



RENEWABLE ENERGY SOURCE PLANNING WITH REGIONAL DATA

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- Deployment of RES is expected to increase in the next years
- Energy storage is a promising strategy, but technological and economic sustainability are still debated
- Risks related to the returns and intermittency of wind and PV generators
- As the need for larger share of renewable electricity penetration becomes more pressing, it is necessary to carefully manage intermittency.

Start by taking care of the issues from the very beginning:

- **Reduce fluctuation from renewable intermittent sources** by carefully planning the deployment of RES at regional level
- How to manage the **risk**?
- Is there an **optimal regional configuration**?

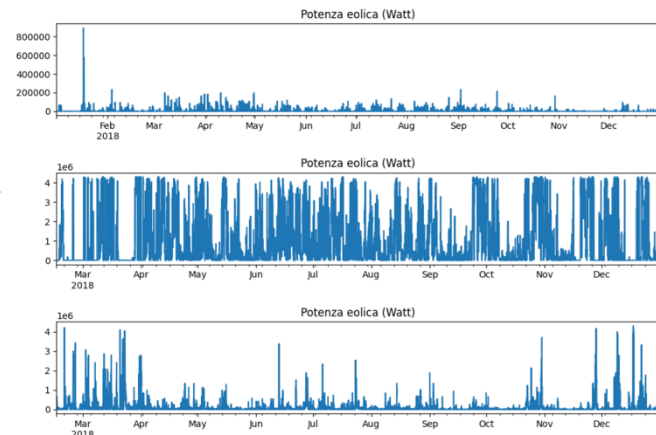
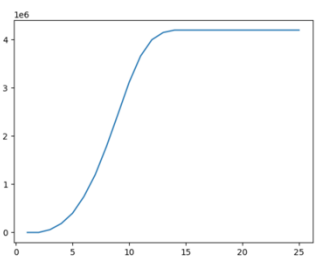
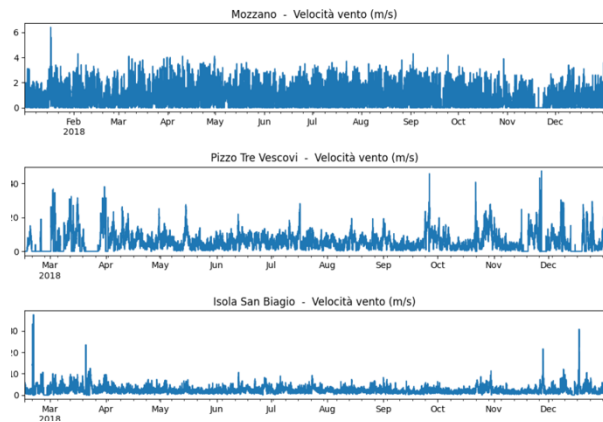
- From the operator side
- From the Transmission System side
- Minimise the risk (fluctuation) while increasing the profit (generation).
- Borrow methods from finance
- Network Science
- Markowitz

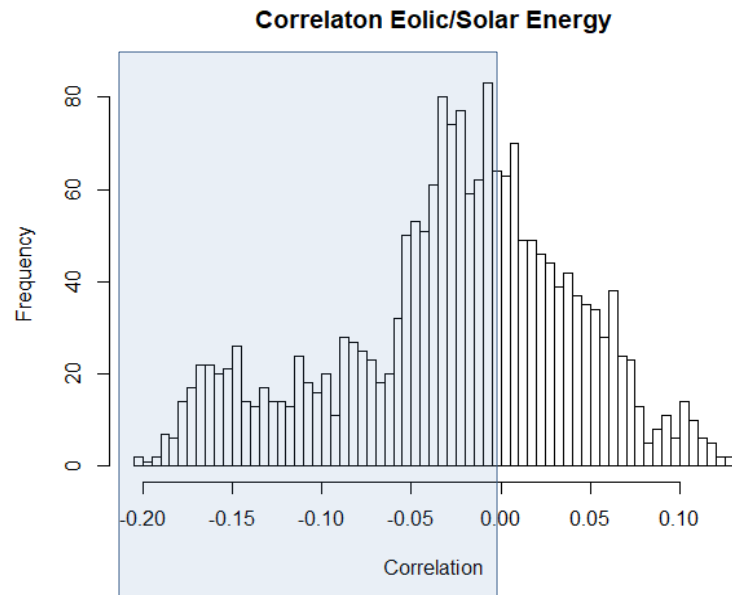
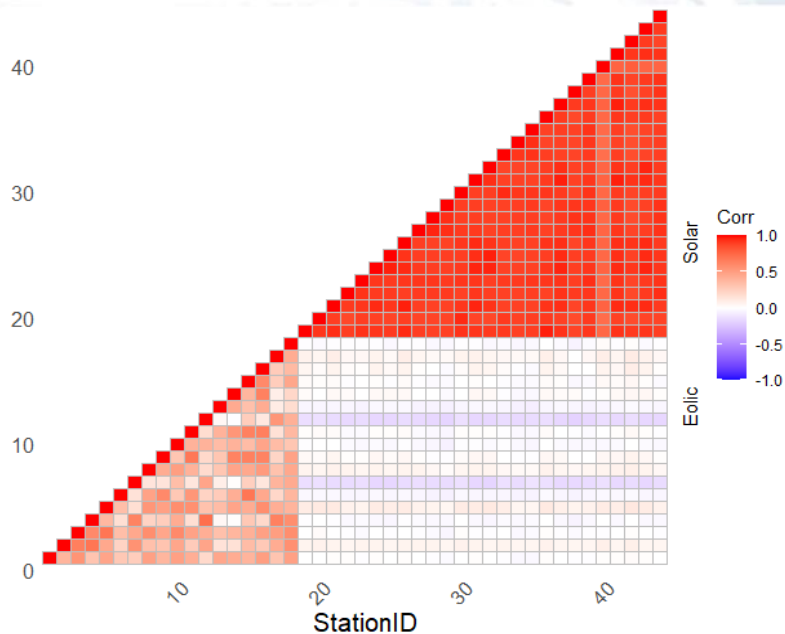
Optimality condition: global fluctuation is minimised while maximising the average production over the time span of one year.

- Location matters
- Use accurate generation profiles
- Investigate spatial and temporal correlations
- but...

How to compute accurate generation profiles?

Use weather data and accurate models of PV and Wind generators





A. Scala, A. Facchini, U. Perna, R. Basosi, Portfolio analysis and geographical allocation of renewable sources: A stochastic approach, *Energy Policy*. 125 (2019) 154–159

F. Surmonte, U. Perna, A. Scala, A. Rubino, A. Facchini. A Data-driven approach to renewable energy source planning at regional level, *Energy Sources, Part B Econ. Planning, Policy*. 00 (2021) 1–12.

Total Load

From: **07/09/2023** To: **07/09/2023**

Last update: 07/09/2023 07:45



Actual / Forecast load per bidding-zone [GWh]

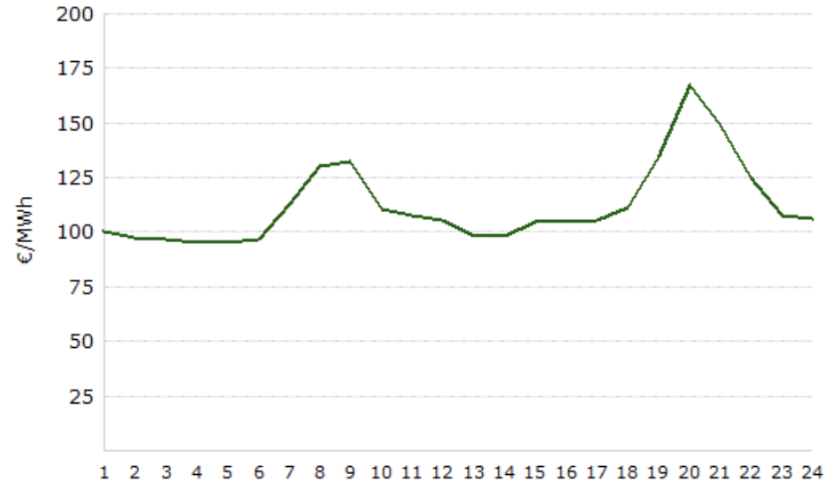
Source: terna.it

Actual / Forecast load per bidding-zone [GWh]

North	145.9	
Centre-South	39.8	
Centre-North	21.8	
South	19.3	
Sicily	15.1	
Sardinia	7.4	
Calabria	4.9	

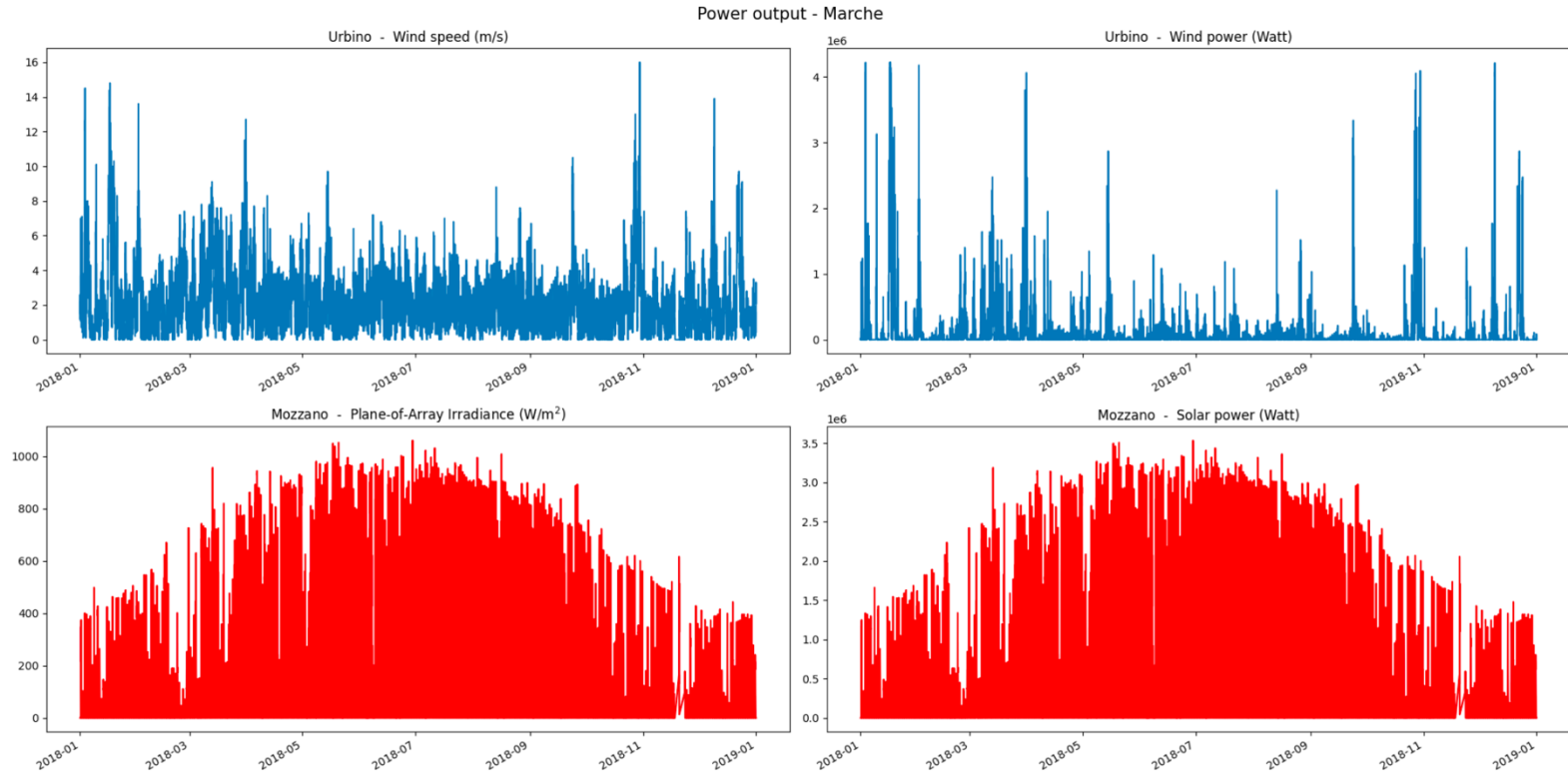


Zona: Centro Nord



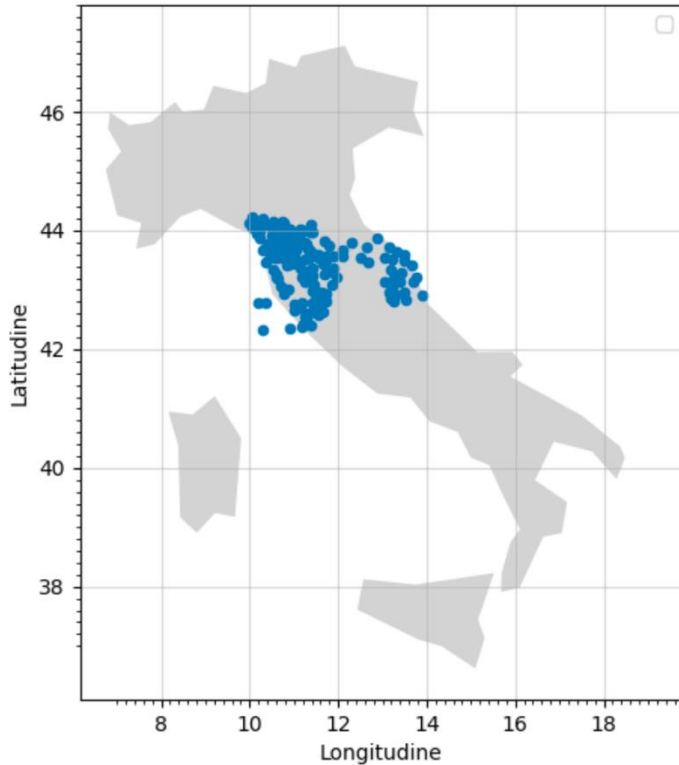
Source: mercatoelettrico.org

Example of solar PV and wind generation profiles

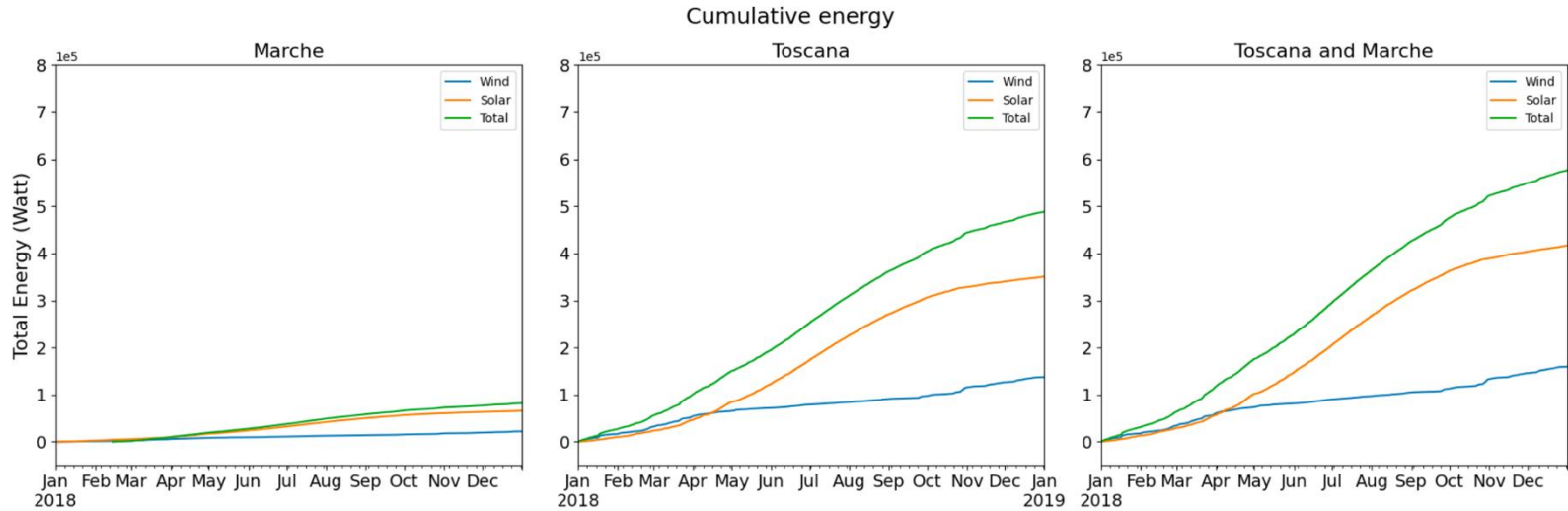


Toscana and marche: generators distribution

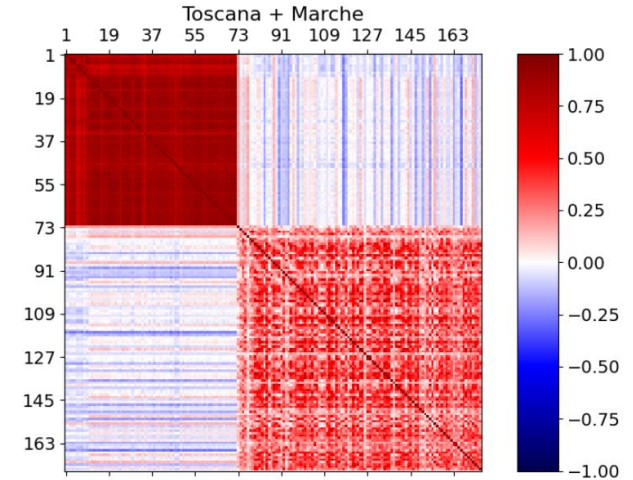
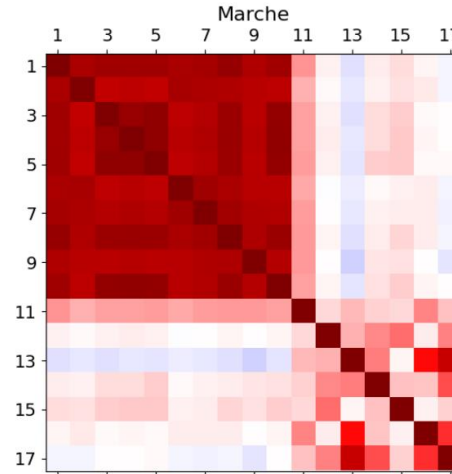
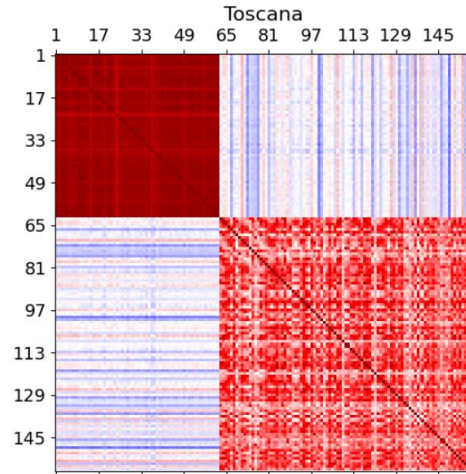
Solar and Wind sensors location



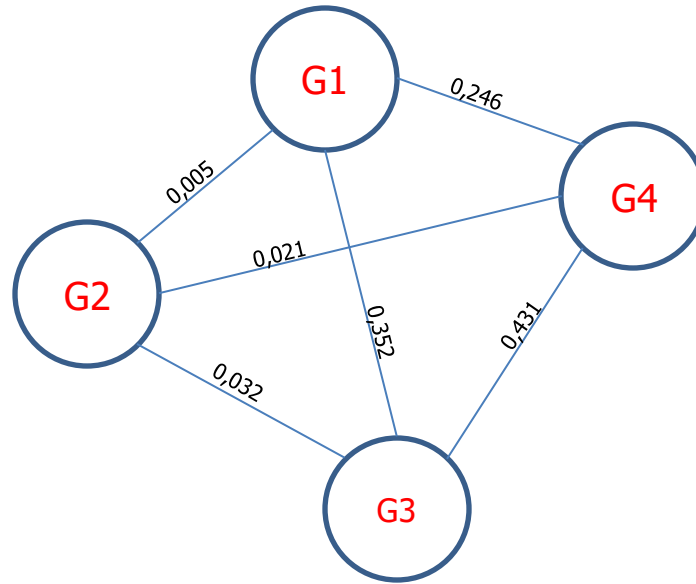
Type	Toscana (Num./kW)	Marche (Num/kW)	Both (Num/kW)
Solar	67 / 598	14 / 537	81 / 587
Wind	95 / 165	13 / 194	108 / 168
Both	162 / 344	27 / 371	189 / 348

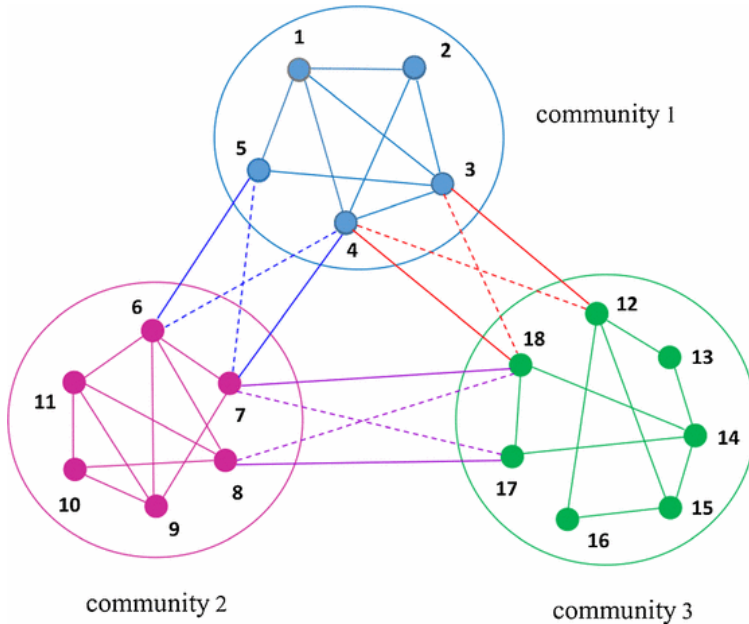


Power plants correlations matrices



Use of networks science methods to convert the correlation matrix into a weighted network





- ✓ A network is said to have **community structure** if the nodes of the network can be easily grouped into (potentially overlapping) sets of nodes such that each set of nodes is densely connected internally.
- ✓ Individual communities also shed light on the **function of the system** represented by the network since communities often correspond to functional units of the system.

Different communities mean complementary evolution of the generation profiles

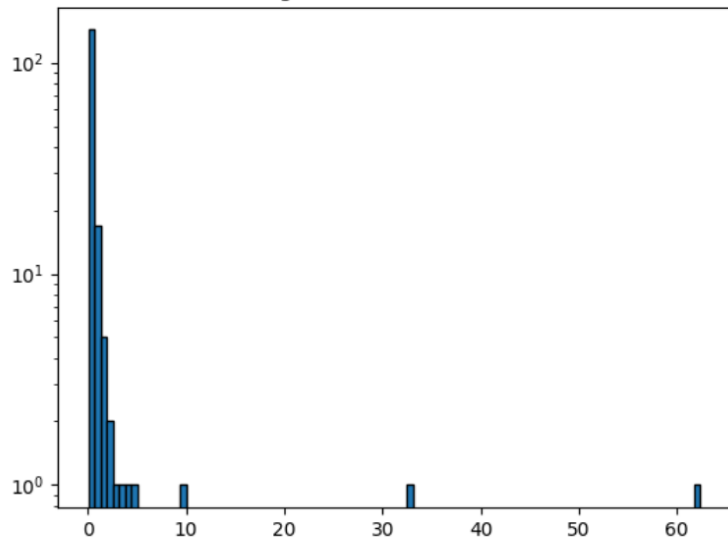
Decomposition of the power generation

Three components are present:

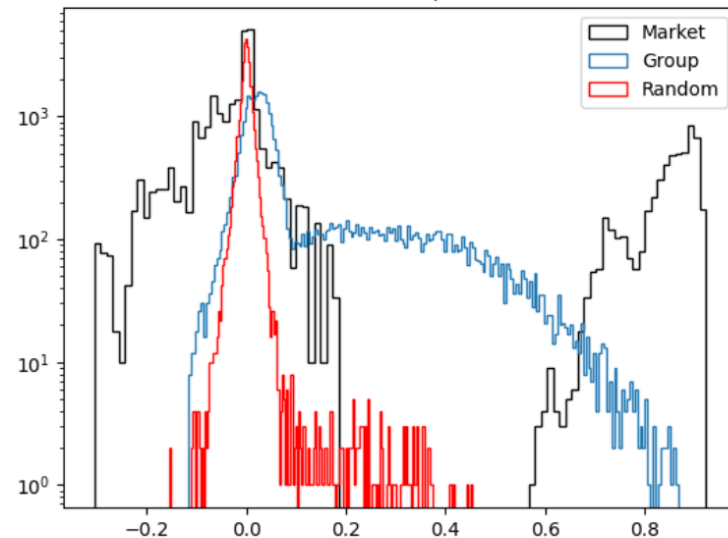
- 1) **Global component:** the common trend influencing the collective motion (e.g. a drift)
- 2) **Random component:** stochastic evolution of the time series
- 3) **Common dynamics:** reflects the coupling of the generators

Eigenvalues and correlations decomposition

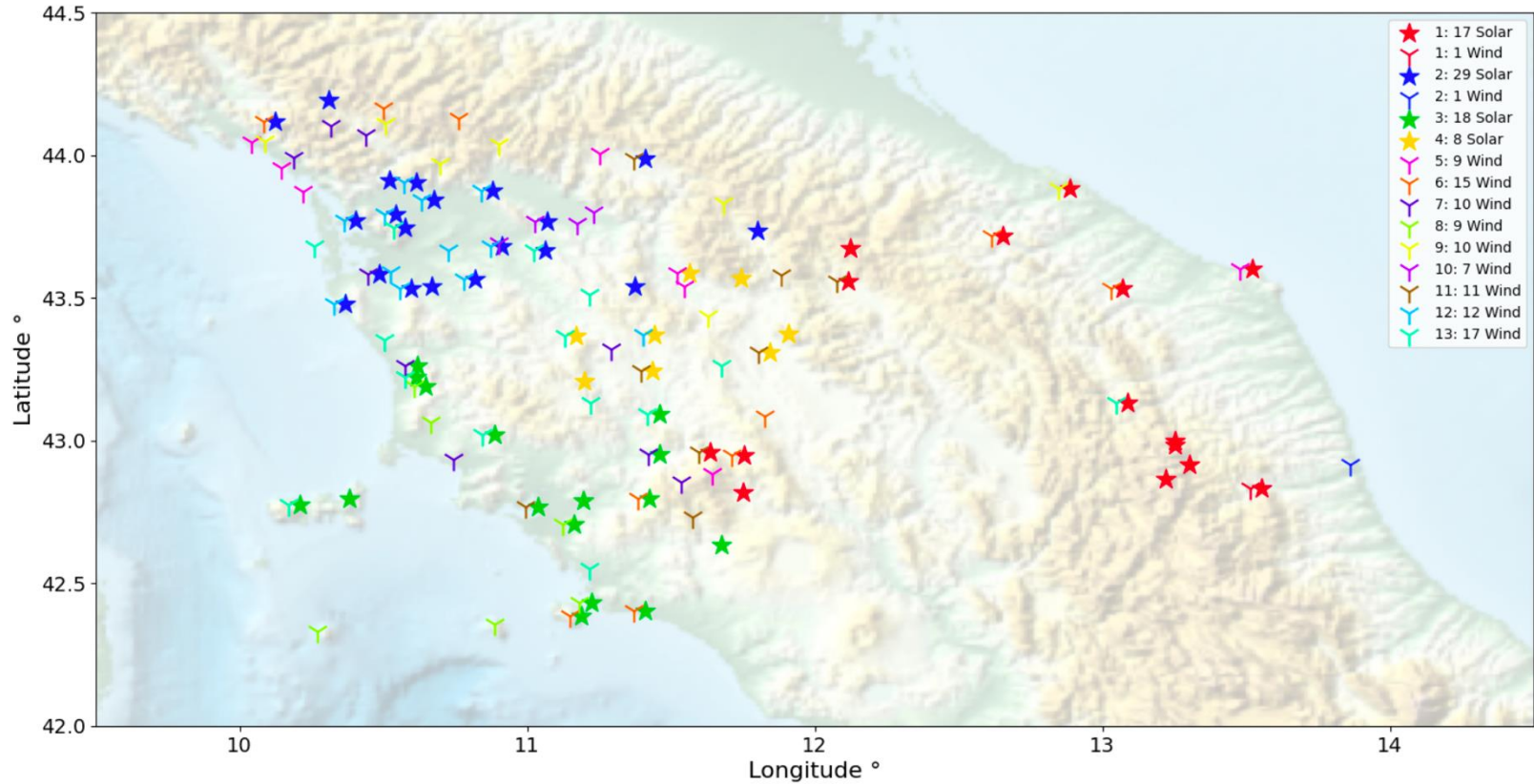
Eigenvalues distribution



Matrix decomposition



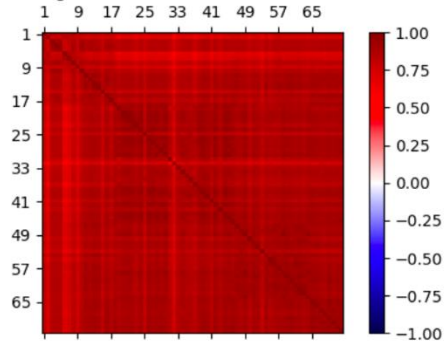
Communities detected



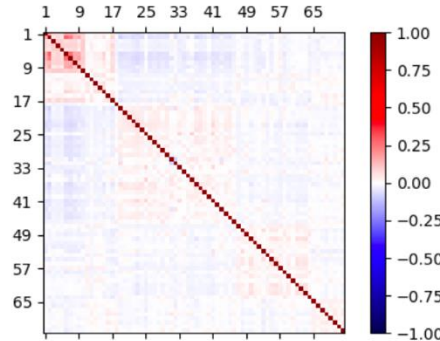
Community	N. Generators	N. Wind	N. PV
1	18	1	17
2	30	1	29
3	18	0	18
4	8	0	8
5	9	9	0
6	15	15	0
7	10	10	0
8	8	9	0
9	10	10	0
10	7	7	0
11	11	11	0
12	12	12	0
13	17	17	0

Filtering solar only generators

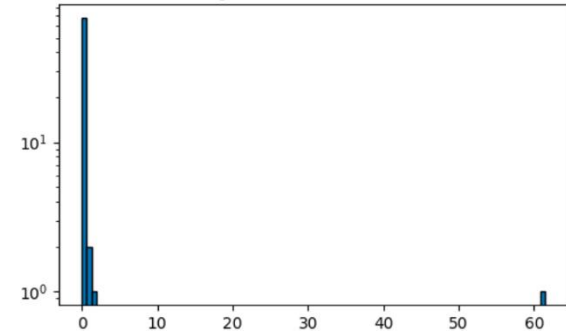
Original Ordered Correlation Matrix



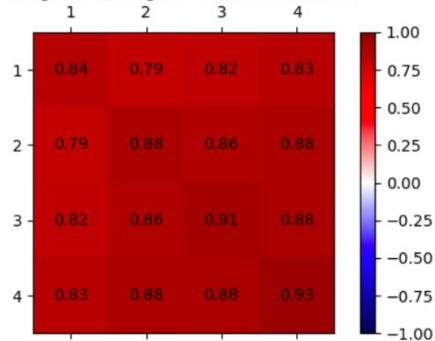
Filtered Ordered Correlation Matrix



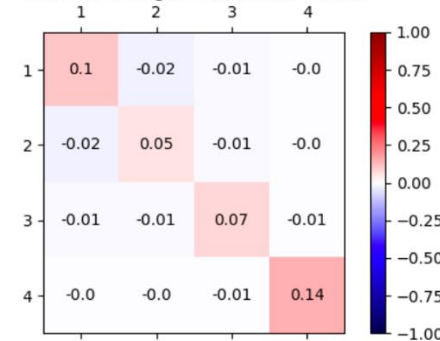
Eigenvalues distribution



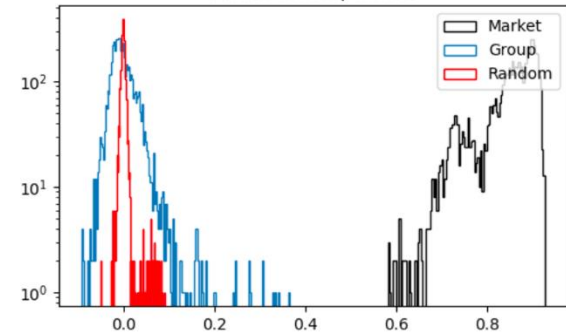
Original Averaged Correlation Matrix

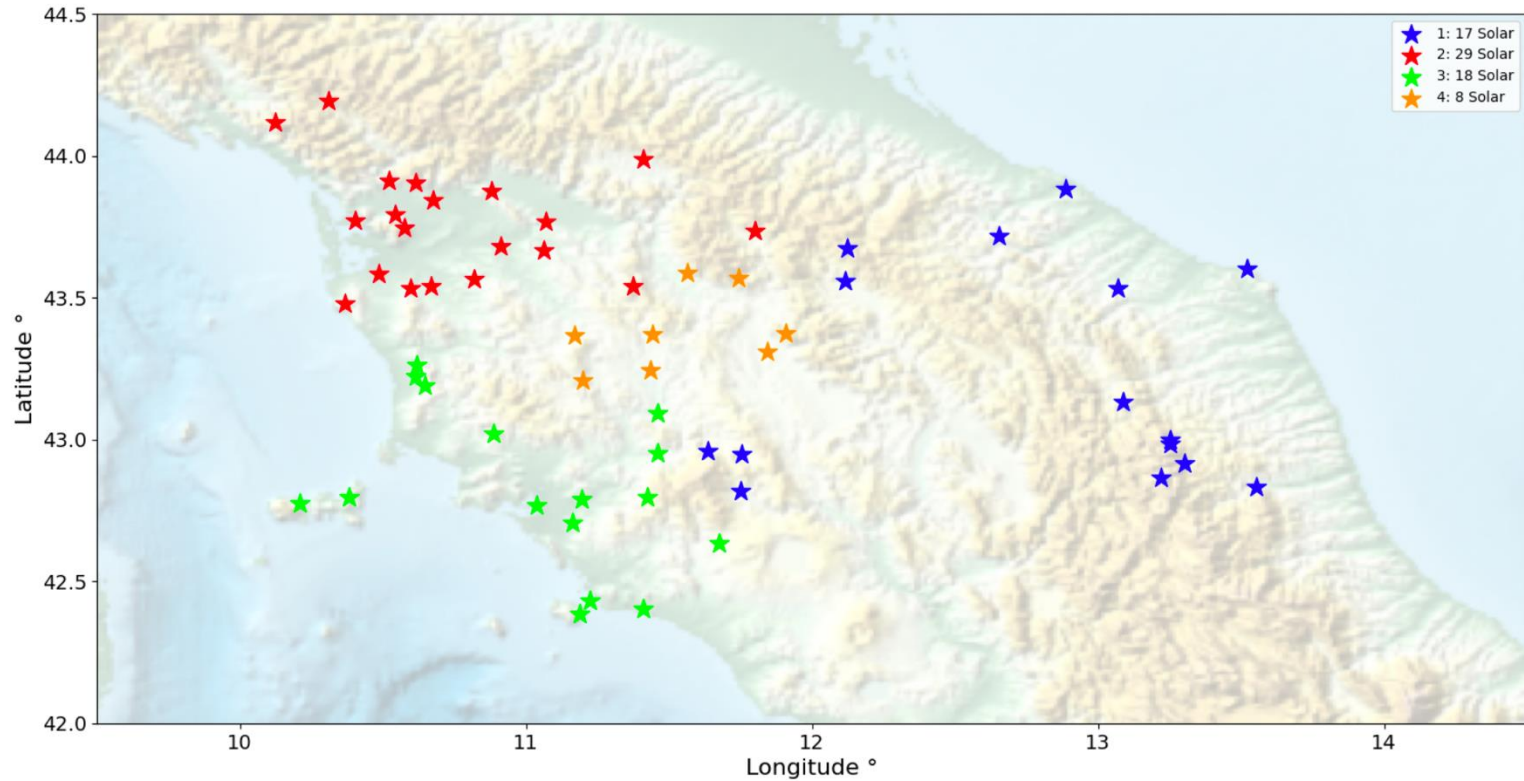


Filtered Averaged Correlation Matrix



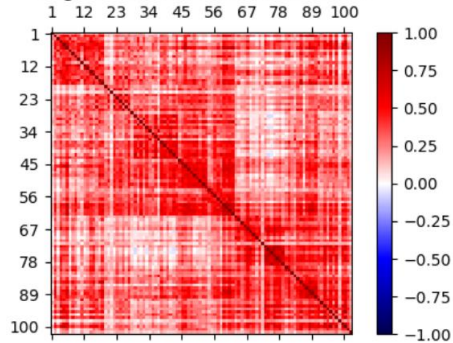
Matrix decomposition



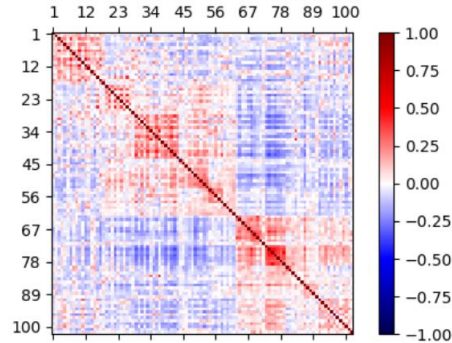


Filtering Wind generators only

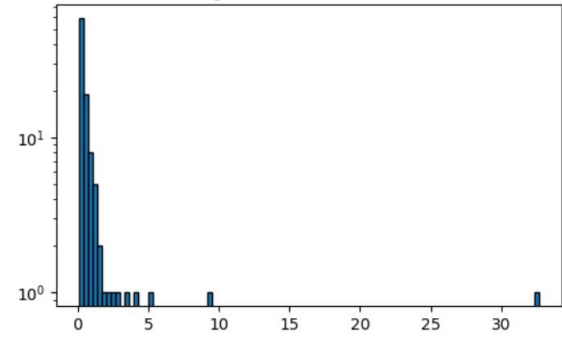
Original Ordered Correlation Matrix



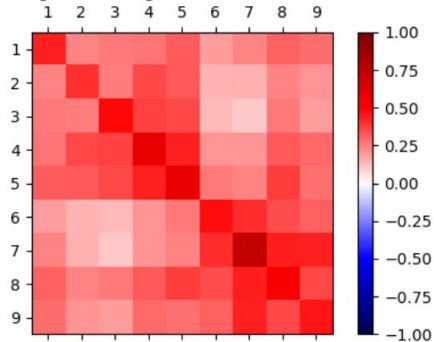
Filtered Ordered Correlation Matrix



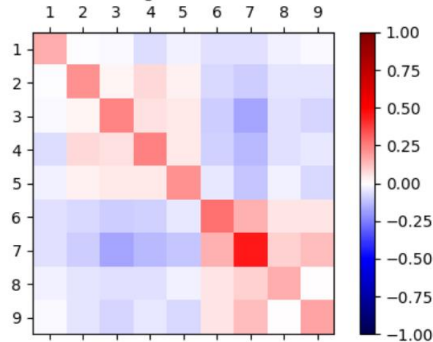
Eigenvalues distribution



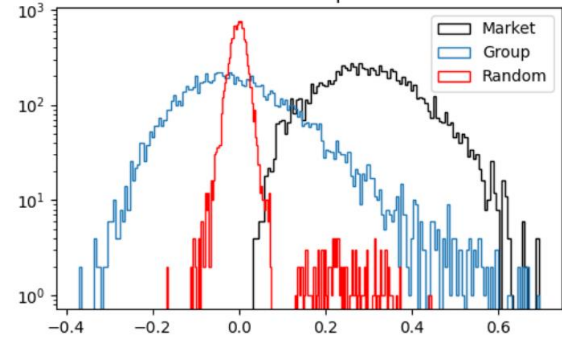
Original Averaged Correlation Matrix

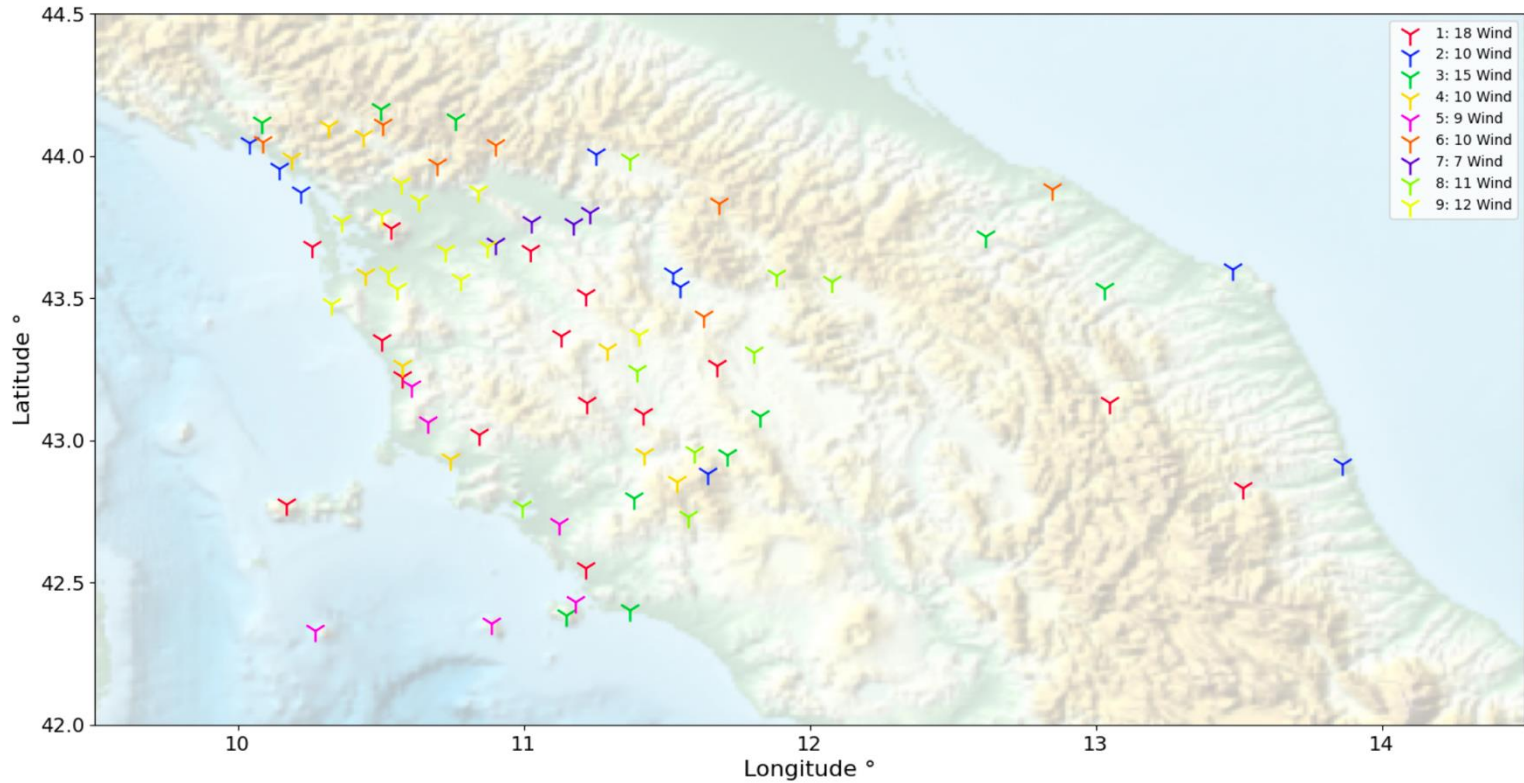


Filtered Averaged Correlation Matrix



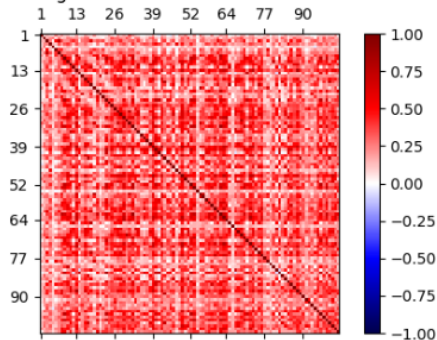
Matrix decomposition



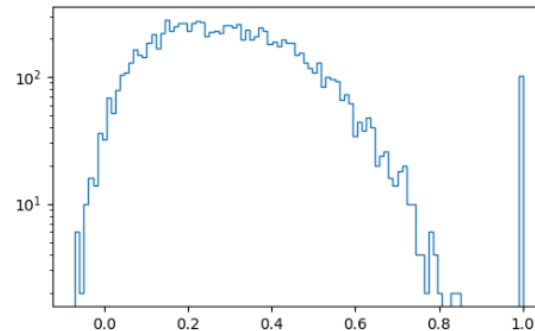
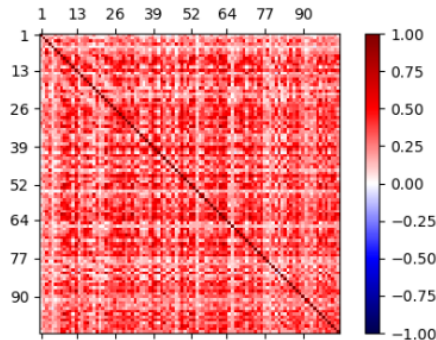


Comparison with non filtered matrix: Wind

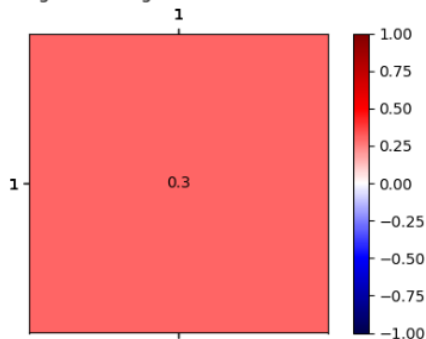
Original Ordered Correlation Matrix



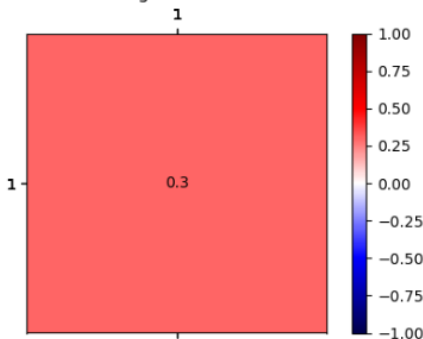
Filtered Ordered Correlation Matrix



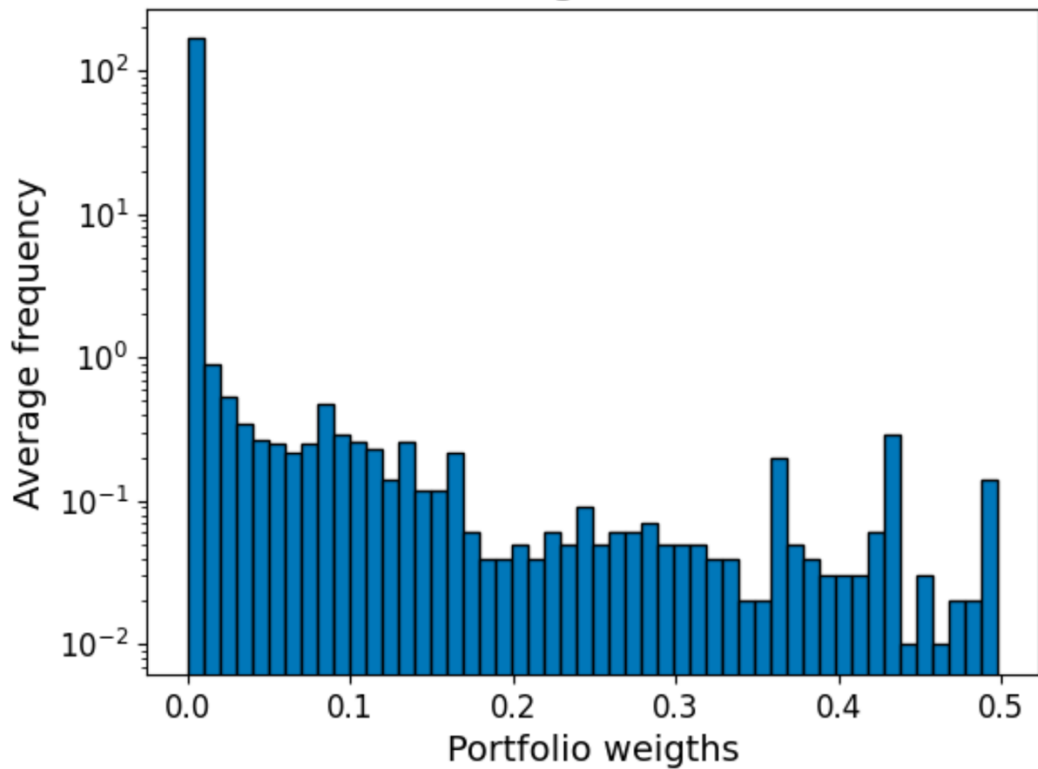
Original Averaged Correlation Matrix



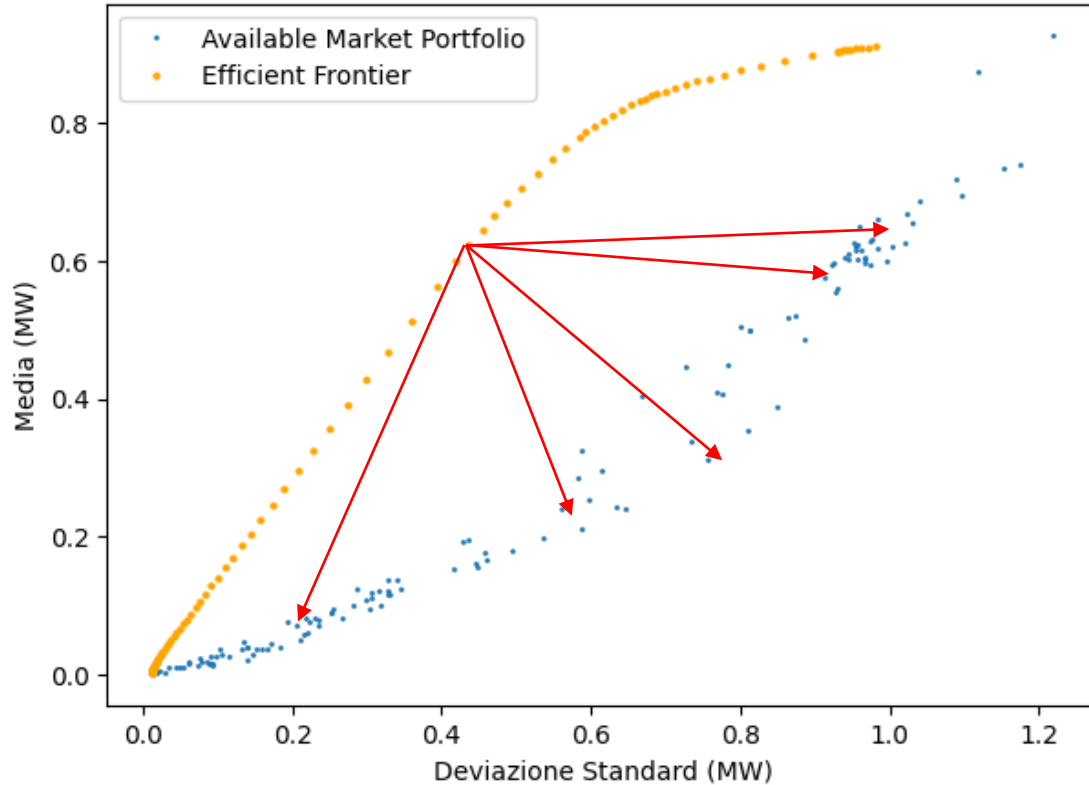
Filtered Averaged Correlation Matrix



Markowitz: distribution of weights



Markowitz optimization



A restricted set of generators represents over 90% of the total weights.

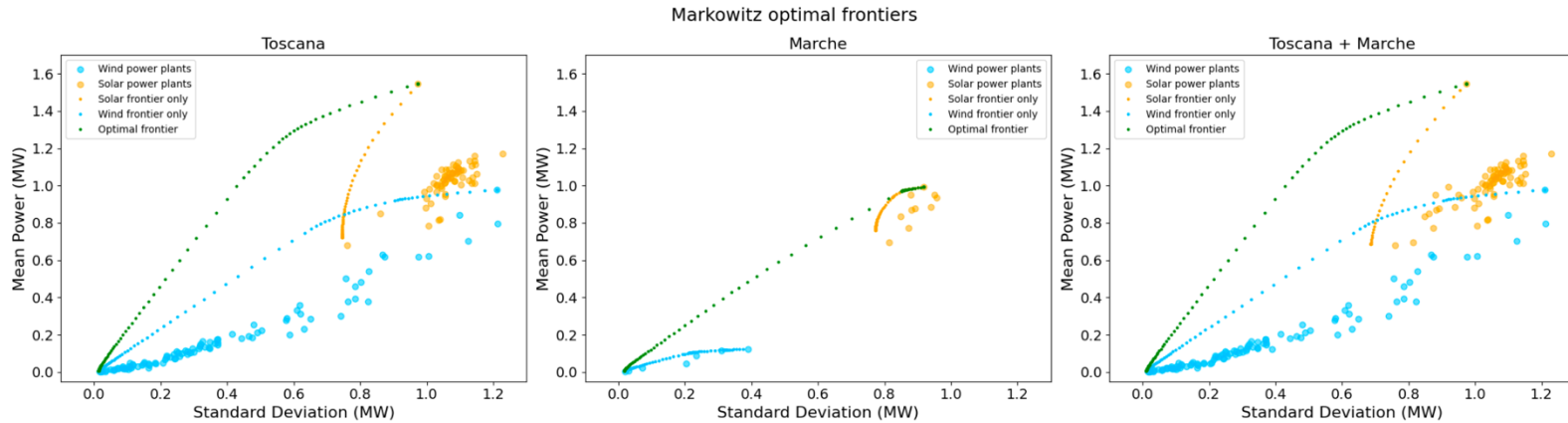
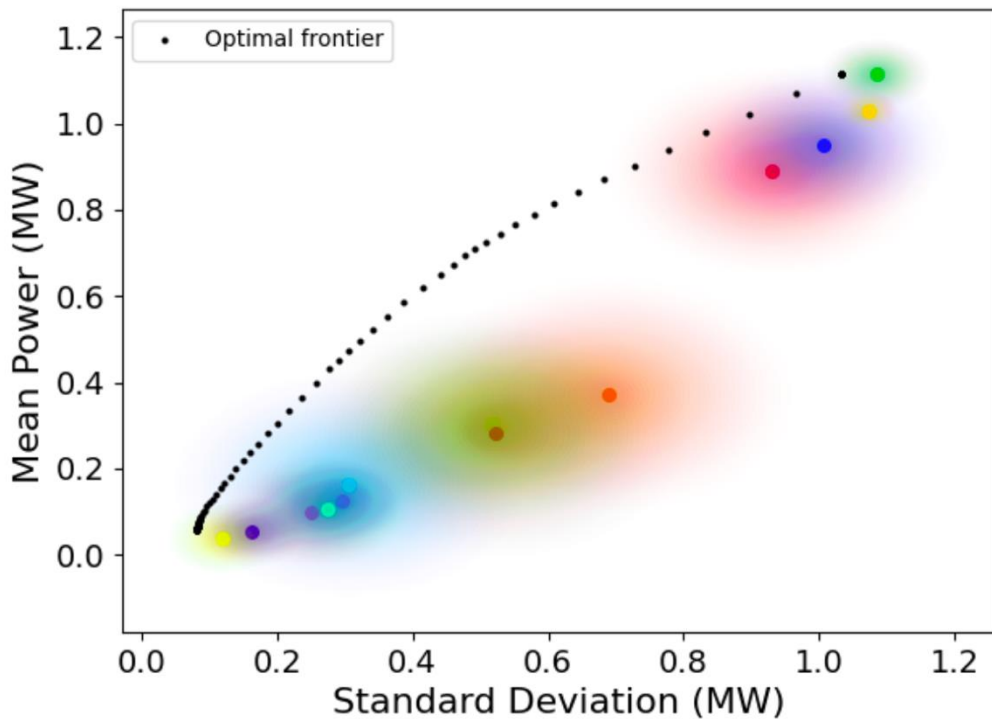


Figure 13: Markowitz optimized mean-variance frontiers for only solar (yellow), only wind (blue), and both power sources (green). Data hourly span is from 7am to 8pm.

Communities and the Markowitz frontier



- Taken into account the spatial effects in power generation within a given geographic region.
- Provide an additional measure of efficiency of the installed generation that is currently not considered by energy investors and planners.
- Given the many constraints that might exist on the geographic positioning of such plants, the feasible portfolios will always be sub-optimal.
- It configures a cheaper option than relying on ancillary markets/spinning reserves.
- Paves the road to local energy markets (regional or province-scale markets).

In the Future:

- Consider correlation with zonal prices and volumes
- Deeper understanding of the foundations of the portfolio approach