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SMARTER, BETTER, CHEAPER? THE POTENTIAL OF AI IN ENERGY SYSTEMS IN TWO EXEMPLARY APPLICATIONS

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Goals

1. Getting an impression of the challenges of a completely revamped (decentralised, flexible) energy sector and how AI could be a part of the answer

2. Learning two examples for the incorporation of AI into typical engineering workflows, regarding the underlying
   - Motivation
   - Technical implementation
   - Potential benefits

3. Motivate us to add certain AI/ML approaches to our fields‘ tool-boxes, either by DIY or in cooperation with CS experts

Agenda

Motivation: AI in Energy Systems

Example #1: Power plant optimisation

Example #2: Model predictive process control

Summary & Concluding remarks

Setting: German energy system

Coal power plants
Nuclear Energy plants

→

Decentralised
wind, pv,
biomass plants

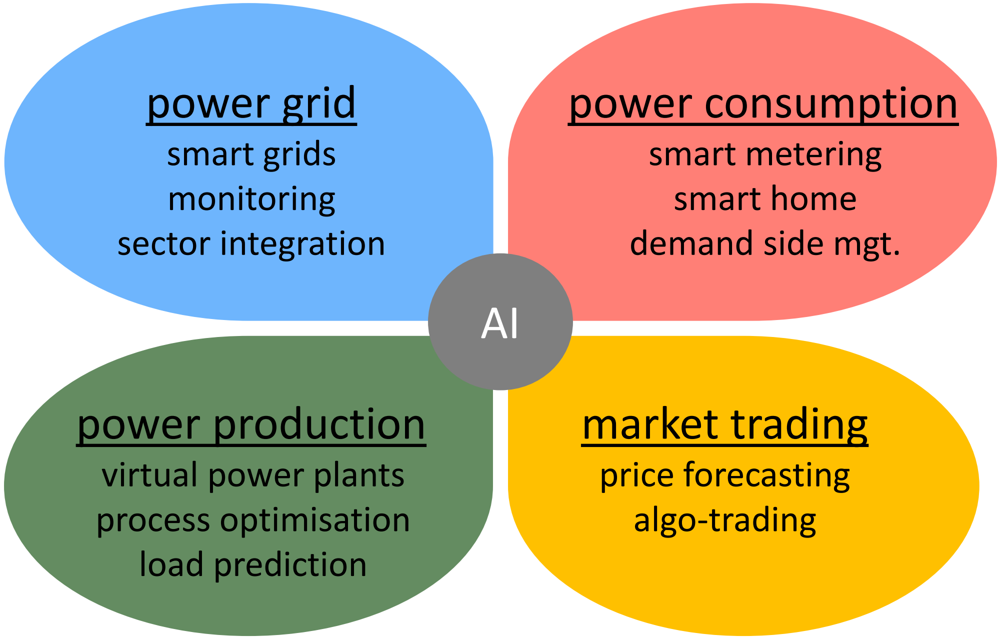
- Germany attempts to fulfill Paris Agreement Goal in the energy sector by drastically increasing the share of renewable energy and enhanced energy efficiency
- Consequences:
  - Shift towards (many!) small, decentralised power plants
  - Intermittent production requires flexible operation and transmission
  - High demand for energy storage systems
  - Economic pressure esp. on „novel“ or less established technologies

Setting: AI in energy systems

This transition is no trivial task. More precisely, we face

- a vast increase in **complexity**,
- an **abundance of data**, and
- economic pressure / **fluctuating** commodity prices

Unsurprisingly, AI is considered as (part of) the solution to these challenges.



Motivation

In the following, we will present two examples for our approaches of AI-integration into tasks in the field of energy process engineering:

1. Optimisation of traditional/existing facilities
2. Process development of emerging energy systems

Agenda

Motivation: AI in Energy Systems

Example #1: Power plant optimisation

Example #2: Model predictive process control

Summary & Concluding remarks

Example #1: Power plant optimisation

Optimisation and flexbilisation of biomass power plants

- *Case:* biomass power plants suffer from high economic pressure and expiring subsidies
- *Idea:* biomass power plant operator wants to move towards cheaper combustibles (like residual forest or industrial wood)
- *Constraint:* stable, safe and low-emission operation has to be guaranteed at all times

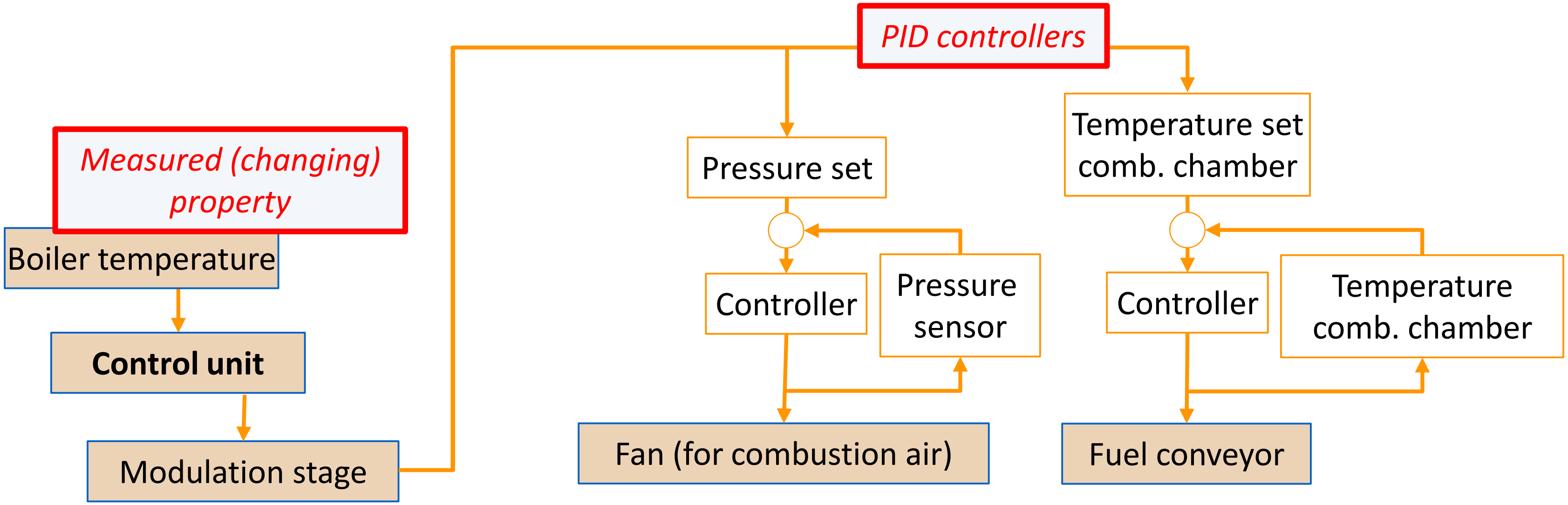
Possible OPEX reduction of 30%

90 €/t 75 €/t 55 €/t

Example #1: Power plant optimisation

Challenges:

- Low quality feedstock and fluctuating fuels require specific optimal process conditions
- However, process control is slow and trailing

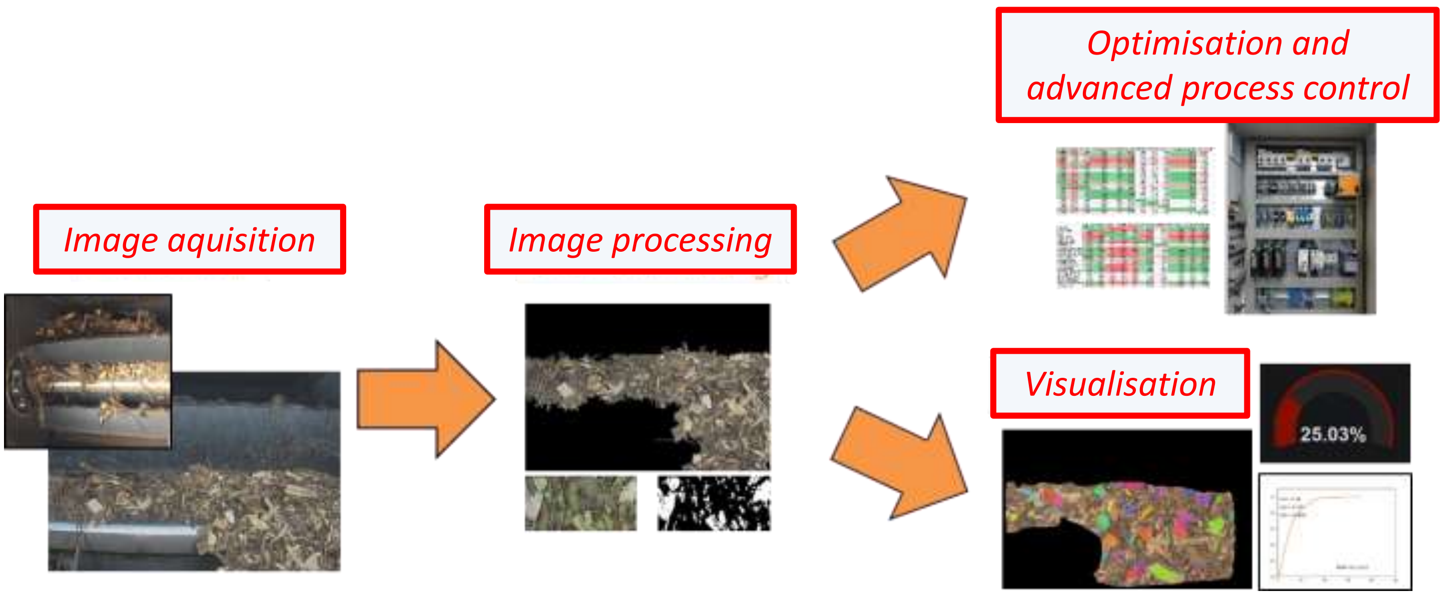


→ Fuel quality (and load) forecasting would allow proactive furnace operation

Example #1: Power plant optimisation

Approach: Just-in-time optical analysis of fuel properties prior to combustion (≈ 30 min)

- Installation of a camera system
- Automatic image acquisition and image analysis
- Determination of relevant fuel properties
- Deduction of improved operational points
- Modification of existing PID controllers



Example #1: Power plant optimisation

Principal steps:

- Camera installation and system coupling (interface to power plant PLC)



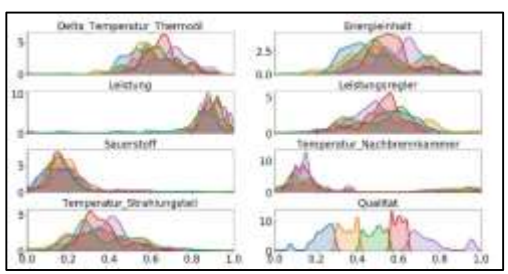
- Image processing: Combining image information and physical

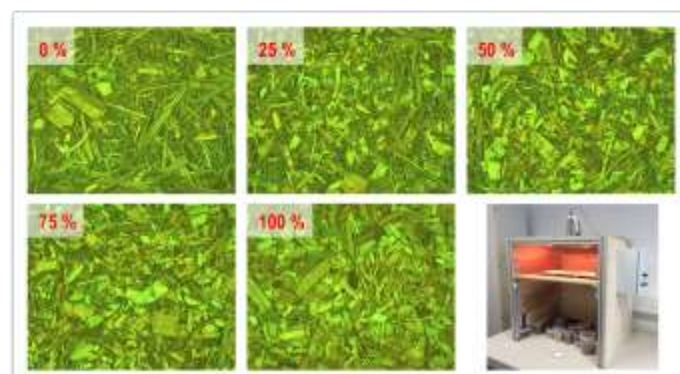
  Approach: Univariate property „fuel quality“ (or „mixture rate“)

Empirical approach (operator training)

Correlations with plant data

Lab-scale images of typical fuels

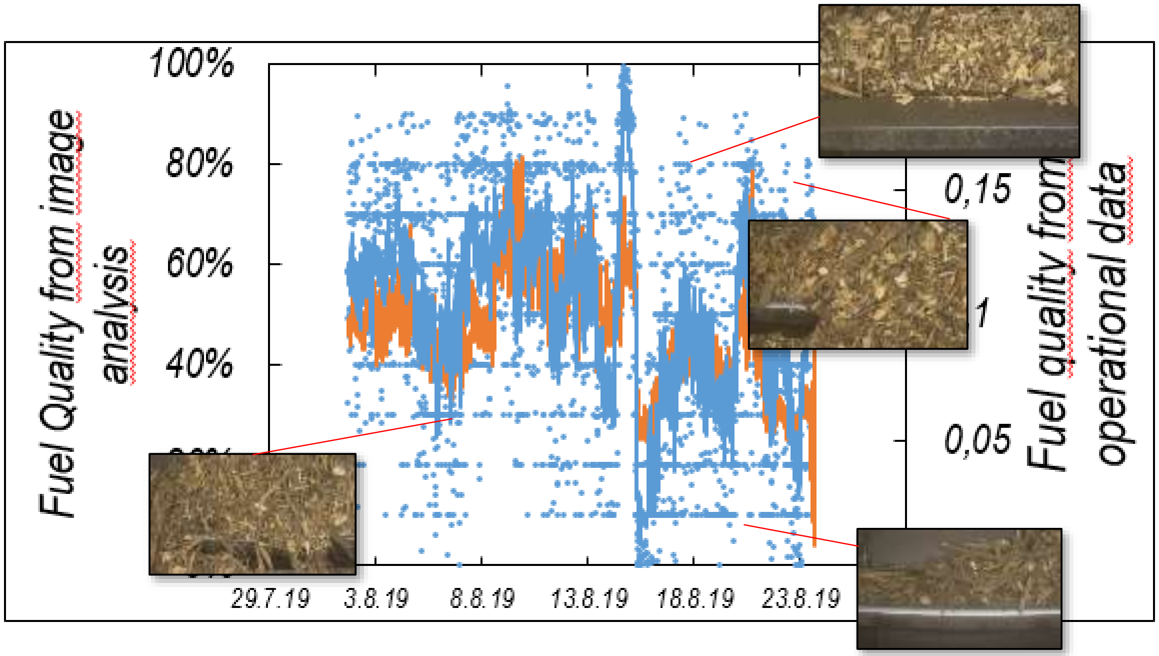




Example #1: Power plant optimisation

Principal steps (cont.):

- Evaluation: Comparing model predictions with (independent/unused) data



- Implementation: Modifying physical parameters (air supply, combustion grate speed, flue gas recirculation) based on predicted fuel quality
  - → „closed-loop“ process control in operation for ca. 6 months now
  - → observable beneficial effect on combustion behaviour
  - → load prediction reduces (peak load) natural gas burner runtimes

Agenda

Motivation: AI in Energy Systems

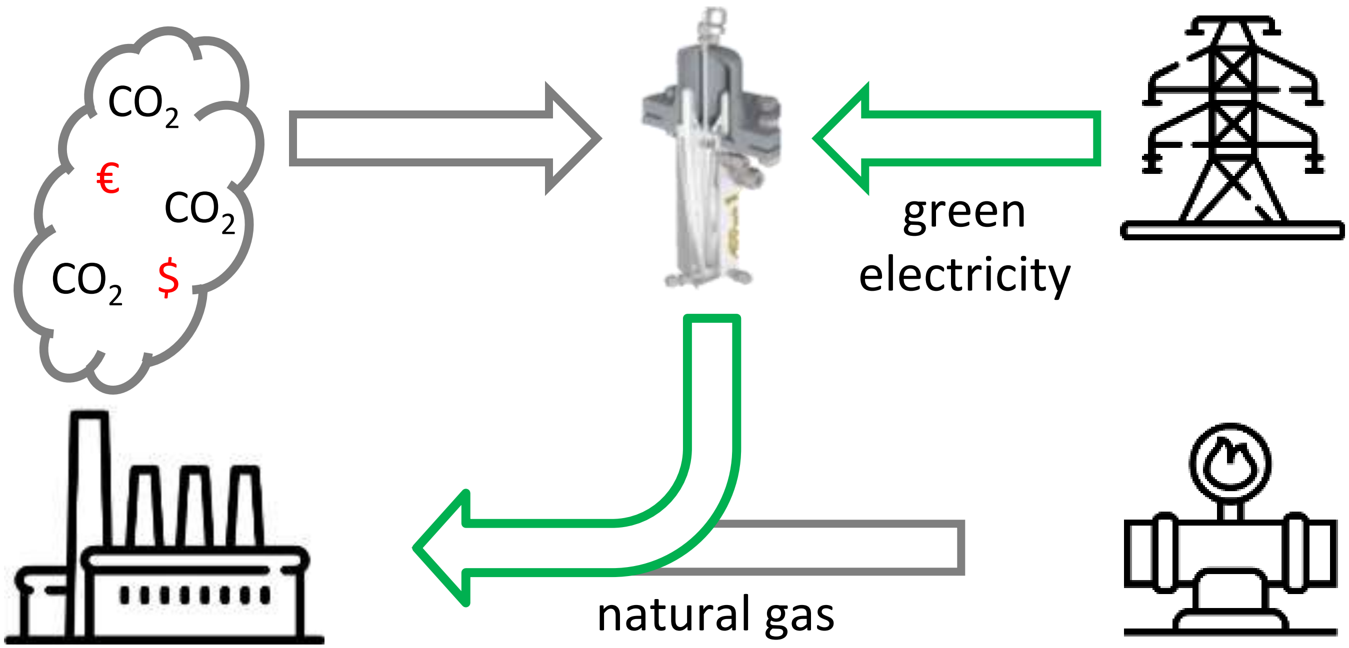
Example #1: Power plant optimisation

Example #2: Model predictive process control

Summary & Concluding remarks

Example #2: Model predictive process control

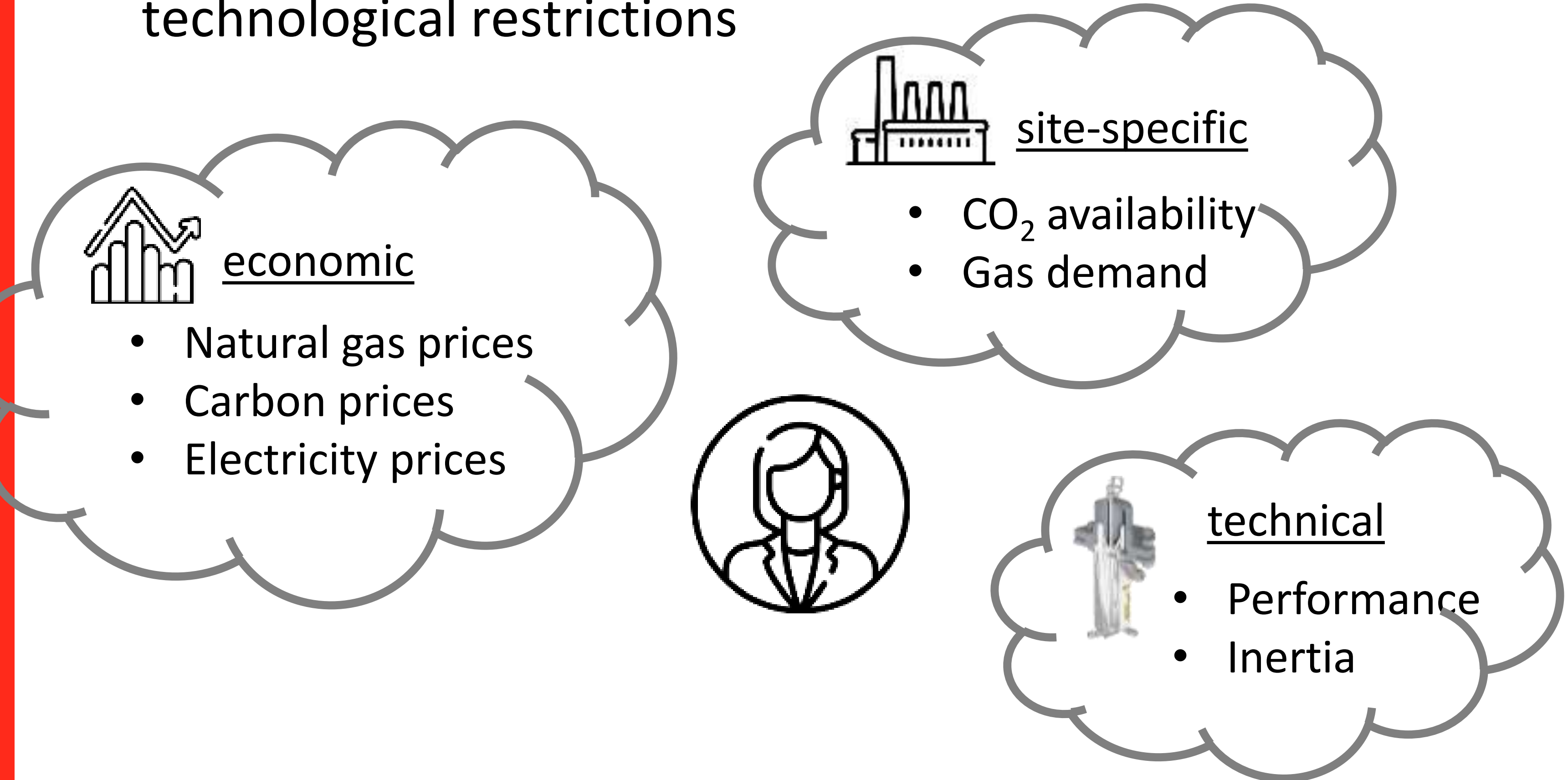
- *Case:* industrial player wants to green ist gas consumption
- *Idea:* produce methane from renewable electricity (Power-to-Gas)
- *Constraint:* operation has to be economically feasible



[Icons from flaticon.com]

Example #2: Model predictive process control

- *Challenge:* interplay of economic, site-specific, and technological restrictions

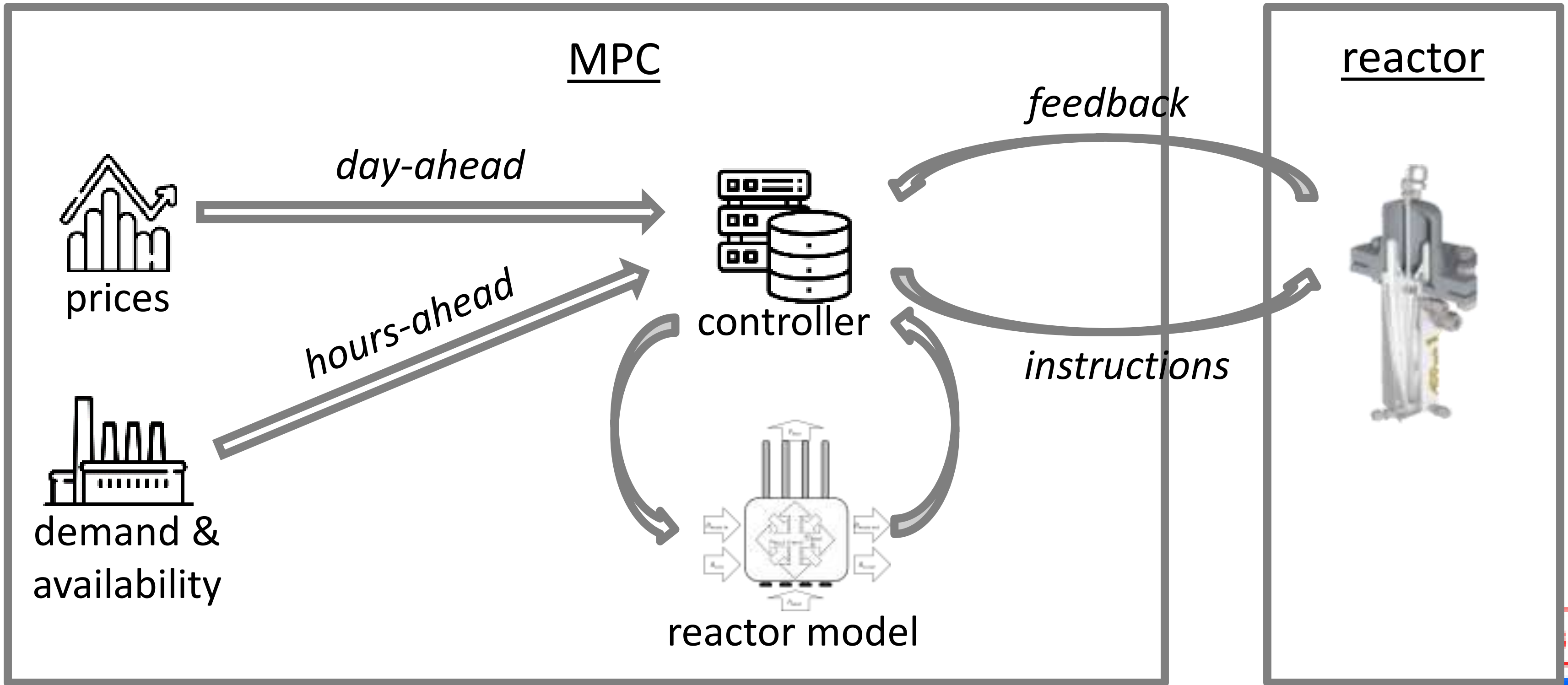


- All of those restrictions are time-dependent →need to forecast developments

[Icons from flaticon.com]

Example #2: Model predictive process control

- *Approach:* model predictive process control
    - Cost-minimising controller (MILP)
    - Detailed reactor model (Simulink)
    - Forecasts for prices, demand and CO_2 availability (AI)



[Icons from flaticon.com]

Example #2: Model predictive process control

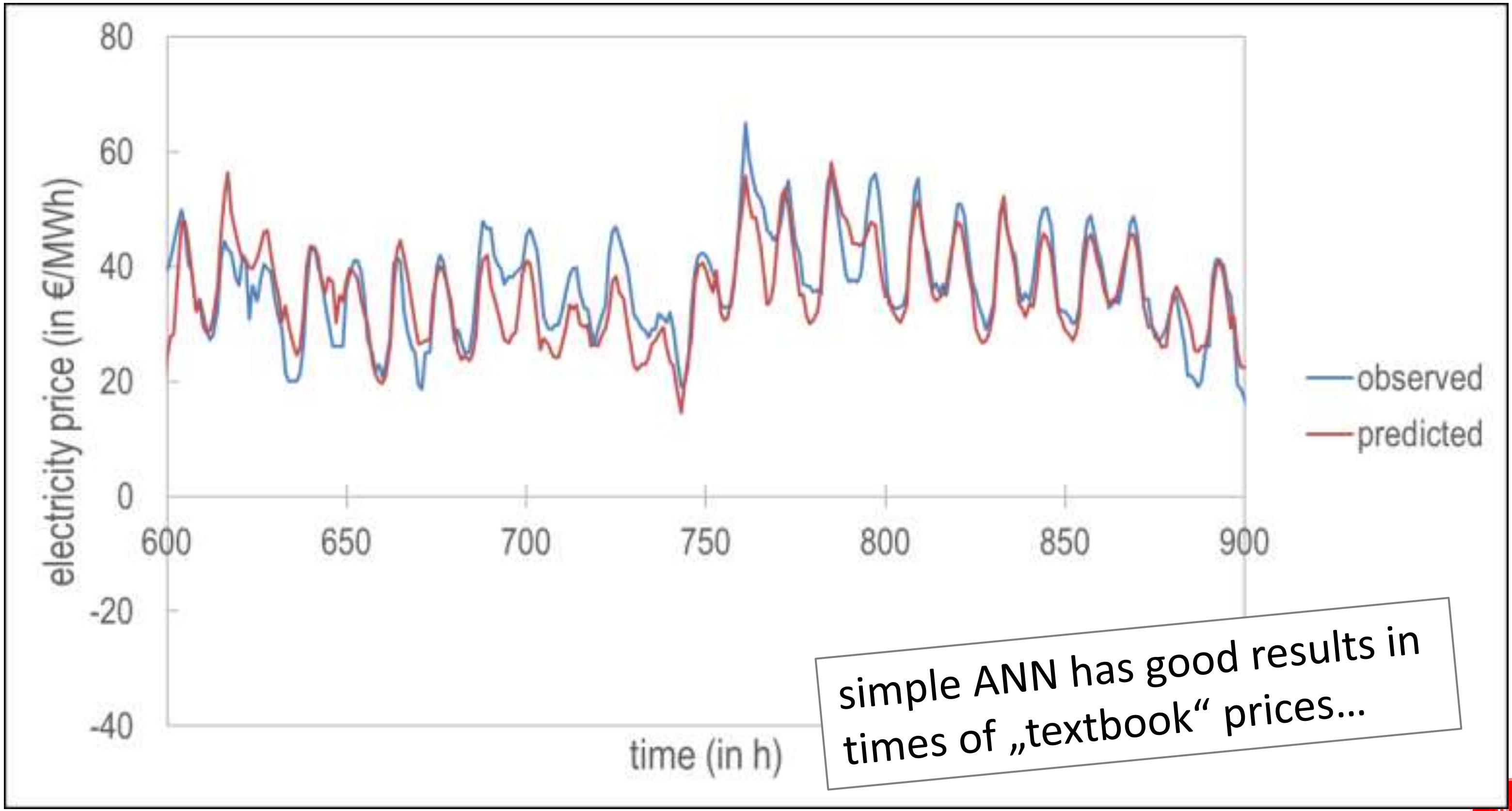
- *Example:* Electricity price forecasting with ANN

ANNs offer the **benefits** of

- Considering the non-linear pricing mechanisms,
- Being computationally inexpensive, and
- Dealing with a multitude of determinants, e.g.
    - Day and time
    - Weather
    - Load
    - Commodity prices
    - Power plant availabilities

Example #2: Model predictive process control

- Electricity price forecasting with a very simple ANN
- Inputs: electricity prices (-1d, -7d), actual hour, actual day



simple ANN has good results in times of „textbook“ prices…

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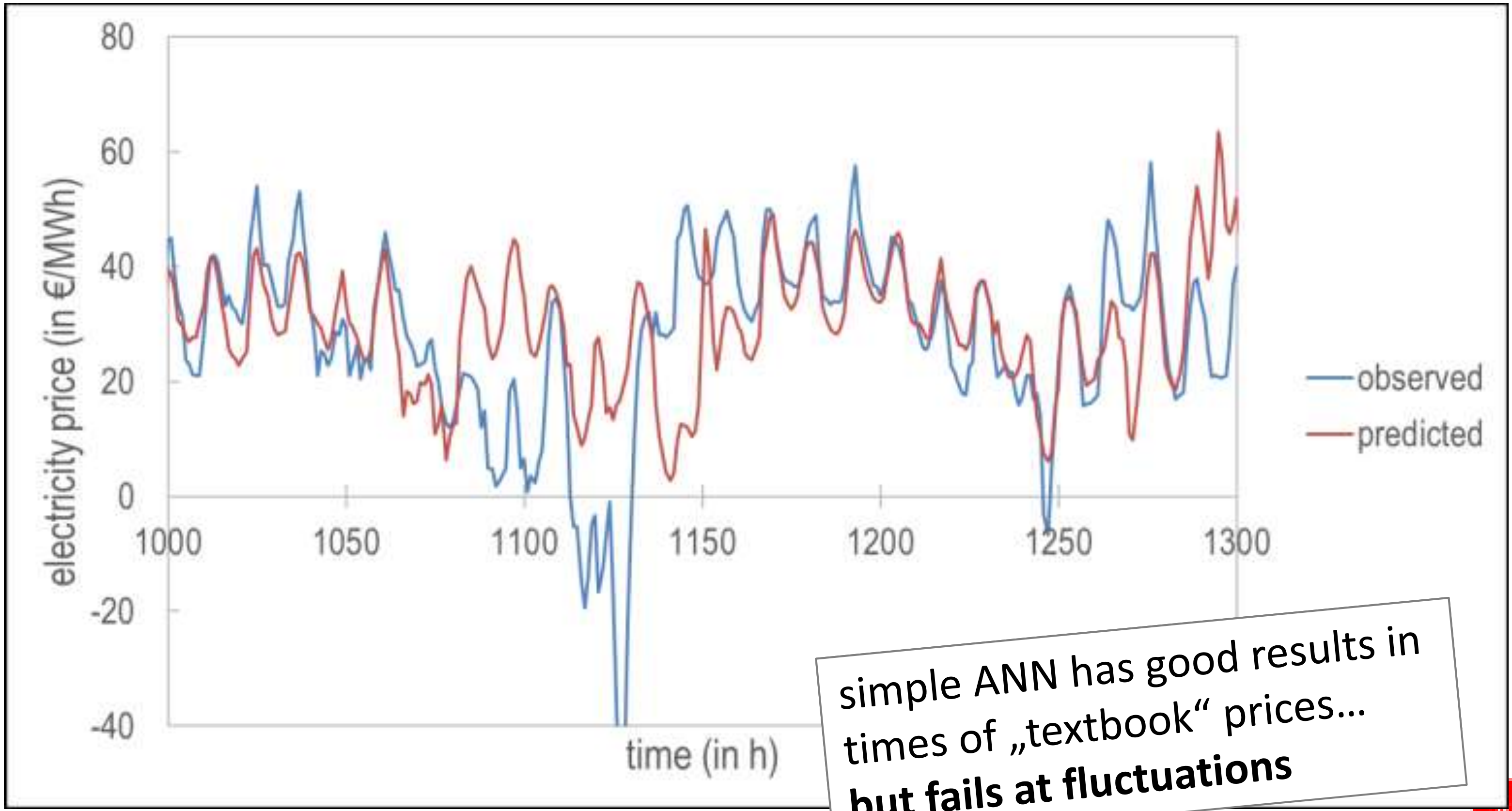
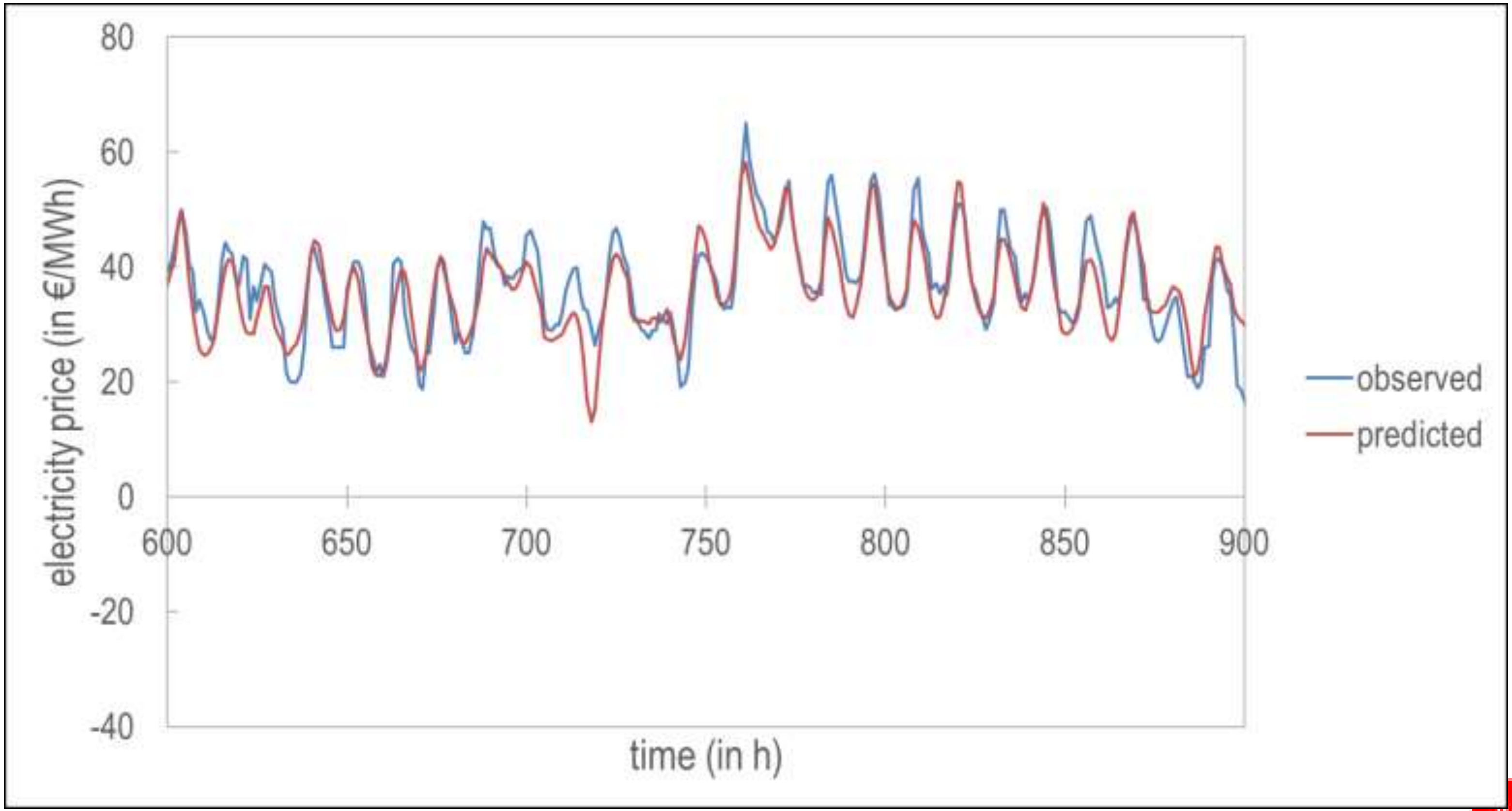


simple ANN has good results in times of „textbook" prices…
but fails at fluctuations

Example #2: Model predictive process control

- Electricity price forecasting with an enhanced ANN
- Inputs: electricity prices and load (-1d, -7d), predicted load, predicted RES, predicted gas price, actual hour, actual day



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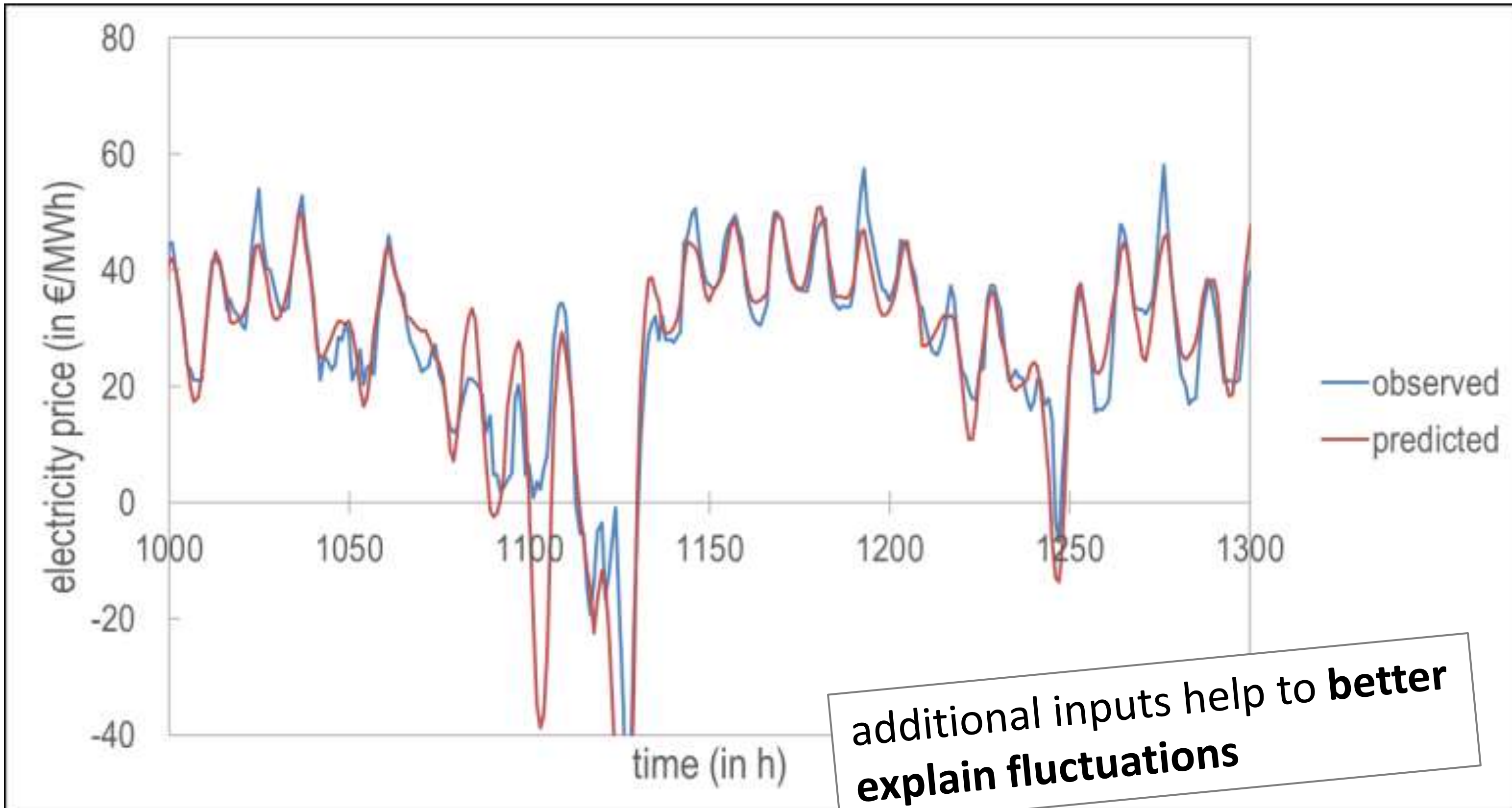

additional inputs help to **better explain fluctuations**

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Take home messages

AI in existing energy infrastructure (Example #1)

- *Smarter?* Power plant starts acting instead of reacting
- *Better?* Biomass and gas consumption decreases
- *Cheaper?* OPEX savings of up to 30%

AI in emerging energy systems (Example #2)

- *Smarter? Better? Cheaper?* Even more:
- AI is (one of) the prerequisites to operate such systems in an economically feasible way

AI is not the universal remedy for the energy transition. It is **one element** to increase the efficiency of existing infrastructure and to promote emerging energy systems.