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IER Institute of Energy Economics
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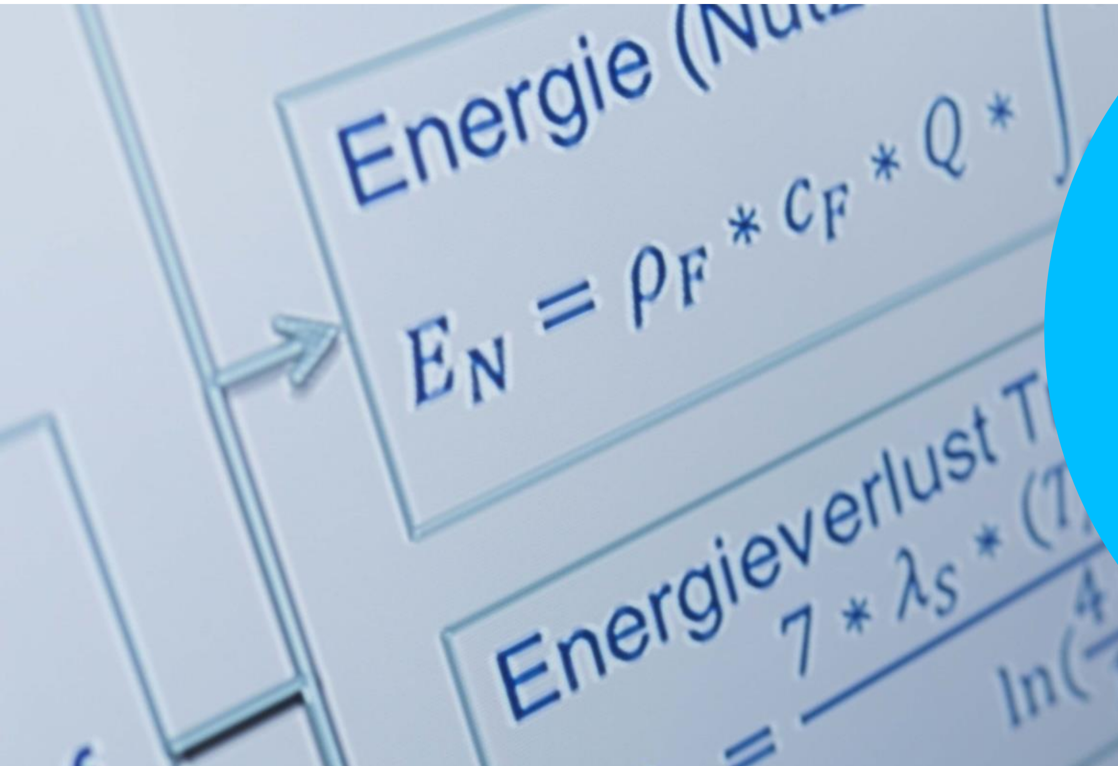

How well do we understand our power system models?

A HANDS ON EXEMPLARY ANALYSIS OF THE TIME RESOLUTION

42nd IAEE International Conference,
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Model Description

E2M2 - European Electricity Market Model (Sun, 2013)

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- **Fundamental, bottom-up, LP** model for Europe
- Electricity (spot market) **prices** for a market with **complete competition**
- **Simultaneous** optimization of **unit commitment** and **investment decisions**
- **MILP mode** for highly detailed unit commitment and investment decisions **available** (disregarded for the current work)
- Depicts: **generation technologies** (conventional, CHP, RES), **storages, grid, PtX, DSI, curtailment**
- Simplified cost function: $$c_0 = \sum c_{var} + \sum c_{fix} + \sum c_{inv} \overset{!}{=} min$$
- Most important restriction: *Satisfaction of demand in every hour*

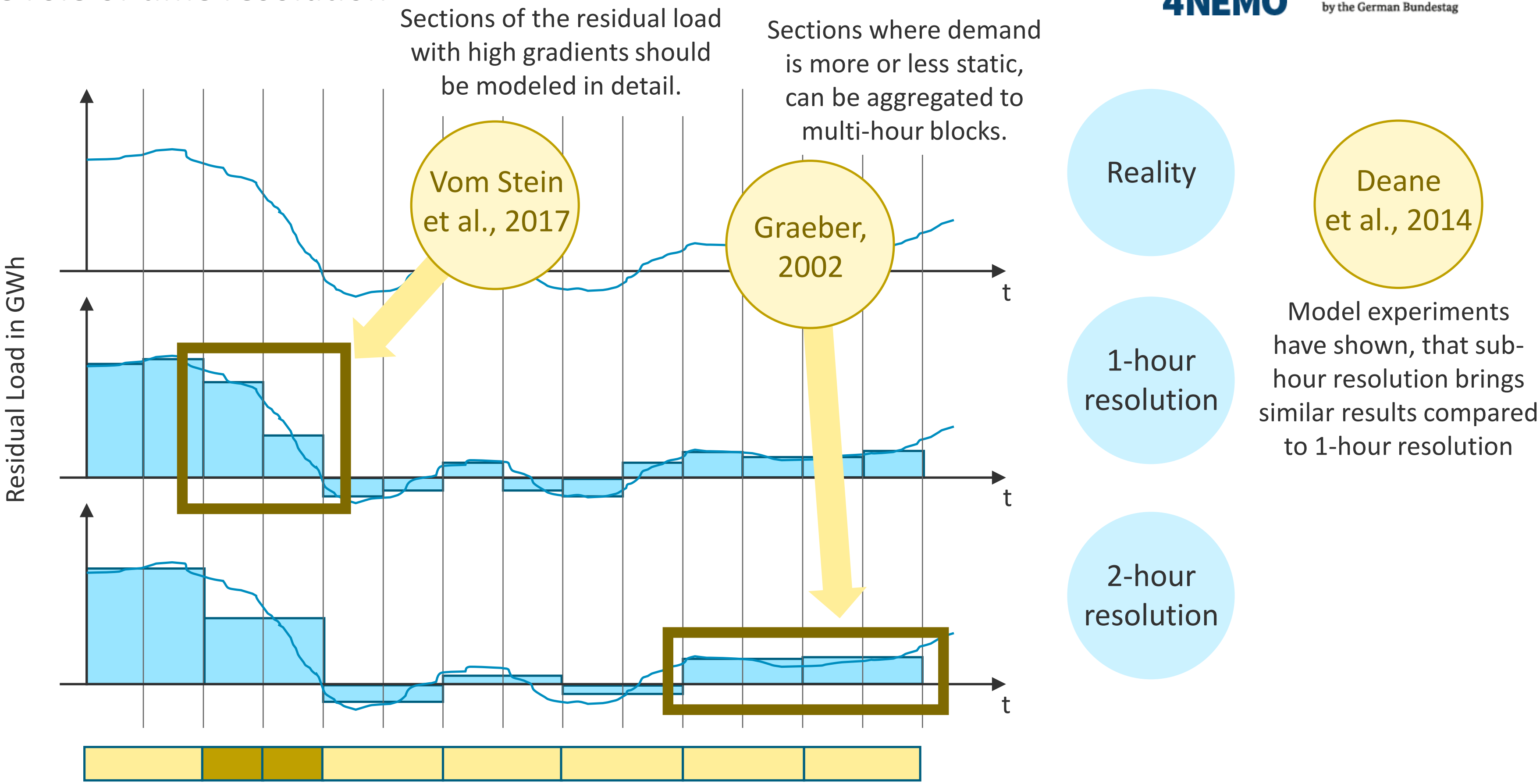
c_{inv} → Annualized investment costs

c_{fix} → Fix costs of all units

c_{var} → Variable cost of all units

Motivation

The role of time resolution



Motivation

The role of time resolution

Graeber, 2002

Vom Stein et al., 2017

Savvidis et al., 2018

Propose a {**variable**, **dynamic**, **adaptive**} time resolution approach in order to REDUCE the model size while keeping the MAXIMUM possible result quality

OUR APPROACH

Use such {variable, dynamic, adaptive} methods

to provoke errors

at specific points in time

without altering the rest of the time series

which allows a focused analysis of single effects

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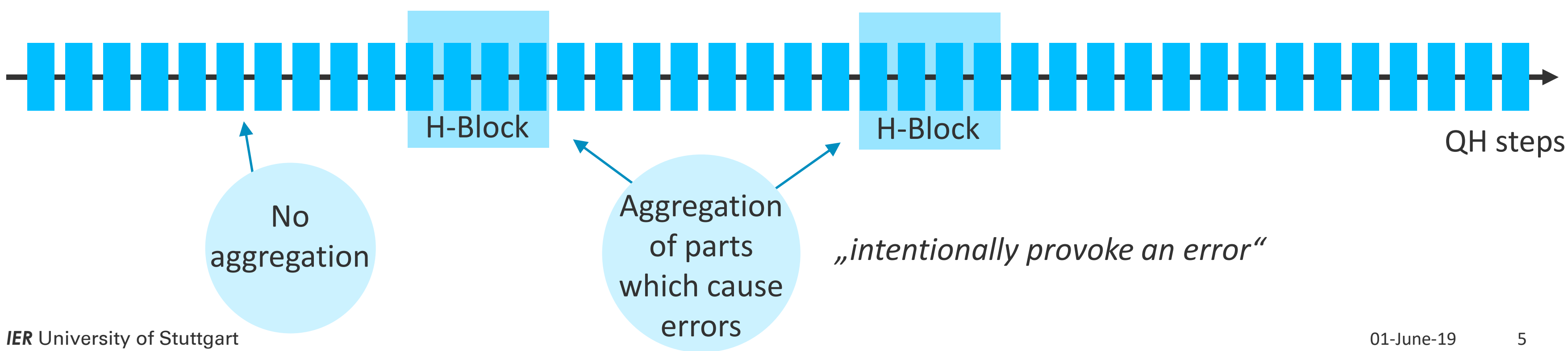
4NEMO



„intentionally provoke an error“

Method

Explaining the zero crossing effect

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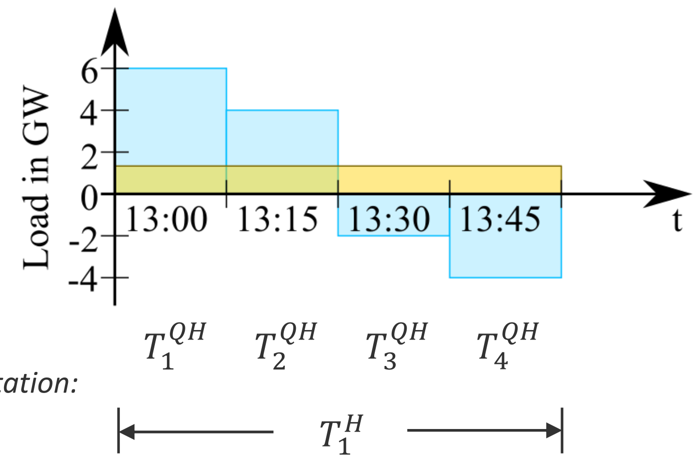

Time step notation:

Difference after aggregation

Saved generation: 1.5 GWh

Lost pump energy: 1.5 GWh

Hour (1H) step

	Generation	Pumping
13:00	**1.0 GWh**	**0.0 GWh**

Quarter hour (QH) steps

	Generation	Pumping
13:00	1.5 GWh	0.0 GWh
13:00	1.0 GWh	0.0 GWh
13:30	0.0 GWh	0.5 GWh
13:45	0.0 GWh	1.0 GWh
Total	**2.5 GWh**	**1.5 GWh**

Method

Introducing the 2 most important metrics

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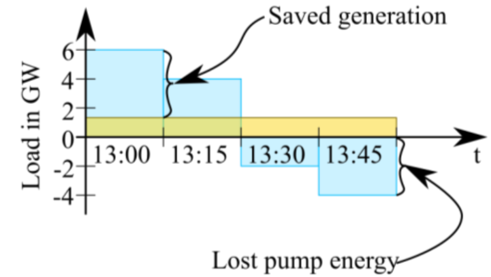
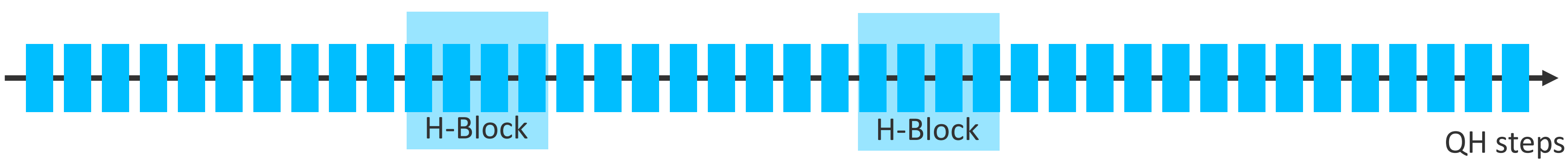
$$R_{Gen}(T) = \begin{cases} R(T) \ for \ all \ R(T) > 0 \\ 0 \ for \ all \ R(T) \leq 0 \end{cases} \qquad R_{Pump}(T) = \begin{cases} R(T) \ for \ all \ R(T) < 0 \\ 0 \ for \ all \ R(T) \geq 0. \end{cases}$$



$$E^{Pot}_{savedGen}(T^{1H}_{\kappa}) = \sum_i \left(R_{Gen}\left(T^{QH}_i\right)\right) - R_{Gen}(T^{1H}_{\kappa}), \qquad \forall i \ which \ belong \ to \ j \in Z$$

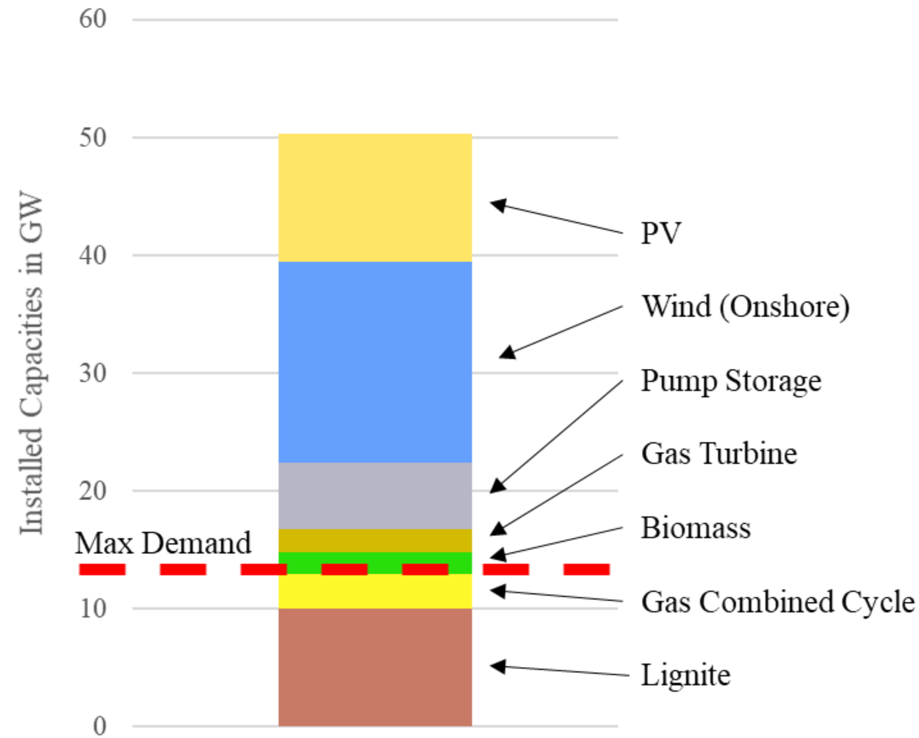
$$E^{Pot}_{lostSto}(T^{1H}_{\kappa}) = \sum_i \left|R_{Pump}\left(T^{QH}_i\right)\right| - \left|R_{Pump}(T^{1H}_{\kappa})\right|, \qquad \forall i \ which \ belong \ to \ j \in Z.$$



Method

The model: keeping it simple

- Simplified unit commitment model:
  - No investments
  - No ramping restrictions
  - No grid
  - Aggregated unit types
- Model scope (year 2015):
  - 50 Hertz Region of Germany (isolated) (ENTSOE, 2019)
  - Scaled RES to match German 2030 targets
  - Scaled storage capacities
- 127 zero crossing occurences



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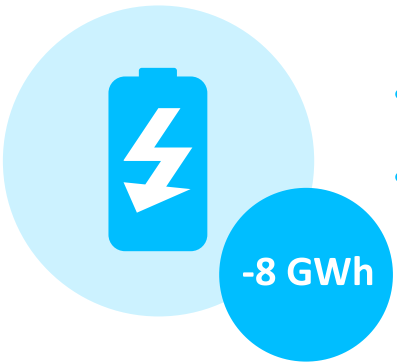
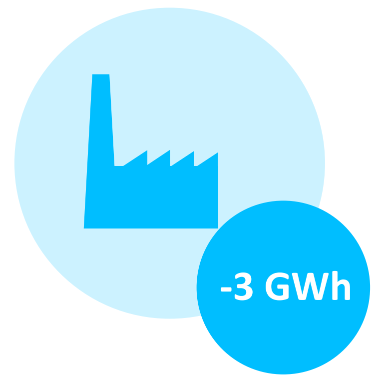
Results

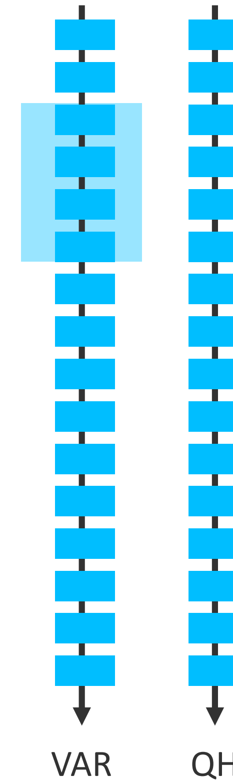
Differences between QH and VAR (zero crossing = 1H; rest = QH)



- Storages are less used in the aggregated model
- Underestimation of storage use: -8 GWh (1.2% difference)

- Thermal power plants are less used in VAR model
- Overestimation of RES: -3 GWh thermal plant usage

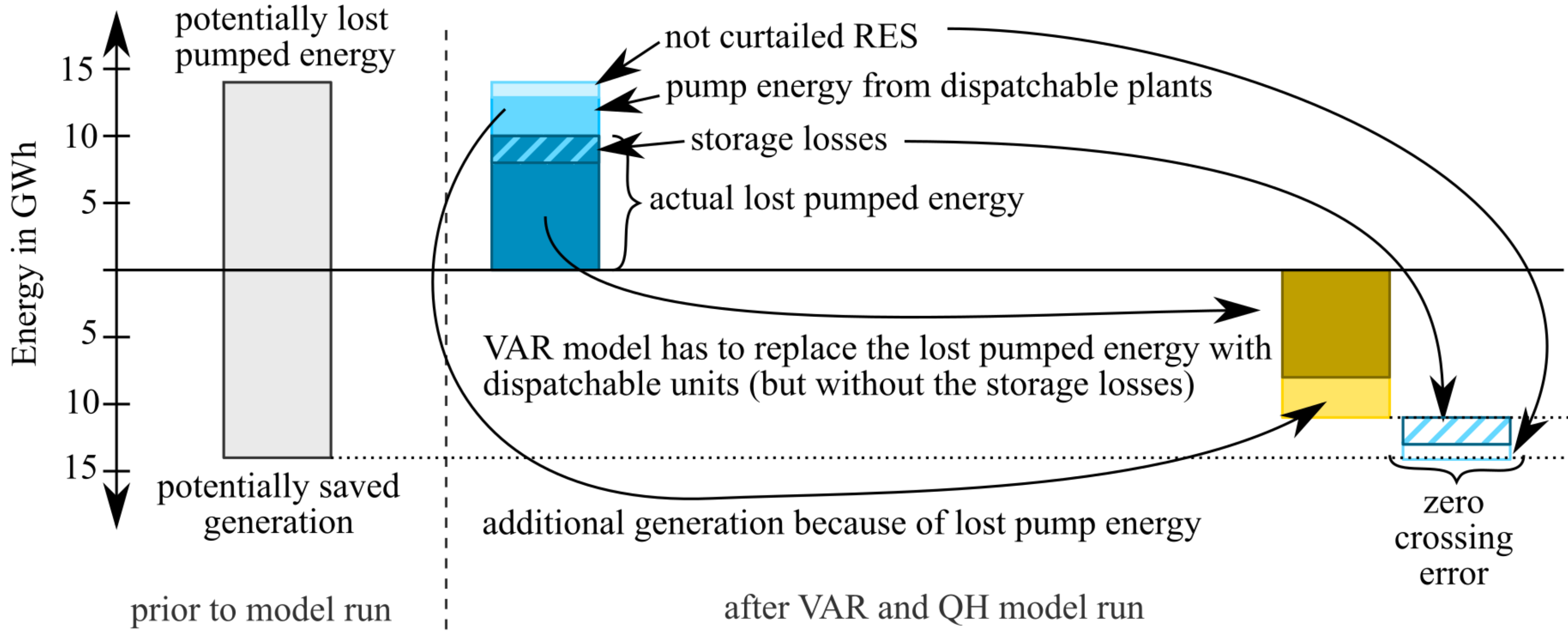




But what EXACTLY happens?

Results

Detailed analysis



Summary and Outlook

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- **Aggregating time steps** in order to minimize model size leads to **result deviation** of the model (e.g. total operation cost changes)
- We propose a **quantification method** for the **potential error** caused by the zero crossing effect which can be calculated **prior to a model run**
- Models with **variable time resolution** capabilities can be used to **analyze the error mechanism** behind time aggregation
- We analyze the error mechanism at zero crossing points by **comparing a highly resolved model (QH) to a variable resolved model** (1H aggregation at zero crossing points, QH at the rest)
- We observed: **storage efficiencies** and **storage volume** drive the deviation
- **Future topics** to be addressed: ramping restrictions, availability of units, linearized start-up costs, grid, PtX technologies, investments

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Thank you!

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Literature

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