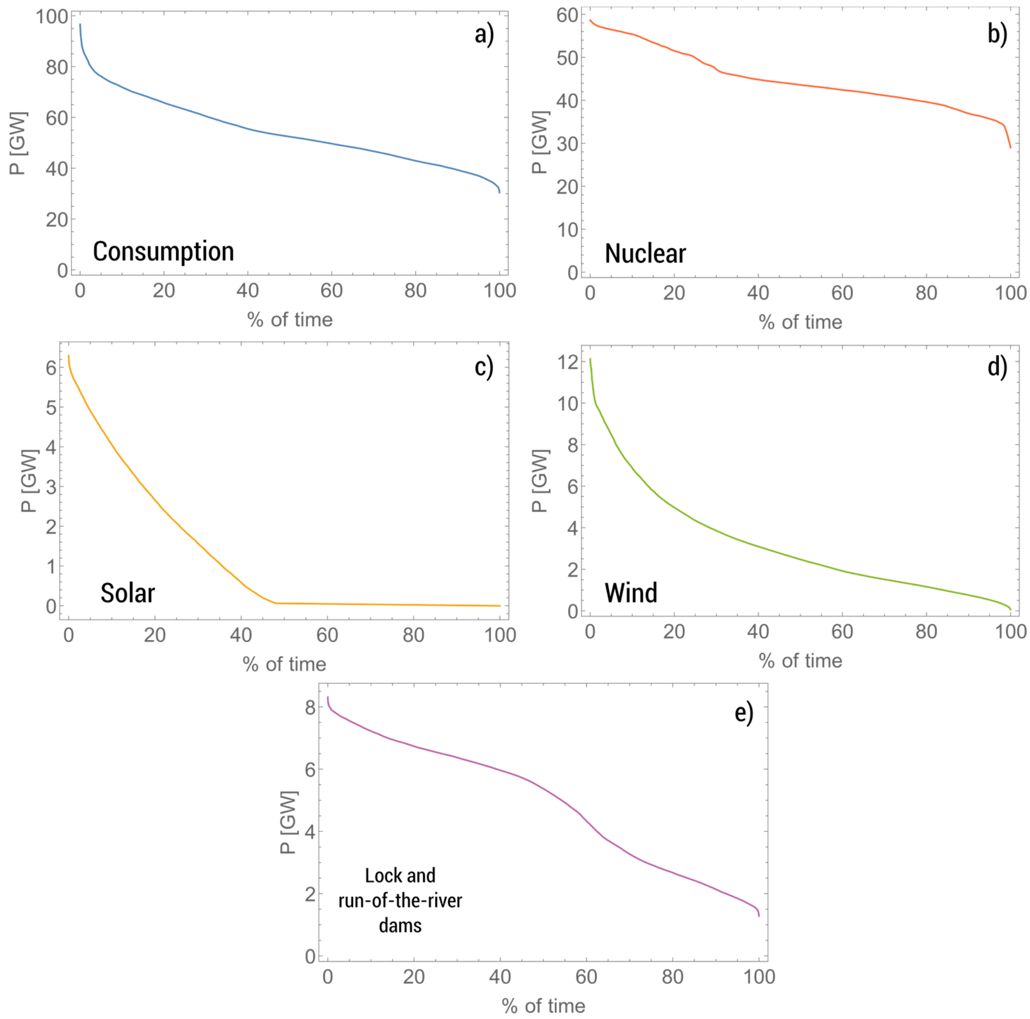


**Figure S1.** Load duration curve of the electric consumption (a) and electric productions (nuclear (b), Photovoltaic (c), Wind (d) and Lock and run-of-river hydroelectric (e)) in France over 2018, showing how often (in %) a given power is called or made available by such production sector.

As one would look for a more dynamic measure, the autocorrelation function is interesting as it displays a direct comparison between two instantaneous powers, as shown in Figure S2. One can note the 24h-long pattern of the consumption, related to the daily cycles of our lives, as well as on the solar PV production, foreseeably. Identically, consumption and nuclear production display a local maximum for $\Delta t = 7$day due to repetitive behaviours exactly a week apart (recalling that, the nuclear sector being dispatchable, its production is partly following the power consumption). Two scales can be considered: the short term (daily) variations and the mid-term (weekly) trends, except for nuclear and wind productions, whose daily cycles amplitudes are small compared to the weekly trends. These different behaviours make it very difficult to compare the intermittency of wind and solar PV productions, or of nuclear production and consumption, using only the autocorrelation function.

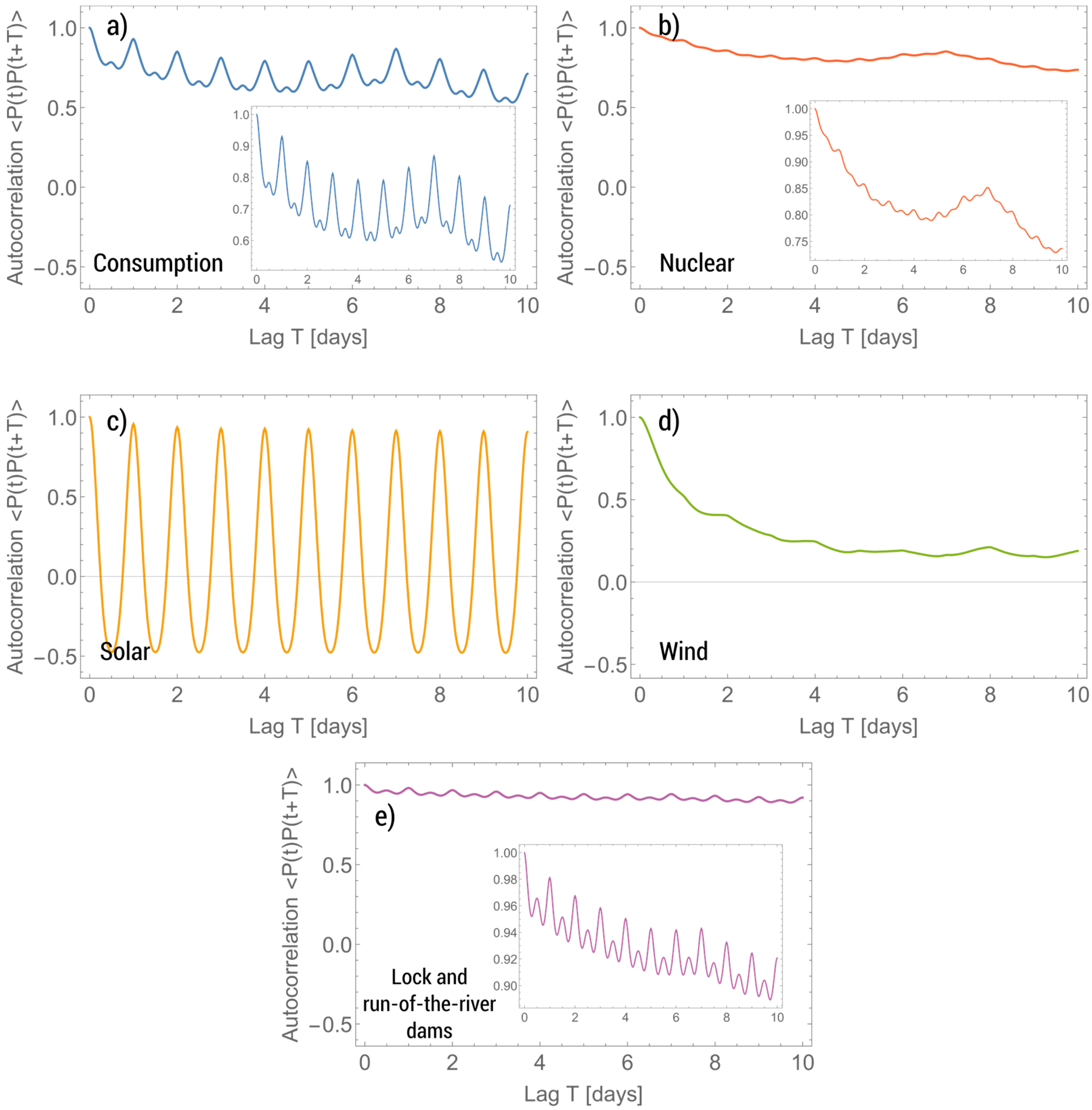


**Figure S2.** Autocorrelation function of the electric consumption (a) and electric productions (nuclear (b), Photovoltaic (c), Wind (d) and Lock and run-of-river hydroelectric (e)) in France over 2018. The autocorrelation function $A(T)$ at any lag T is defined as $A(T) = \frac{1}{A(0)}\int (P(t+T) - \langle P\rangle)(P(t) - \langle P\rangle)dt$, here displayed for $0 \leq T \leq 10$ day.

Alternatively, the Fast Fourier Transform (FFT), given in Figure S3, yield a different dynamical analysis of these power demand and supply. This indicator provides a wealth of information, highlighting notably the daily period of all cycles. However, the interpretation in terms of intermittency is ambiguous. It is not straightforward to read from this indicator how wide are fluctuations from one moment to the next one, or how the amplitude of these excursions depend on the interval between these two moments, or whether it happens that the time series drops suddenly to quasi-extinction. A qualitative analysis can be provided by the relative amplitude of the constant contribution, which gives some insight on the typical value around which oscillations take place. However, despite the similar constant contributions of the consumption and wind production FFTs, it makes no doubt their variations are very different. Conversely, it is very difficult to compare the intermittency of wind and solar based on their FFTs, as one shows a small offset and very few peaks, while the other one features with a large offset but much broader peaks.

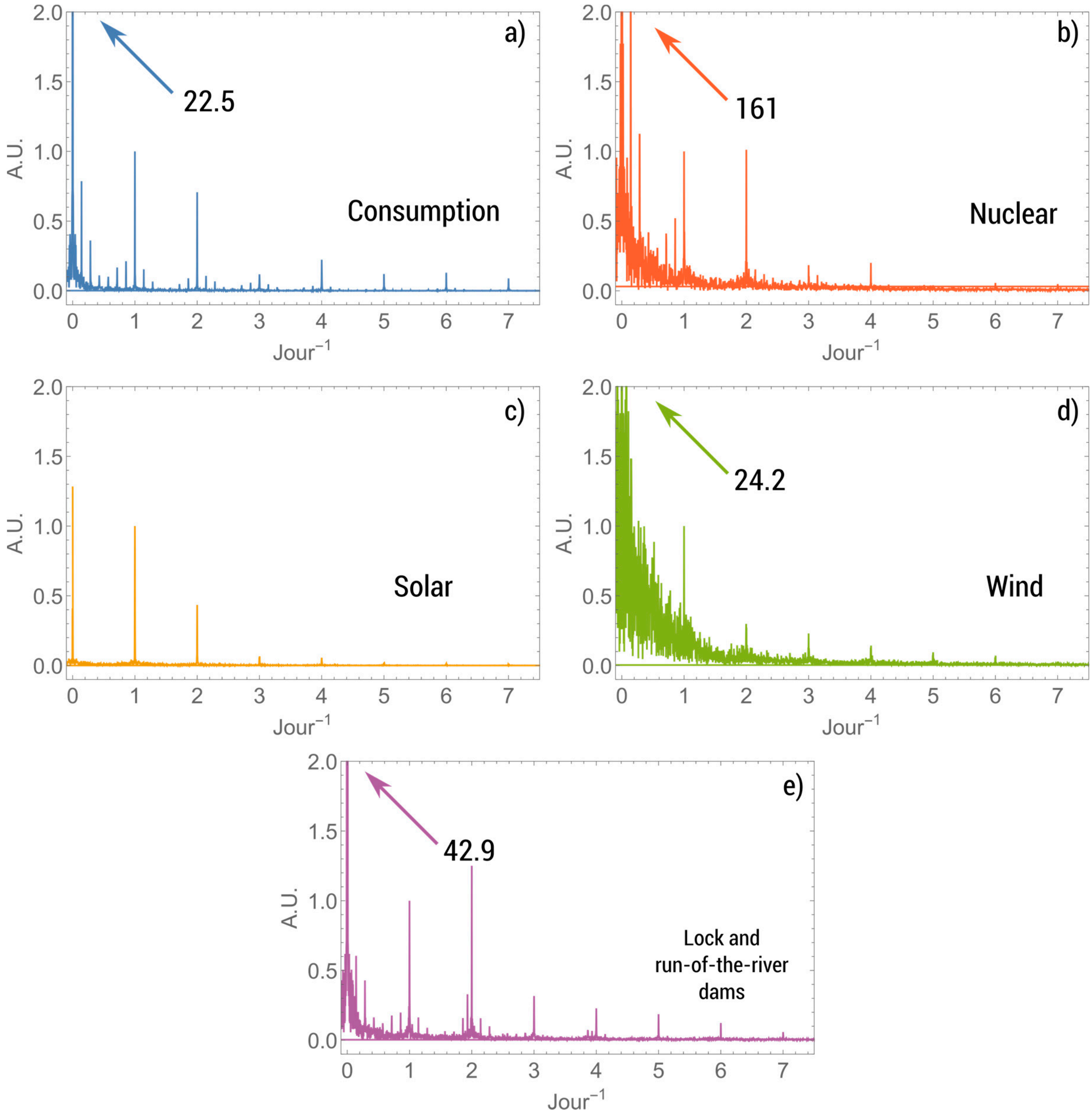


**Figure S3.** Fast Fourier Transform (FFT) of the electric consumption (a) and electric productions (nuclear (b), Photovoltaic (c), Wind (d) and Lock and run-of-river hydroelectric (e)) in France over 2018.

In conclusion, none of the aforementioned tools checks the necessary criteria to devise a proper intermittency measure, including being generic to all sources as well as consumption, containing some dynamical data, and allowing to unambiguously compare each stream at all necessary timescale. This confirms the need for developing a new, specific tool.