Predictive control of biomass and biogas-based CHPs at the intersection between the electricity grid and heating networks

Improving electricity market participation through optimization and demand side management

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Motivation

- **Power Grid**
  - Increased integration of fluctuating renewables (photovoltaics, wind)
  - Big questions: Who provides base load, who compensates fluctuations?
  - Biomass CHP could provide base load in winter (heating networks), biogas CHPs flexibility all year

- **Operators‘ Dilemma**
  - Austria: Old funding schemes for CHPs run out (2017: up to 185,7 EUR/MWh for electricity from biogas), new funding schemes encourage *power market participation*
  - Waste heat *must* be used → connection to *heating network*
  - Continuous operation unattractive, „best“ operation difficult to realize

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  - Increased integration of fluctuating renewables (photovoltaics, wind)
  - Big questions: Who provides base load, who compensates fluctuations?
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A systematic solution is required that
efficiently uses
available forms of flexibility

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Flexibilities to match production and demand

- **Goal**: Run when power prices are high
- **Constraint**: Waste as little „waste heat“ as possible
- **Possible flexibilities**:
  - Production (modulation)
  - Thermal storage, biomass drying
  - Network temperature
  - Demand side management
- **Challenge**: Use these flexibilities efficiently – predictive control!

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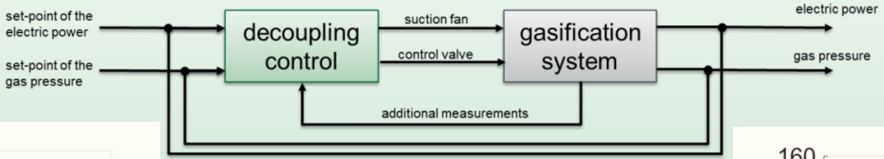
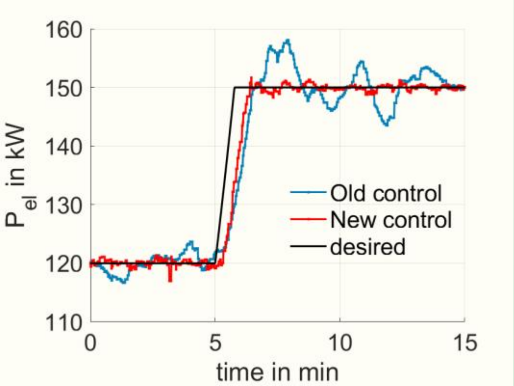
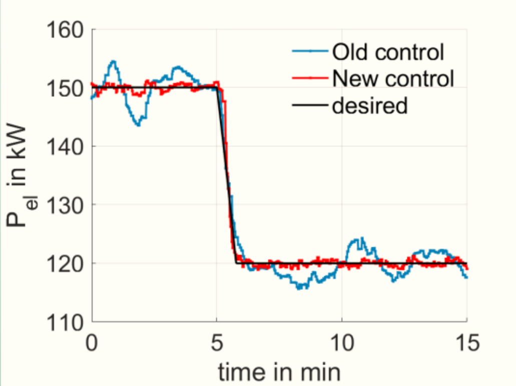
Production: Modulation







C. Hollenstein: Erhöhung der Flexibilität von Biomasse-Festbettvergasern durch modellbasierte Regelungsstrategien: Methoden und praktische Verifizierung

- Biogas and even fixed-bed biomass gasifiers can be modulated quickly enough to participate in balancing energy market!

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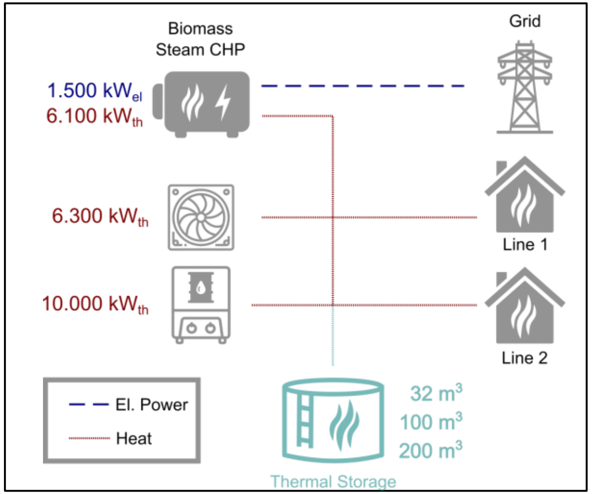
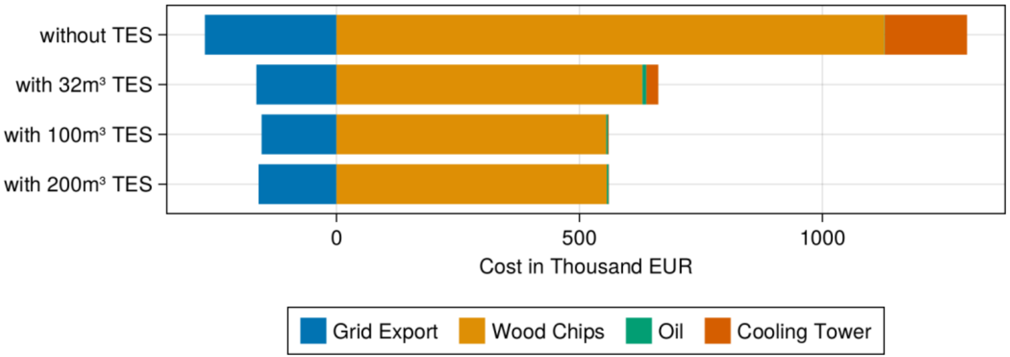
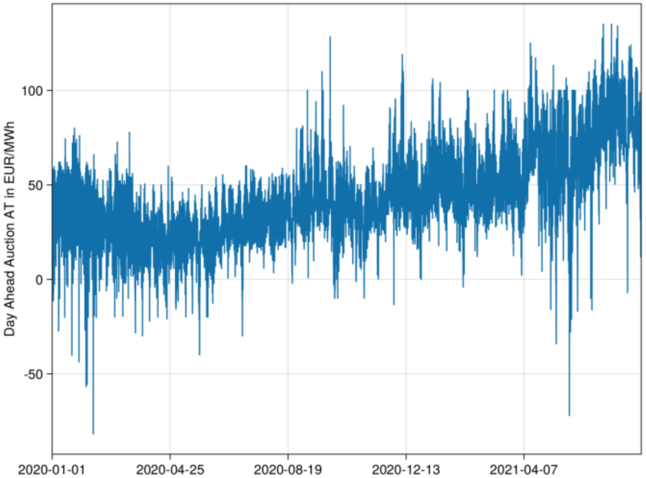
Thermal Energy Storage (TES)

- **Example: Biomass Steam CHP**
  - **Restriction**: Cannot be modulated
  - **Condition**: Heat demand must be met (revenue from heat is constant)
  - **Electricity price**: EXAA day ahead prices of 2020
  - **Simulation**: One year using predictive control







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Network Temperature

- **Standard**: Heating curve (satisfy higher demand in winter)
- **Restriction**: Big variations are undesirable (mechanical strain)
- **But**: Big volume!

- **Challenges**:
  - Only available if there is demand! Charge rate depends on mass flow
  - State Estimation (how hot is the network?)

- **Example**: Cooling network

$$Q \approx c_{\mathrm{p}} \cdot V \cdot \rho \cdot (T_{\mathrm{Feed},1} - T_{\mathrm{Feed},0})$$

$$Q \approx 4.2 \frac{\mathrm{kJ}}{\mathrm{kg \cdot K}} \cdot 1000\mathrm{m}^3 \cdot 1000 \frac{\mathrm{kg}}{\mathrm{m}^3} \cdot (1° \mathrm{C})$$

$Q \approx 4.2\ \mathrm{GJ} \cong 50\mathrm{m}^3$ buffer with $\Delta T = 20\ °\mathrm{C}$

Roundtrip time: 15 min:

$$\dot{Q} = \frac{Q}{t} \approx \frac{4.2\ \mathrm{GJ}}{900\ \mathrm{s}} \approx 4{,}7\ \mathrm{MW}$$

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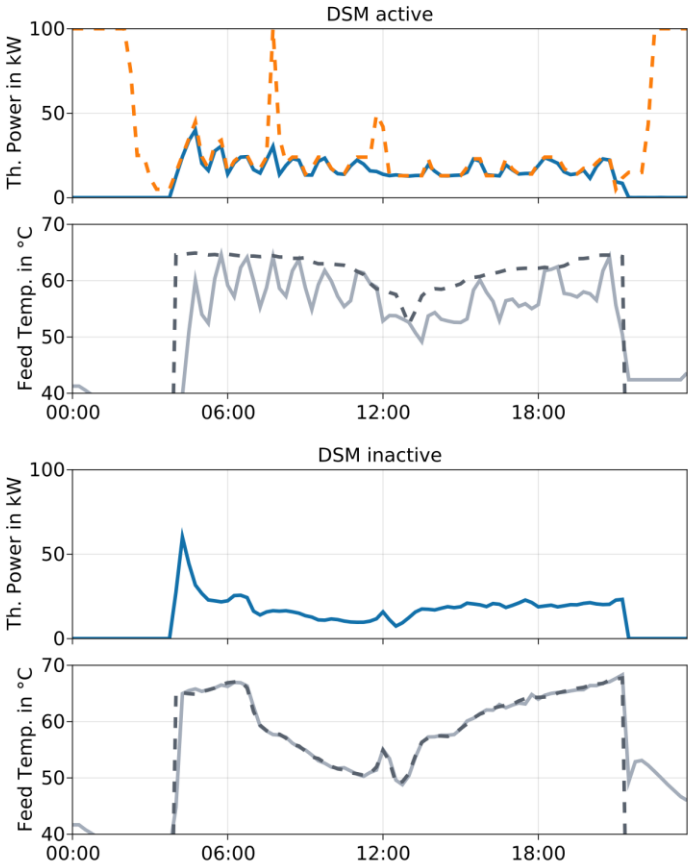
Demand Side Management

- **Actively influence viable consumers**
  - Temporarily restrict demand (connection power) to avoid peak loads
  - Pre-heat homes (fake outdoor measurement)
  - Force recharging of heat storages

- **Challenges**
  - Technical issues (communication with consumers)
  - Legal issues / contracts
  - Estimate effect of measures / estimate current state



V. Kaisermayer et al.: Smart control of interconnected district heating networks on the example of „100% Renewable District Heating Leibnitz“. Smart Energy, 2022

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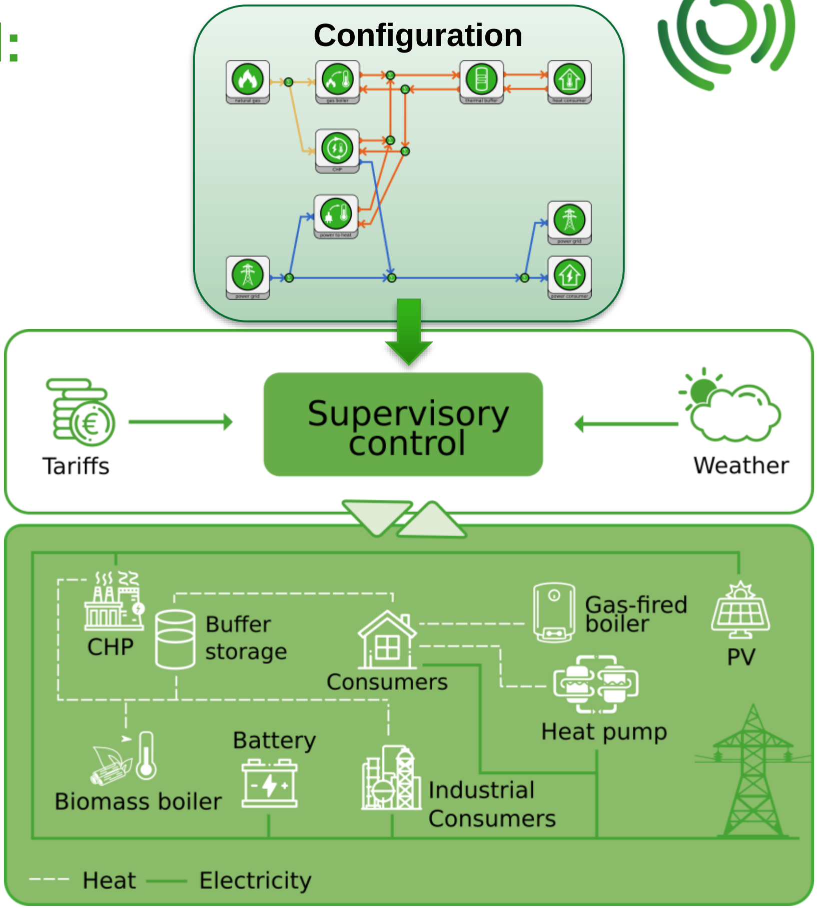
Optimization-based predictive control: „Energy Management System“ (EMS)

- **Optimization-based**:
  - Computer translates „what“ to „how“ (goals and restrictions are automatically considered in operating strategy)
  - Automatically adapts to changing prices / environment conditions

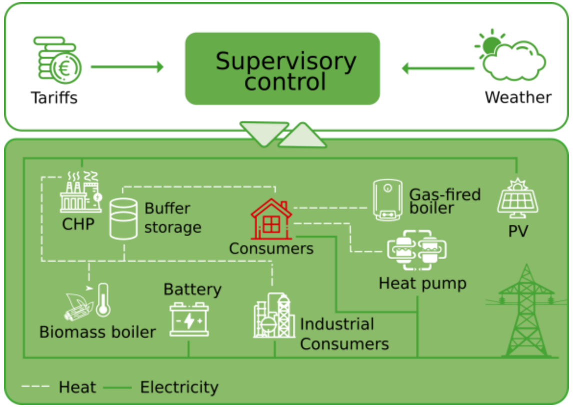
- **Predictive**: Learns from the past and considers (weather) forecasts to effectively use flexibilities



Current Status and Challenges

- EMS has been implemented and operational in 3 heating networks[1]
- Current work on resolving the following challenges:

Demand Side Management
- State Estimation
- Modeling of impact of DSM measures



[1] E.g.: V. Kaisermayer et al.: Smart Control of Interconnected District Heating (DH) Networks. BEST Day, CEBC 2023

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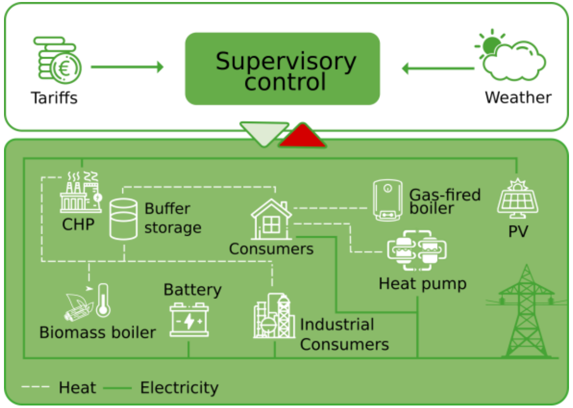
Network State Estimation
- Use *Digital Twins* to validate operating strategies and obtain virtual measurements



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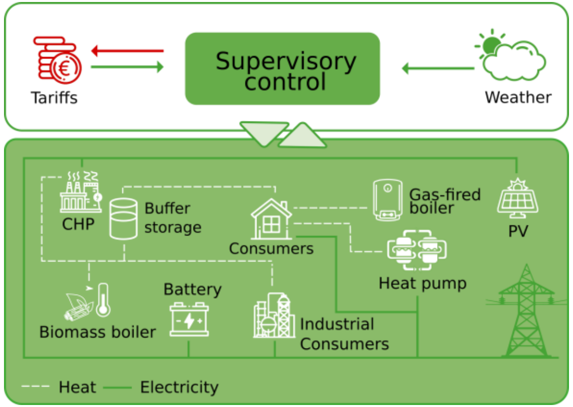

Electricity Market Participation
- Actively support operators in electricity market participation

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Conclusion and Outlook

- Biogas and biomass-based CHPs do have strategic importance in the energy supply of the future if they manage to **efficiently use available flexibilities**
  - Modulation through better controllers
  - Predictive use of thermal storage (buffers, network, consumers)

- **Optimization-based predictive control** ideally supports this and automatically adapts to changing conditions (yield, demand, tariffs)

- Current and future projects of BEST with **established** and/or **innovative automation companies** work towards
  - reducing warranted scepticism by providing fail-safe solutions
  - expanding the technological capabilities and
  - developping viable business models

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