Climate change-resilient future energy systems

Assessing the impact of heatwaves

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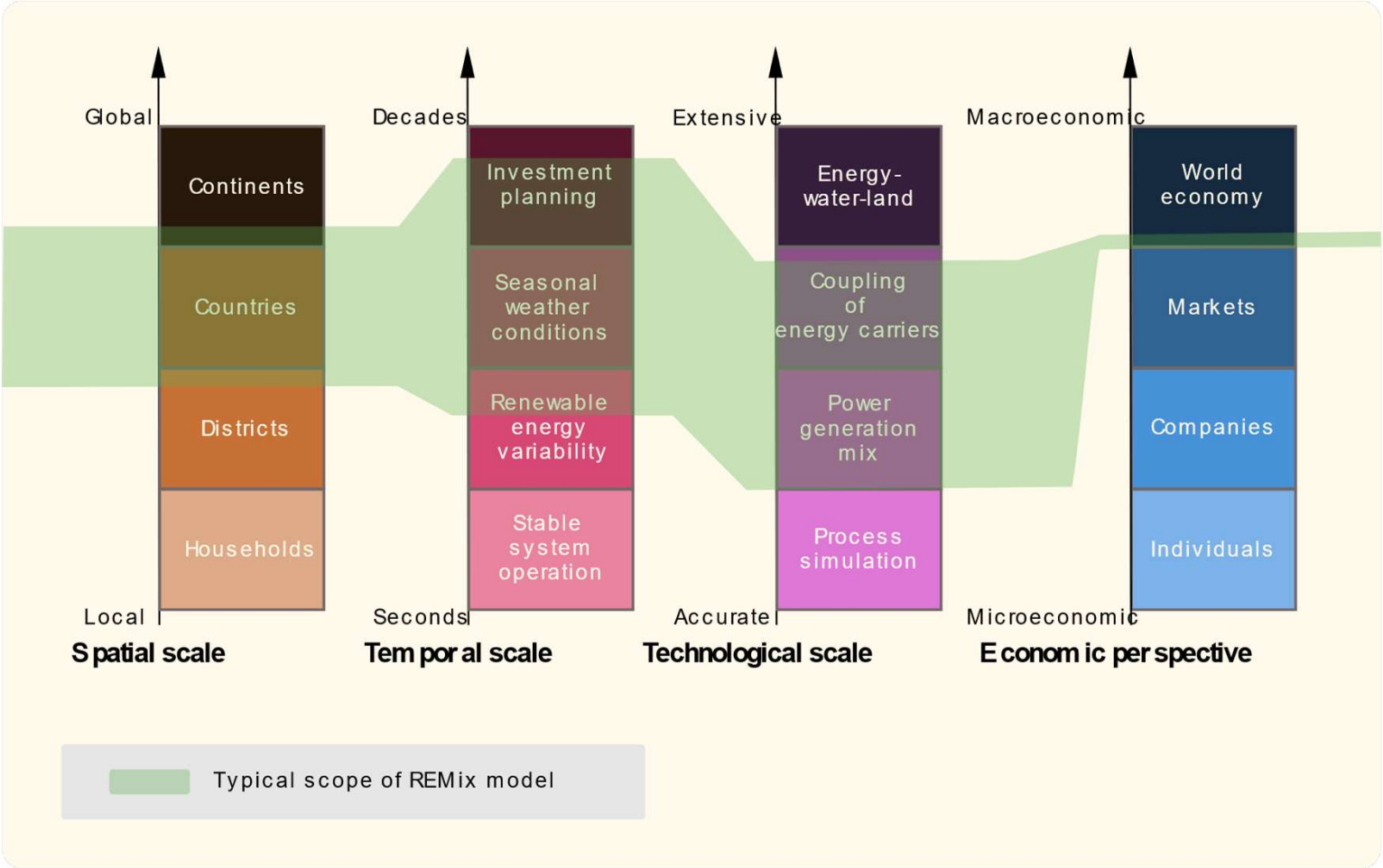
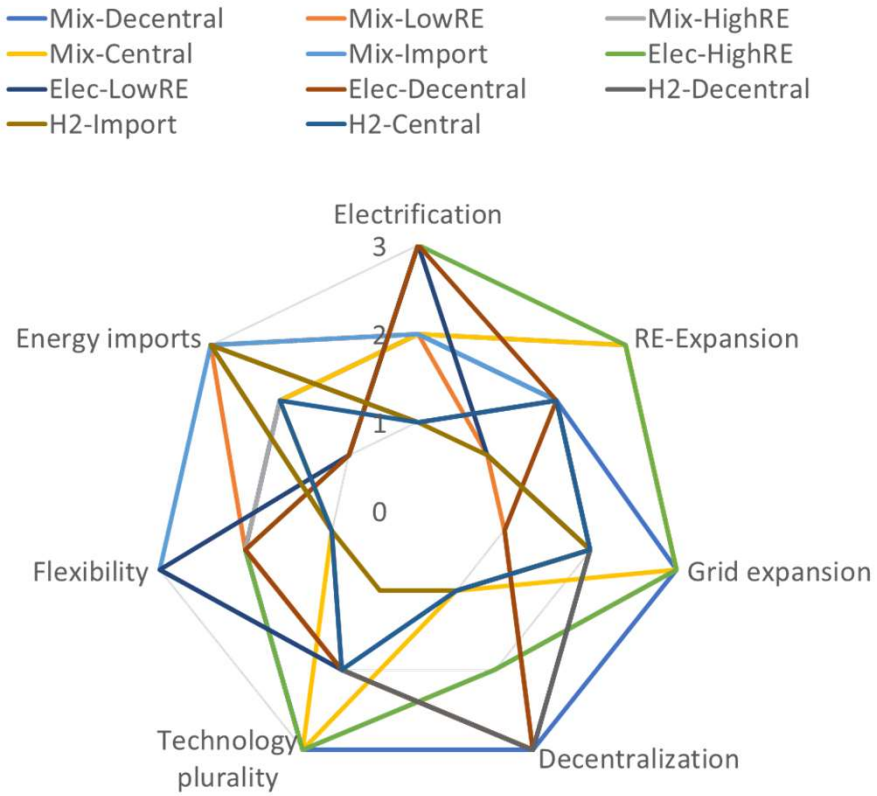
REMix in perspective



Karl-Kiên Cao, Jannik Haas, Evelyn Sperber, Shima Sasanpour, Seyedfarzad Sarfarazi, Thomas Pregger, Oussama Alaya, Hendrik Lens, Simon R. Drauz, and Tanja M. Kneiske. Bridging granularity gaps to decarbonize large-scale energy systems—the case of power system planning. *Energy Science & Engineering*, 9(8):1052–1060, May 2021. doi:10.1002/ese3.891 .

Project: **ReMo-Digital**

Resilience Monitoring for digitalization of the Energy Transition



Scenarios for future derived with cross-impact balancing

Key factors considered :

- Degree of Decentralization
- Technological plurality
- Grid expansion
- Renewable Energy Expansion
- Social acceptance
- European Integration
- Technological development in mobility
- Degree of automation

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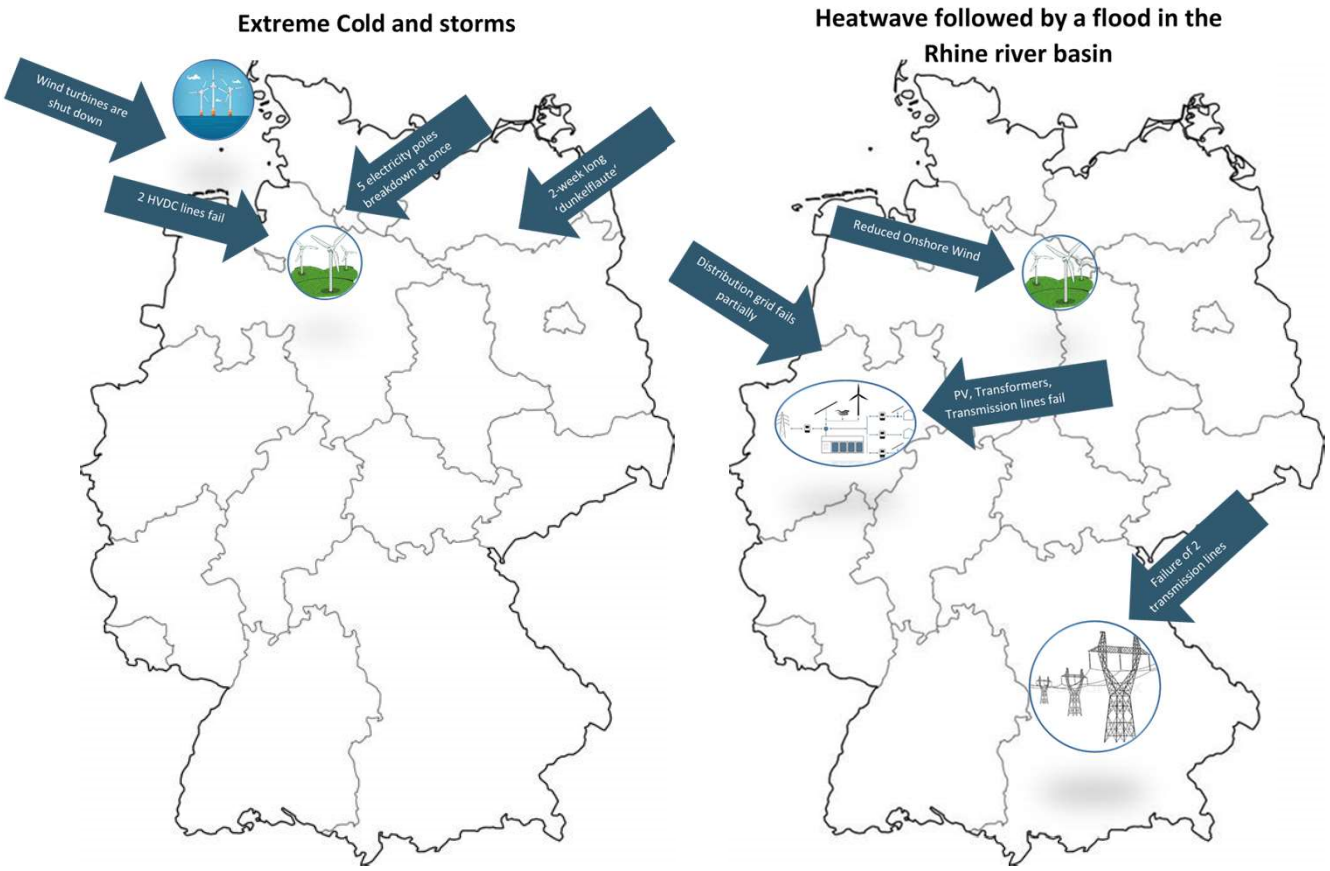
Resilience Monitoring for digitalization of the Energy Transition

Stress Cases of extreme events



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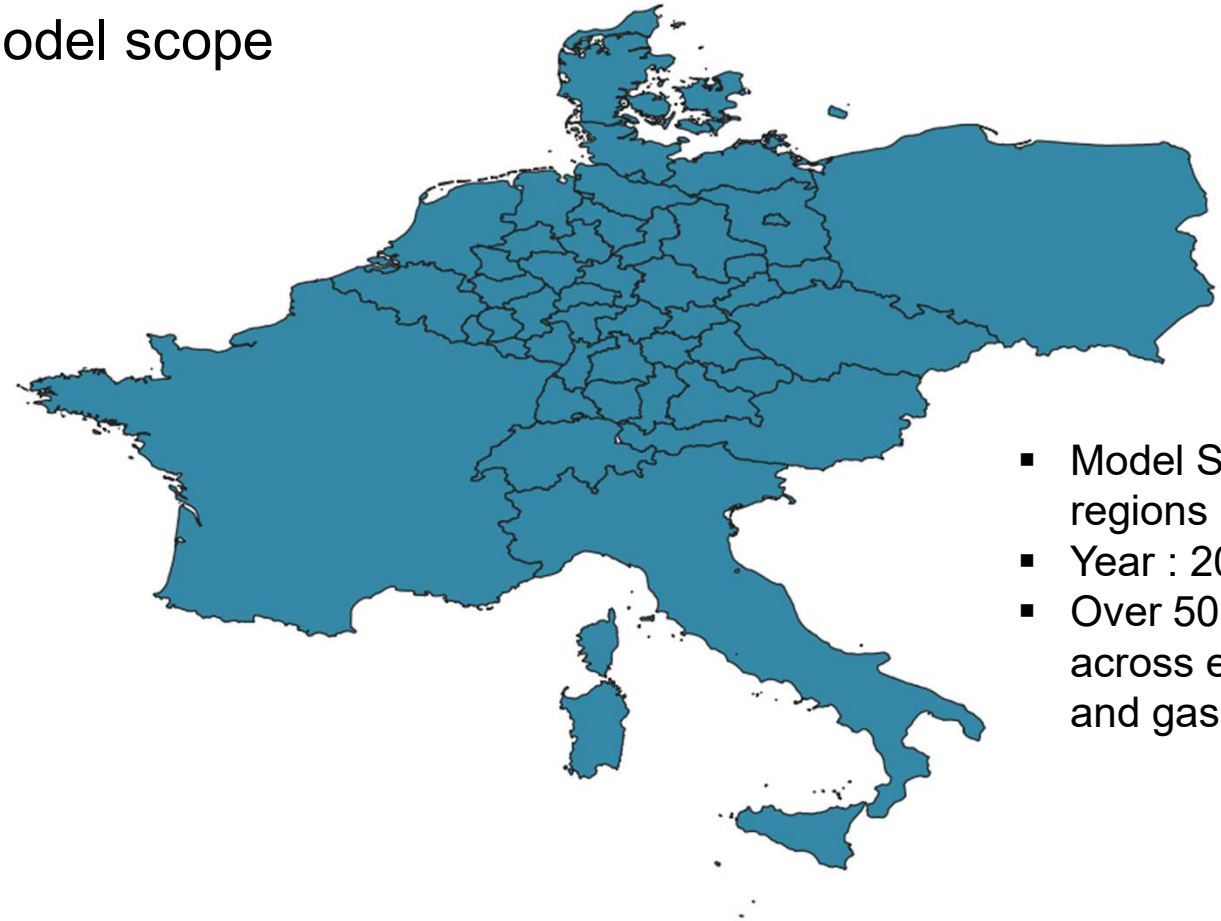
Resilience Monitoring for digitalization of the Energy Transition

REMix model scope



- Model Scope : 48 regions
- Year : 2050
- Over 50 technologies across electricity, heat and gas sector

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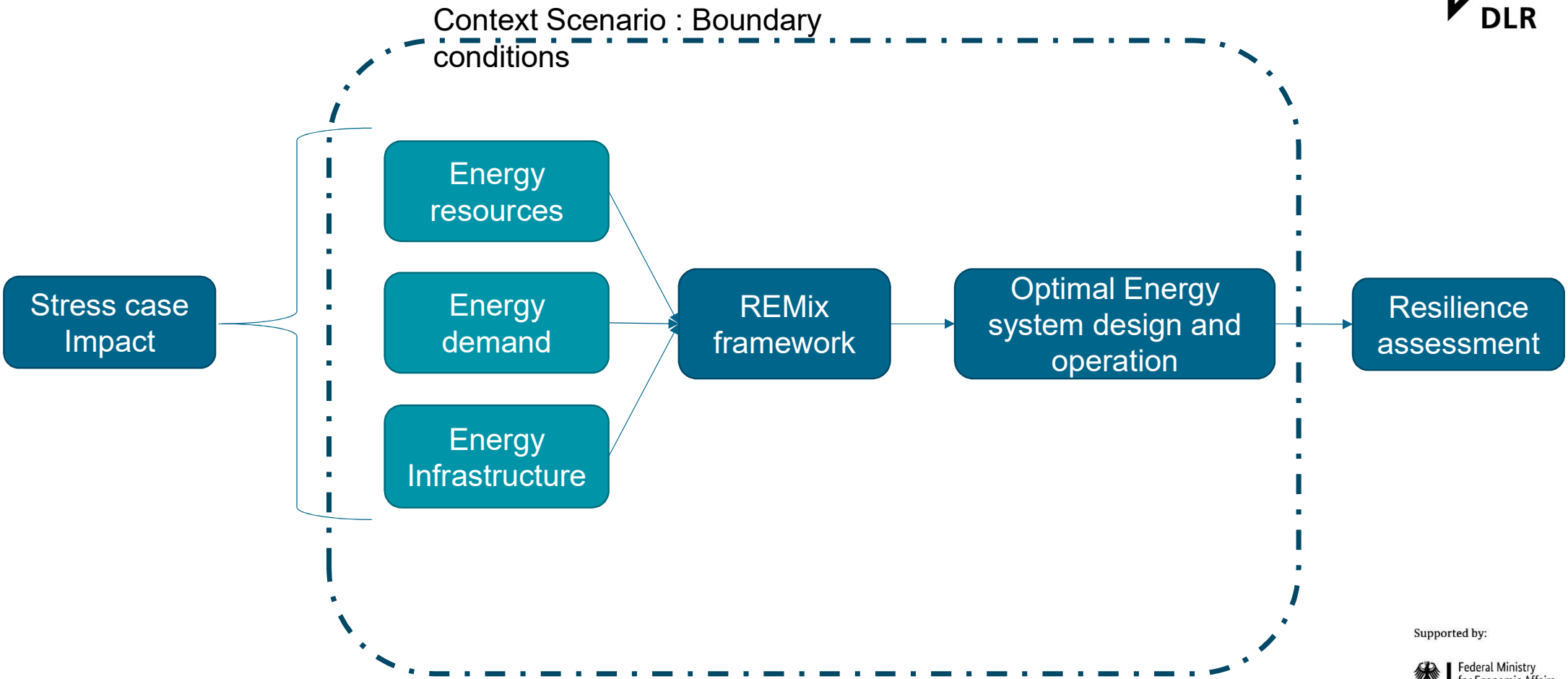
Workflow at a glance



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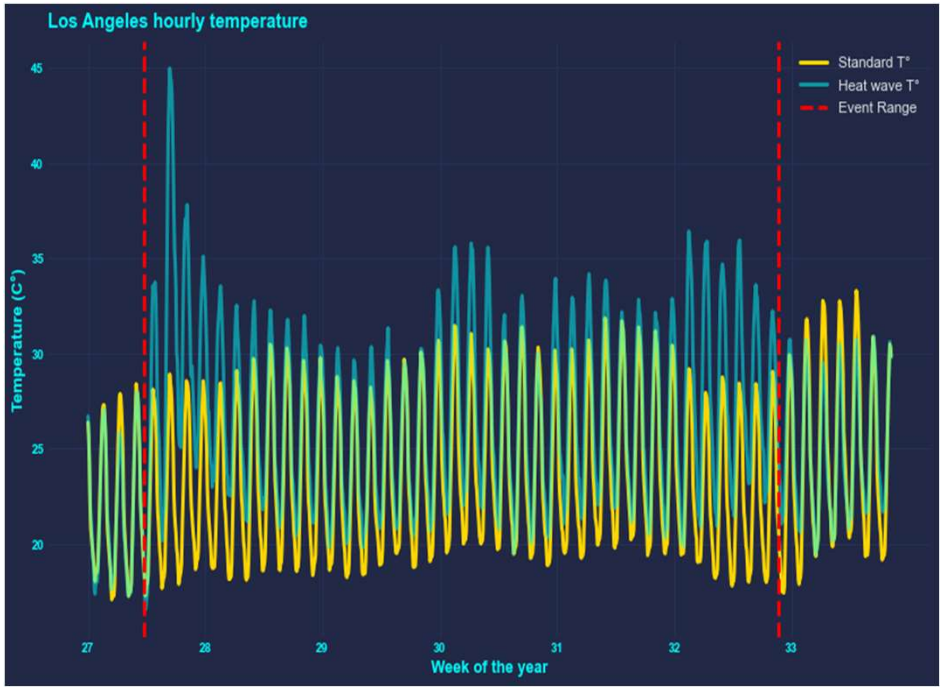
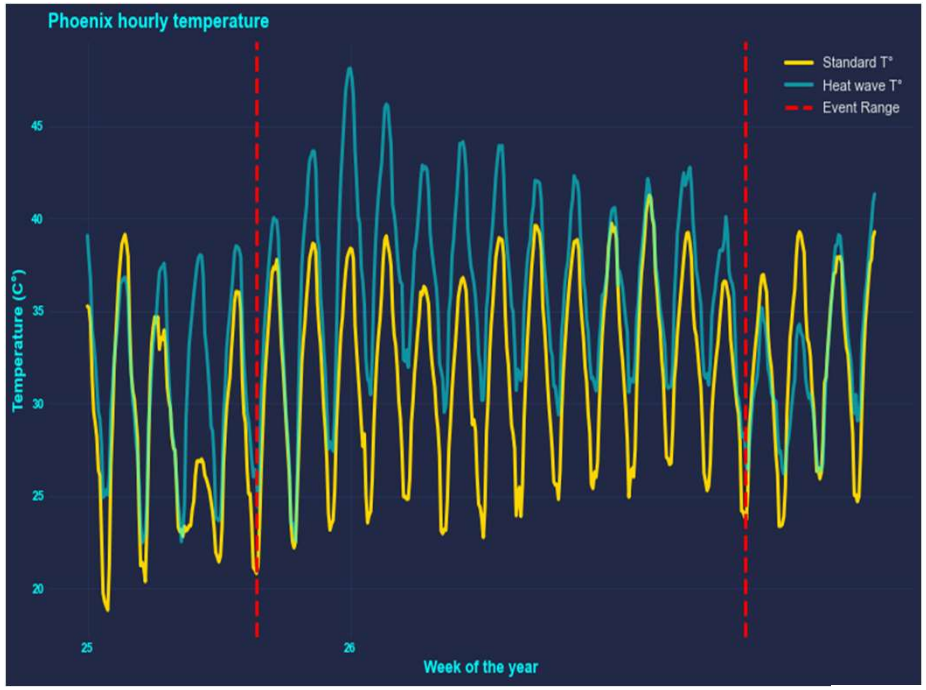
Case of a heat wave : estimating impact on demand

Heat waves in history with open data : temperature

Los Angeles, USA, 2018



Phoenix, USA, 2016



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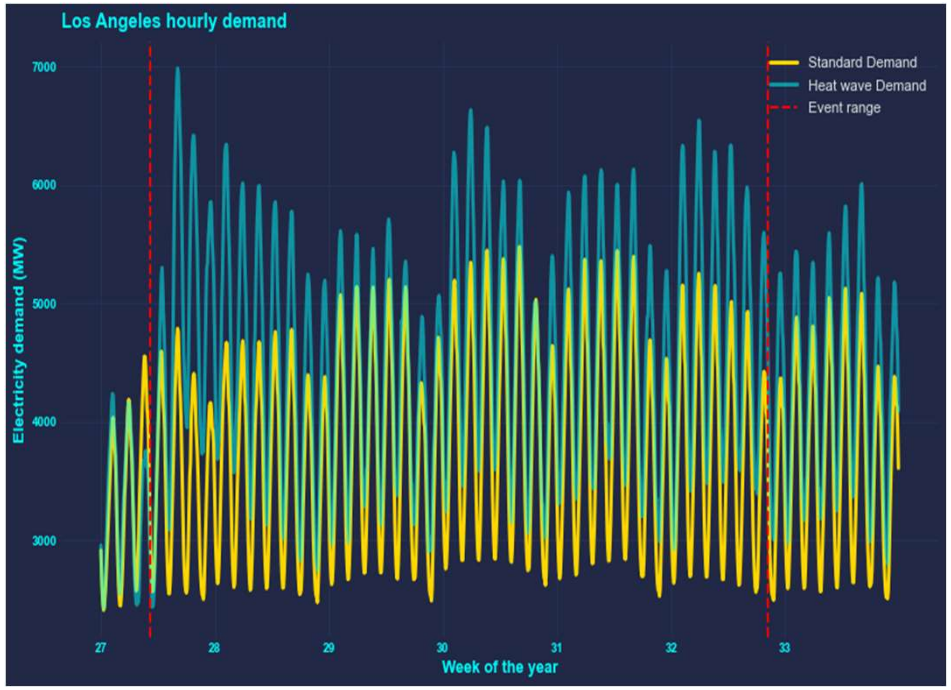
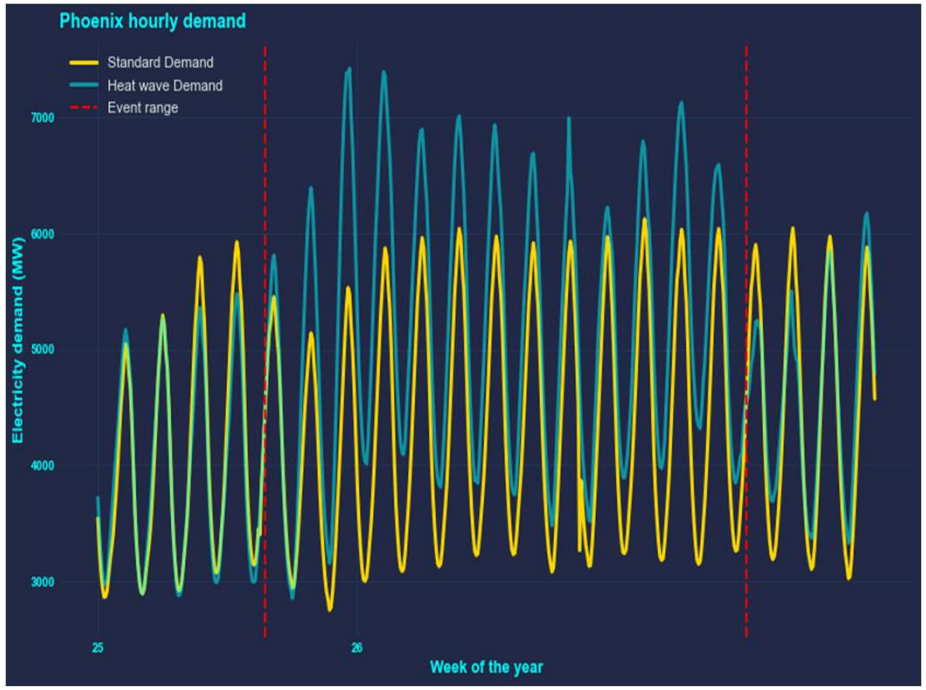
Heat waves in history with open data: demand

Los Angeles, USA, 2018



Phoenix, USA, 2016



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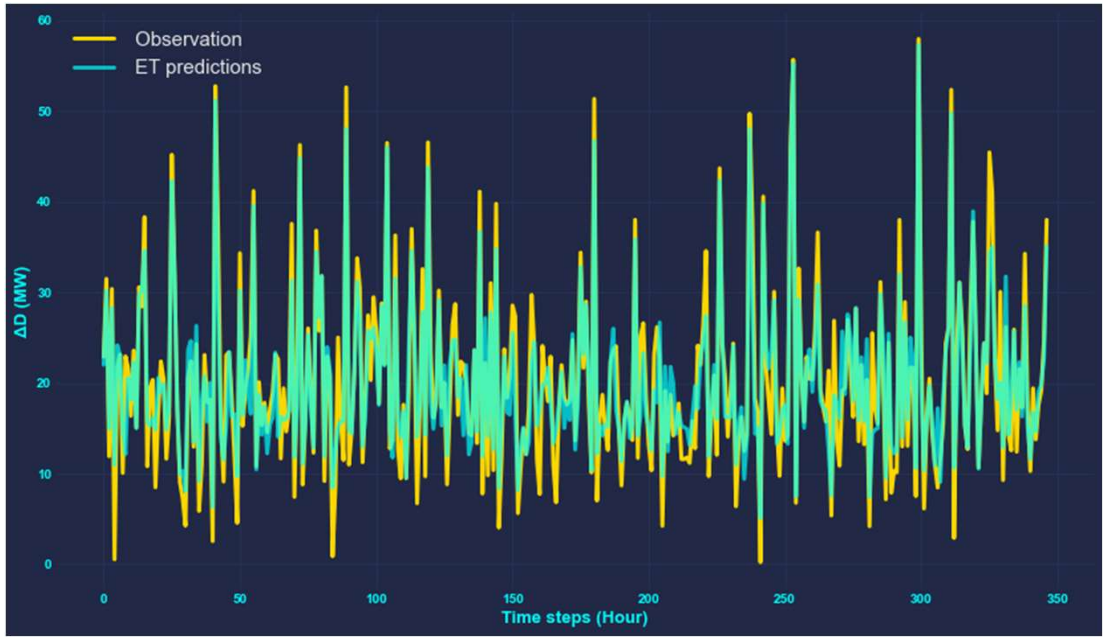
Machine Learning regression

Key features

- Temperature°
- Delta T° from standard historical data
- Standard Demand values
- Hour of the day
- Day of the week
- Lag 12 & 24 T°
- Lag 12 & 24 Standard Demand
- Week index: weekday or weekend
- Hour index: whether the hour is sleeping or awake hour



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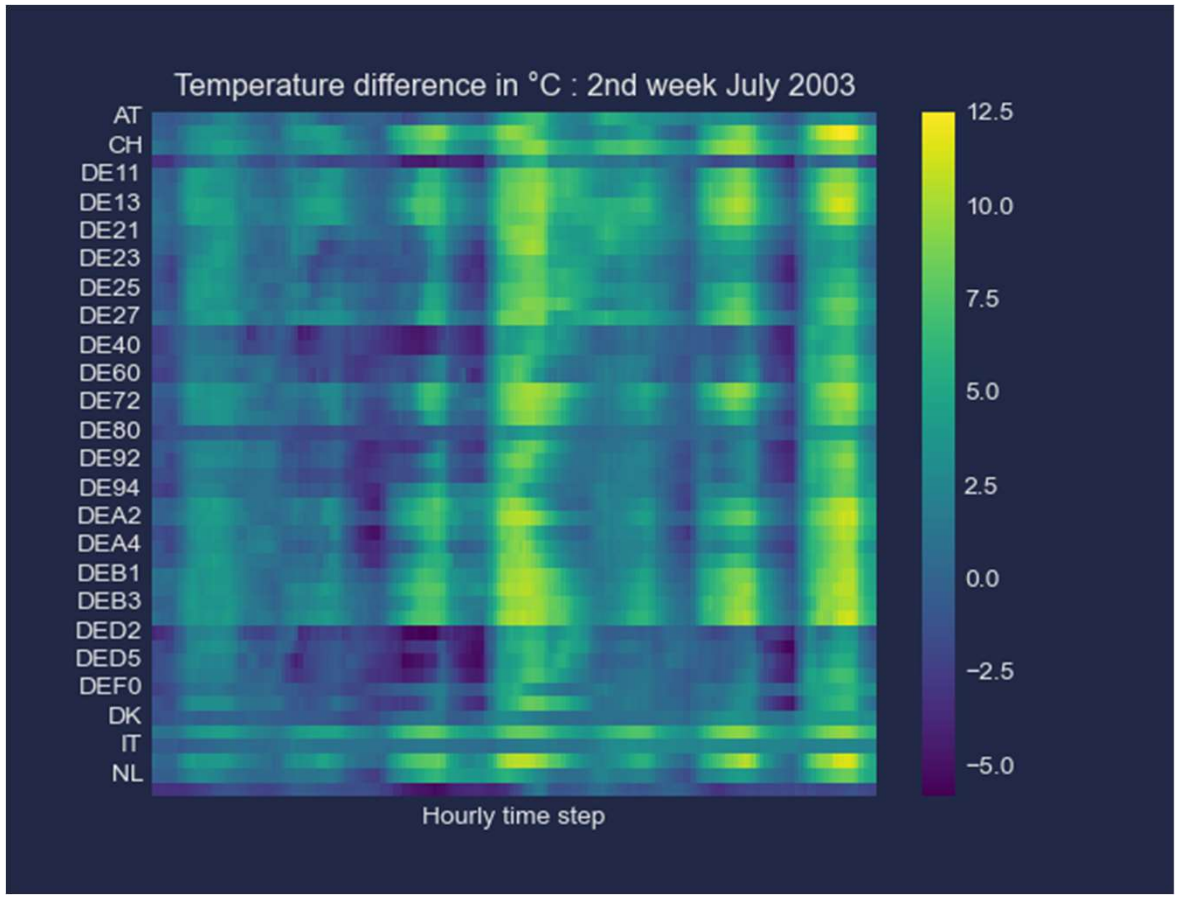
Preparing heatwave data for Energy System Model

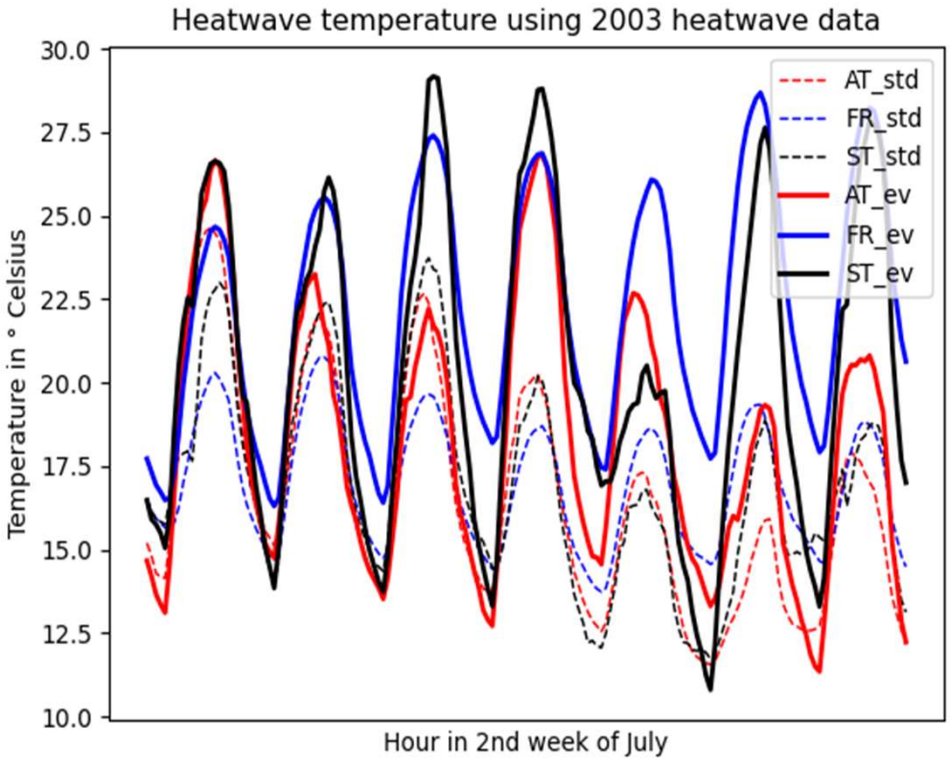
Basis : 2003 heatwave

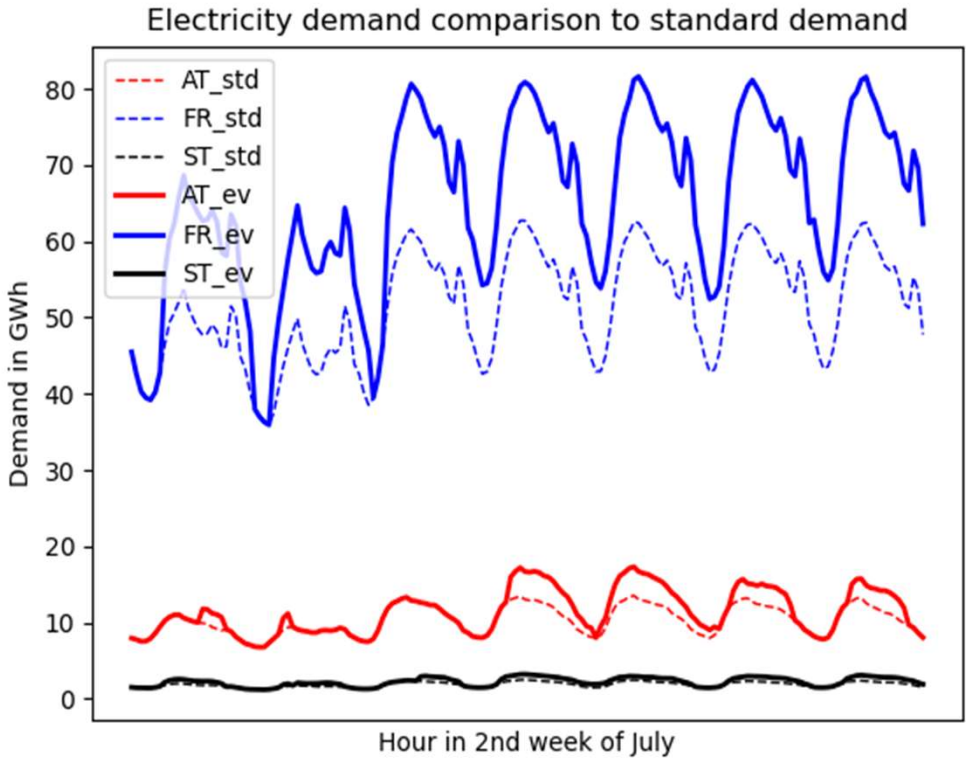
- Model weather year : 2012
- Idea :

Temperature rise in 2003 compared to neighbouring year is used as a stencil for temperature rise in the model year

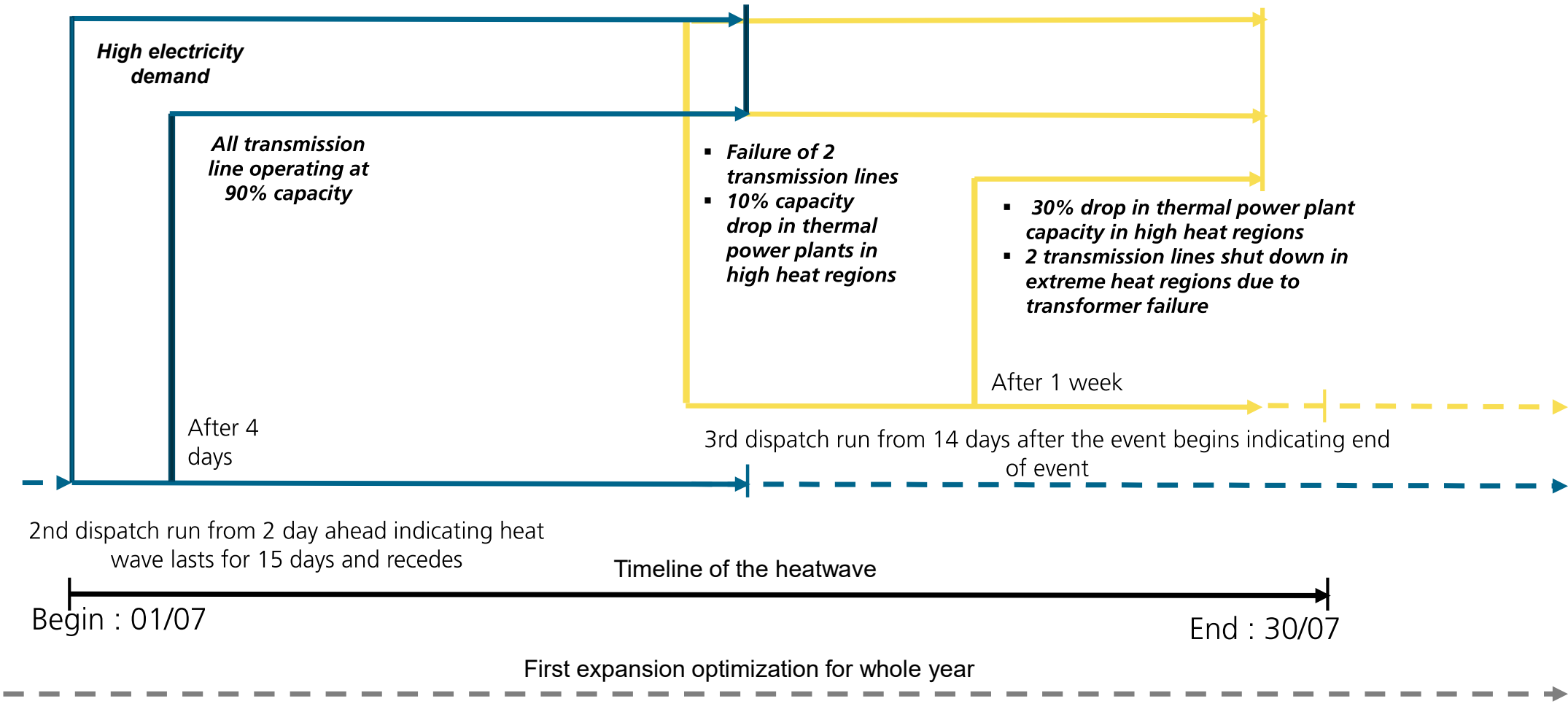


Heatwave temperature and demand for model



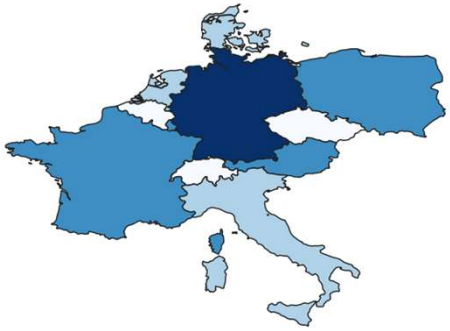


Materializing heatwave effects on system



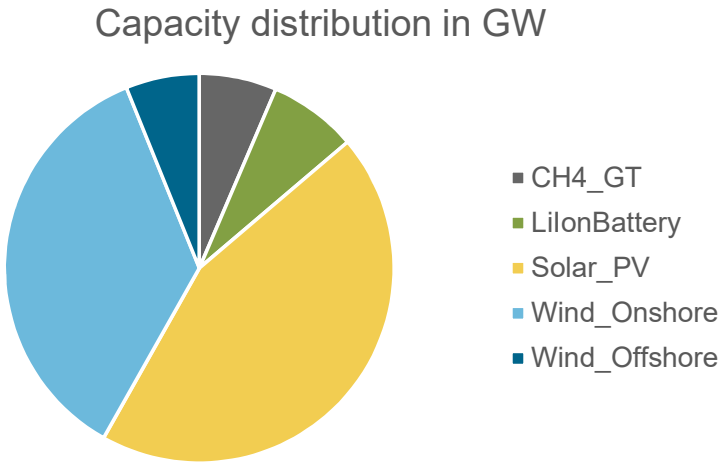
Testing with Energy System Modelling: simple case for 2050

Model scope and Inputs



Geographical scope:
Regions: Germany + 10 neighbouring countries (France, Switzerland, Italy, Belgium, Netherlands, Luxembourg, Czech Republic, Poland, Denmark, Austria)
Temporal scope:
Temporal Resolution: 1 hour
Year : 2050
*Scenario : BMWK FlexMex2 -2d**

Technologies modelled :
- Solar PV
- Wind Onshore and Offshore
- Li-Ion Battery
- AC Transmission

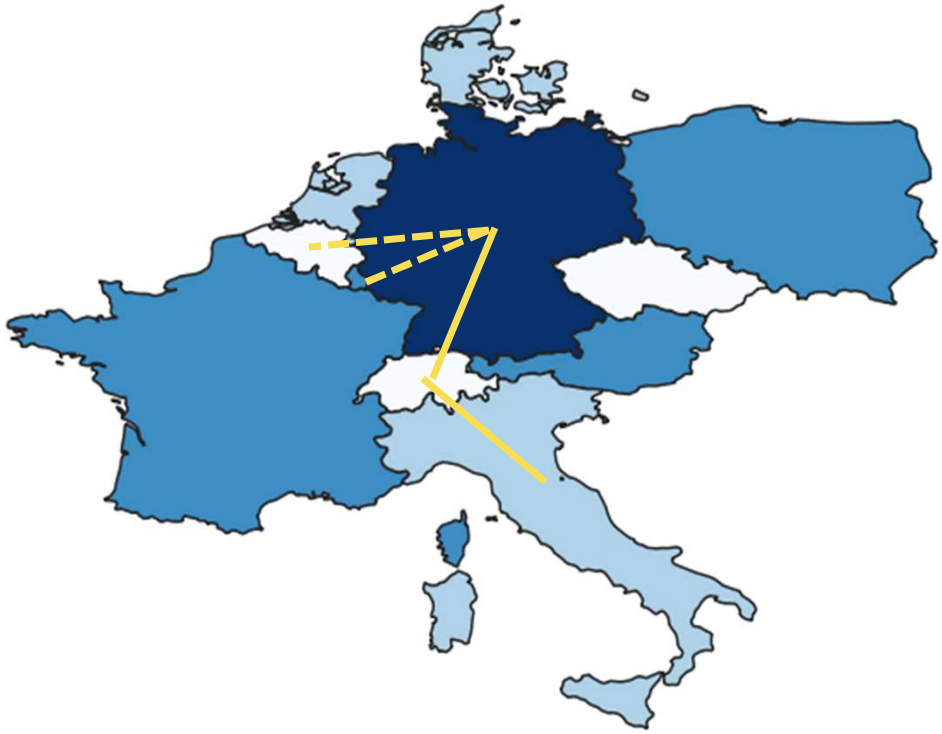


*FLexMex2 complete References
- Gils, H. C., Gardian, H., Kittel, M., Schill, W., Murmann, A., Launer, J., Gaumnitz, F., van Ouwerkerk, J, Mikurda, J., Torralba-Díaz, L. (2021). Model-related outcome differences in power system models with sector coupling - quantification and drivers. In Renewable and Sustainable Energy Reviews. Elsevier. ISSN 1364-0321.
- Gils, H. C., Gardian, H., Kittel, M., Schill, W., Zerrahn, A., Murmann, A., Launer, J., Fehler, A., Gaumnitz, F., van Ouwerkerk, J., Bußar, C., Mikurda, J., Torralba-Díaz, L., Janßen, T., Krüger, C. (2021). Modeling flexibility in energy systems - comparison of power sector models based on simplified test cases. In Renewable and Sustainable Energy Reviews. Elsevier. ISSN 1364-0321.
- van Ouwerkerk, J., Gils, H. C., Gardian, H., Kittel, M., Schill, W., Zerrahn, A., Murmann, A., Launer, J., Torralba-Díaz, L., Bußar, C. (2021). Comparison of power sector models by analyzing the impact of modeling features on optimal capacity expansion. In Renewable and Sustainable Energy Reviews. Elsevier. ISSN 1364-0321.

Heatwave conditions

Horizon 1 of the heat wave : 15 days

- Demand increases
- All transmission lines start to operate at 90% capacity



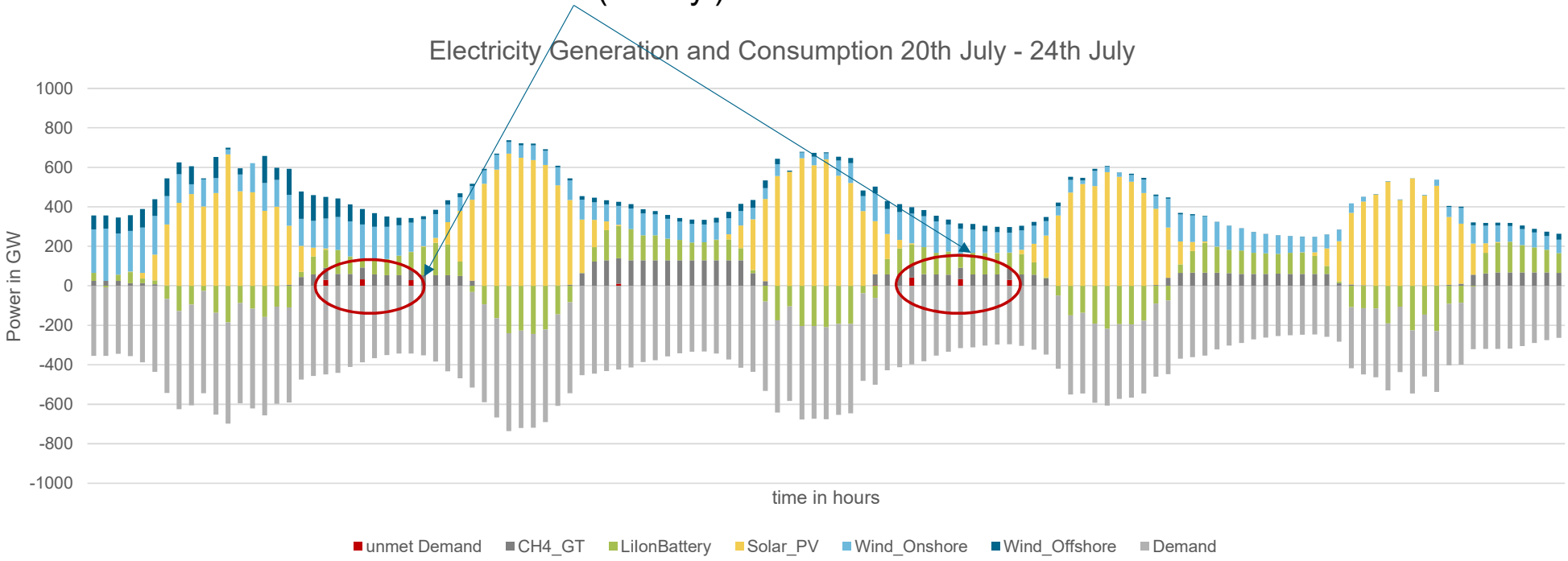
Horizon 2 of the heat wave : 15 days

- Continuation of horizon 1 conditions
- Only 70% Gas turbines operating in DE, CH, IT, AT
- Links DE-CH and CH-IT shut down
- 1 week later, links DE-BE and DE-LU shut down

(Not-so-exciting) results

Horizon 1 of the heat wave : system reorganizes
Generation with Gas turbines increases slightly to meet increase in demand

Horizon 2 of the heat wave :
- First half sees further reorganization : increase in localized generation
- 2nd half witnesses unmet demand (in Italy!)



Summary & Outlook

- Impact-based resilience assessment with energy system optimization model
- Simple heatwave-demand model can predict rise in electricity demand during heat wave, using historic events
- Electricity demand rises upto 40% based on the 2003 heat wave
- Higher spatial resolution in modelling drastically enhances the effects of modelled heatwave
- Supply security is critical typically in regions with combination of higher demand and infrastructure failure

Next steps :

- Resource effects of heatwave
- More realistic test cases

Any suggestions?

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Appendix

REMix workflow