House of Energy Markets & Finance

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Link between Generation Adequacy and Market Modeling: Unveiling Vulnerabilities of the Energy System

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Project workshop (VeSiMa)

amprion verbindet

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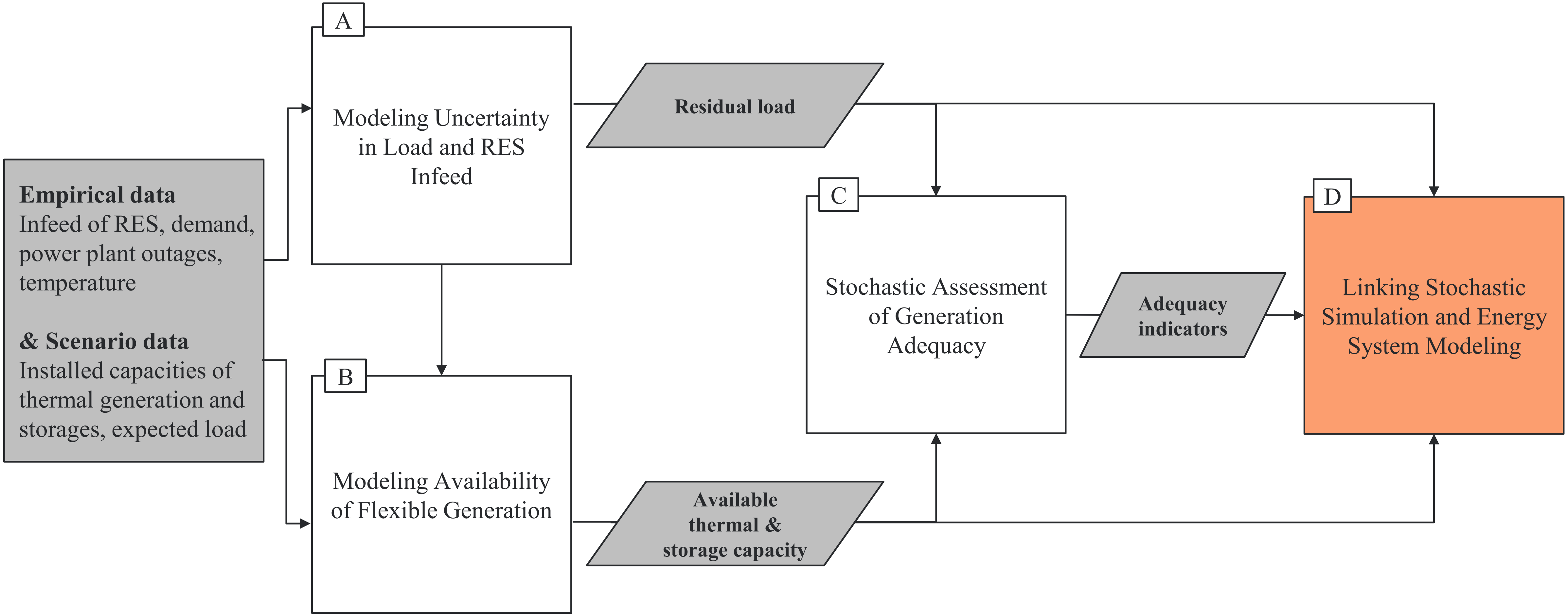
Dealing with stochasticity in Generation Adequacy evaluation

- Focus so far: comprehensive quantification of stochastic variations in key power system characteristics, but no market modeling
  - Simulation model to assess generation adequacy based on expected energy not served (EENS) and loss of load expectation (LOLE)
  - Not modeled: a) Detailed technical and economic power plant restrictions, b) Economically driven unit commitment of power plant or storages

- Problem a): No assessment of market outcomes possible (under adequacy risk) using the simulation model
  - Open question: How does the power system and markets deal with rare but extreme scarcity events?

- Problem b): Large-scale fundamental electricity market models are deterministic
  - How to link the probabilistic simulation model and the deterministic electricity market model?

Generation Adequacy – How to involve deterministic market modeling?



Link of stochastic and deterministic modeling

- Identification of a suitable simulation for Generation Adequacy Assessment
  - Selection of an „extreme“ simulation

- Characteristics for extreme simulation:
  - Key indicator: Annual ENS
  - Interdependencies between different regions should be taken into account

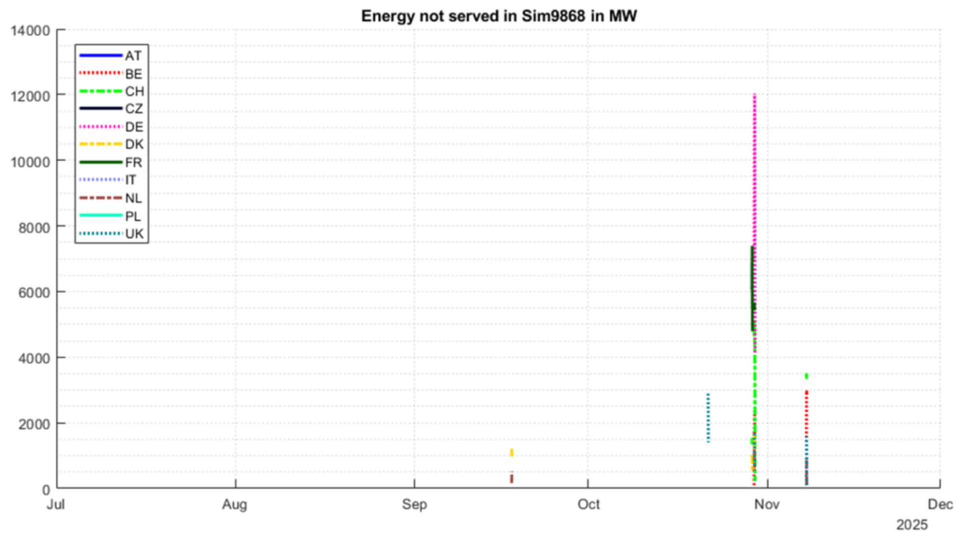
- Geometric mean over all simulated regions r:

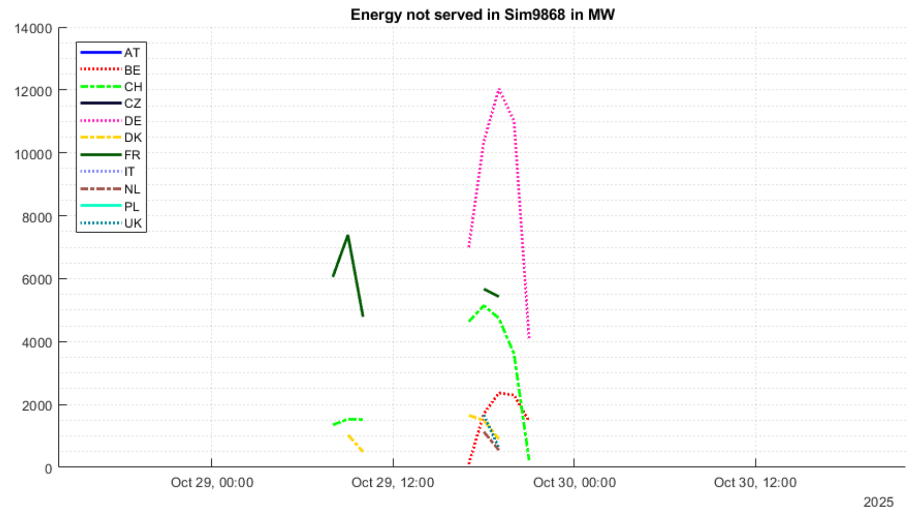
$$ENS_{geom} = \sqrt[n]{\prod_{r=1}^{n} ENS_r}$$

Charateristics of the extreme simulation

- Nowhere more than 10 LOLE-hours in any region, ENS concentrated in limited number of scarcity events
- Four time periods with ENS up to 12 GWh in one region
- Simulateinity of ENS events observable for different regions

	Sum of Annual ENS [MWh]	Number of LOL - Events [h]
AT	0	0
BE	15,592	9
CH	29,608	10
CZ	0	0
DE	47,577	8
DK	7,774	7
FR	29,332	5
IT	0	0
NL	4,083	7
PL	271	1
UK	9,970	10
Sum	144,207	57





Basics of deterministic electricity market model JMM

- Deterministic electricity market model
  - Heat market (CHP restrictions), reserve market included
  - Widely used in previous studies (e.g. Trepper et al. (2015))

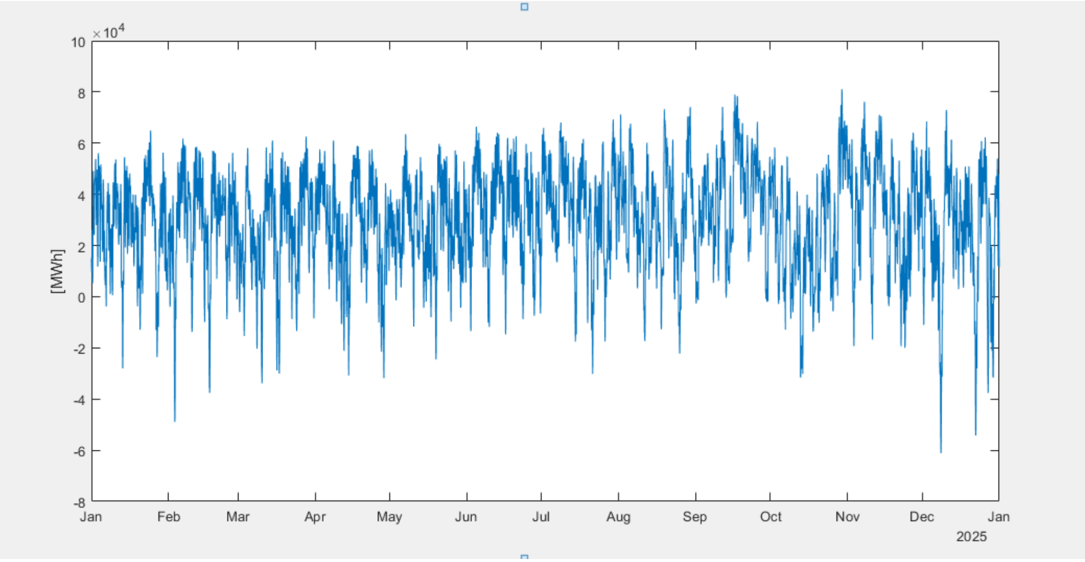
- Model output: Dispatch decisions of power plants and storages
  - No investment decisions

- System cost minimization
  - Only variable cost (mainly fuel prices, emission costs)
  - Restrictions e.g. demand covering and technical restrictions (minimum up- and down-times etc.)

- Usually, simulation of one year in an hourly resolution
  - Rolling planning horizon with weekly looping

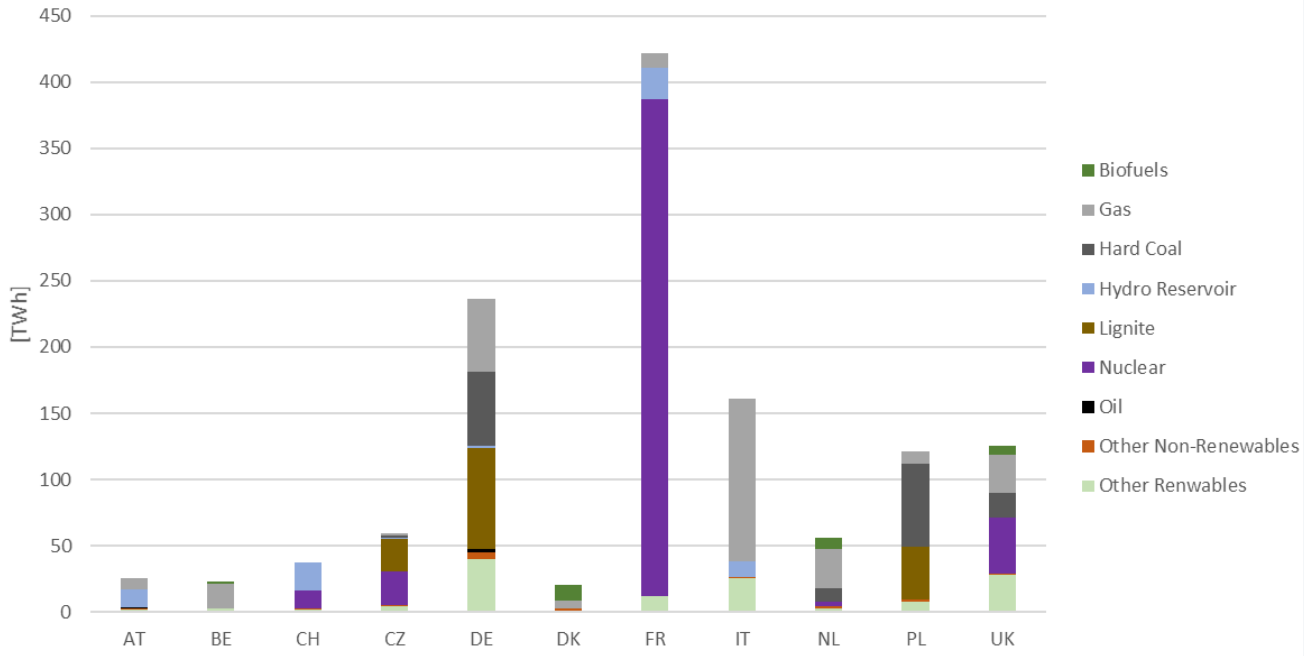
Input data based on extreme simulation for deterministic modeling

- ERAA 2021 National Estimates Scenario as basis
  - Simulation year 2025
  - 11 regions: AT, BE, CH, CZ, DE, DK, FR, NL, IT, PL, UK
  - Harmonization of input data for VeSiMa and JMM especially for power plant and storage capacities based on ERAA 2021
- Timeseries for power plant availabilities and electricity residual demand (electricity demand, PV, wind, RoR) as an input from the VeSiMa model based on extreme simulation

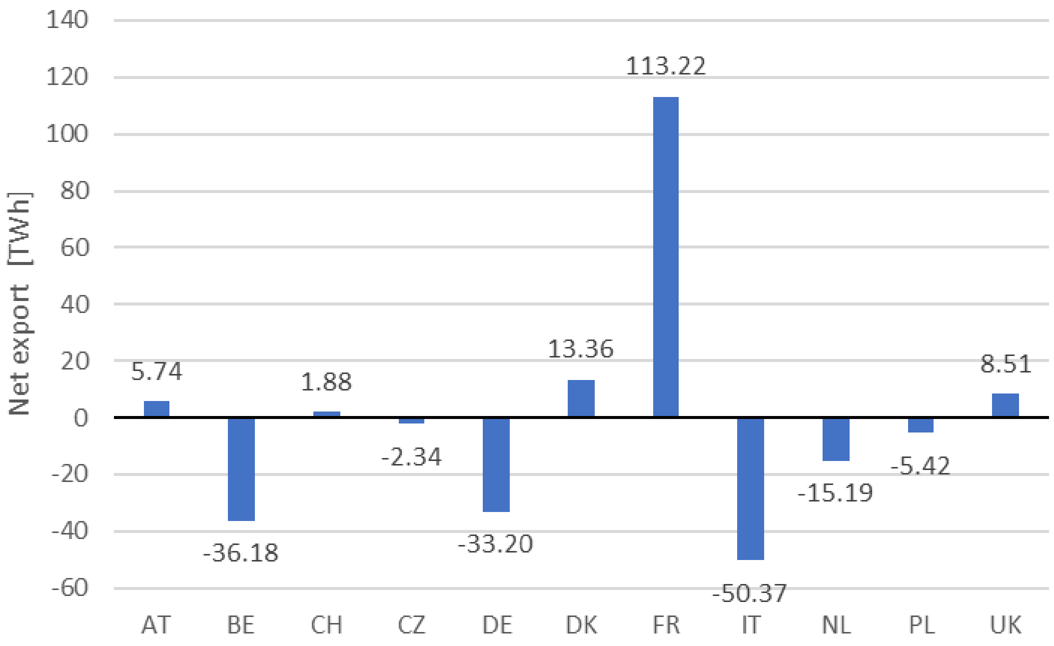


Market results of deterministic modeling

- Annual generation mix (without PV, Wind, RoR, battery and pump storage discharge)

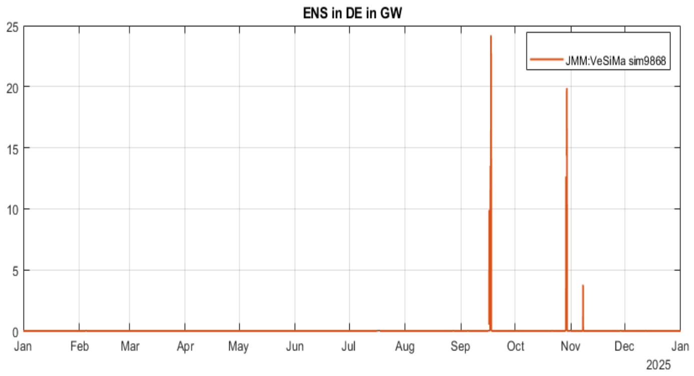


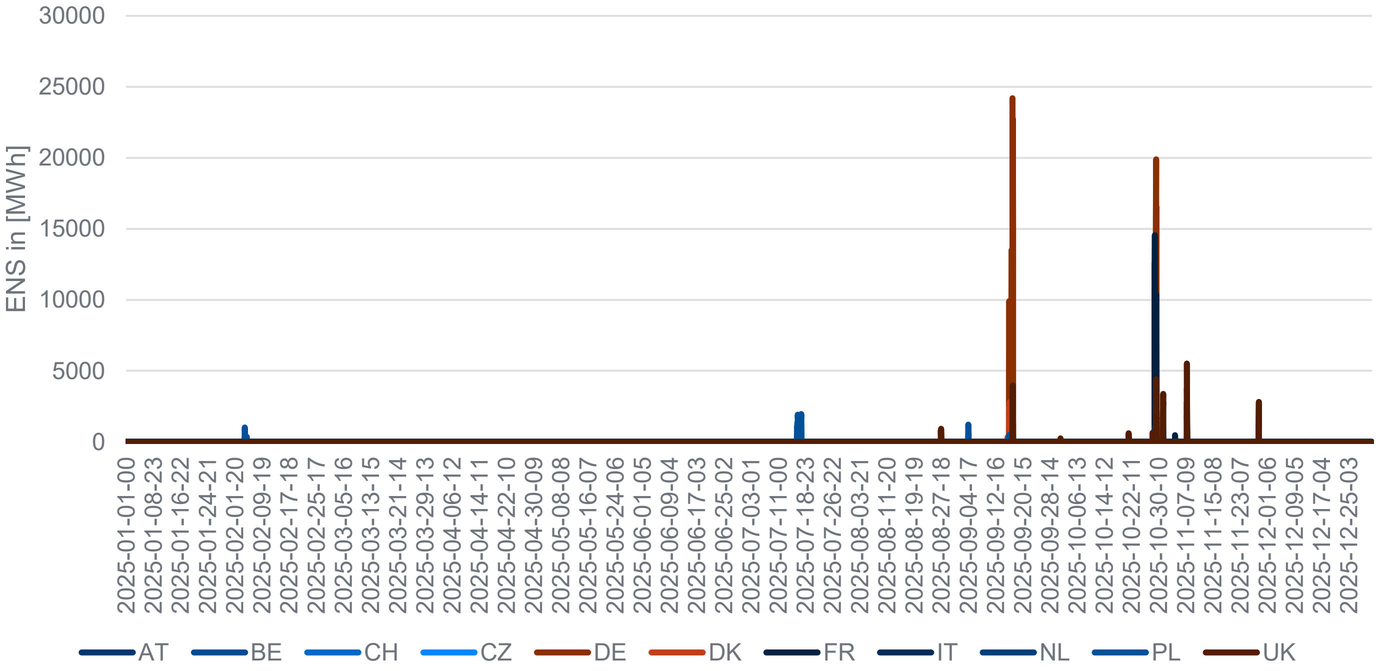
- Annual net export



Generation Adequacy: ENS concentration on limited peak periods in JMM

- Energy Not Served can be seen in 81 hours over the whole year in JMM
  - Concentration in September (16th-17th) and October (29th)
- Highest ENS can be seen in Germany (up to 24,2 GWh in 09-17-17 and 19,9 GWh in 10-29-18)
  - Remember: case that happens one time in 10,000 years
- Maximum simultaneity of 6 six countries can be seen in three hours of the year, in 49 hours ENS appears just in one single country





Generation Adequacy: Higher ENS in the deterministic market model

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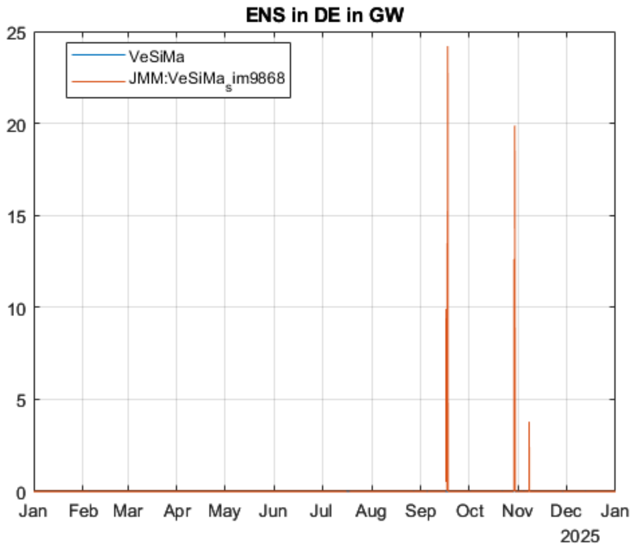
- In JMM, remarkably higher ENS and LOLE than in stochastic VeSiMa model
  - Significant differences especially in DE, DK, PL
- No ENS for both models in AT and IT
- Highest annual ENS in DE for both models, but more than 285 GWh additional ENS in JMM



	Sum of Annual Energy not Served [MWh]		Number of LOL - Events [h]	
	JMM	VeSiMa	JMM	VeSiMa
AT	0	0	0	0
BE	34,669	15,592	22	9
CH	0	29,608	0	10
CZ	745	0	2	0
DE	333,310	47,577	32	8
DK	38,092	7,774	32	7
FR	92,125	29,332	15	5
IT	0	0	0	0
NL	9,554	4,083	8	7
PL	34,606	271	36	1
UK	39,177	9,970	20	10
Sum	582,277	144,207	167	57

Differences in ENS estimation in VeSiMa and JMM: Example Germany

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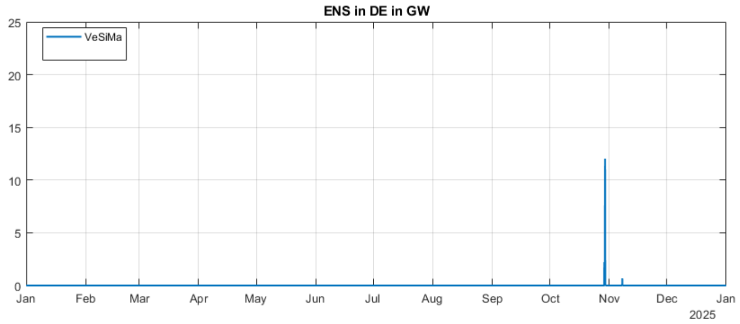
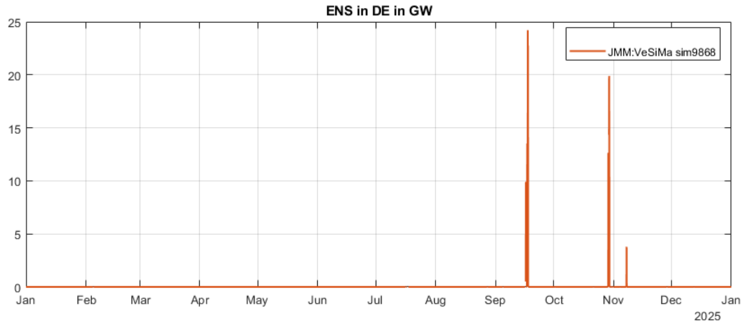
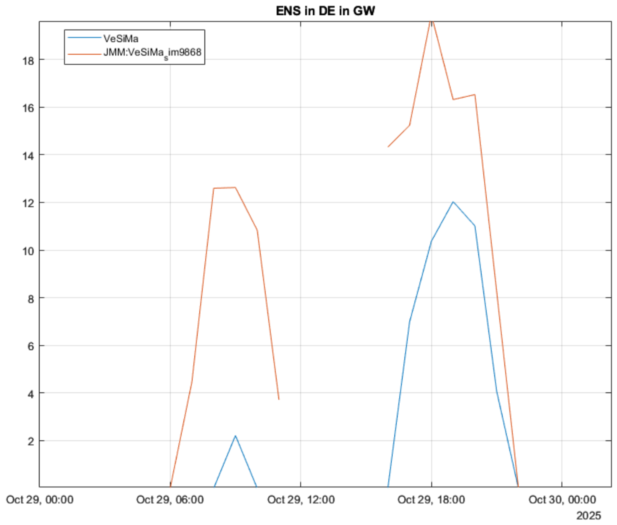
- In September, ENS on two consecutive days in JMM, whereas in VeSiMa, no ENS occured
- In October, ENS developments similar in both models, but on a higher level in JMM







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ENS differences between JMM and VeSiMa: root cause analysis

- Key reason: JMM is more restrictive than VeSiMa model
  - **CHP restrictions** -- *reduce electricity generation capability of CHP power plants*
  - **Reserve provision** -- *implicitly increases total electricity demand*
  - **Minimum up- and downtimes** -- *reduce flexibility of power plants*
  - **Start-up costs** - *reduce flexibility of power plants*

- Different modeling of seasonal hydro reservoirs
  - Natural inflows replaced by pumping in VeSiMa

- Rolling planning in JMM may also have an impact because of limited foresight
  - Relevant e.g. for storage usage

Sensitivity analysis : Convergence in energy not served (ENS) with aligned model configuration

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- Sensitivity: ***Neglection of heat restrictions, reserve restrictions, start-up costs and minimum up- and down-times***
- Significant reduction of ENS in JMM, but sum of ENS over all regions is still higher than in VeSiMa
  - High impact especially for DE and Poland
- ENS values of JMM deterministic and stochastic modeling are converging, partly even lower values in JMM

	Sum of Annual Energy not Served [MWh]			Number of LOL - Events [h]		
	JMM	JMM_sensitivity	VeSiMa	JMM	JMM_sensitivity	VeSiMa
AT	0	0	0	0	0	0
BE	34,669	12,595	15,592	22	5	9
CH	0	0	29,608	0	0	10
CZ	745	0	0	2	0	0
DE	333,310	84,451	47,577	32	12	8
DK	38,092	5,684	7,774	32	6	7
FR	92,125	56,806	29,332	15	10	5
IT	0	0	0	0	0	0
NL	9,554	59	4,083	8	1	7
PL	34,606	0	271	36	0	1
UK	39,177	2,085	9,970	20	3	10
Sum	582,277	161,681	144,207	167	37	57

Conclusion

- Outcomes of the stochastic VeSiMa approach have been compared to the results of the deterministic market model JMM based on two runs:
  - a median simulation (not shown here)
  - an extreme simulation

- Results not be overinterpreted in absolute terms: the extreme simulation is an extremely rare case (1 out of 10,000 years)

- Yet in this extreme case, the more complex representation of power plant and storage dispatch restrictions in the market model **impact substantially the generation adequacy indicators**

- Additional restrictions increase the expected energy not served
  - partly in hours without any supply deficit in VeSiMa

Thank you for your attention.

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