FFF online event: The role of energy storage in power sectors with fossil fuel phase-out

How time-series reduction impacts storage modelling

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Introduction

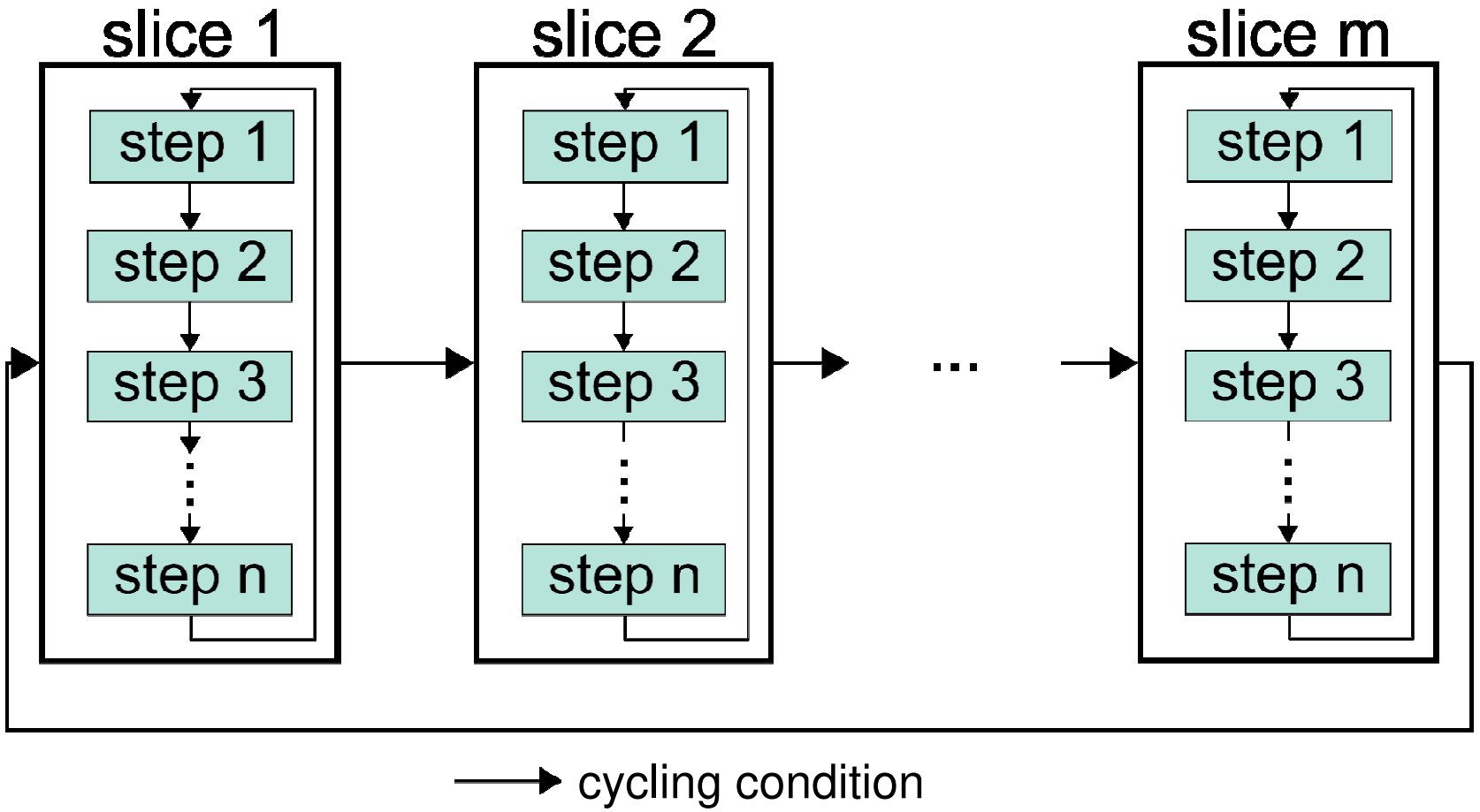
Background

- Reducing the input-series to a small number is a common strategy to reduce the complexity of energy system models
- Methods for time-series reduction (TSR) were originally developed and tested for energy systems characterized by fossil fuels

Research Question

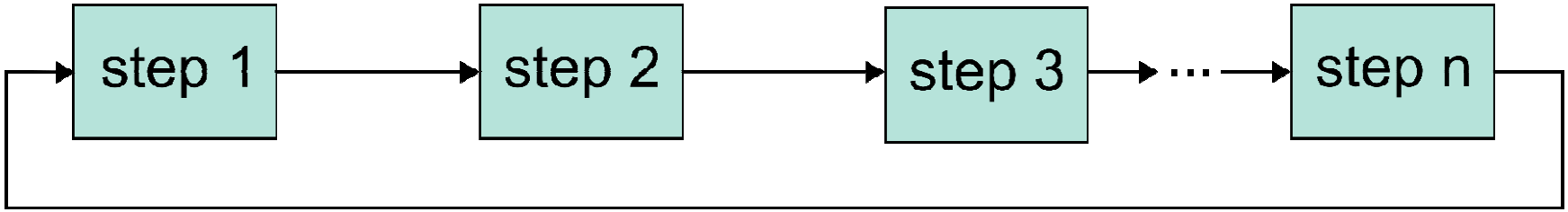
- How well is TSR suited be used in the context of renewable energy systems characterized by fluctuating generation and storage?

Discontinuous time-slices to implement reduced time-series



- Allows for weighting of time-slices
- Implementation of cycling conditions from Kotzur 2018 used

Continuous time-steps to implement reduced time-series



- No weights!
- Two ways to aggregate reduced time-series to steps
  1. Scale-up variables that relate to the entire year → α
  2. Scale-up parameters that relate to single time-steps → β

$$\min \quad FixCosts + VarCosts \cdot \alpha$$

$$\text{s.t.} \quad \sum Gen + \sum StOut = dem \cdot \beta + \sum StIn$$

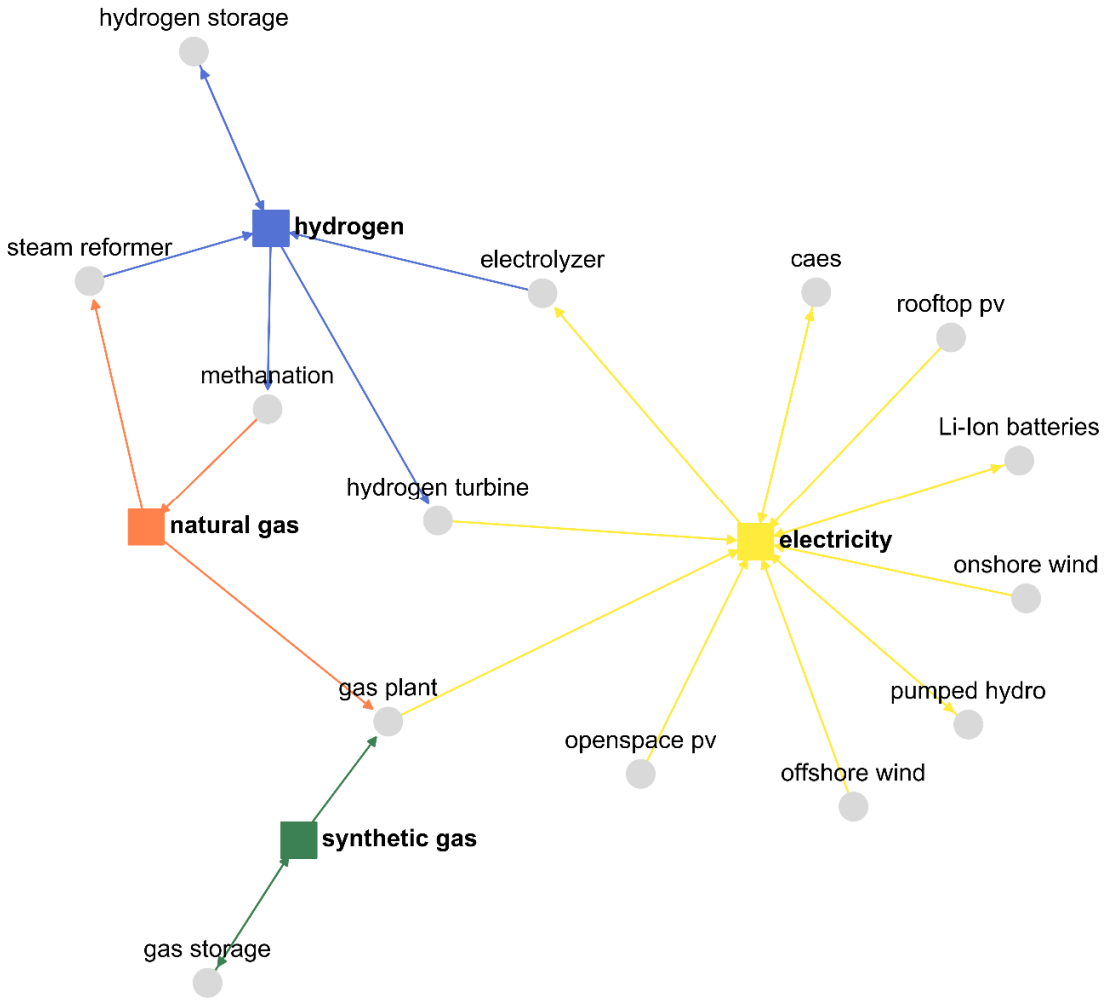
$$Emissions \cdot \alpha \leq emissionLimit$$

$$etc.$$

Methods to reduce time-series

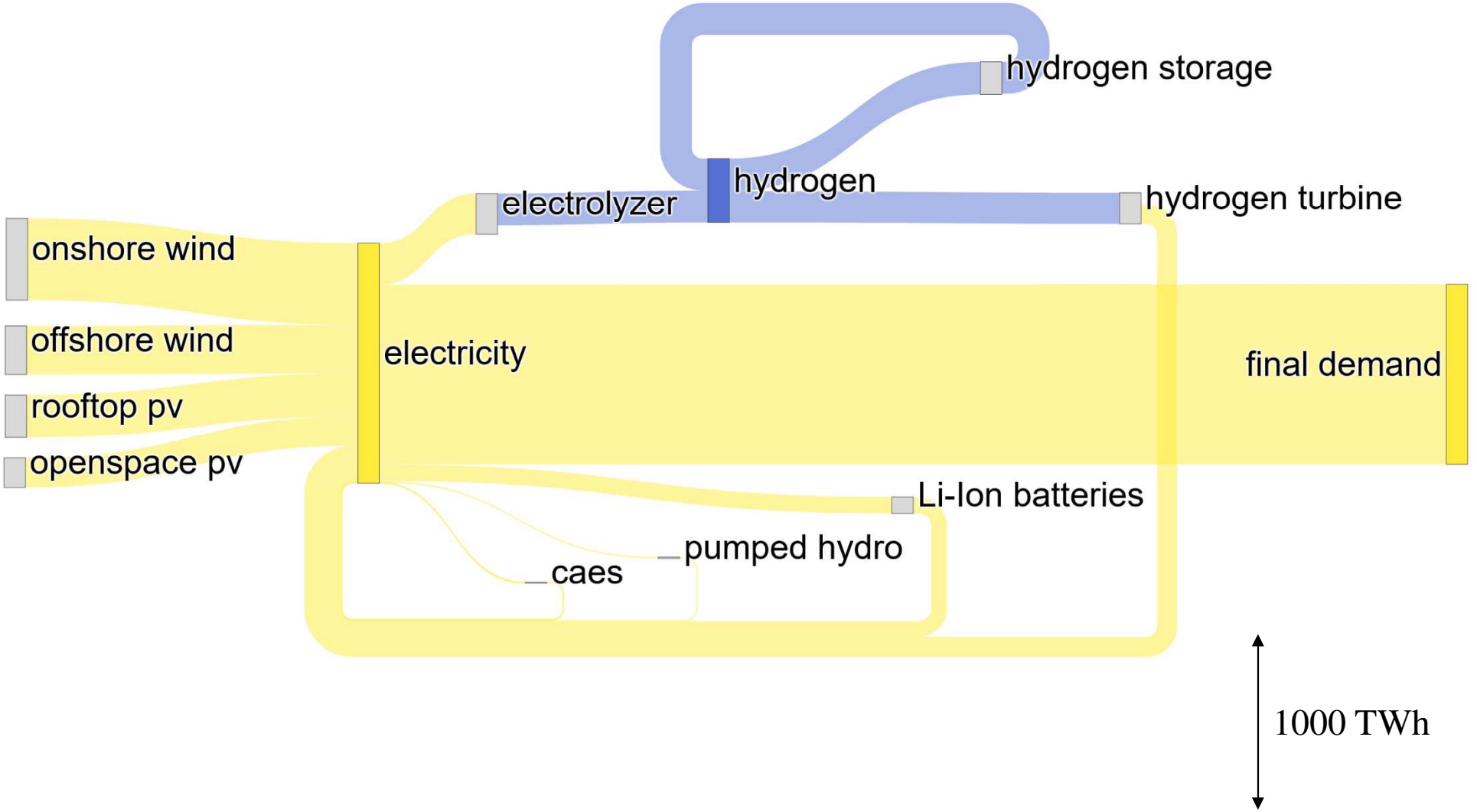
		Slices	Steps
k-Means	centroid	X	
	medoid	X	
hierarchical	centroid	X	
	medoid	X	
Poncelet	10 bins	X	X
	20 bins	X	X
	30 bins	X	X
Gerbaulet			X
Re-Sampling			X

Overview of test model



- Capacity expansion model for a single year
- Germany modelled as a single node
- Green field approach
- Electricity demand is based on Hainsch (2020) and accounts for sector integration
  - → 956 TWh of total demand
  - → More pronounced seasonal fluctuations
- Already includes load shedding as a peak-load measure

Test model solved at full temporal resolution



General results for time-slices

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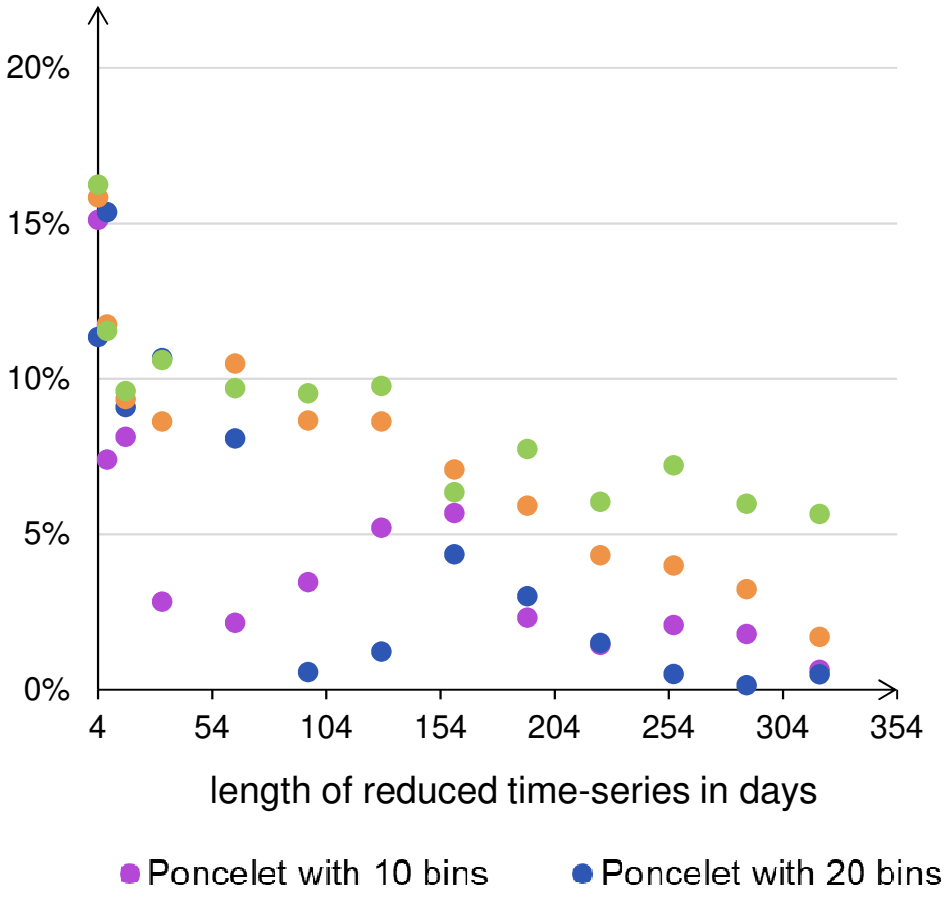
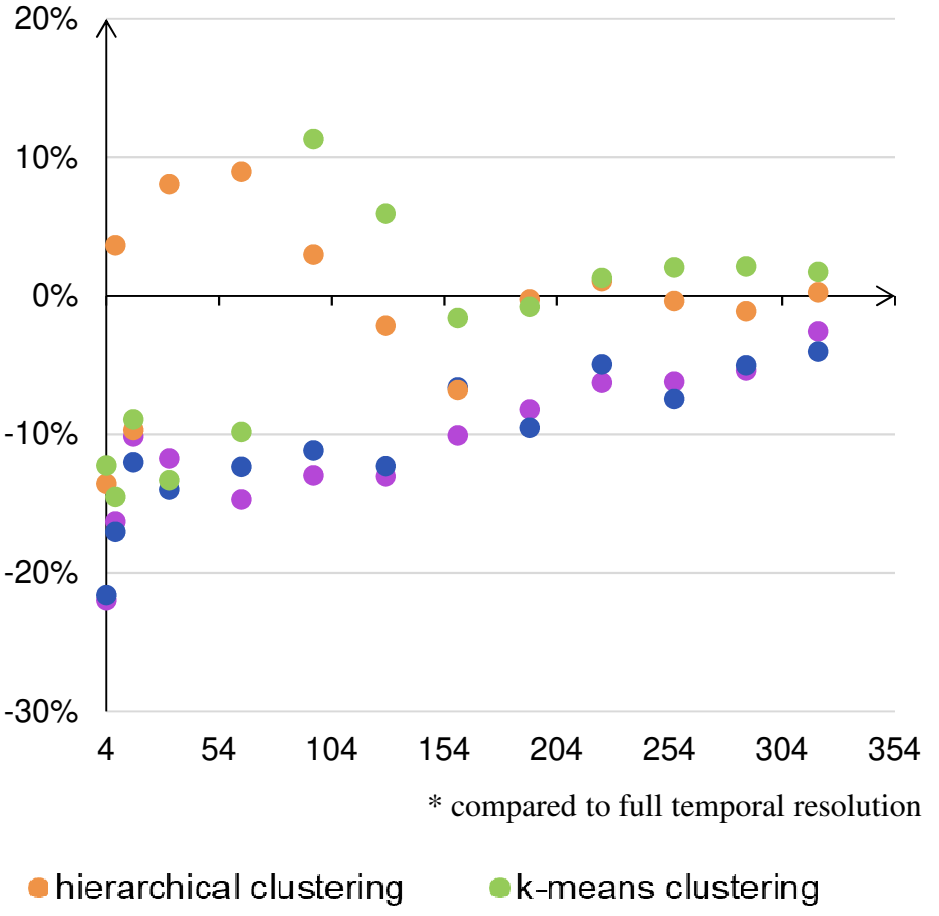


System costs*



Poncelet with 10 bins Poncelet with 20 bins hierarchical clustering k-means clustering

General results for time-steps with α-scaling

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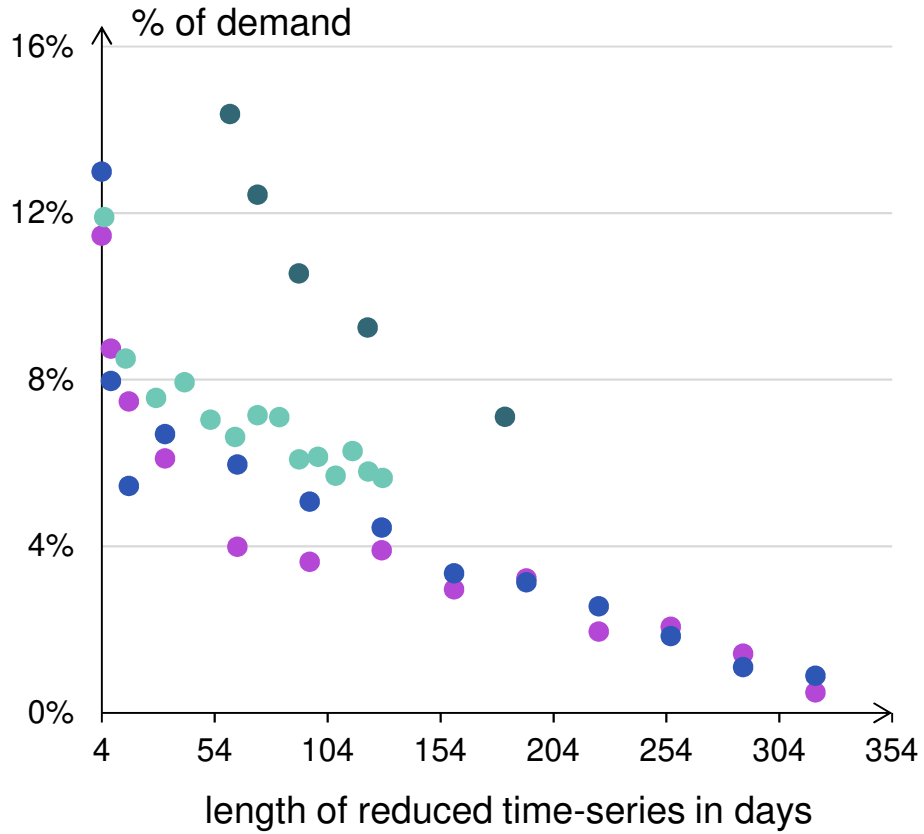
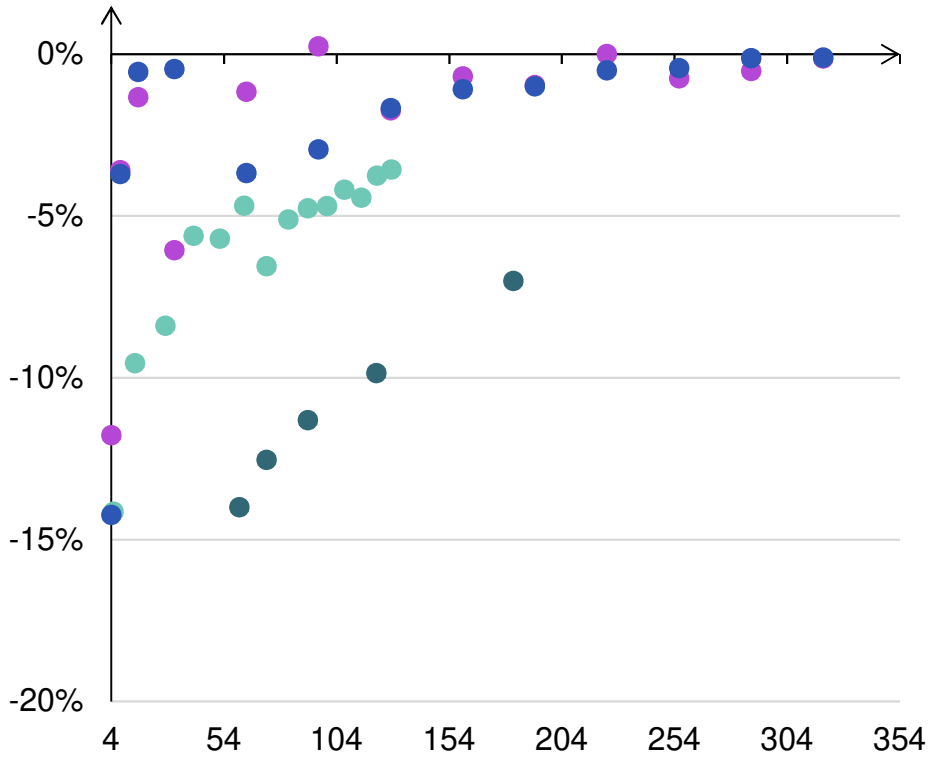


System costs*



* compared to full temporal resolution

Poncelet with 10 bins Poncelet with 20 bins Gerbaulet Re-Sampling

General results for time-steps with β-scaling

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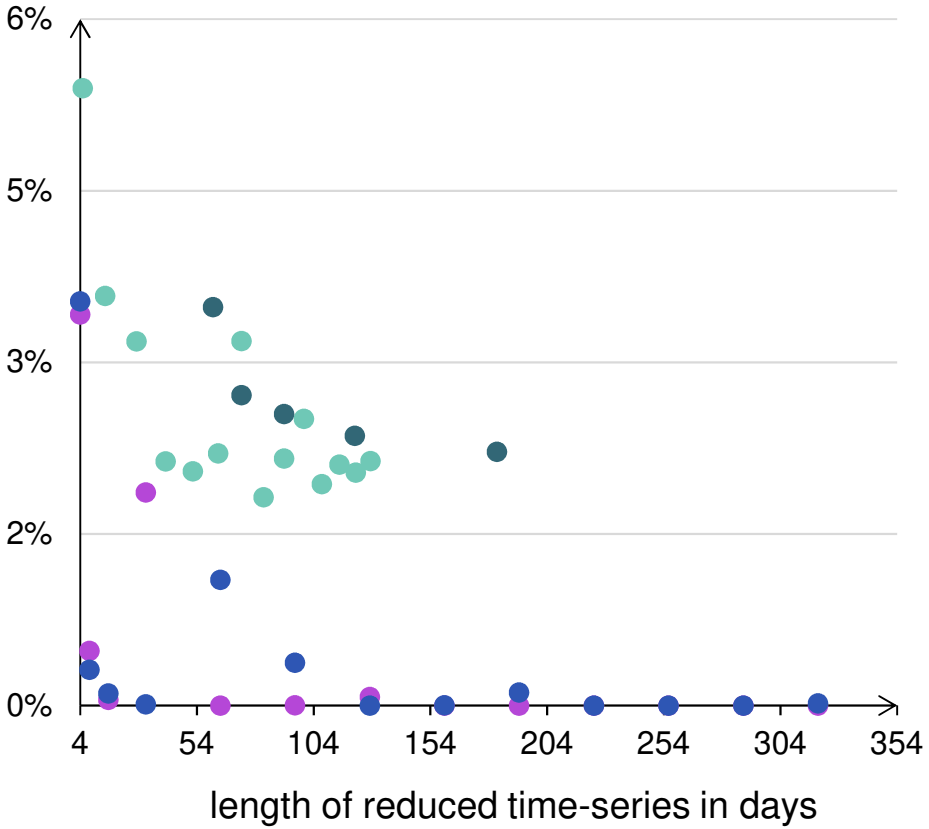
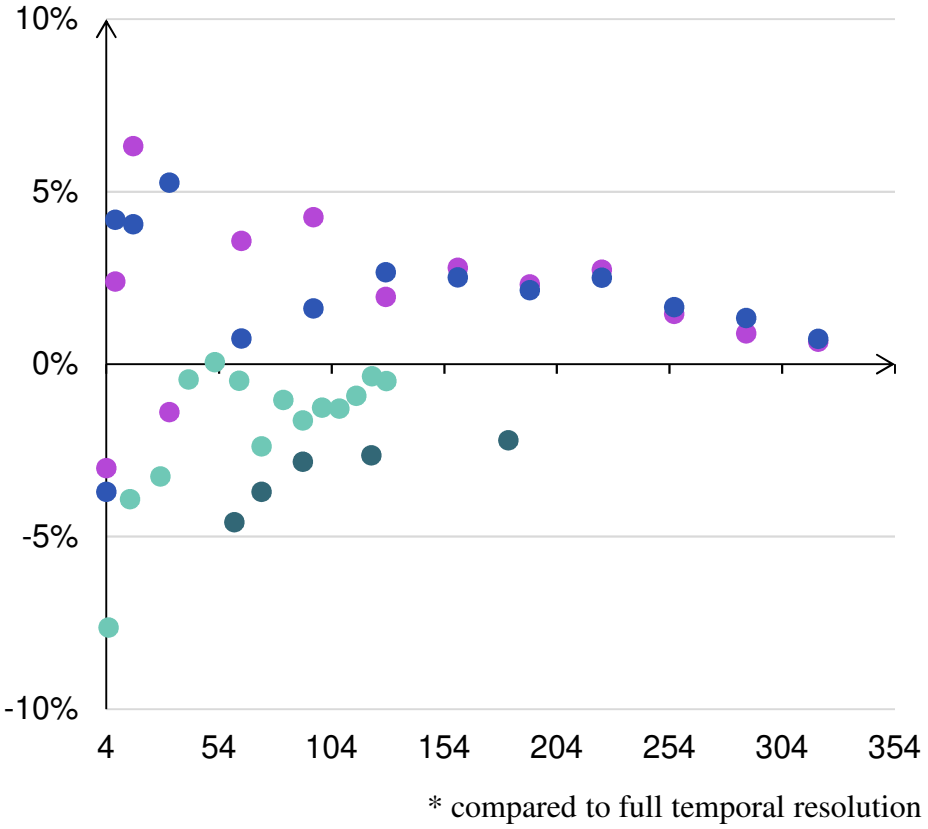
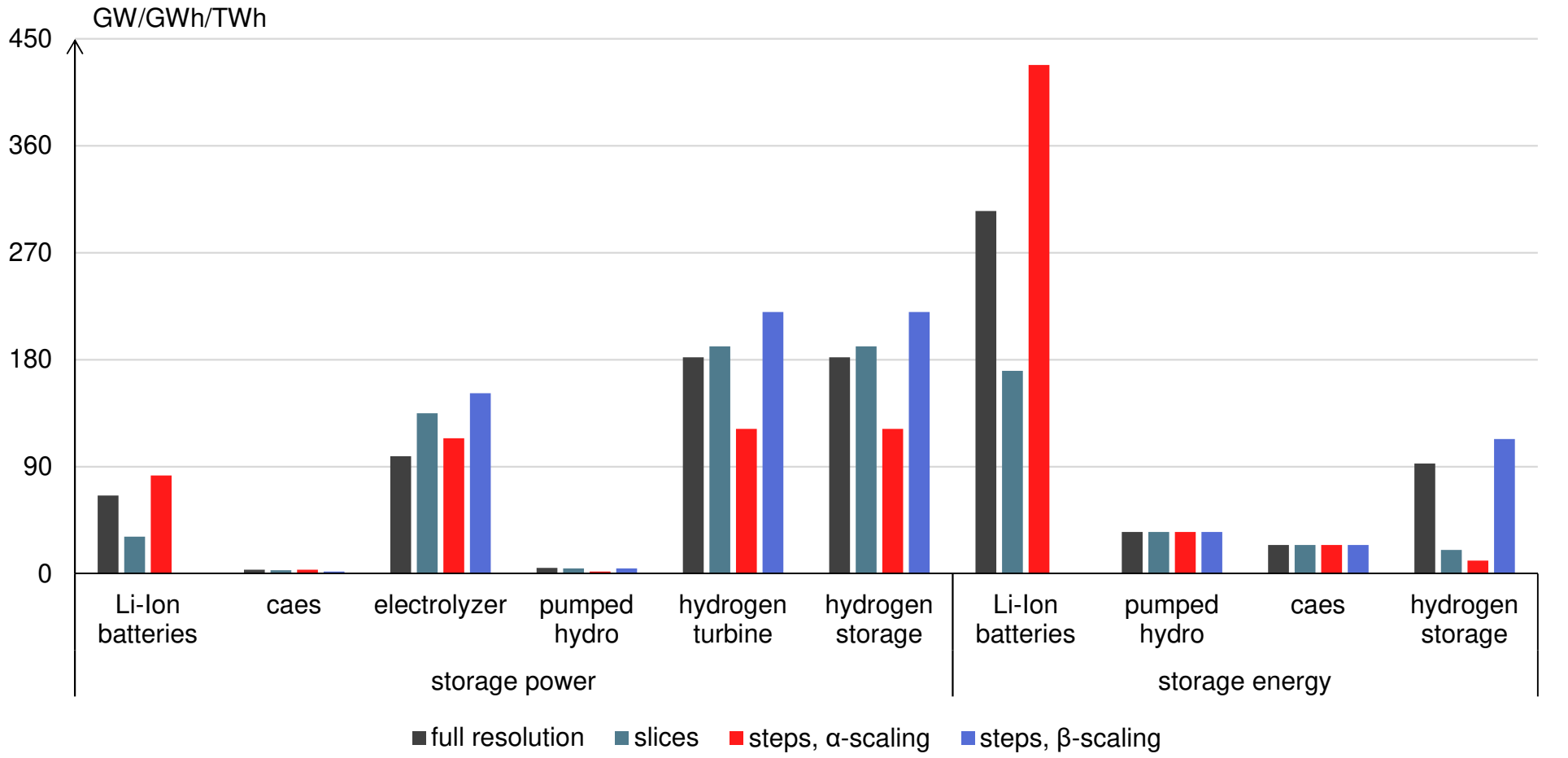


System costs*



Poncelet with 10 bins Poncelet with 20 bins Gerbaulet Re-Sampling

Comparison of storage investment



- All results were obtained with 20 bins Poncelet and 64 days & 1536 hours
- Results show clear show different storage bias from α and β-scaling

Sensitivity without long-term storage

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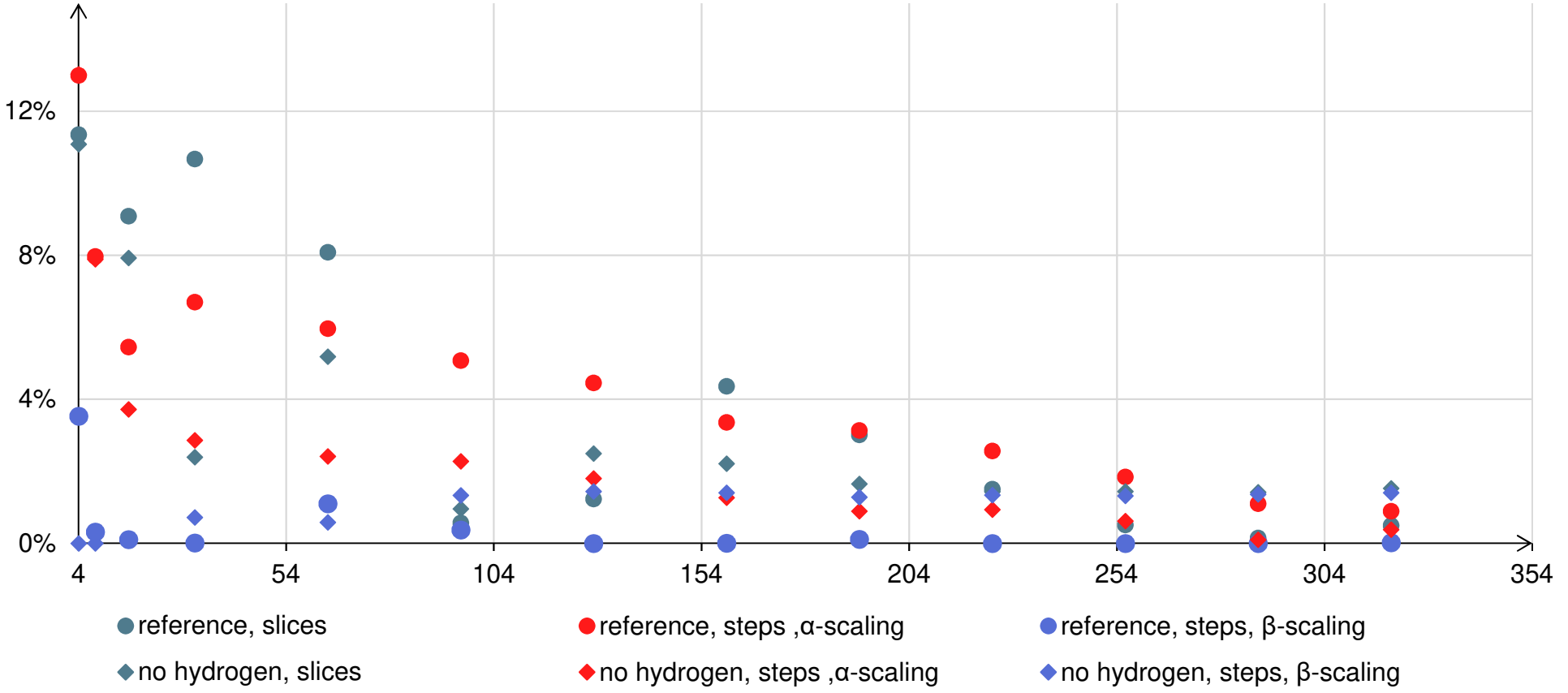

Conclusion

Conclusion

- Fluctuating nature of supply and necessity for seasonal storage distort results obtained using TSR
- How reduced time-series are implemented has much more significant effect than how they were obtained

Outlook

- TSR methods should be chosen and used with great care when modelling fully renewable energy systems
- Bias from TSR suggests similar effects from only considering a single weather year

References

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