ENERGIAKLUB
CLIMATE POLICY INSTITUTE
APPLIED COMMUNICATIONS

SHORT STUDY

The combined use of wind and solar energy in Hungary

For any energy system, it is true to say that its average stability and resilience increases with the number of resources used. The stability of Hungary's energy supply is enhanced by the diversification of resources, especially when we talk about domestic and freely available resources such as solar, wind, geothermal or biomass/biogas.

For weather-dependent renewable energy sources, such as solar and wind, the basic assumption of system stability is also true; the coexistence of two hectically operating/producing systems reduces the number and magnitude of extremes, balances fluctuations and results in a more predictable system, as well as simpler and more cost-effective regulation.

In order to compare parallel production and seasonality, the utilisation of Hungarian solar and wind power plants was examined for a five-year period (2015-2019). The input data were based on daily production data by MAVIR, the Hungarian Transmission Operator. Figure 1 shows the monthly breakdown of solar and wind utilisation rates.

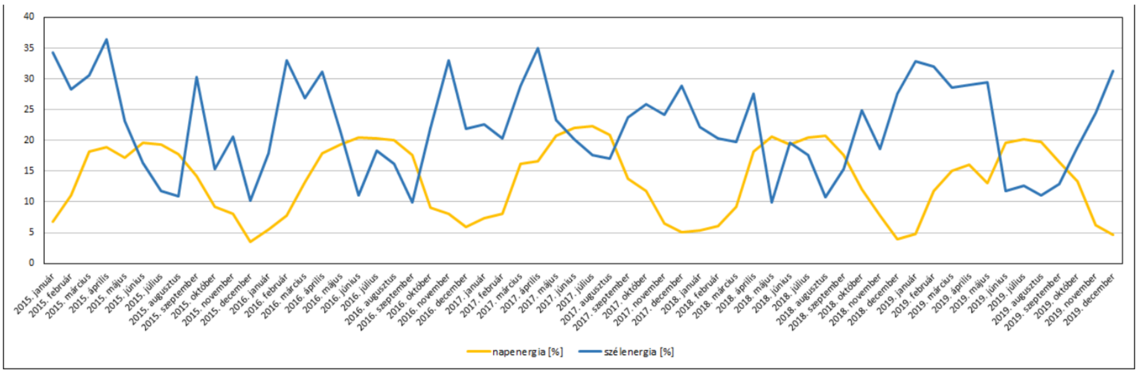

Figure 1: Solar (yellow) and wind (blue) production in Hungary in the period 2015-2019, based on daily production data, broken down by month. The vertical axis shows the capacity factor, which indicates the percentage of the maximum output that power plants can produce at their nameplate capacity (on average over the time period).

<u>General findings</u>

- Wind farms operate at a higher capacity utilisation rate than solar farms, i.e. wind farms produce more energy per year for the same installed capacity.
- Wind farms typically provide more electricity in the winter half of the year, compared to the spring-summer peak for solar farms.
- The monthly sums of the solar and wind utilisation rates show less variation than the monthly values for the two energy sources separately.
- The annual variability of wind power utilisation for a given month (e.g. December) is higher than for solar power.

The average daily capacity factor (utilisation) of solar parks in the summer is typically 15-20%, while in the winter it is 5-10%. For wind farms, the winter period is the most favourable, with an average daily capacity factor of 20-30% (but daily capacity factors above 70% are also common), while in summer they typically reach 15% (occasionally up to 40%). The annual capacity factor for Hungarian solar farms is around 14%, while for wind farms it is around 22%.

From November to April, the monthly average wind energy production is much higher than in summer. The combined peak of solar and wind power is expected in March and April, when wind power is still producing above average, while solar panels are also producing exceptionally well thanks to the many hours of sunshine and lower air temperatures, which are important for efficiency.

During the months of November-December-January, the low number of hours of sunshine and the lowest angle of incidence result in solar power production being significantly below the annual average. This shortfall is significantly offset by above-average production from wind farms.

Another problem for solar power plants is that their production is limited to the daytime and they cannot cover peak electricity consumption in the evening. Wind farms can also act as a balancing complement to solar farms in the system in the event of daily fluctuations, as illustrated in Figure 2. Also looking at the 2015-2019 period, it is clear that wind generation at night is slightly, but statistically significantly, higher than during the day: in some years (2017, 2019) by only a few percent, in other years (2015, 2018) by more than 10%.

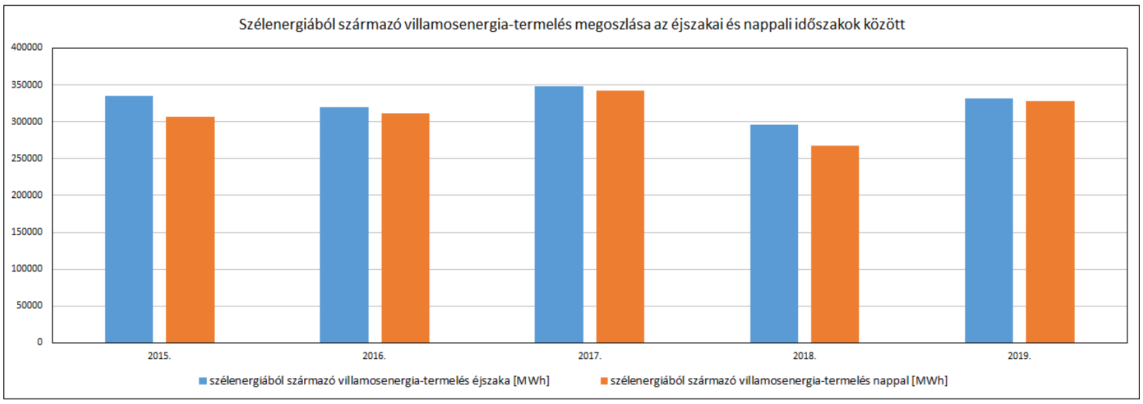

Figure 2: Distribution of wind power generation between night (blue bars) and day (orange bars) for the total wind power fleet in Hungary, by year, between 2015-2019.

In addition to the positive effects on the national grid, individual power plants were also examined. Figure 3 shows the 15-year energy production of the wind power plant in Kulcs, broken down by month. It is striking that the higher production values in the winter months are not only typical for the overall wind fleet but also for individual plants. The figure clearly shows a windier period from roughly November to April, which can also be considered climatologically plausible due to the long measurement period (15 years).

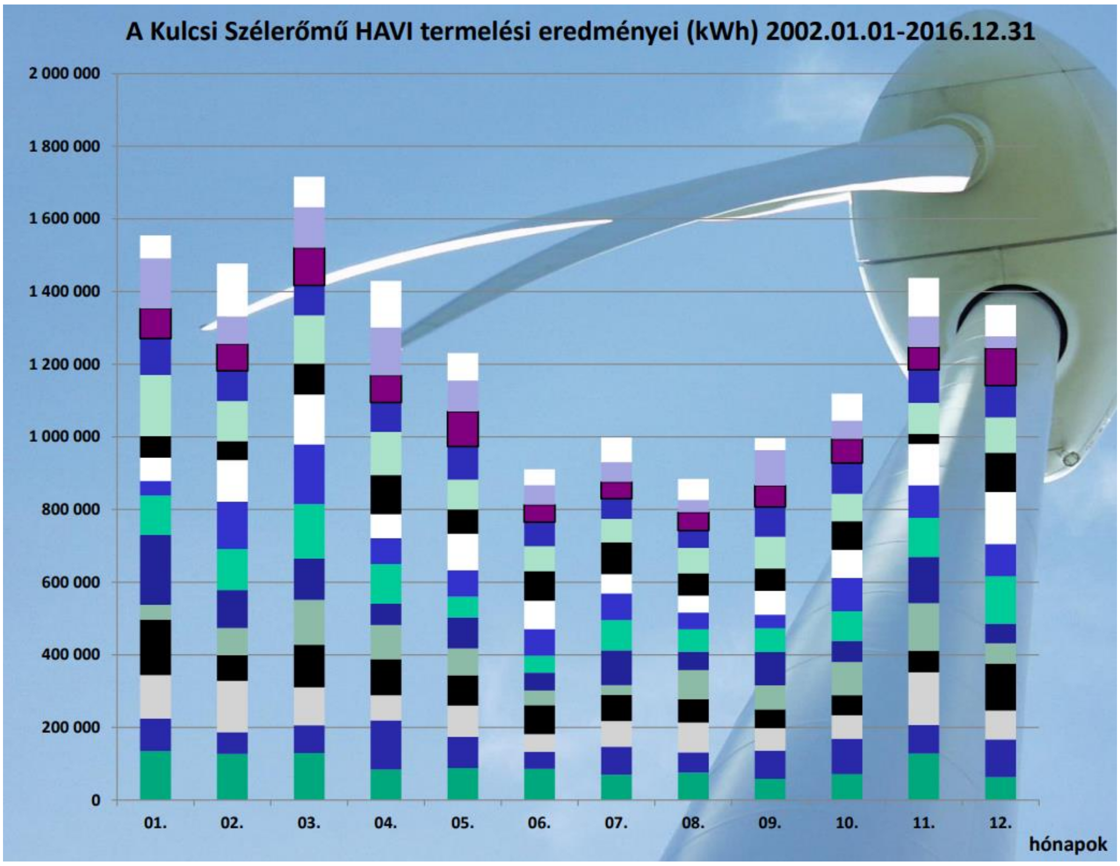

Figure 3: Monthly production data of the wind power plant in Kulcs, Hungary, between 2002-2016 (x=months, y=kWh)

In addition to resource diversification, i.e. the use of several types of renewable energy, territorial diversification also reduces the use of balancing capacity and the cost of balancing energy. For example, in the autumn of 2022, there were several days when only the Great Plain had areas with sufficient wind speed to start a wind farm. However, currently there are only a few small wind farms in the Great Plain (Erk, Mezőtúr, Törökszentmiklós), which were unable to produce due to lower turbine heights and therefore 0 MW of the national wind capacity was in operation on these days (or hours).

In the case of solar and wind energy, the spatial variability is especially prominent on a European scale. Fluctuating production, peaks and troughs can be tackled by balancing at international level, by building more cross-border capacity. The same can be done more easily within Hungary through the national grid. Although Hungary is not that large with its 93,000 square kilometres, there are sometimes significantly different weather conditions on the same day or at the same hour in different parts of the country. This is particularly true for wind. If the spatial distribution of power plants is more even, seasonal and spatial weather variations (cloudy and sunny, windy and calm) are evened out more and the frequency of periods when no wind power plant is producing is reduced.

The average wind speeds in the Great Plain are also suitable for the economic exploitation of wind energy (5-8 m/s on average at an altitude of 150 m, while modern power plants produce from 3 m/s), therefore there is no obstacle to territorial diversification. The higher turbine height and rotor diameter (140 m on average) of today's modern power plants significantly increases their utilisation (capacity factor) due to the higher average wind speeds at this altitude.

Since a new type of wind power plant would be able to produce twice as much energy as a solar power plant with the same installed capacity and the same geographic and climatic conditions in Hungary, we could get roughly the same amount of energy from the sun and wind if we had 2000 MW of wind power in addition to the current 4000 MW of solar power. To ensure balance and stability, it is advisable to add at least half as much wind capacity to solar capacity in Hungary. In the future, expansion should be implemented in parallel, step by step, for solar and wind.

Many countries in Europe and beyond are investing heavily in the combined use of weather-dependent renewable energies, and hybrid power plants are being installed in many places. Examples include Europe's first hybrid wind and solar project, Parc Cynog in the UK, EDPR's first projects in Spain (Lomillas, Cuenca) and BayWa r.e.'s project near Bayreuth.

The combined installation of solar and wind power is a cost-effective and efficient alternative not only nationally, but also locally. Co-location can save some of the investment costs of grid connections as well as land use and other permits. In an Australian hybrid project, 20% of the costs were saved by co-locating wind and solar plants.[1]

It is also important to note that the combined use of solar and wind power can also be the basis for the economical application of hydrogen technology in Hungary. According to the results of the RePowerEU country report on hydrogen carried out by Energiaklub, only green hydrogen can be a viable alternative in Hungary, and it can only be economical if produced by a combination of solar and wind power.

Solar and wind energy at local level – the example of Pfaffenhofen

The combined use of solar and wind energy should be examined not only at national energy supply level, but also at local, municipal and community level. This provides information on how a solar and a wind power plant at a given location (spatially close together) produce electricity during the year and also shows how production from different renewable sources can supports the self-sufficiency of a community, municipality or sub-region.

Since no local time-parallel wind and solar data series were available in Hungary, the small town of Pfaffenhofen in Bavaria was chosen as a sample area.

The choice was based on several criteria: on the one hand, the entire energy supply (power plants and electricity network) of the German town is owned by the municipality, which enables uniform data collection and, on the other hand, Energiaklub has established a close professional cooperation with the experts of the municipal company operating the energy system in an EU project, which provided the professional framework for data collection.

In the sample site in Pfaffenhofen, German colleagues provided many years of data on the energy production of the community-owned Lustholz wind farm and a solar PV system in a large car park, also community-owned. The wind power plant has a capacity of 3 MW and the solar plant 382.5 MW. Production data were available from January 2017 to October 2022 for the wind plant and from January 2014 to October 2022 for the solar system.

The production curve of Lustholz wind farm varied monthly and annually as follows:

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[1] https://www.scientificamerican.com/article/wind-and-solar-are-better-together/

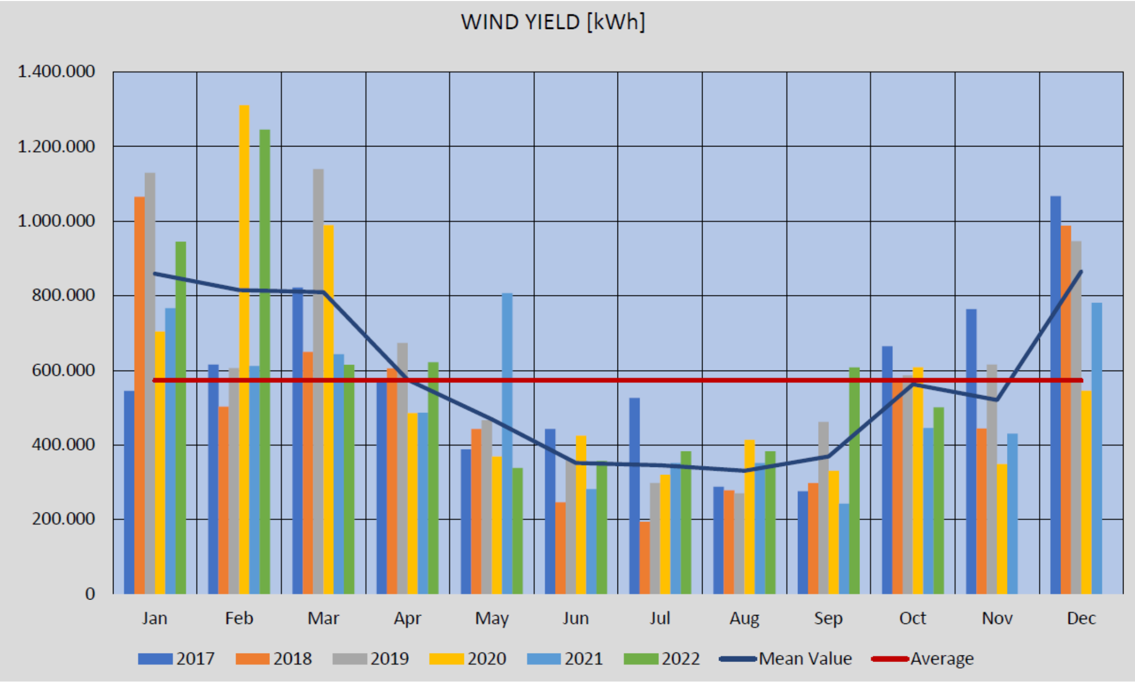

Figure 4: Monthly energy production data for Lustholz wind farm in Pfaffenhofen, Germany, 2017-2022 (x=months, y=kWh) blue line=monthly av., red line= av. Production (Source: Bürger-Energie-Genossenschaft im Landkreis Pfaffenhofen a.d.Ilm e.G.)

The production data of Lustholz wind power plant is conspicuously similar to the monthly production figures of the Kulcs plant; low yield in the summer months and high yield from December to March. For some months, there can be large fluctuations from year to year; for example, there were two years when February production exceeded 1200 MWh, while in other years it was around 600 MWh. Therefore, long data series provide a much more reliable source for calculating average expected yields.

Over the 6-year interval, the wind farm operated at an average utilisation rate (capacity factor) of 26%, which is significantly higher than the German and EU averages. This is mainly due to technological progress (it is a new power plant), not to the region's outstanding wind conditions.

Figure 5 shows the data for the Pfaffenhofen solar power plant for the period 2014-2022. The monthly production data form a typical Gaussian curve, with peaks in summer and low production in winter months, at about one fifth of summer values. The annual variation for a given month is much smaller in percentage terms for solar than for wind.

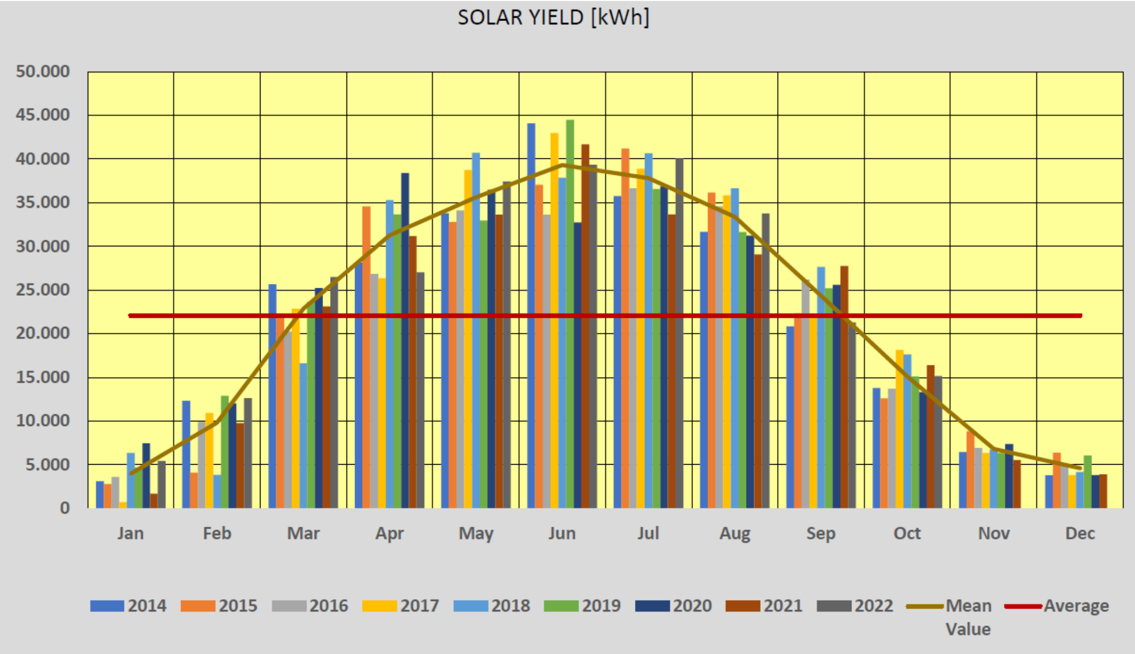

Figure 5: Monthly production data for the solar car park in Pfaffenhofen, 2014-2022 (x=months, y=kWh) brown line=monthly av., red line=av. Production (Source: Bürger-Energie-Genossenschaft im Landkreis Pfaffenhofen a.d.Ilm e.G.)

We also have data on the monthly share of the solar and wind power plants in Pfaffenhofen in proportion to their total annual production. This also makes it possible to compare the production of wind, and a solar power plant which would each produce exactly the same amount of energy in a year. We can examine what proportion of the monthly production would be generated by a wind farm and what proportion by a solar farm under certain climatic conditions, if their total annual production would otherwise be the same. This is illustrated in Figure 6 (the blue bars show what percentage of total annual production a wind plant would deliver in a given month, the yellow bars indicate the same for a solar plant.)

The data show that the spring-summer period is very well balanced, i.e. the sum of the monthly amounts of solar and wind power is almost constant. This can drastically reduce the amount of balancing energy needed. In addition, the winter and autumn months (except for November) are capable of producing roughly 70% of the total monthly production in spring and summer, which is a very good ratio. This also offers a partial alternative to the problem of seasonal energy storage.

Based on data from Pfaffenhofen (similar to the experience in Hungary), November is the most critical month, when both wind and solar generation are relatively low. The amount is roughly half of the monthly averages in spring and summer.

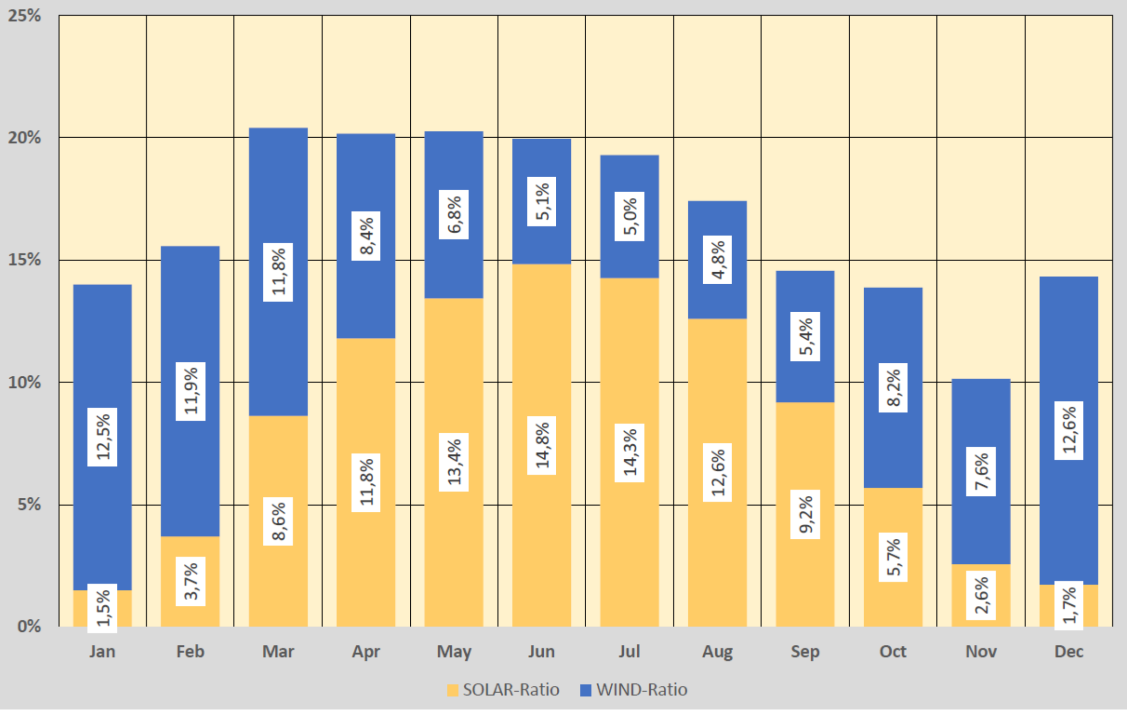

Figure 6: The percentage of the annual production of the solar (yellow) and wind (blue) power plants in Pfaffenhofen in a given month (Source: Bürger-Energie-Genossenschaft im Landkreis Pfaffenhofen a.d.Ilm e.G.)

Wind and solar power plants installed in close proximity to each other, as in Pfaffenhofen, significantly balance each other's production for most of the year. This makes balancing the (local) grid considerably easier and cheaper. Furthermore, combined solar and wind power in local energy grids that can be disconnected from the grid and operated independently can also help to reduce battery costs.

Figure 7 shows the 2021 municipal electricity consumption data for Pfaffenhofen alongside the wind and solar generation targets for the city for 2024. These will be achieved after the construction of three additional wind turbines for the "Citizen Wind Park" and their commissioning in 2024. By then, wind and solar alone will be able to meet 70% of the electricity demand in the municipality. Local hydro, biogas and biomass power plants will further increase this figure, approaching 100% self-sufficiency in terms of electricity consumption.

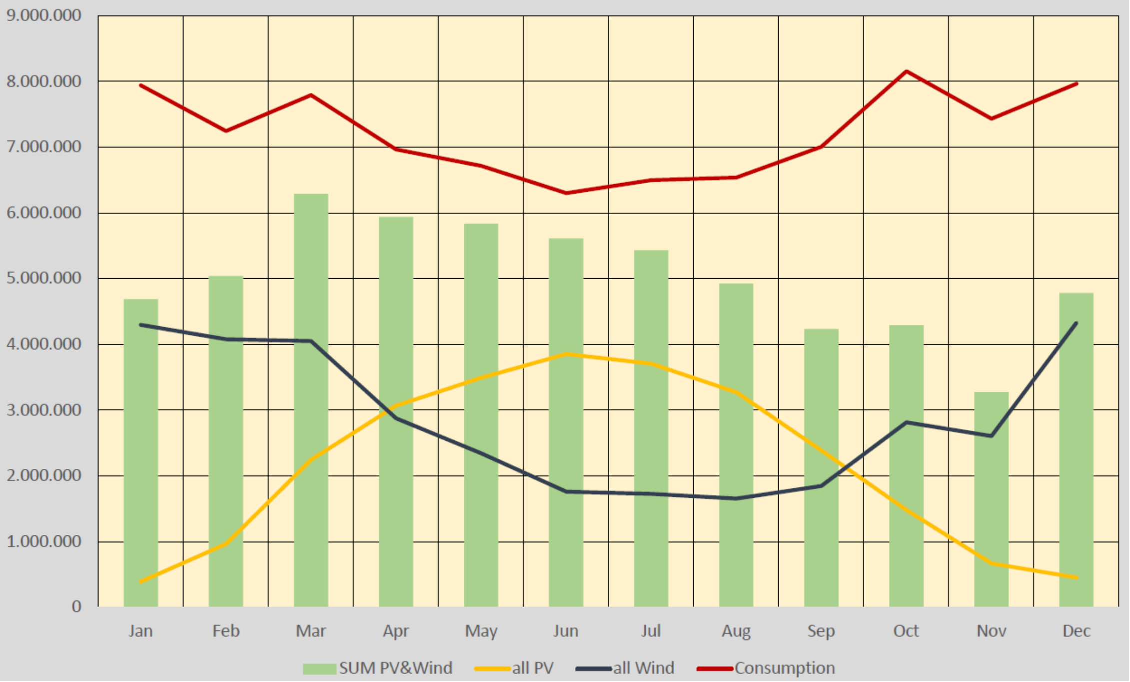

Figure 7: Calculated monthly solar (yellow) and wind (black) generation for 2024 in Pfaffenhofen and their sum (green bars) and electricity demand in 2021 (red). (Source: Bürger-Energie-Genossenschaft im Landkreis Pfaffenhofen a.d.Ilm e.G.)

In order to put the potential of the combined (and economical) use of solar and wind energy into context, based on the German experience, we have examined the climatic conditions in Pfaffenhofen. According to the online European Wind Atlas database, the wind power density in the city area is 330 W/m^2 at an altitude of 150 m. Similar values are found in the Hungarian Great Plain. For example, the wind power potential in the area of Törökszentmiklós, where a wind farm was built in 2006, is similar to the above at around 330 W/m^2, at a height of 150 m. The difference between the two municipalities is that while Pfaffenhofen has about 1700 hours of sunshine per year[2], Törökszentmiklós has around 2200, based on data from the last decade.

Conclusion

In most of Hungary, the climatic conditions for wind and solar are similar or better than in a small German town, which relies mainly on the combined local use of solar and wind energy to aim for total self-sufficiency. By boosting wind power significantly in the country, bringing it into line with solar power (installation of 500 MW of wind power for every 1000 MW of solar), we can take a big step towards balancing the fluctuating weather-dependent generation, reducing the costs of balancing and achieving self-sufficiency based on clean, renewable energy.

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[2] https://www.currentresults.com/Weather/Europe/Cities/sunshine-annual-average.php