cea i-tésé

EXPLORONS
LES POSSIBLES

Pour une Transition Énergétique
Soutenable et Économique

Sensitivity Analysis of Load Profiles: Implications for Resource Adequacy in Future Power System by 2050

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1. Origin of the paper

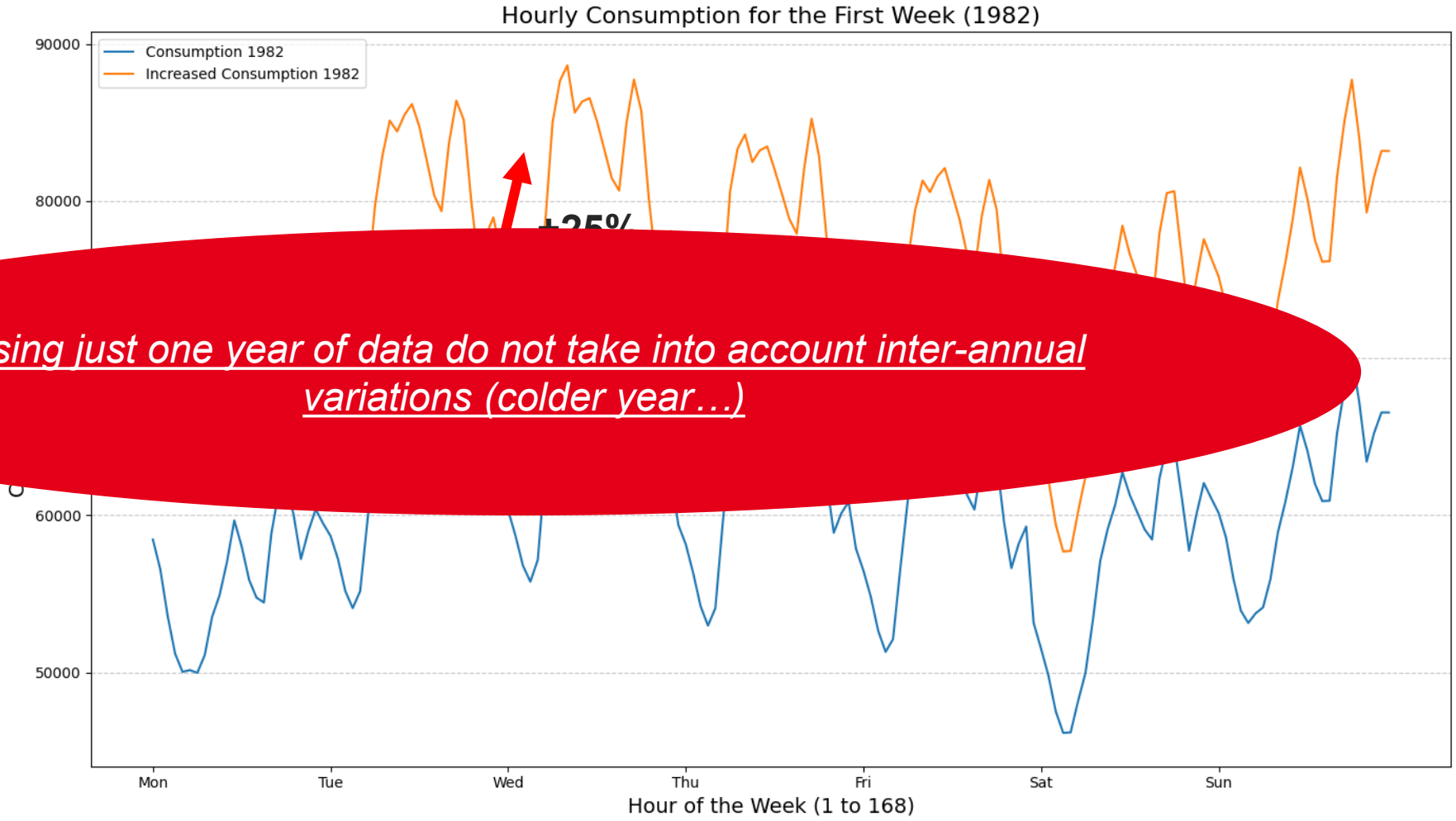
Context

Research question

The importance of forecast in the energy transition

How to create a energy system model by 2050 using forecast?

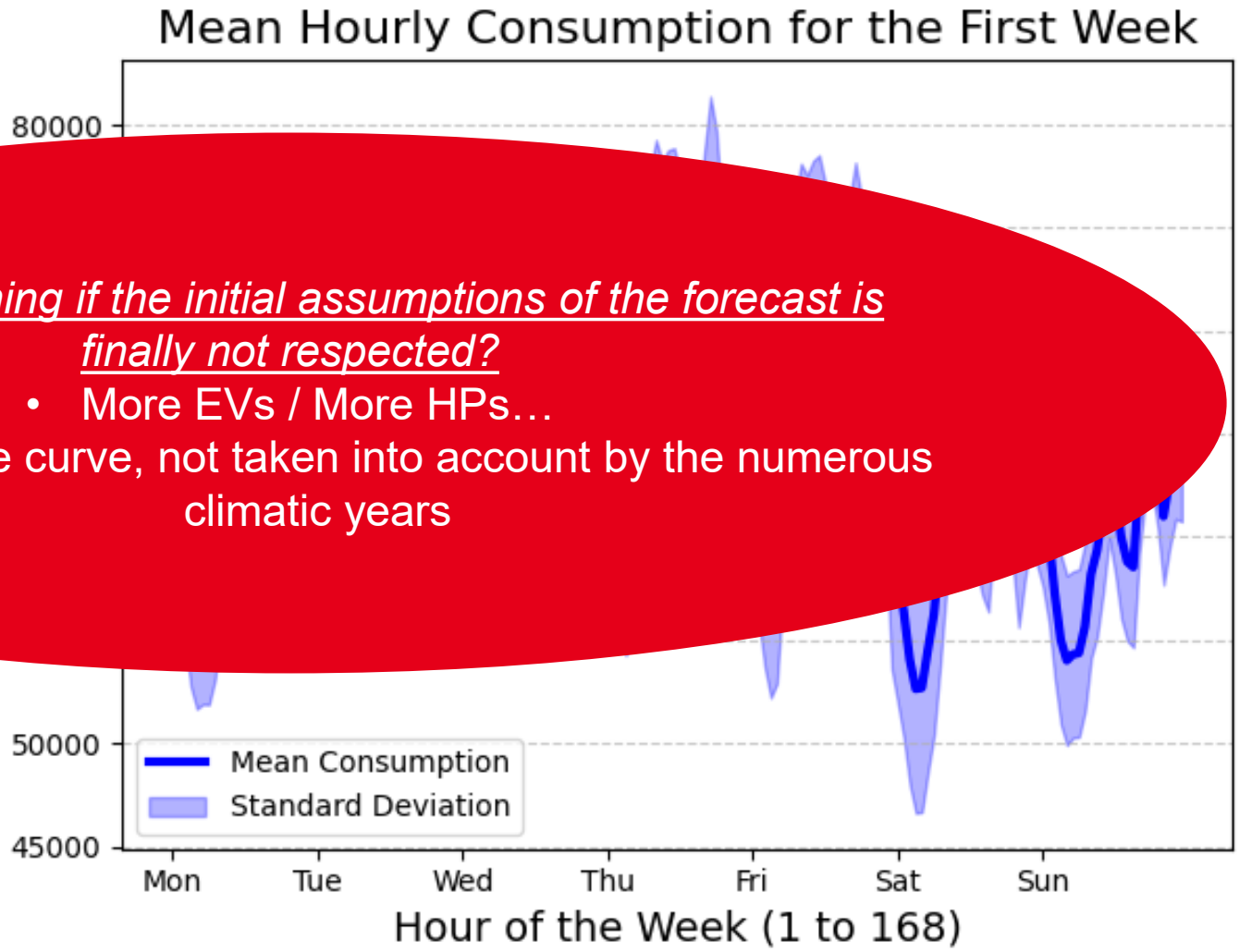
- Use historical load data (ENTSO-e ERAA 2023) or create your own load profile depending on your assumptio
- Increas x% to re by 2050 (pe heat pumps (HPs) o electric vehicles (EVs)…)
- Use state reports or expansion model
- Analyse the security of the system (balance between load and demand)



Using just one year of data do not take into account inter-annual variations (colder year…)

Resource Adequacy for numerous climatic years

- Use **numerous climatic years** of data (33 years)
- **Final 2050 pow**
  (power mi
  exchan
- Resou
  - Differe
  - Balance betw
    resources: choice of th
    power mix
  - Loss of Load Duration (LOLD)
    (< 3 hours for France)
- ➢ **Enough to validate the model?**



What is happening if the initial assumptions of the forecast is finally not respected?

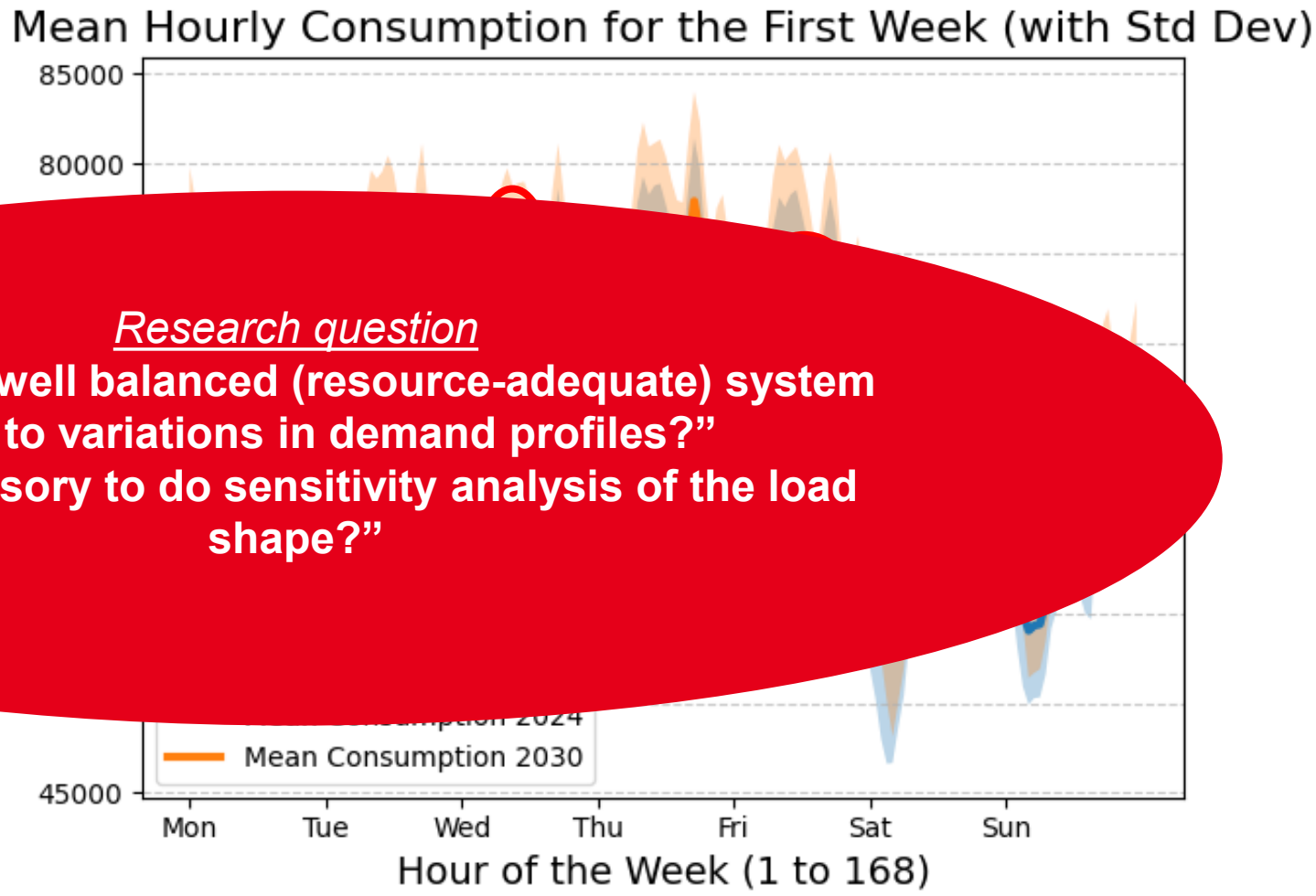
- More EVs / More HPs…

➢ Distortion of the curve, not taken into account by the numerous climatic years

Structural changes and limitations of RA assessments

- **Different assumptions** lead to **different load shape**
  - Distortions was not present in the initial scen
  - Distortion **inter-**

- **How doe to new load s**



Research question

"How does a well balanced (resource-adequate) system adapt to variations in demand profiles?"
"Is it compulsory to do sensitivity analysis of the load shape?"

2. Methodology

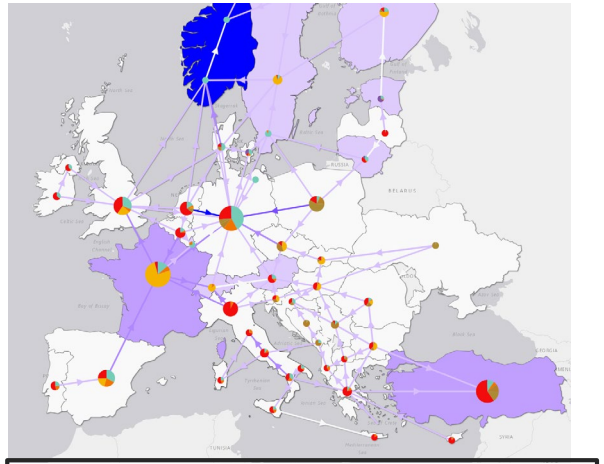
Explanation of the model

The different scenarios

Summary of the methodology

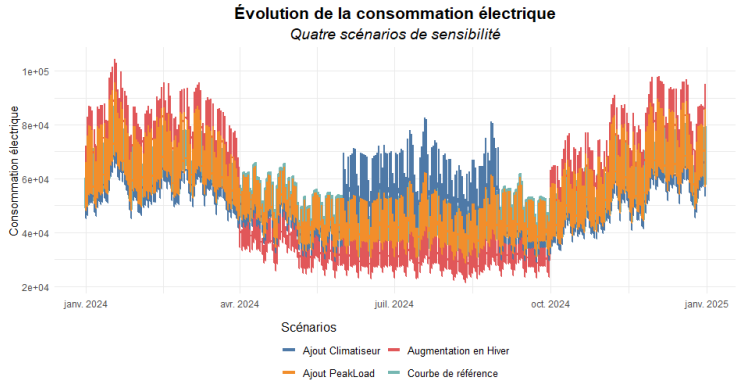
Electricity European model well balanced

- < 3h of LOLD
- 2050 dataset (33 climatic year)



Modeling details
AntaresSimulator, **hourly** time-steps, **UECD**, **MILP**
Dataset: ERAA + French TSO + Osmose (30 countries). 35 climatic years of load and production + capacity mix by 2050

Scenarios of load shape distortion



What are the main drivers of distorition of the curve?

- Literature *(Göke et al., 2023) (Blonsky et al., 2019)* :
  1. **Electrification of heating** (heat pumps…)
  2. **Transportation** (EVs)

Resource Adequacy Assessments

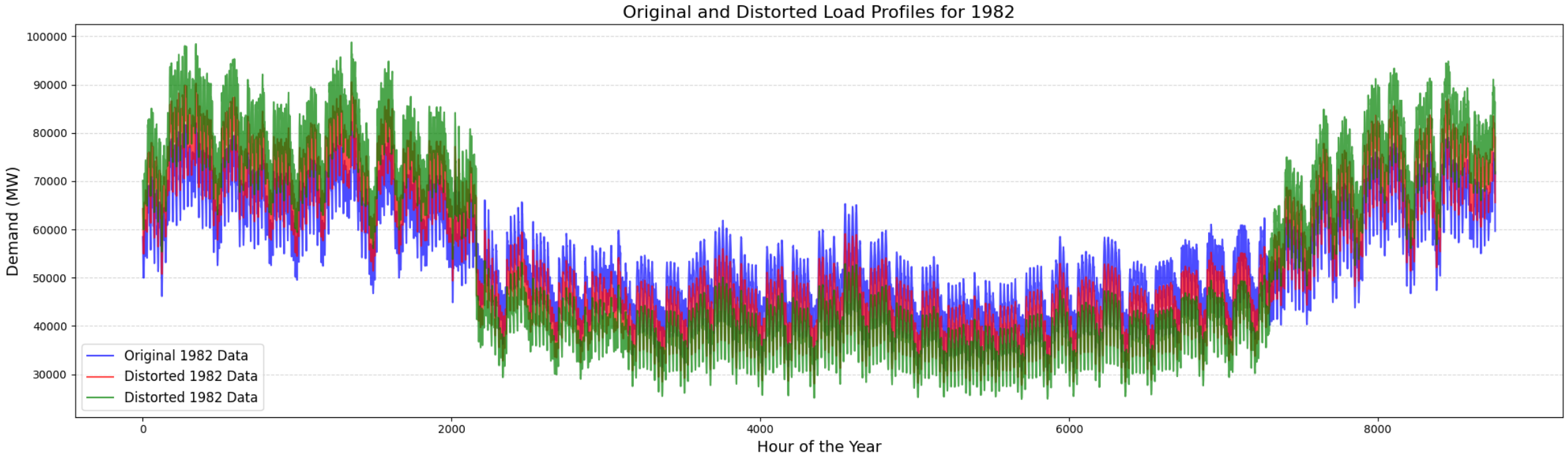
- Sensitivity analysis
- LOLD, LOLH…
- Analysis of stressful time steps for the system

Winter scenario: First scenario of distortion

Simulate a higher thermo sensitivity of the system

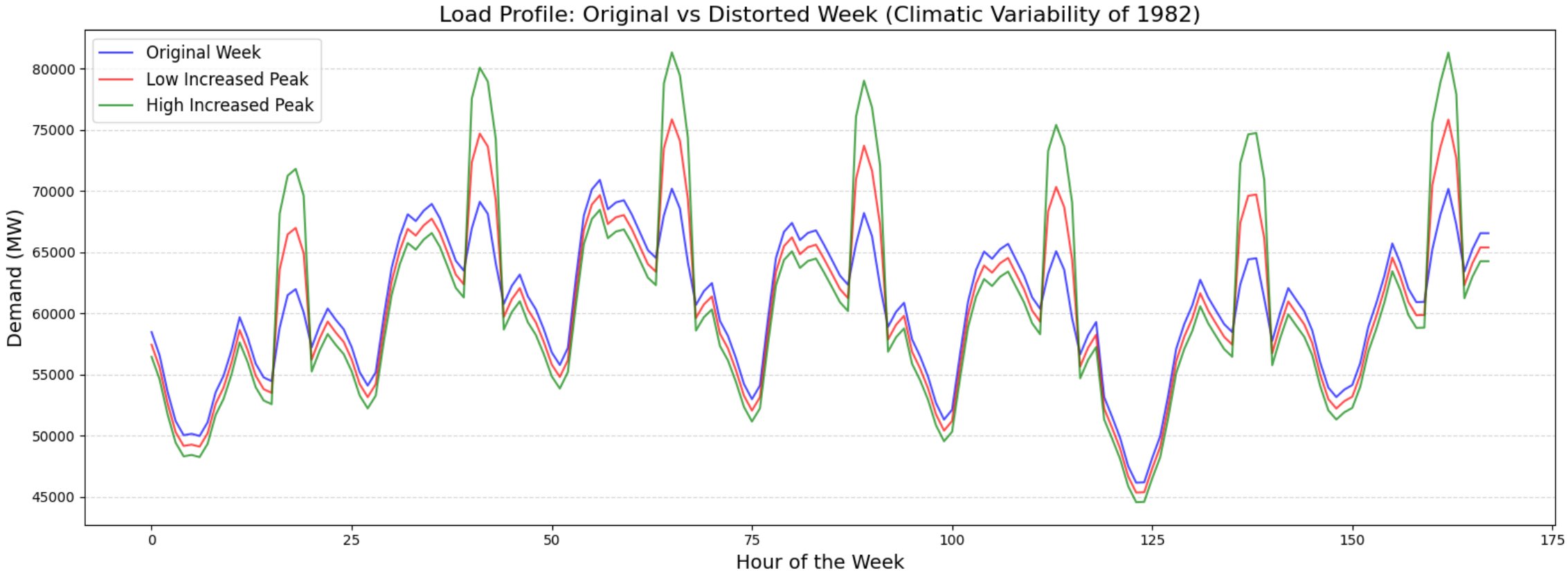
Initial load shape (blue curve)

Increase during winter months (highest share of electrification of heating)



Increase in the seasonality: +[2;4;6;8;10]%

Peak scenario: second scenario of distortion

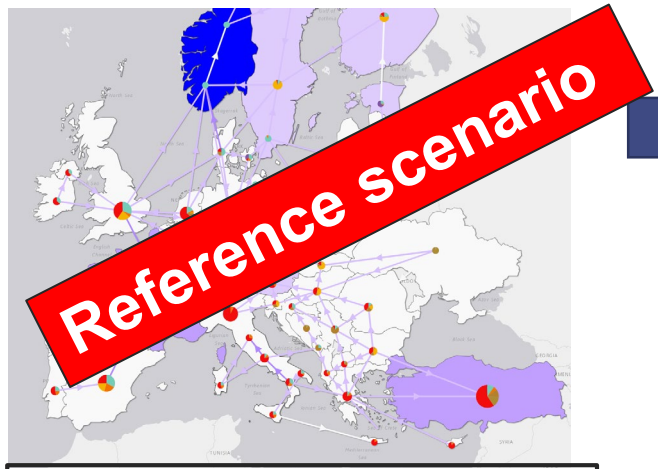


Increase in the peak load hours: +[5;10;15;20]%

Summary of the methodology

Electricity European model well balanced

- < 3h of LOLD
- 2050 dataset (33 climatic year)



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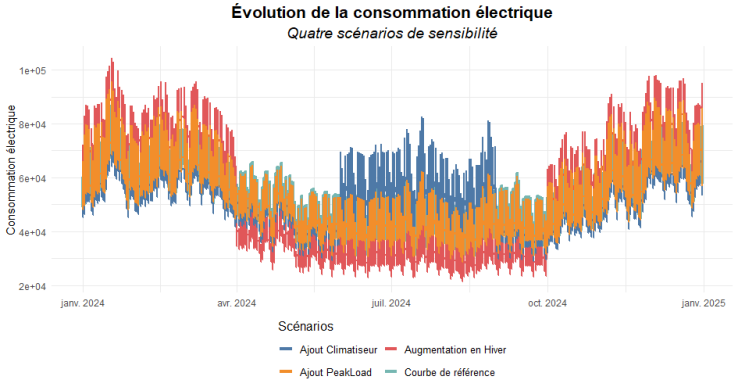


Winter scenario	Peak scenario
+[2;4;6;8;10]%	+[5;10;15;20]%

Resource Adequacy Assessments

- Sensitivity analysis
- LOLD, LOLH…
- Analysis of stressful time steps for the system

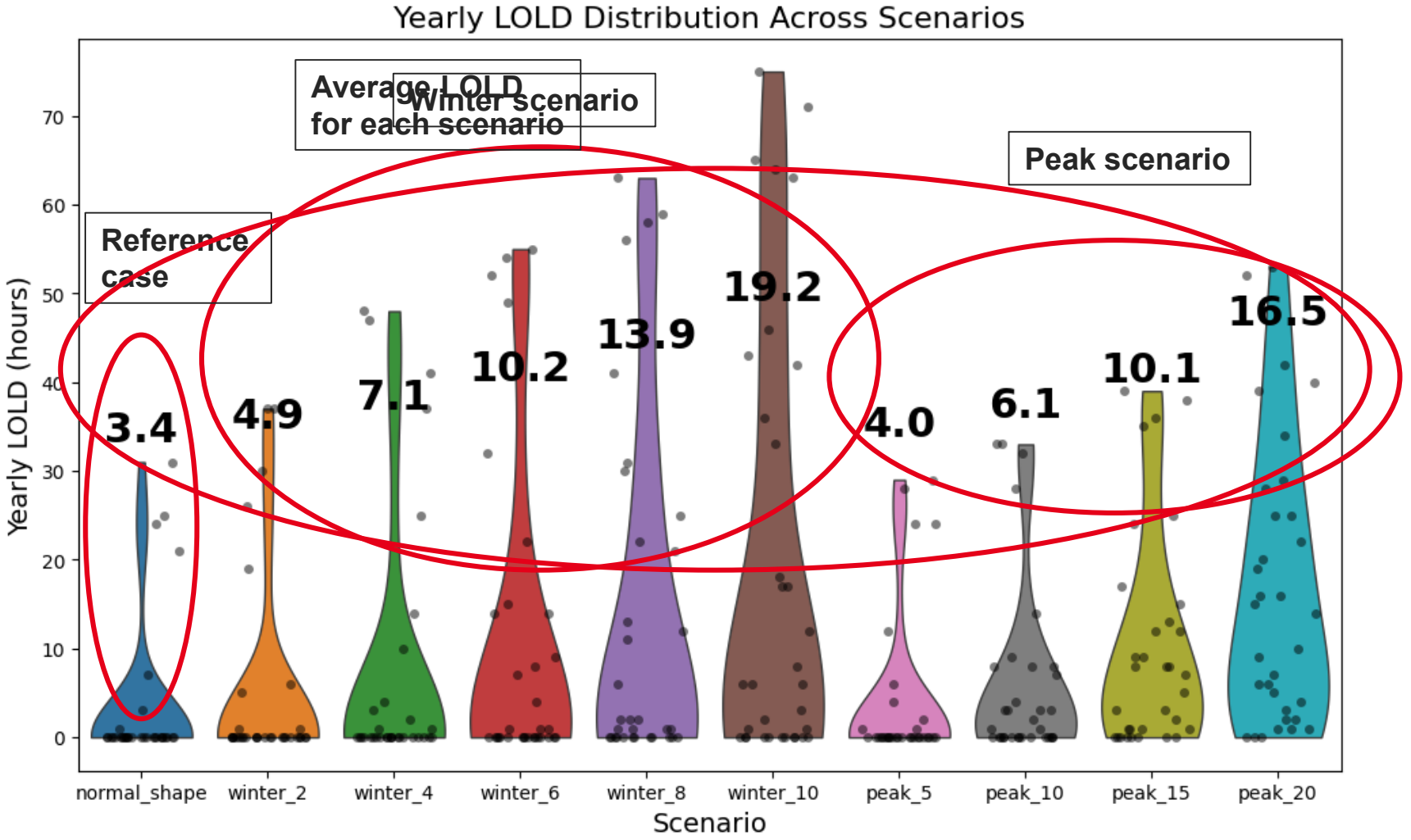
3. Results

Yearly analysis

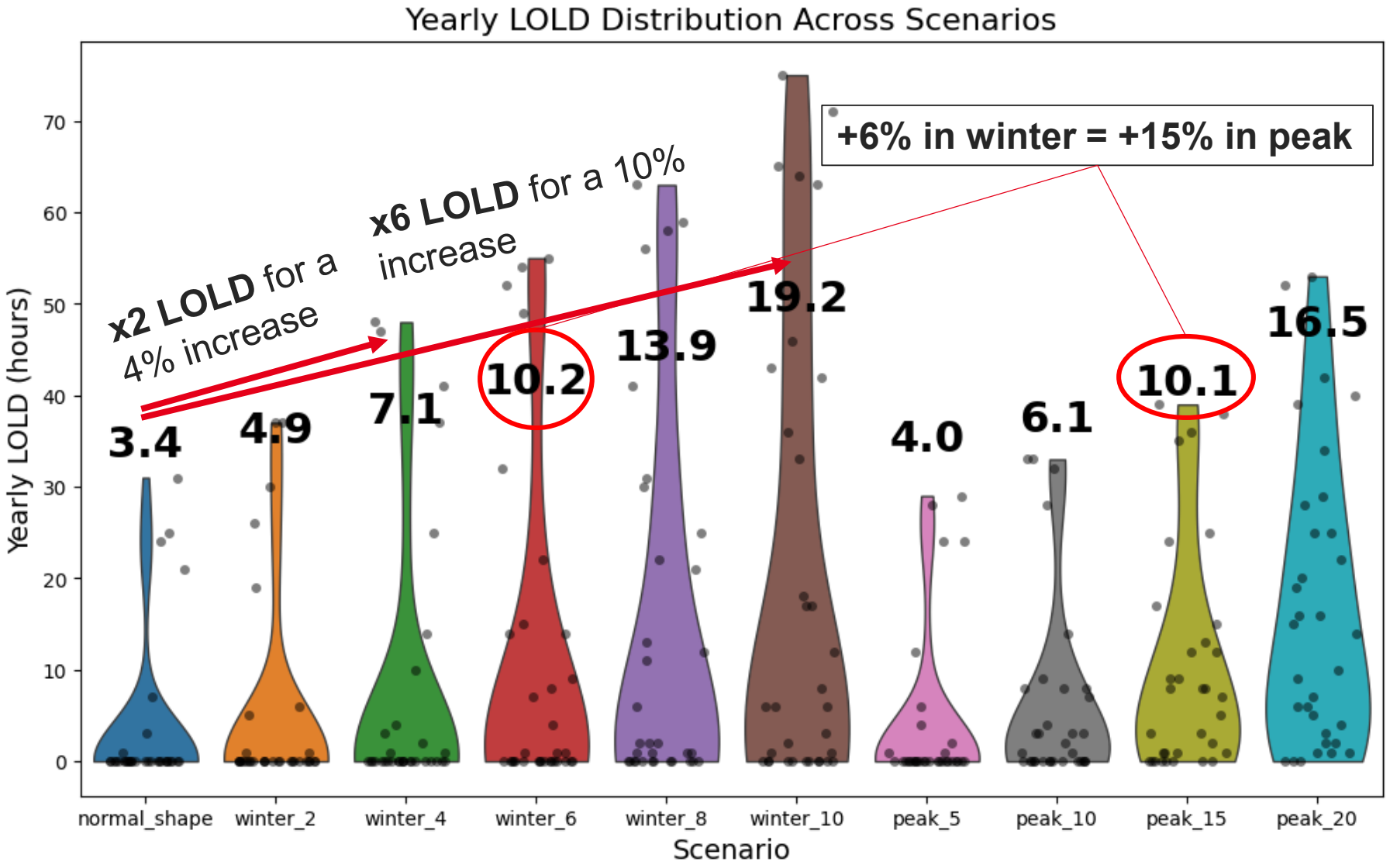
Yearly analysis, average metric

Reminder

- **33 climatic years for each scenario**
- **1 reference scenario**
- **5 winter scenario**
  +[2;4;9;8;10]%
- **4 peak scenario**
  +[5;10;15;20]%



Yearly analysis



Yearly analysis

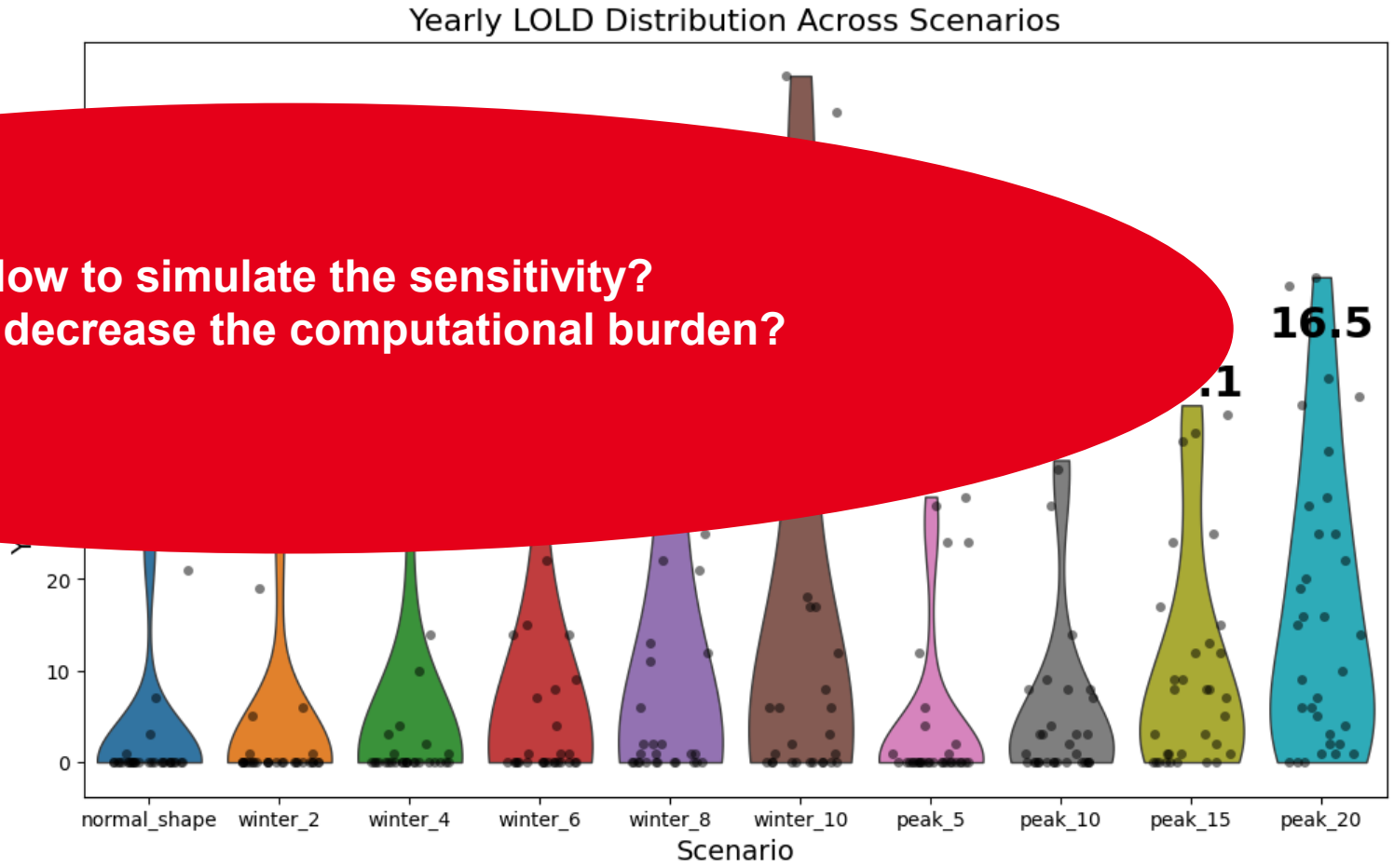
Main results

- The system is **highly sensiti**
  load shape modifi
  the peak an
- A +2% inc
  increase in p
  the system (+30%
- ➢ **Validates the importance of load shape sensitivity analysis**

Interesting results

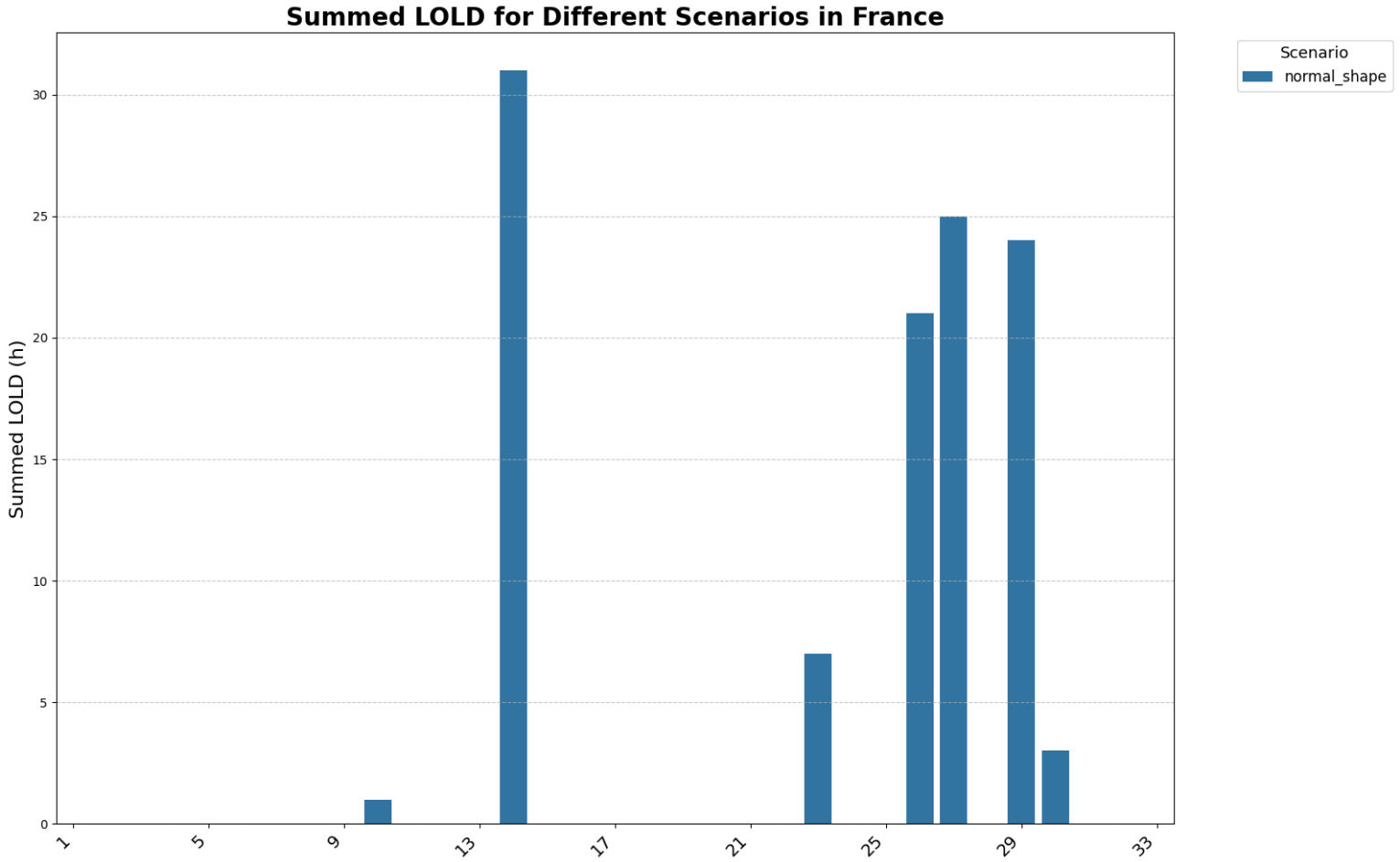
- Winter sensitivity seems higher than peak load sensitivity

1. How to simulate the sensitivity?
2. How to decrease the computational burden?



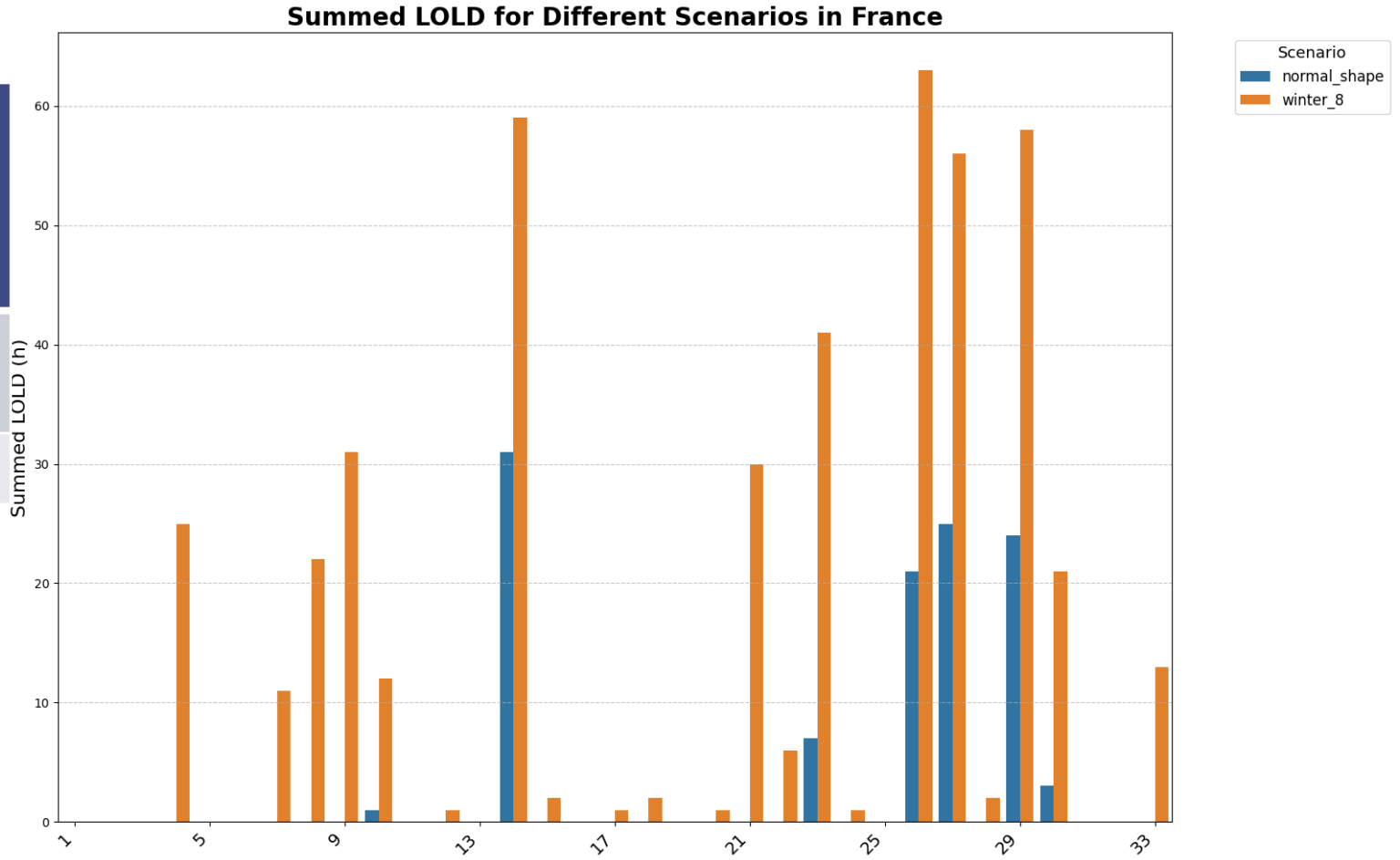
Yearly analysis, climatic year metrics
Reference year

	Number of years with LOLD	Average LOLD (h)
Reference case	7	3,4



Yearly analysis, climatic year metrics
Reference year + Winter_8

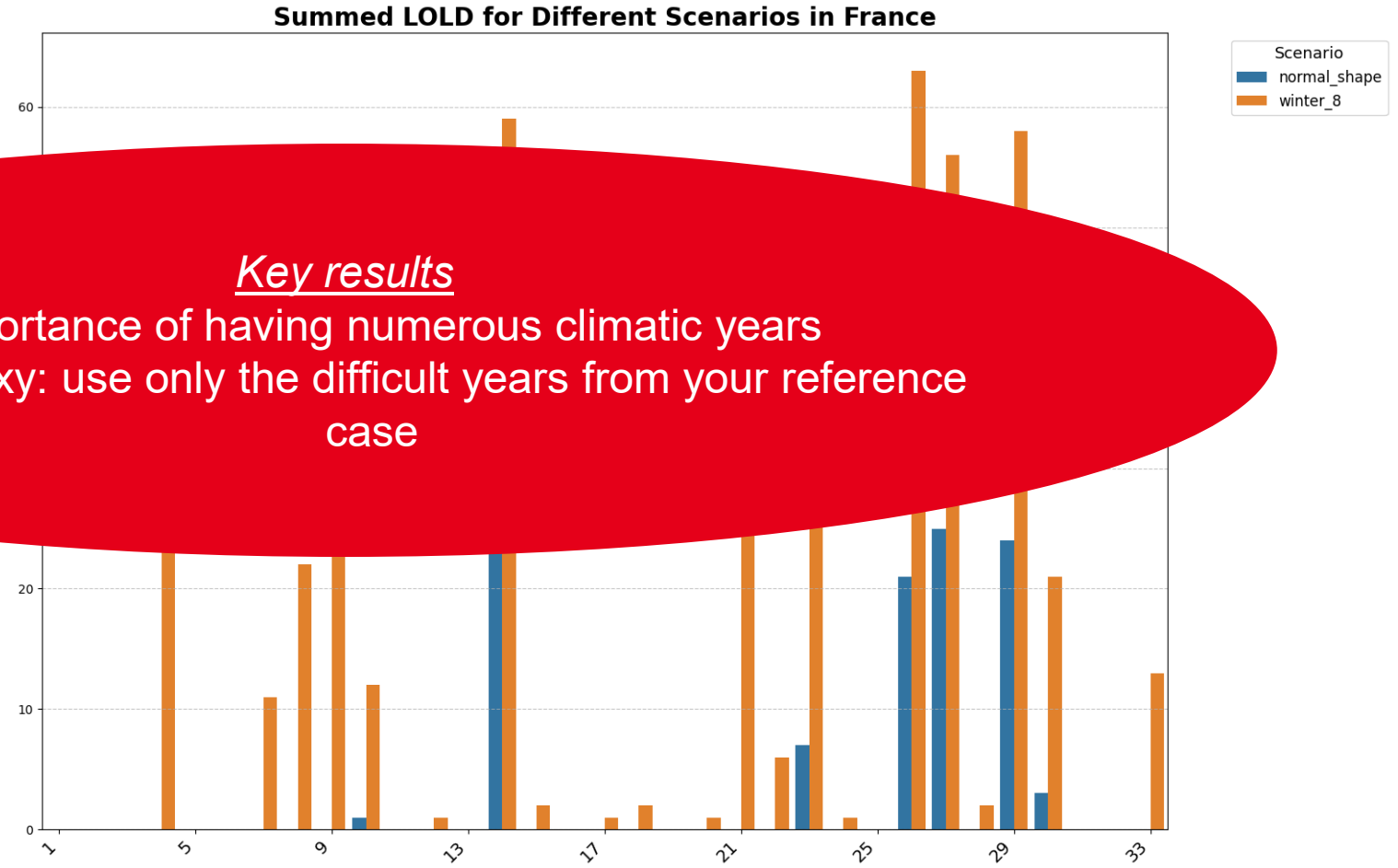
	Number of years with LOLD	Average LOLD (h)
Reference case	7	3,4
Winter_8	**7+14**	**13,9**



- LOLD
  - **+66% of LOLD for already difficult years** (7 years)
  - **+34% of LOLD for new years** (14 years)

Yearly analysis, climatic year metrics
Reference year + Winter_8

	Number of ye	A
Reference case		
Winter_8	7+14	



Key results

- Importance of having numerous climatic years
- A good proxy: use only the difficult years from your reference case

4. Discussions and Conclusions

Main takeaways

Limits and future work

Take-away messages

General messages

- The load shape matters! Using static load shape (historical data) might lead to substantial errors
- **The importance of doing sensitivity analysis** around the initial assumptions
  - A +2% in winter seasonnality and +5% in peak increases LOLD by 30% (!!)

Detailed messages

- Importance of **having multiple climatic years**
- **Focusing on the worst years** for the sizing of the system seems like a good first proxy

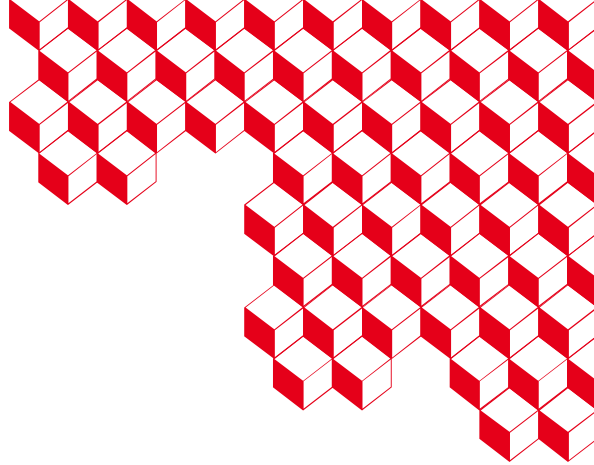
Limits and possible improvements

Limits

- **Discussion about the system**
  - Not optimized (mix of 3 differents dataset)
  - Results might be highly sensitive to the mix used (high share of VRE, percentage of storage capacity, etc.)
- **Choices and modeling of scenarios**
  - Add a « summer case », for southern countries
  - Use of qualitative incrementation (‘by hand’ modification)

Future work

- Go deeper in the analysis of the difficult year
- Go from qualitative incrementation to « precise » distortion



Grazie!
Thank you!
Merci!

Do not hesitate to contact me!

A working paper is in progress

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LinkedIn

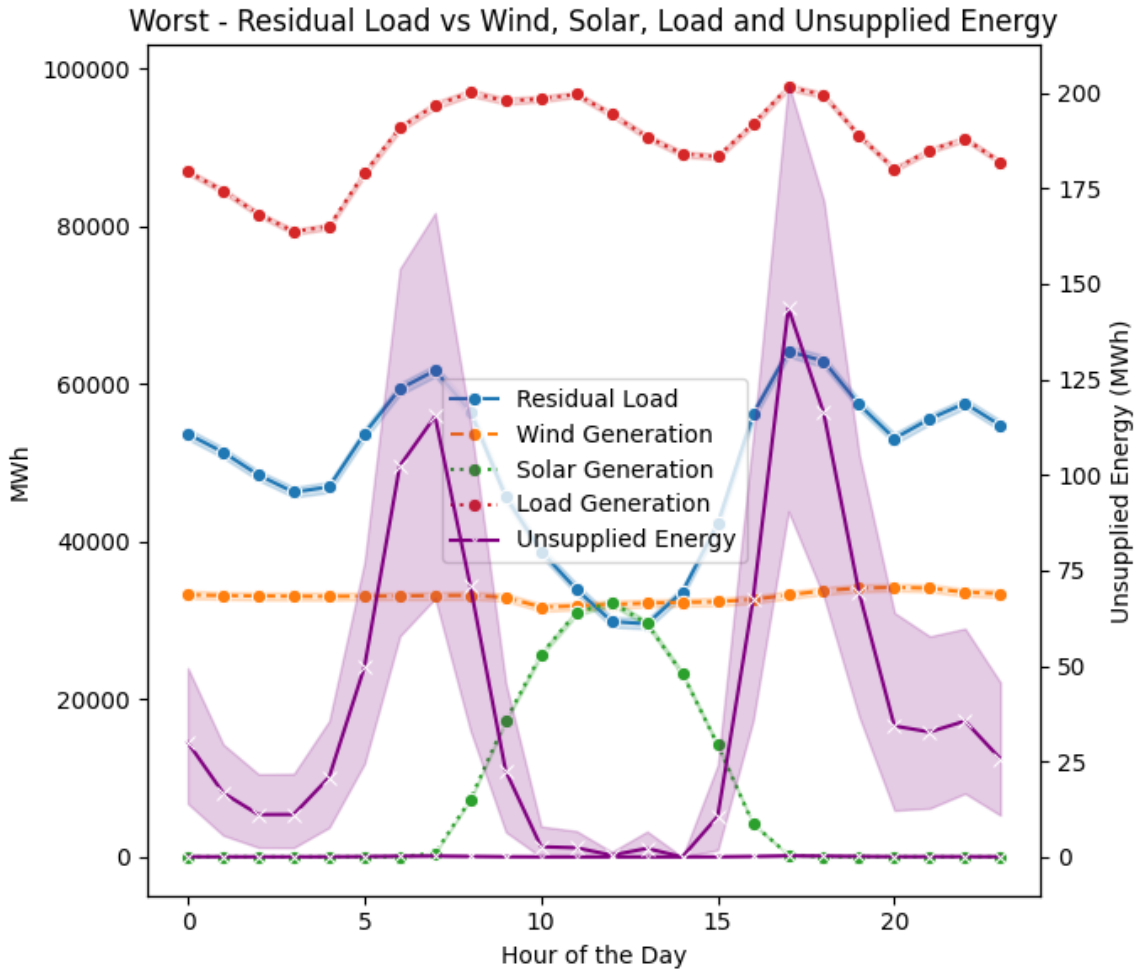
Sources

- **Resource Adequacy Assessments**
  - (Anderson et al., 2024)
  - (Leibowicz et al., 2024) https://www.sciencedirect.com/science/article/pii/S0378779623009458
  - (Sun et al., 2022) https://www.sciencedirect.com/science/article/pii/S0306261922014489
- **Main factor of distortion of the load shape**
  - (Göke et al., 2023) https://www.sciencedirect.com/science/article/pii/S0360544223012264
  - (Blonsky et al., 2019) https://research-hub.nrel.gov/en/publications/potential-impacts-of-transportation-and-building-electrification--2
- **Focus on the residential distortion**
  - (Knittel et al., 2024) : https://www.sciencedirect.com/science/article/pii/S0306261923016975
- **Focus on the EVs distortion**
  - (Martinez et al., 2024) https://iopscience.iop.org/article/10.1088/2753-3751/ad7ebd

Annexes

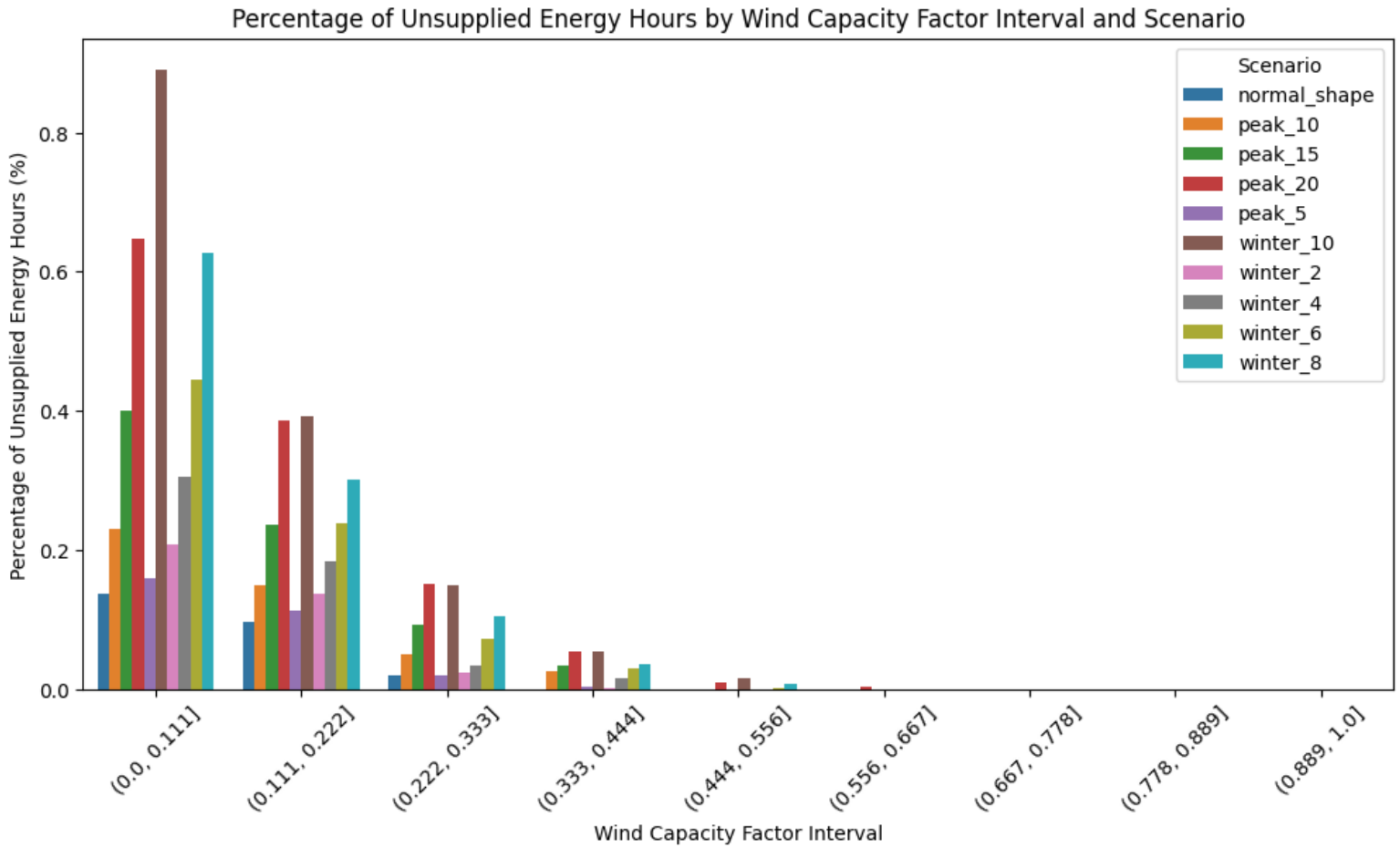
Hourly analysis
Focus on the bad months: Winter case

- High correlation between the residual load and the unsupplied energy.
- Four different zones
  1. Evening peak load: 16h-20h
  2. Morning peak load: 6h-9h
  3. Midday: 10h-15h
  4. Night hours: 21h-5h

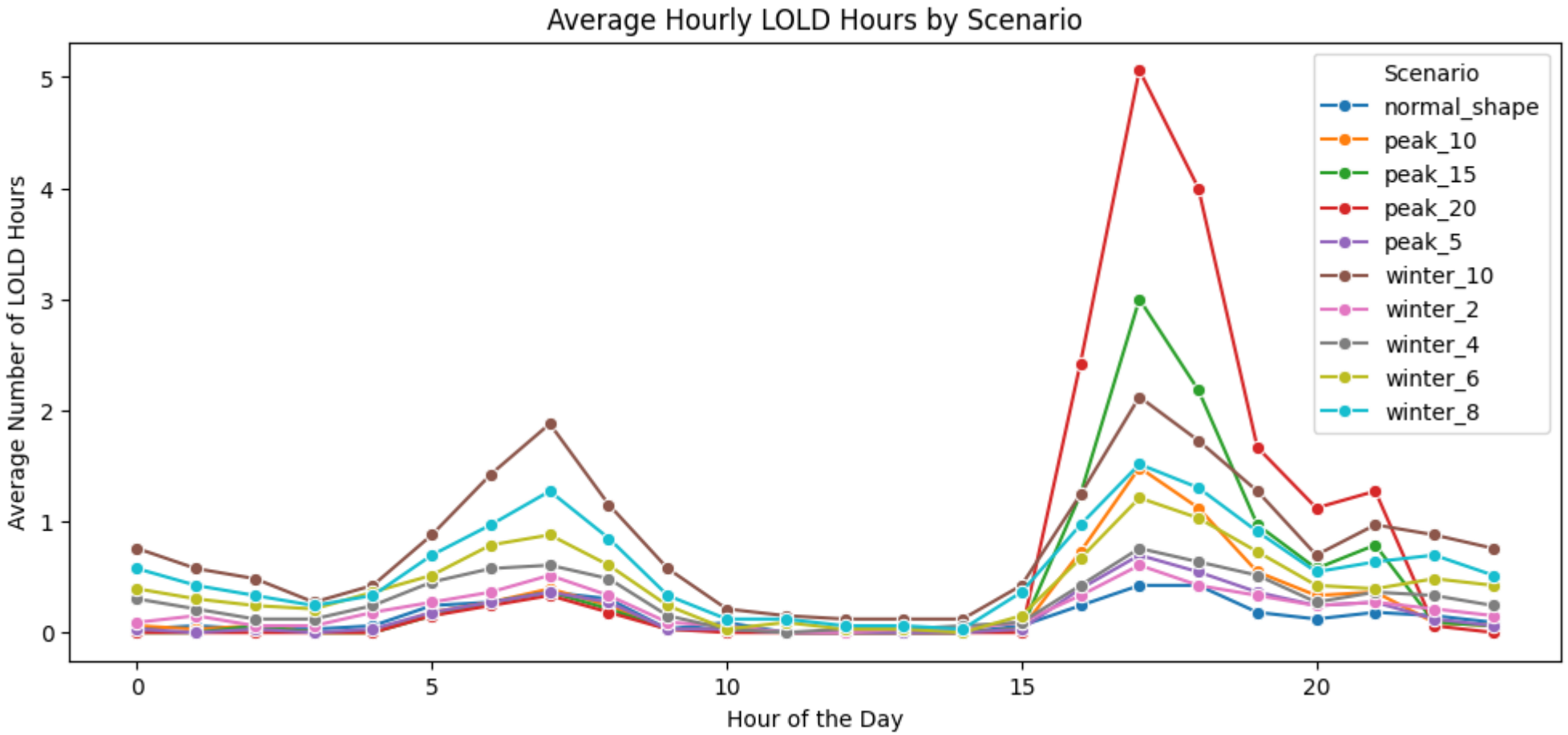


Correlation between wind and LOLD

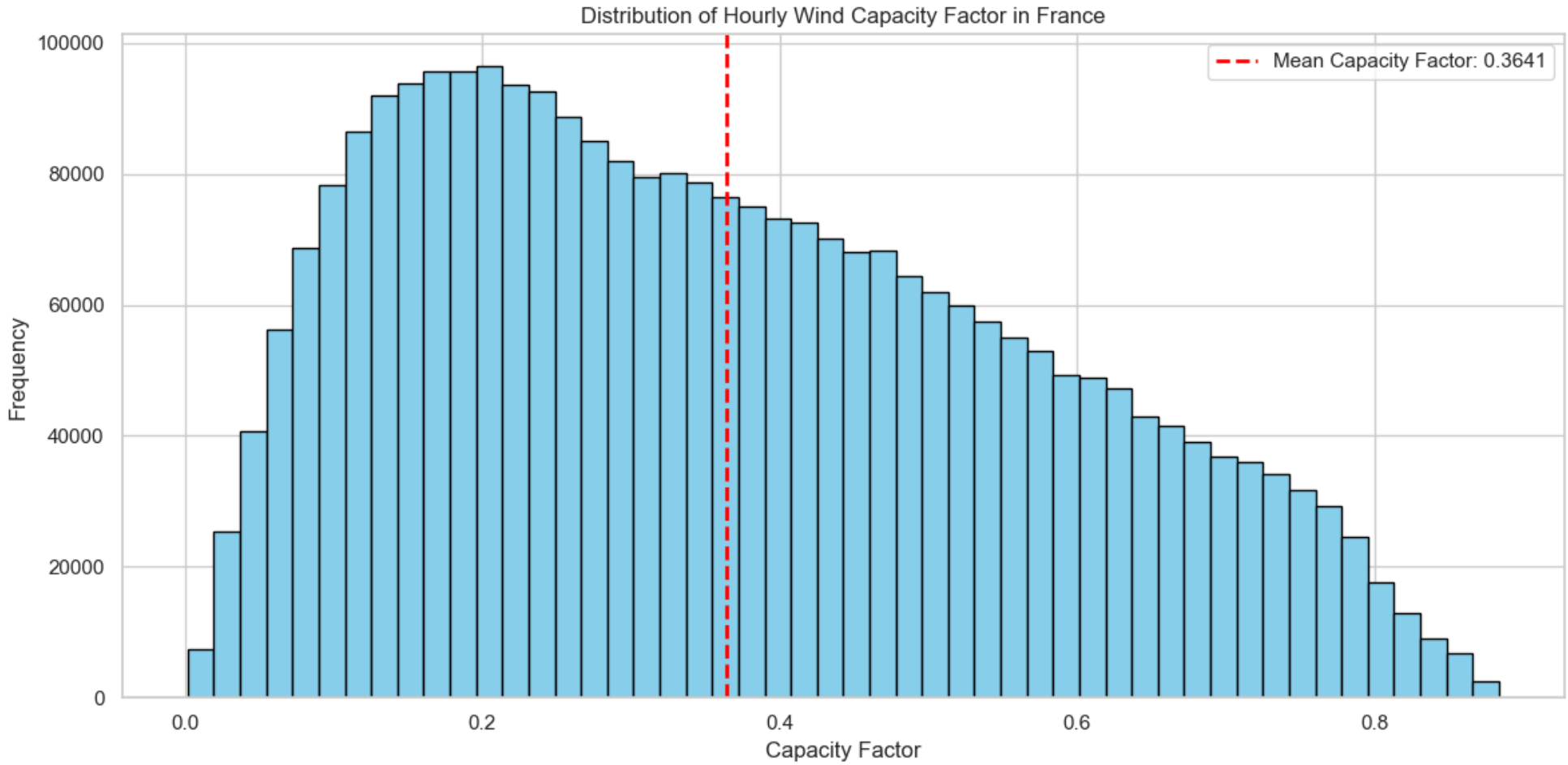
- Wind capacity factor lower than 20% significantly increases the potential LOLD.
- Explain the winter sensitivity: it increases the correaltion between high load and low wind production.



Hourly analysis



Wind capacity factor in France

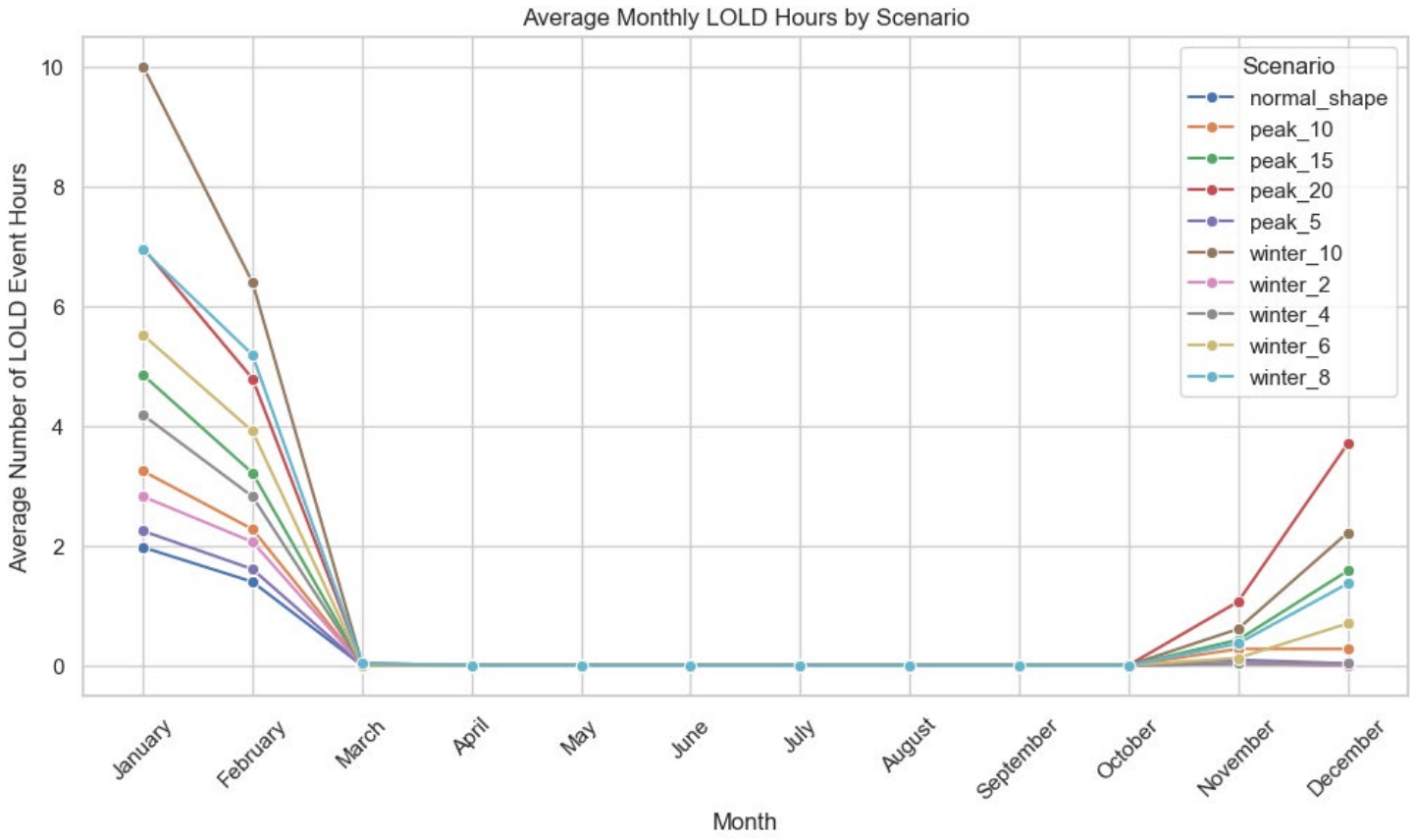


Monthly analysis

Main results

- ❑ Three difficult months
  1. December
  2. January
  3. February

- ❑ France is highly thermo sensitive. Different results for Spain or Italy?



Focus on the bad months
Peak case