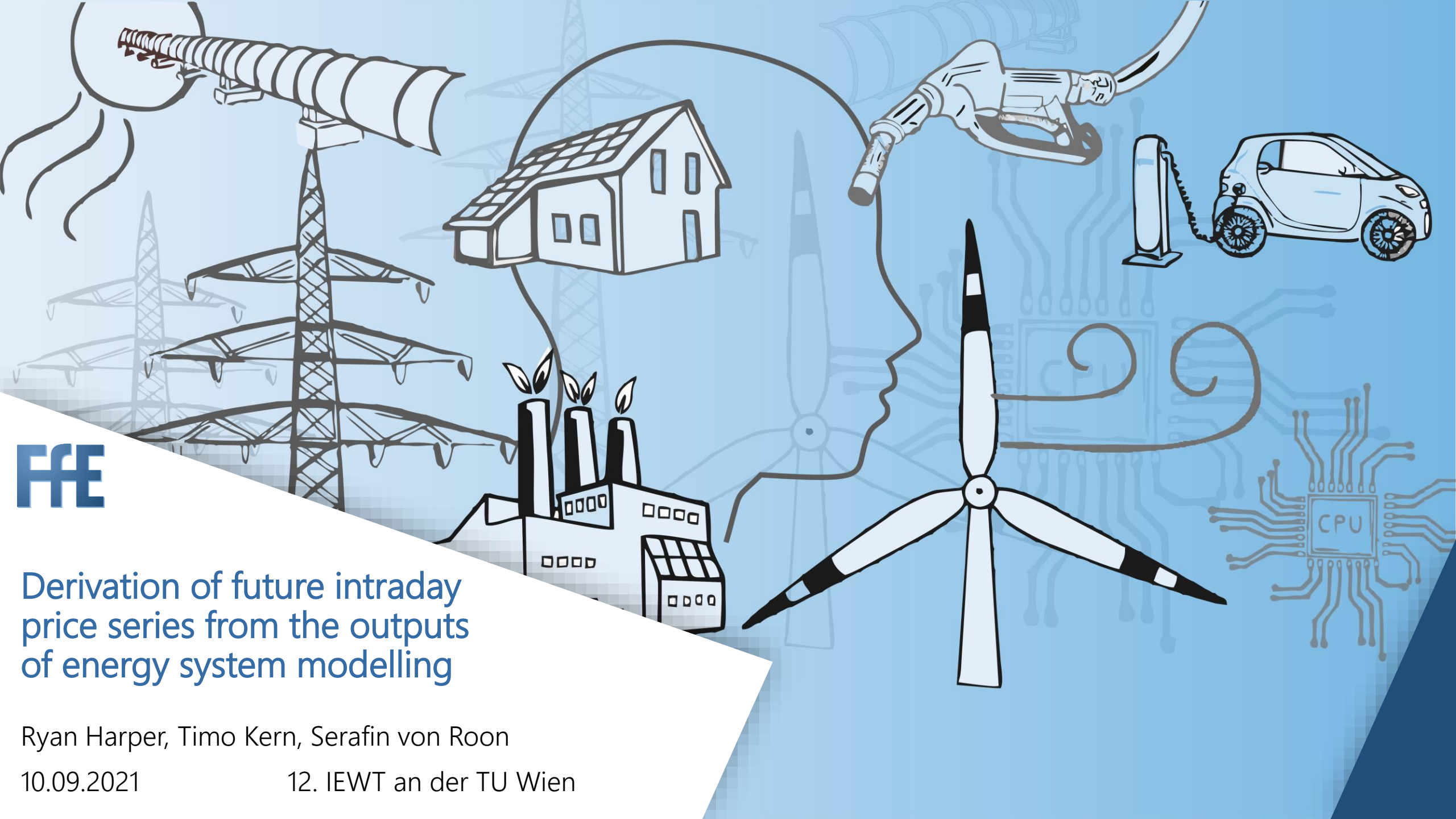


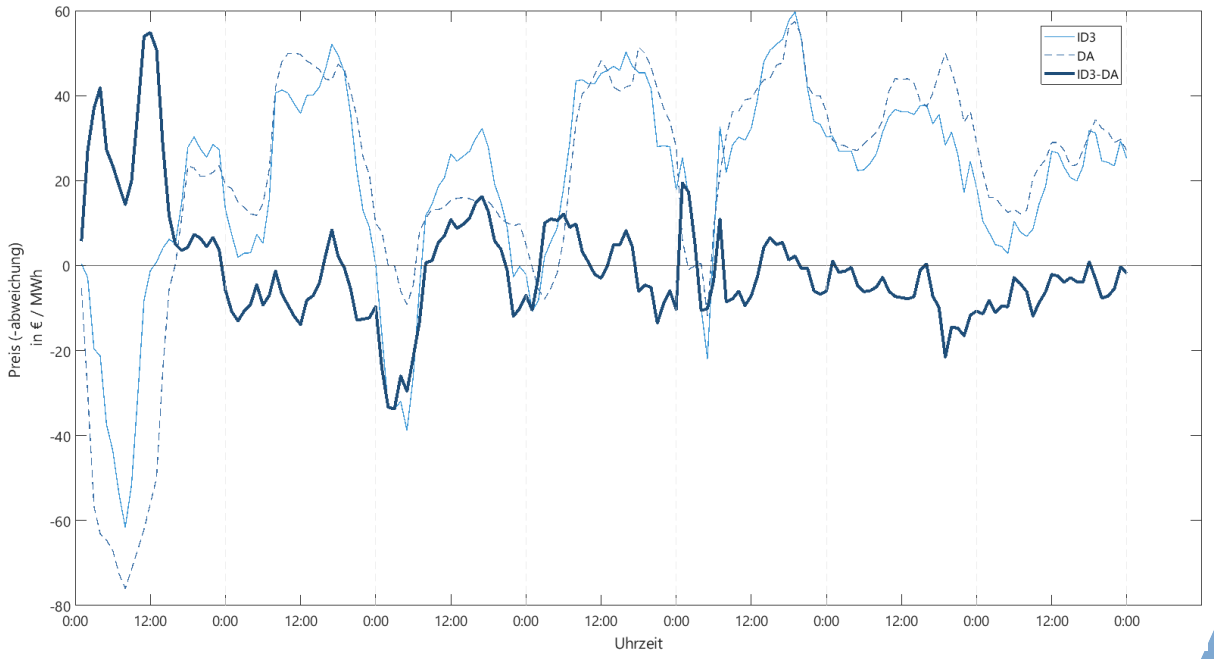
Derivation of future intraday price series from the outputs of energy system modelling

Ryan Harper, Timo Kern, Serafin von Roon

10.09.2021 12. IEWT an der TU Wien

Motivation

- The Energiewende has led to increased shares of generation from volatile renewable sources, primarily wind and solar. This trend can be expected to continue.
- In turn, the importance of intraday trading will also continue to increase, with trading volumes already increasing 300 % from 2012 to 2018
- Price differences between day-ahead and intraday markets offer opportunities for arbitrage by traders and operators of flexible devices

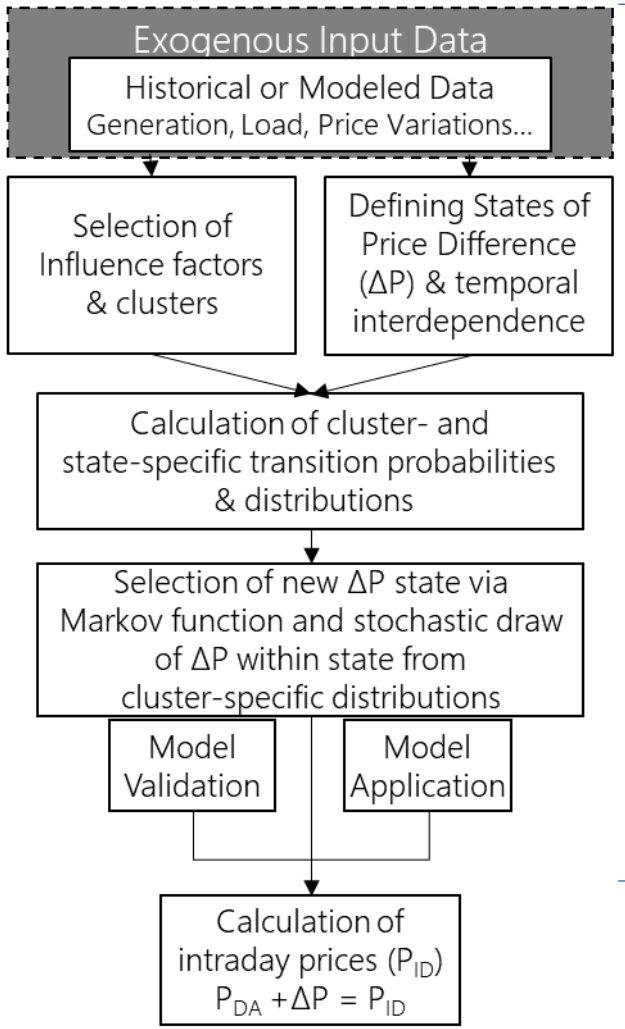


➢ Goal: Development of a method for creating time-series of future price differences reflecting market characteristics

Model Overview

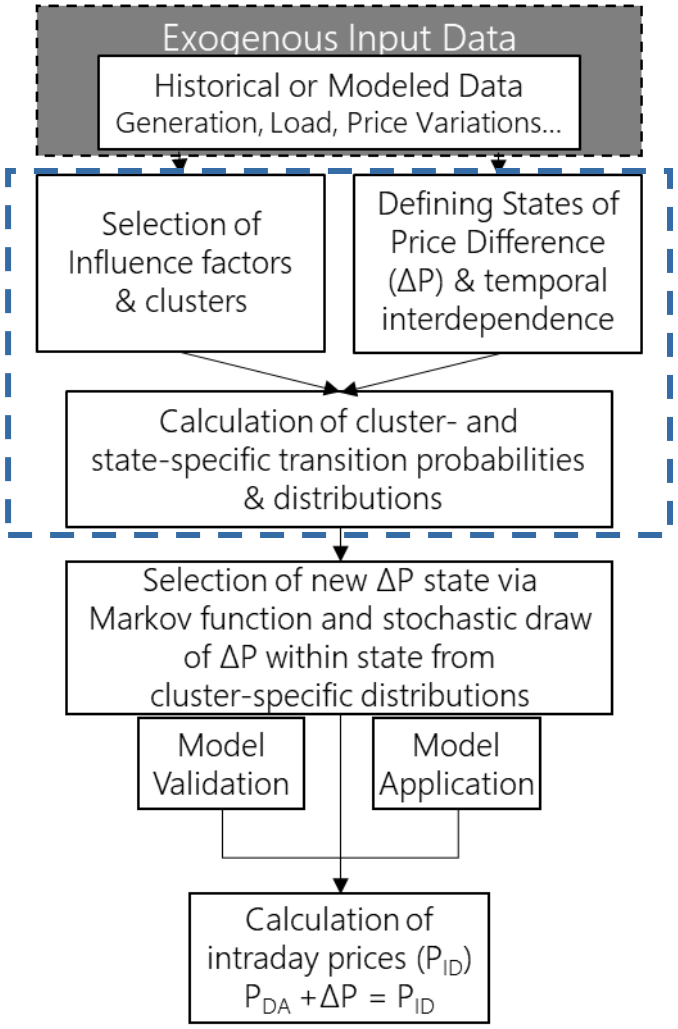
Methods

Results



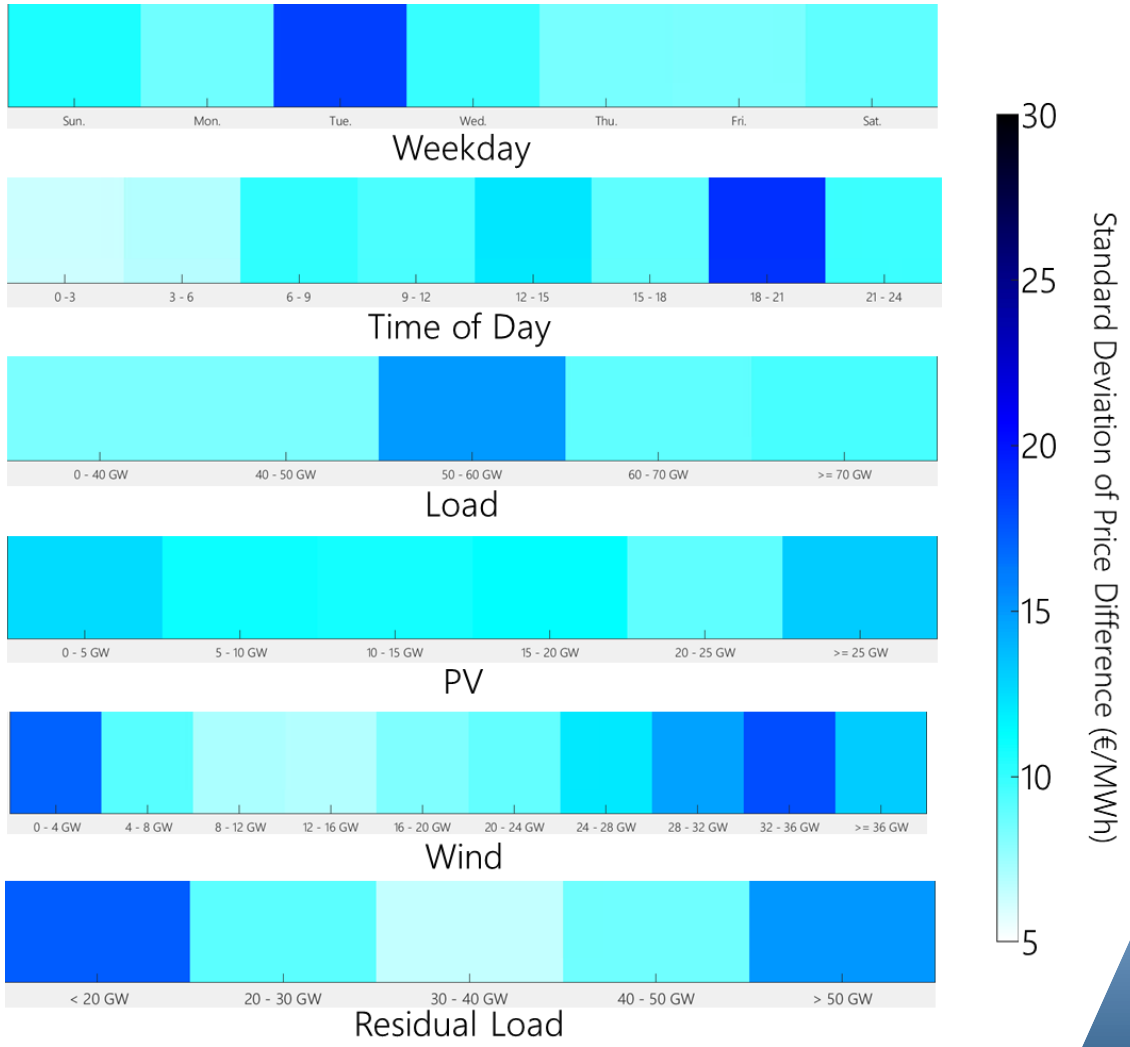
Focus of today's presentation

Methods


Exogenous Input Data
Historical or Modeled Data
Generation, Load, Price Variations…
Selection of Influence factors & clusters
Defining States of Price Difference (ΔP) & temporal interdependence
Calculation of cluster- and state-specific transition probabilities & distributions
Selection of new ΔP state via Markov function and stochastic draw of ΔP within state from cluster-specific distributions
Model Validation
Model Application
Calculation of intraday prices (P_{ID})
$P_{DA} + \Delta P = P_{ID}$

Situation-dependent price uncertainty
Which market characteristics influence price differences?

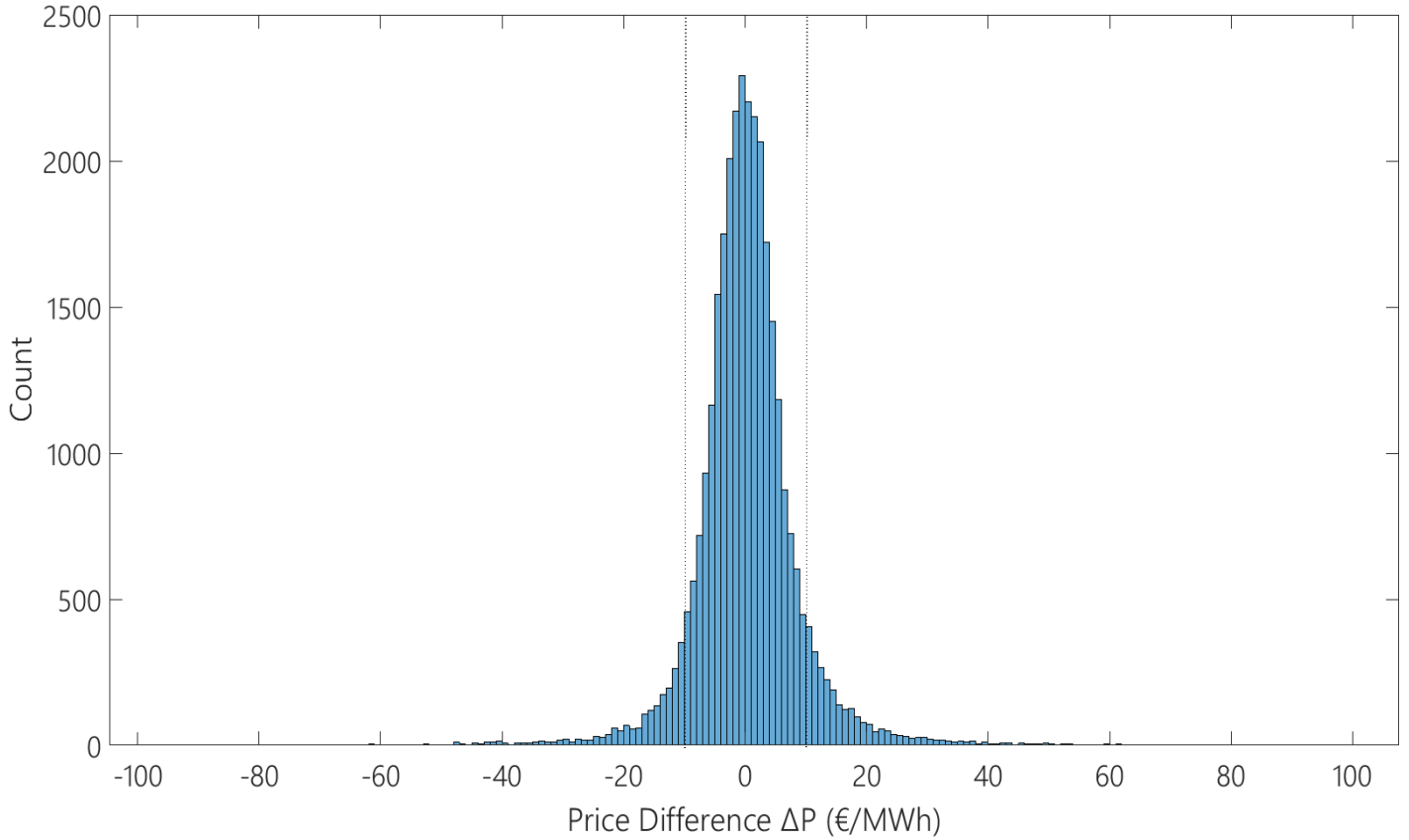
- Data from EPEX & ENTSO-E Transparency Platform
  - Jan. 1st, 2018 – Aug. 31st, 2021
- Visual analysis of correlation between influencing factors and standard deviation of price differences
- Systematic effects: Differences in standard deviation explainable?
  - E.g., Why are price differences more volatile on Tuesdays than Wednesdays?
- Residual Load contains effects of multiple factors (e.g., Renewable Generation, Load, Time)

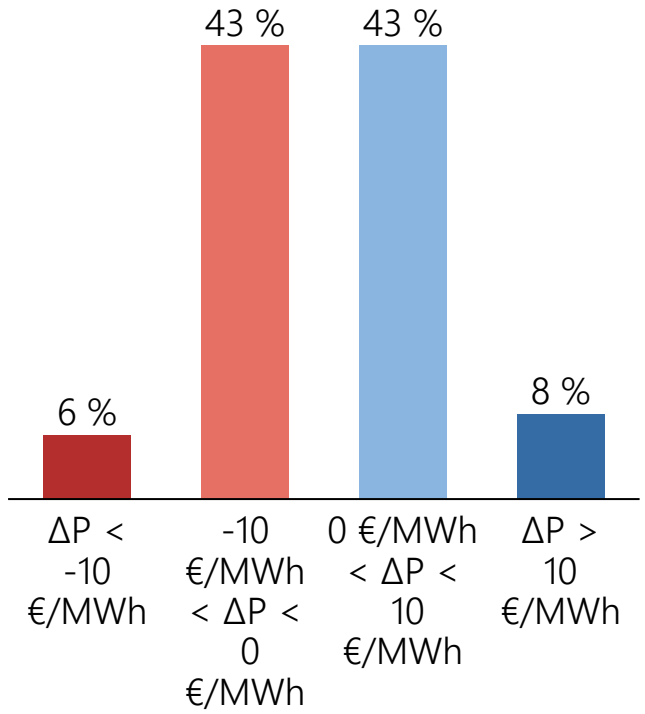


➢ Residual Load used as influencing factor for further steps with clusters low, medium, and high.

Defining States of Price Difference ΔP (P_{ID3}-P_{DA})

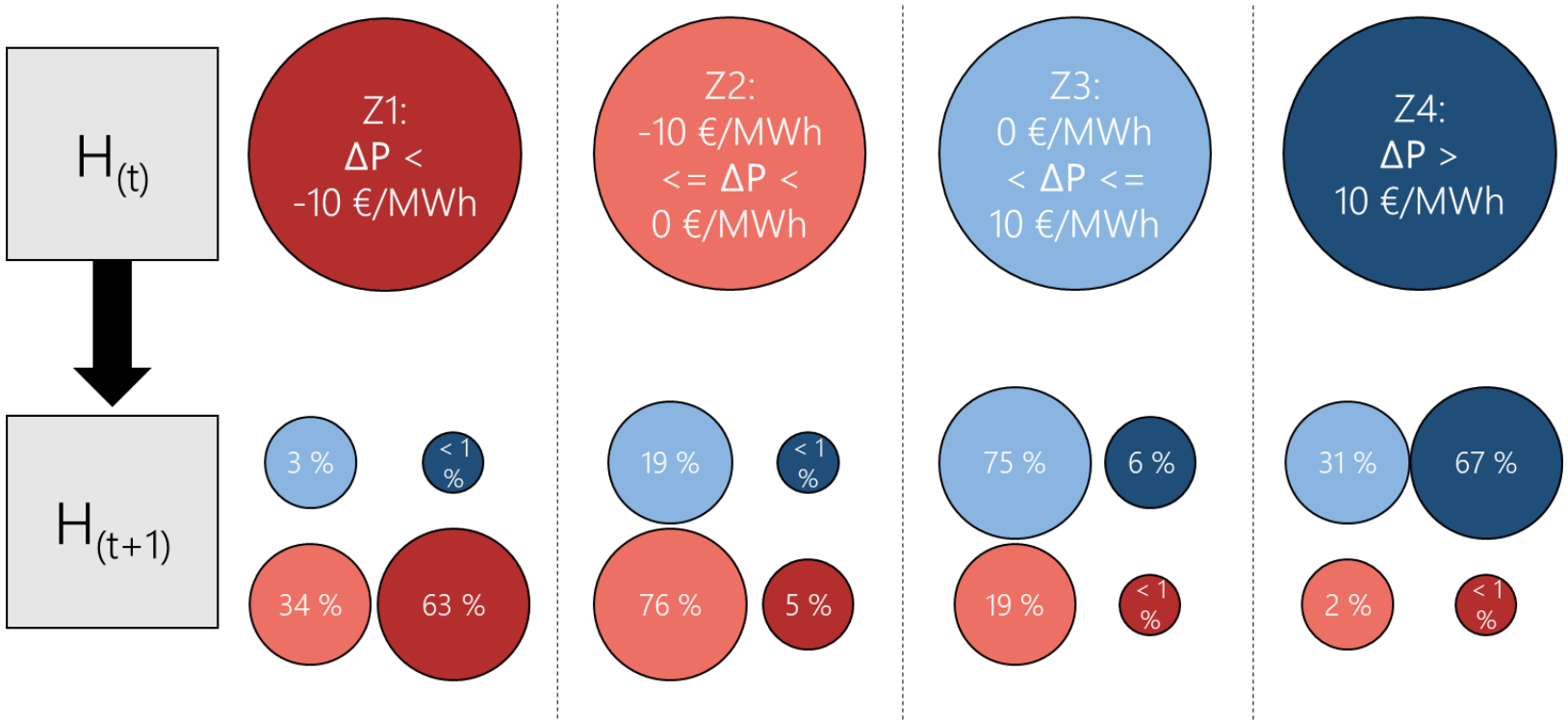
- Distribution of observed hourly price differences reveals a large proportion of hours with a price difference between the day ahead and intraday prices (ΔP) between -10 €/MWh and 10 €/MWh.





➢ Four states identified for use in Markov chain: **Low** (absolute value of ΔP < 10 €/MWh) and **High** (absolute value of ΔP > 10 €/MWh) **Positive** (P_{ID3} > P_{DA}) and **Negative** (P_{DA} > P_{ID3}) price difference

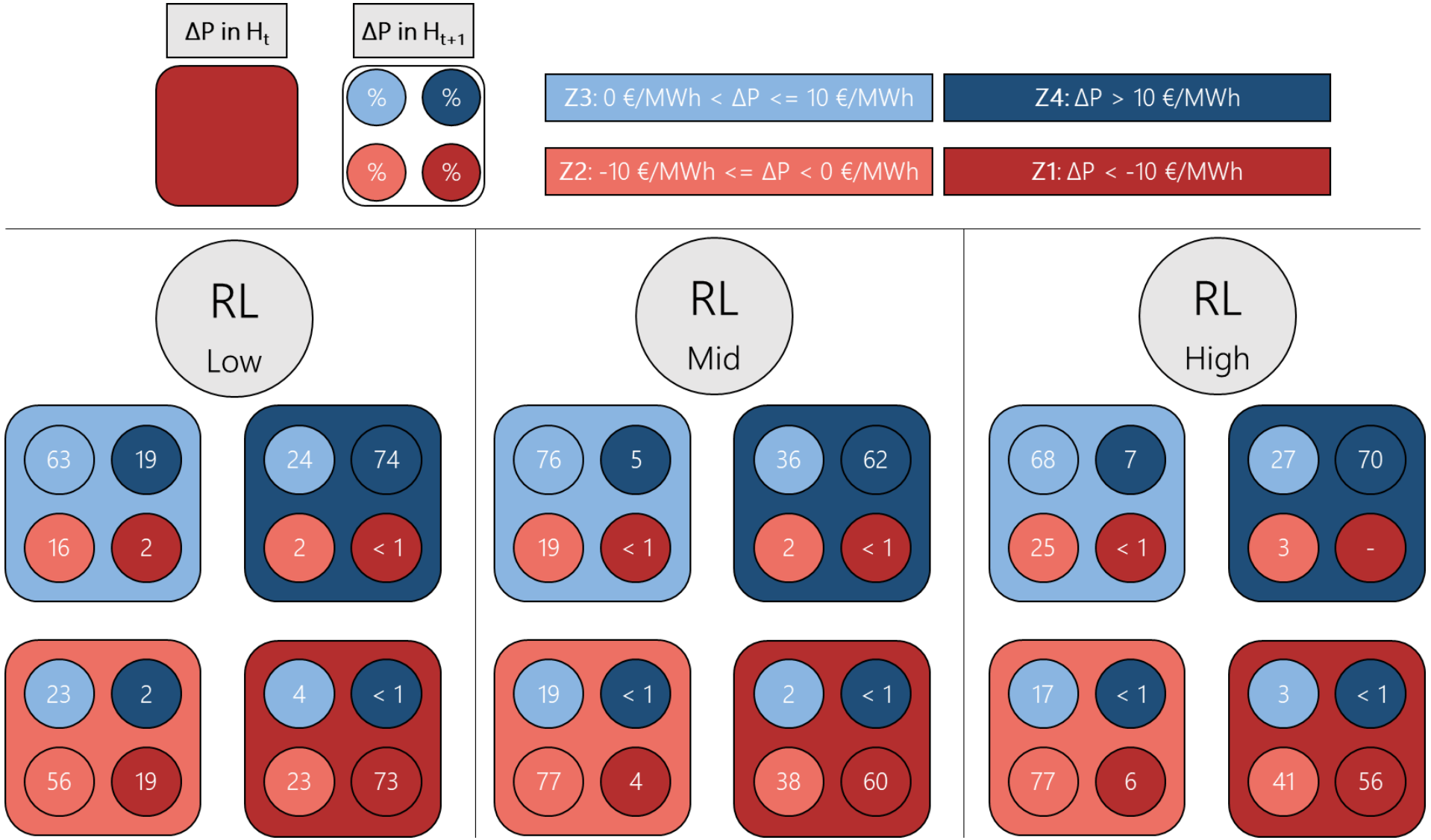
Temporal interdependencies of price uncertainty
Defining tranisition probabilities



- Remaining within the same category is the most common outcome in H_{t+1} over all states
- Changes of category occur largely in the direction of ΔP = 0; From high to low absolute variation (e.g., Z4 → Z3) or from a low positive to a low negative variation (e.g., Z3 → Z2).

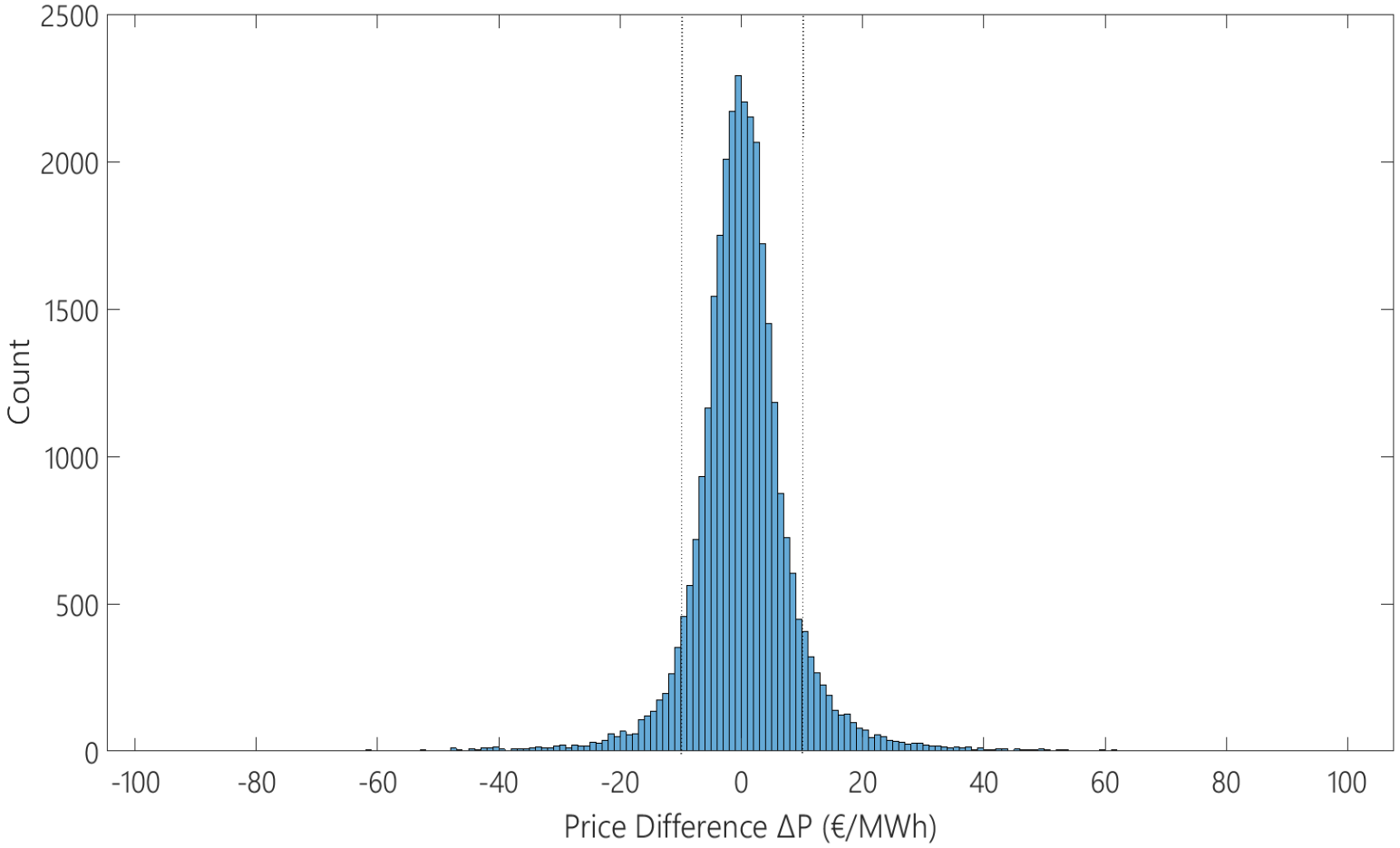
➢ Evidence of correlation between the state of ΔP between a timestep H_t and the following timestep H_{t+1}

Defining cluster-specific tranisition probabilities
Combining influencing factor and temporal interdependence



- Use of cluster-specific transition probabilities necessary, particularly important for cluster low

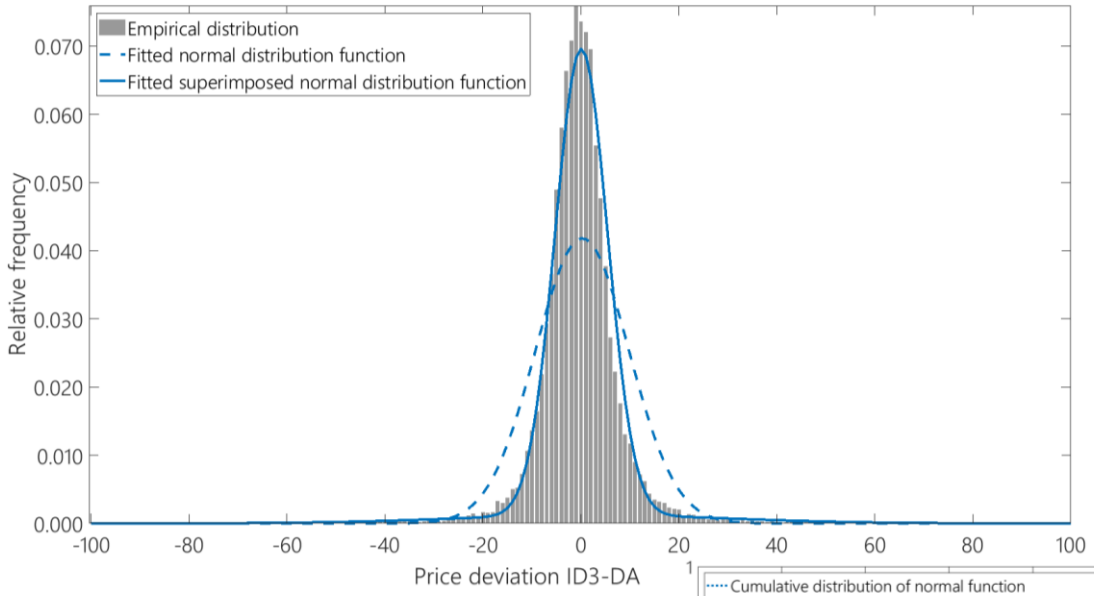
Stochastic Draw of modeled ΔP

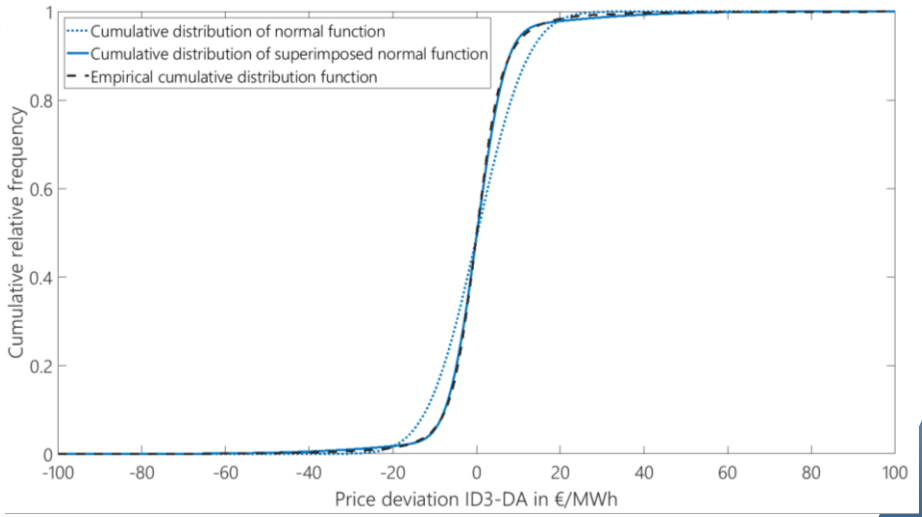


➢ Previously displayed distribution of ΔP suggests a non-normal distribution

Stochastic Draw of modeled ΔP

- Normal distribution curve fit to data & standardized tests both confirm non-normal distribution
- Synthetic function, the additive mapping of two normal functions, provides better representation of the data

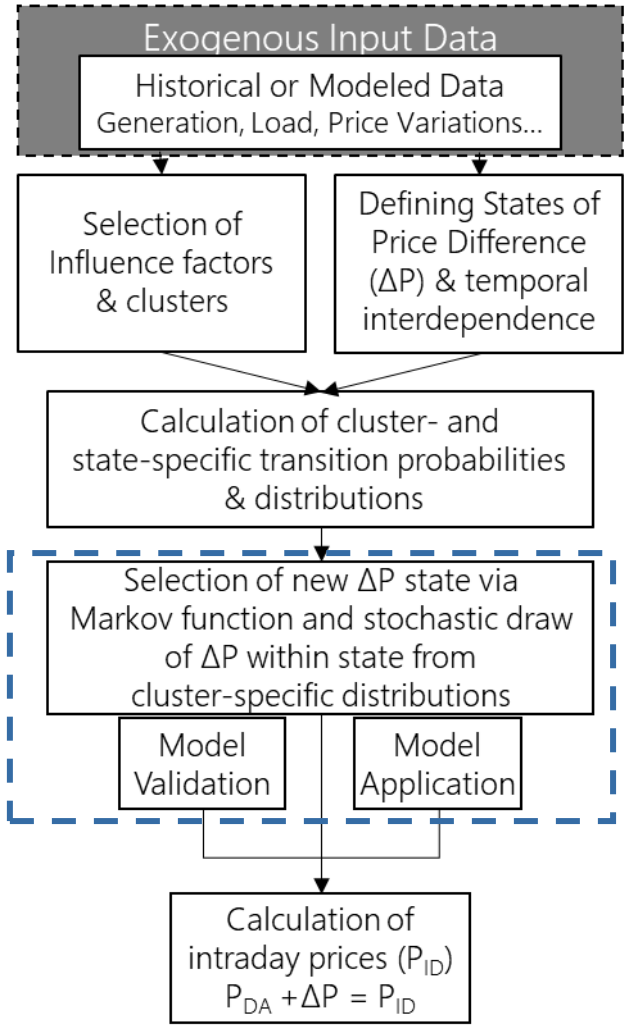




➢ Modeled ΔP are drawn from distributions created using cluster-specific synthetic functions

Results

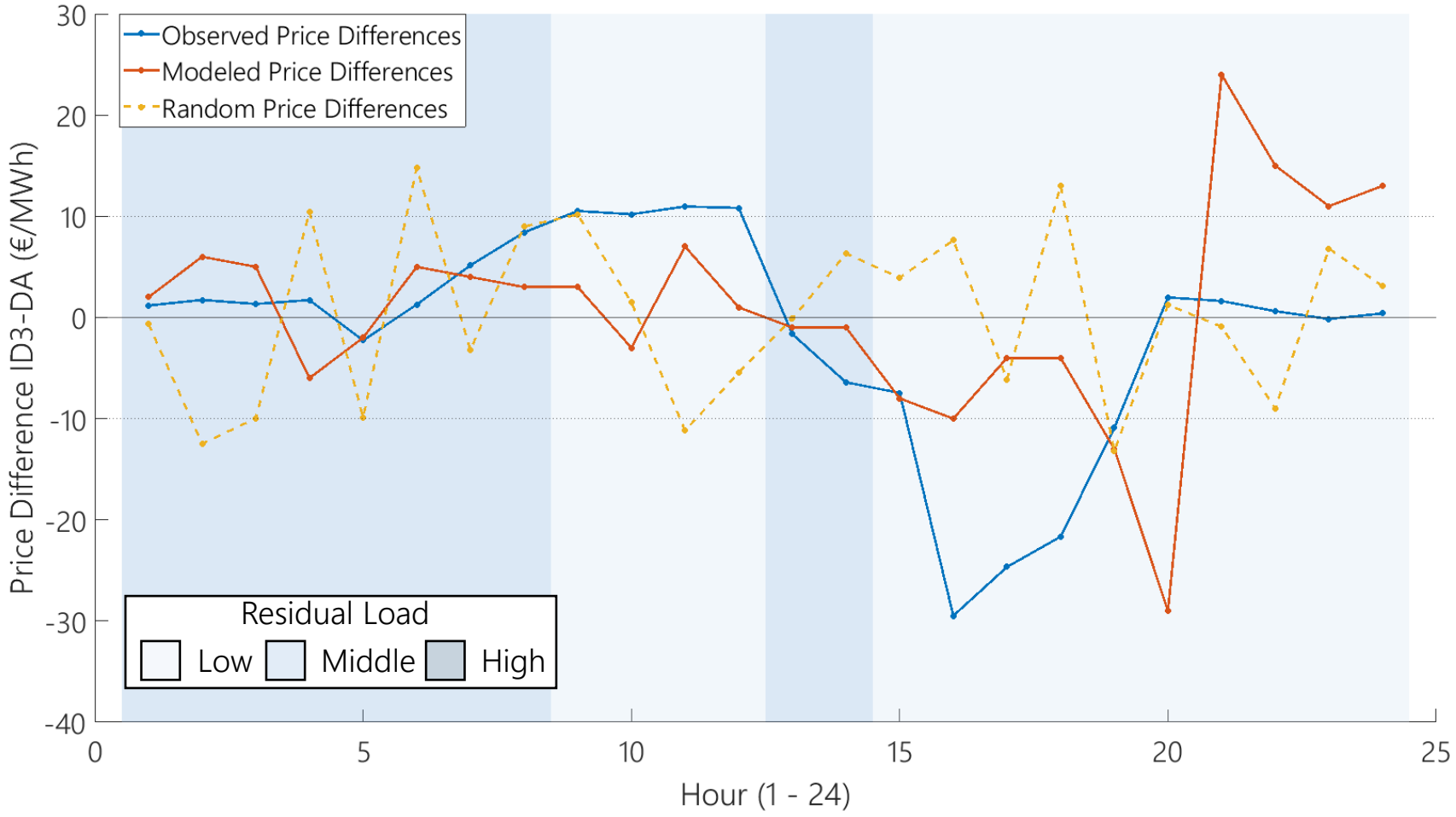
- Model Validation
- Model Application



Model Validation
Modeling of historical data

- Inputs for validation:
    - Training Dataset
        - Price difference & residual load data from 2018-2020
    - Testing Dataset
        - Residual Load data from January 1st – August 31st of 2021
    - Comparison Data
        - Random draw of ΔP from a distribution featuring the pooled mean and standard deviation of the training dataset

Results of Model Validation
Visual Analysis – 24 Hours



- ΔP falls largely within the anticipated band from -10 €/MWh to 10 €/MWh and largely retains the same sign.
- Hours with more extreme price differences correspond to the hours of low residual load, in which more extreme price differences were shown to be more common.
- Random Draw features more pronounced sawtooth/zig-zag pattern and does not reproduce large absolute price differences

➢ Visual analysis of a single day suggests good reproduction of the observed characteristics of ΔP

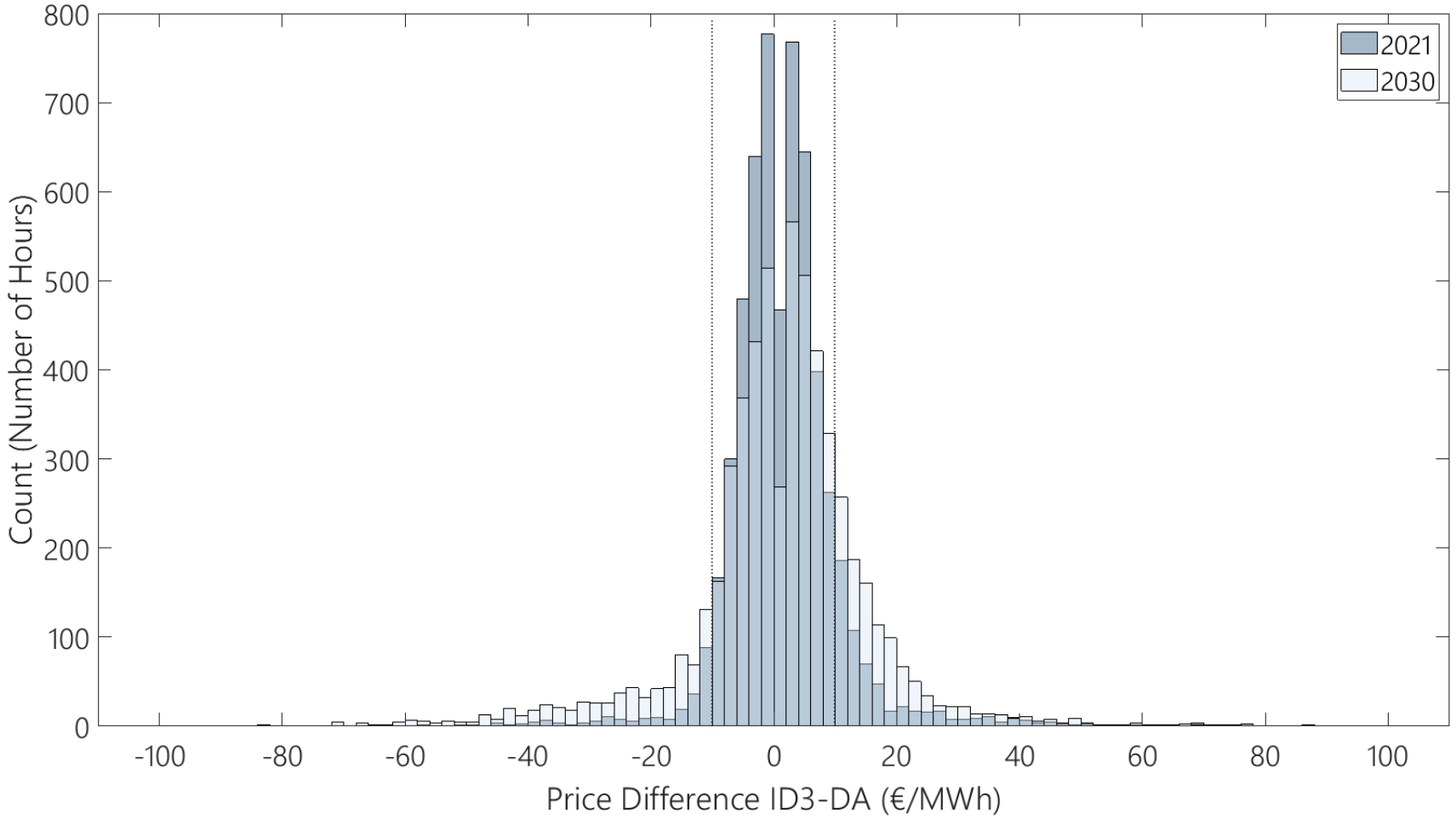
Results of Model Validation
Statistical Comparison – All Hours

	Random Draws (2018-2020 without Clusters)	Observed Values (2021)			100 Model results		
	-	Low	Mid	High	Low	Mid	High
St. Dev. of ΔP (€/MWh)	10.2	17.7	9.2	12.3	16.8	8.4	15.2

- Clear benefit of model use versus random draw of price differences
- Reasonably good reproduction of model input
- Differences to observed 2021 values potentially attributable to sample size versus training dataset, year-specific characteristics, or stochastic effects

➢ Model appears suitable for reproduction of characteristic price differences

Model Application
Modeling of future time series



	100 Model Results	
Standard Deviation of ΔP (€/MWh)	2021	2030
	10.5	15.5

- More extreme price differences more frequent in 2030, leading to a higher pooled standard deviation
- Higher frequency of larger absolute price differences stems from more frequent hours with low residual load

Conclusions and Discussion

Summary of results, open questions, and opportunities for further model development

Results

- Model was able to reproduce historical characteristics reasonably well using a limited number of inputs
- Characteristics of model results for 2030 plausible given an expected expansion of renewable generation driving increased hours with low residual load.

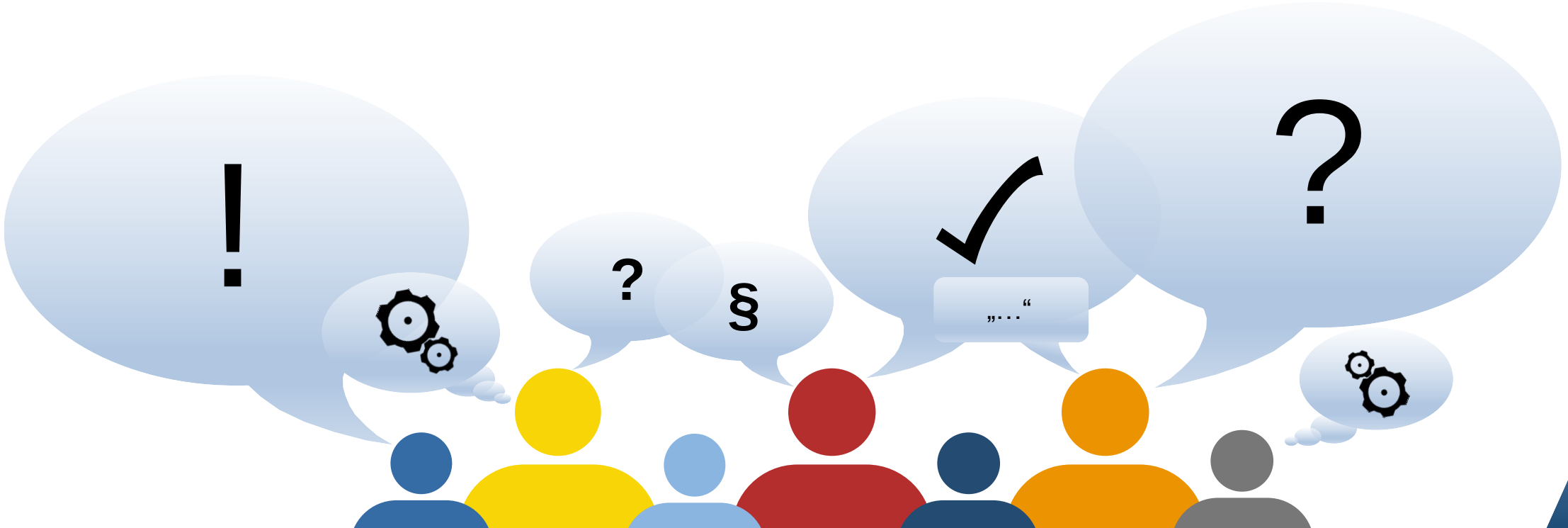
Open Questions

- Can the observed temporal interdependence between timesteps be assumed to remain relevant in the future?
- Can the applied residual load clusters be assumed to retain their characteristics in the future?

Model Development

- Addition of further states of price difference (e.g., 0-5 €/MWh, 5-10 €/MWh, > 10 €/MWh)
- Adjustment of residual load cluster boundaries, or re-definition as % of maximum residual load

Thank you for your attention!



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