Decision-making for integrated energy systems

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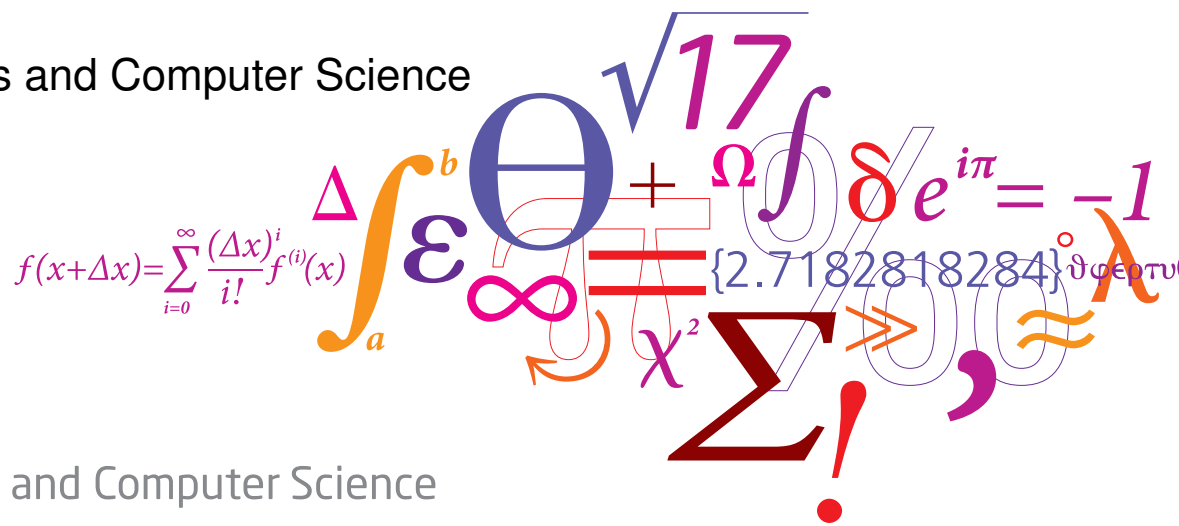

The CITIES Project

funded by Det Strategiske Forskningsråd through the CITIES research center (no.1035-00027B)

CITIES = **C**enter for **IT-I**ntelligent **E**nergy **S**ystems in Cities

AALBORG UNIVERSITET

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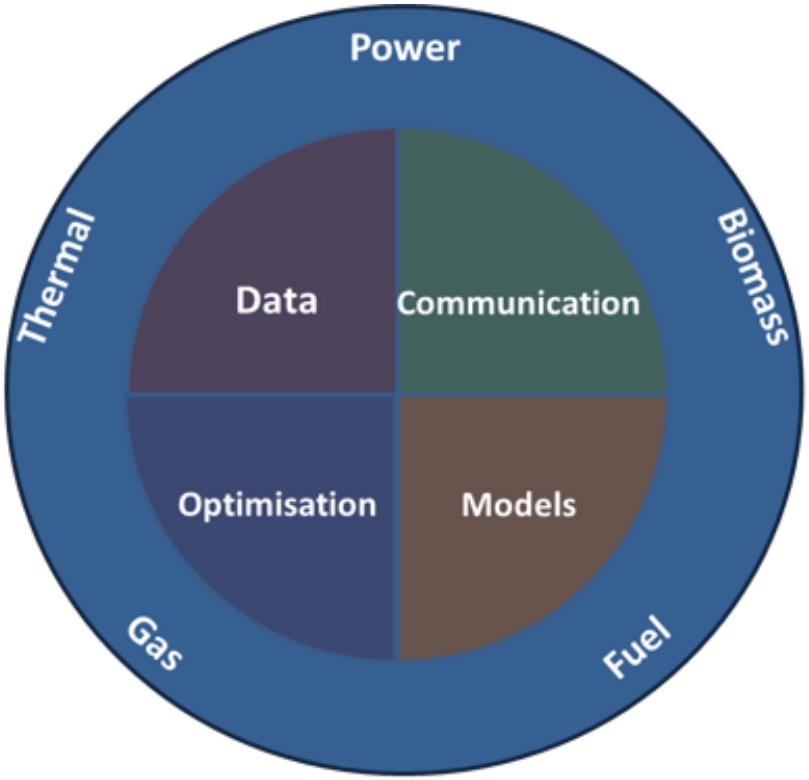
DTU

and many partners from Danish Industry as well as international companies and research institutions

www.smart-cities-centre.org

The CITIES Project



The **central hypothesis of CITIES** is that by **intelligently integrating** currently distinct energy flows (heat, power, gas and biomass) in urban environments, we can enable large shares of renewables, and consequently obtain substantial reductions in CO2 emissions.

Intelligent integration will enable lossless virtual storage.

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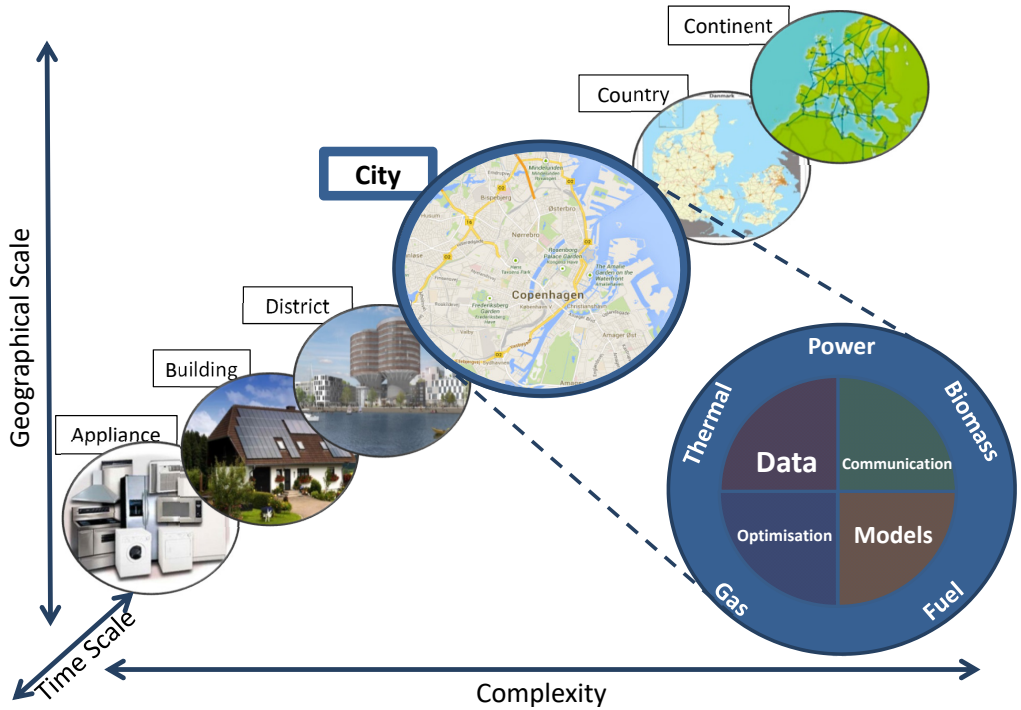

Integration based on data and IT solutions leading to models and methods for planning and operation of future flexible energy systems

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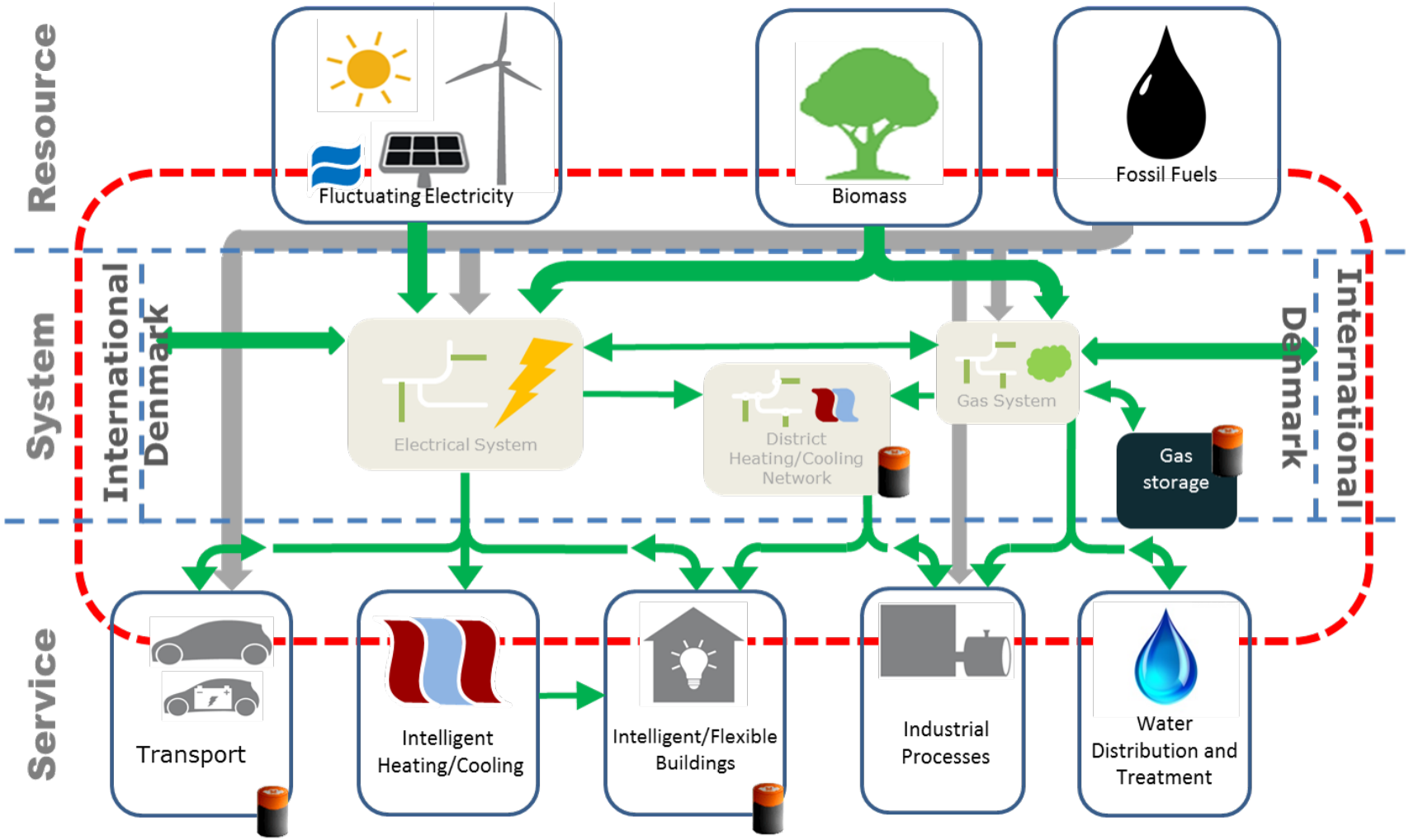

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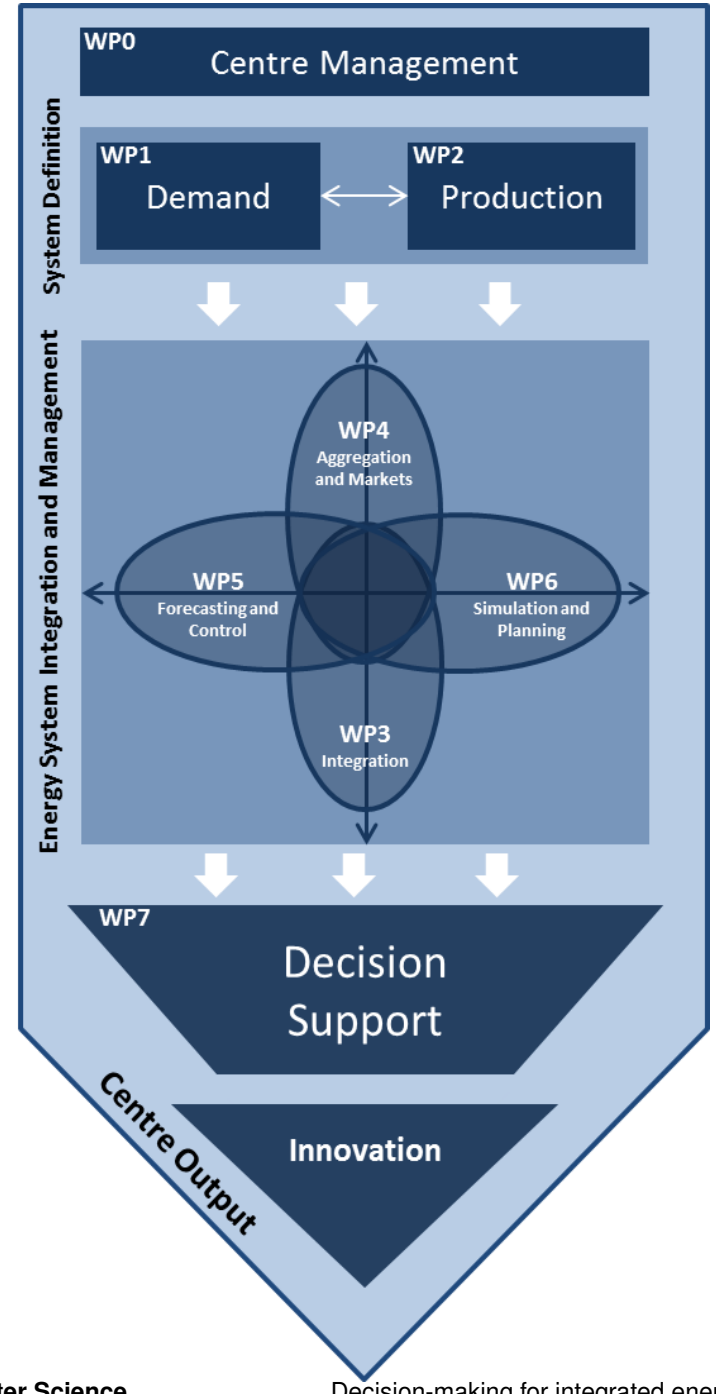


CITIES WP7 - Decision-making and Support Methods

Objectives:

1. Development of decision-making models for the optimal market participation of energy companies
2. Using the decision-making models to perform cost/benefit analyses for smart cities

Methods:

- Decision-making under uncertainty (stochastic programming, robust optimization)
- Large-scale optimization (decomposition, heuristics)

CITIES WP7 - Decision-making and Support Methods

Application areas:

- Planning problems of energy companies
- Evaluation of energy systems

with special focus on:

- Energy systems integration (mostly power and heat)
- Flexibility and controllability of those sources
- Portfolios of energy sources
- Different sources of uncertainty

Work in progress

Decision support methods for

- Biomass supply planning
- Optimal heat production in district heating systems

Work in progress

Decision support methods for

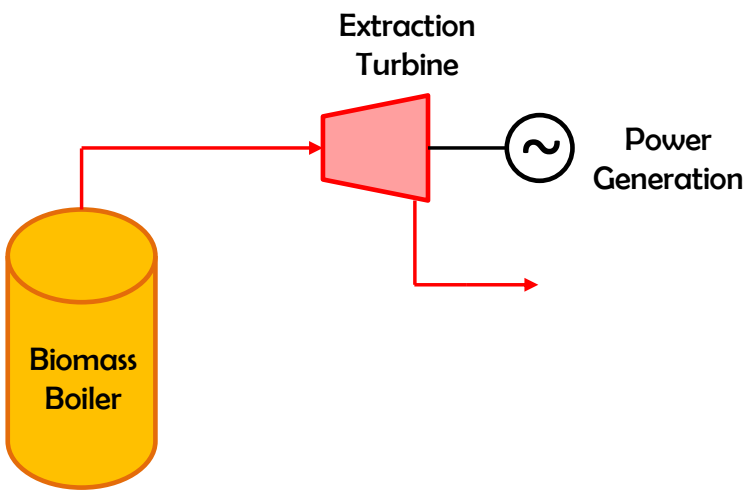
- Biomass supply planning
- Optimal heat production in district heating systems

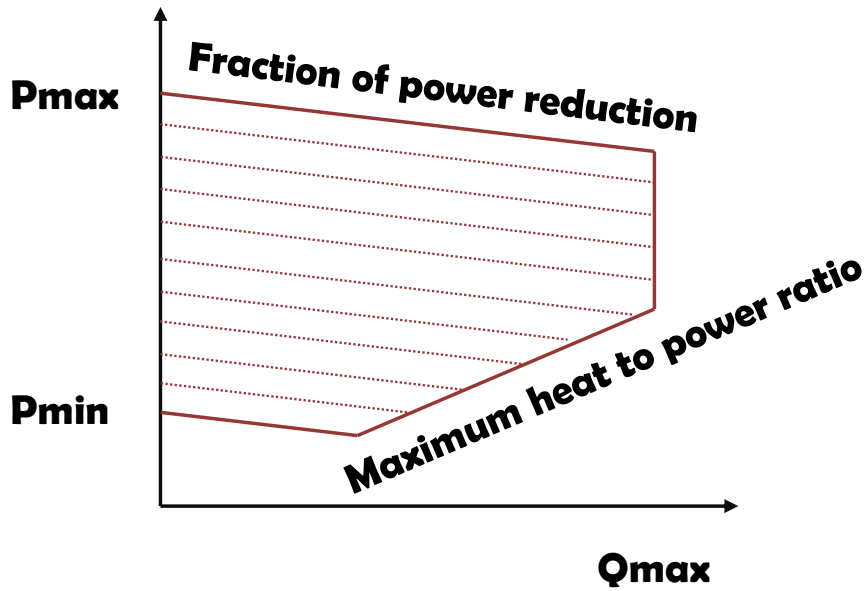
Common background

- Combined Heat and Power (CHP) plants (*Heizkraftwerk*)
- District heating (*Fernwärme*)

Combined heat and power plants

- produce electricity and warm water at the same time
- are connected the electricity grid and the district heating network
- in our case fueled by biomass



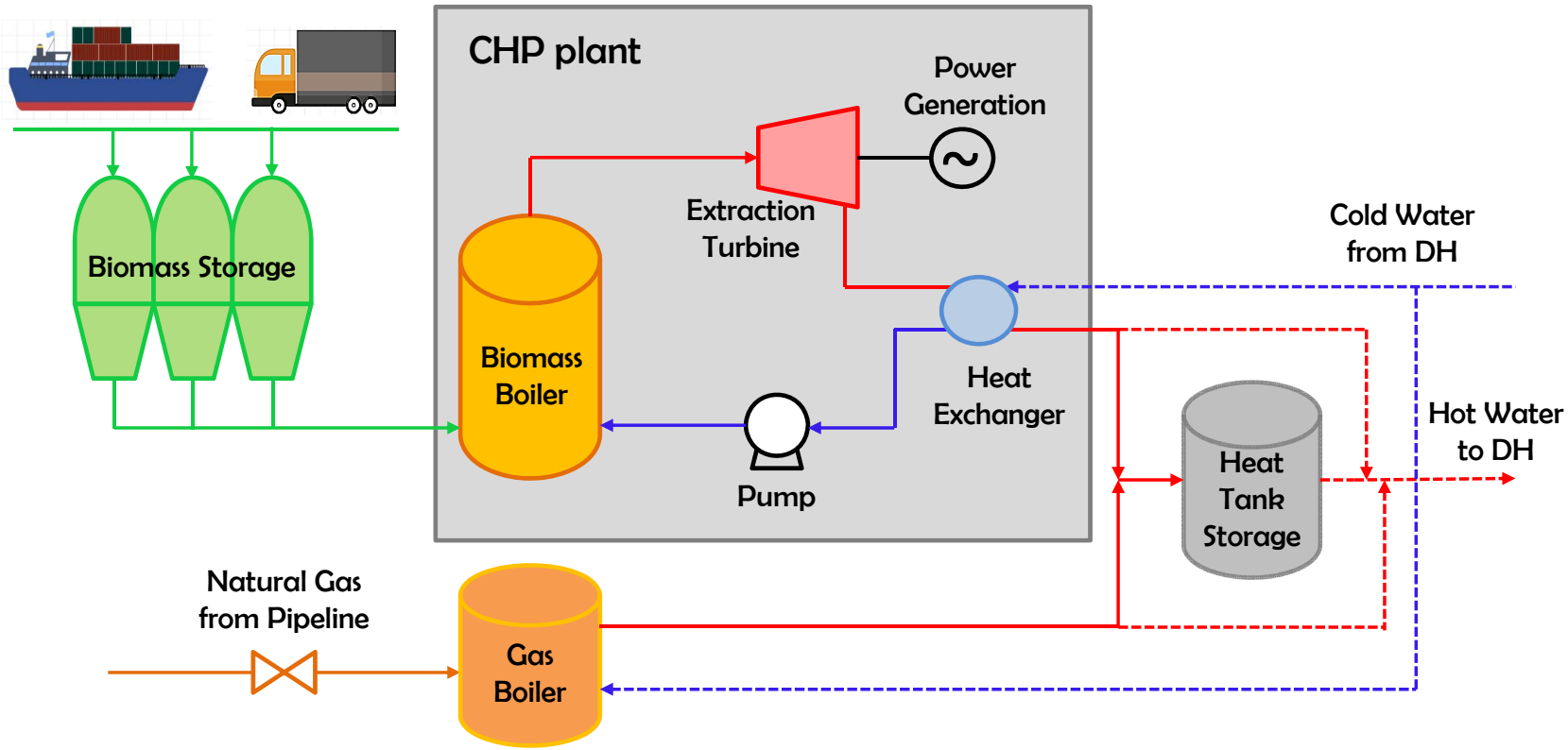


Biomass supply planning

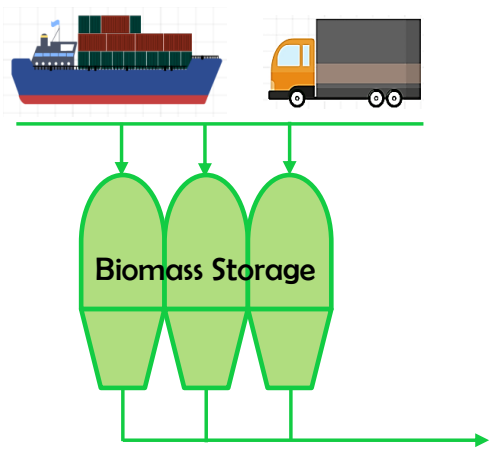
For a large scale producer the biomass is delivered based on supplier contracts which often have a runtime of one year.

Our goal is to determine the optimal portfolio of biomass contracts minimizing the costs and taking uncertainty into account.

Biomass supply planning



Biomass supply planning



Biomass contracts

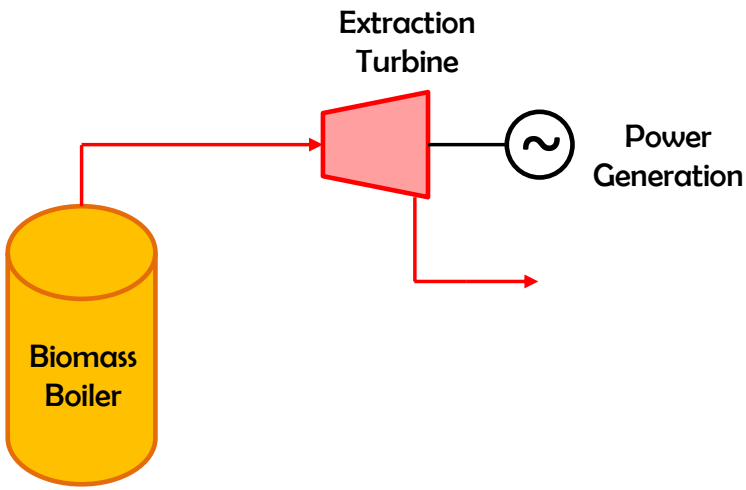
- The biomass can be delivered by a number of suppliers
- Each supplier offers one or more contracts defining the minimum and maximum **amount** of biomass per delivery, the total number of **deliveries** and **frequency**

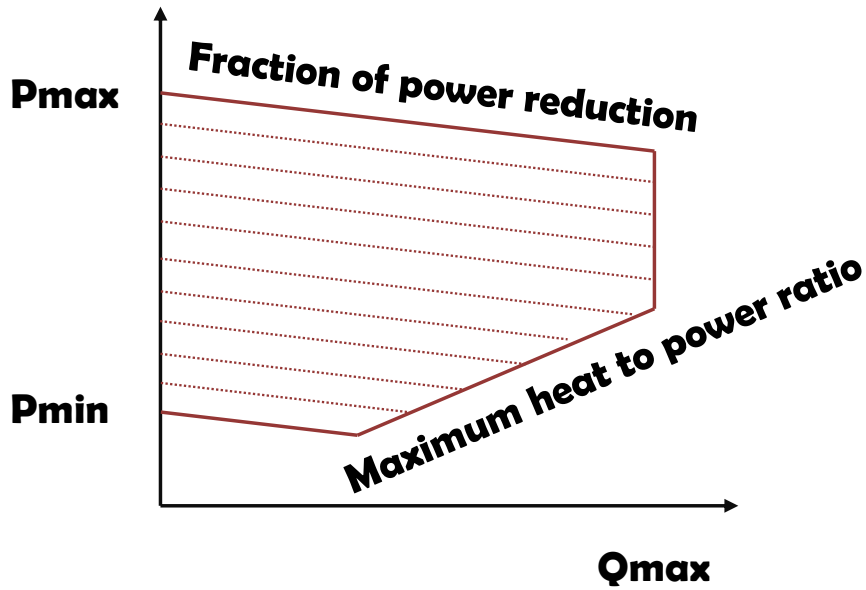
Biomass storage

- The biomass storage has a capacity and the maximum in- and outflow is restricted per period

Biomass supply planning

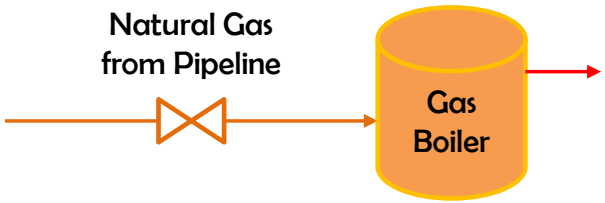
Extraction-condensing CHP unit





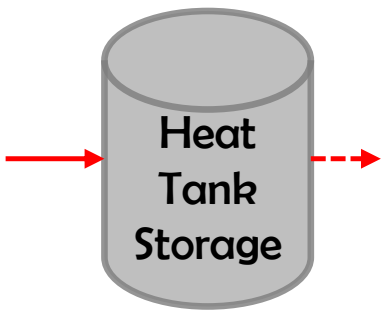
- Technical characteristics and limitations (e.g. min. up and down time, ramping constraints, capacity)
- Commitment status

Biomass supply planning



Gas Boiler

- Handles heat demand peaks
- Gas is bought instantaneously from the gas grid at the natural gas spot price
- Technical characteristics and limitations of the gas boiler (e.g. capacity)
- Cheaper heat production than the CHP



Heat storage

- Stores heat that can be supplied to the DH network
- Provides some flexibility to the system
- Is limited in capacity and flow

Biomass supply management

Objective

Cost minimization

- biomass supply
- operation

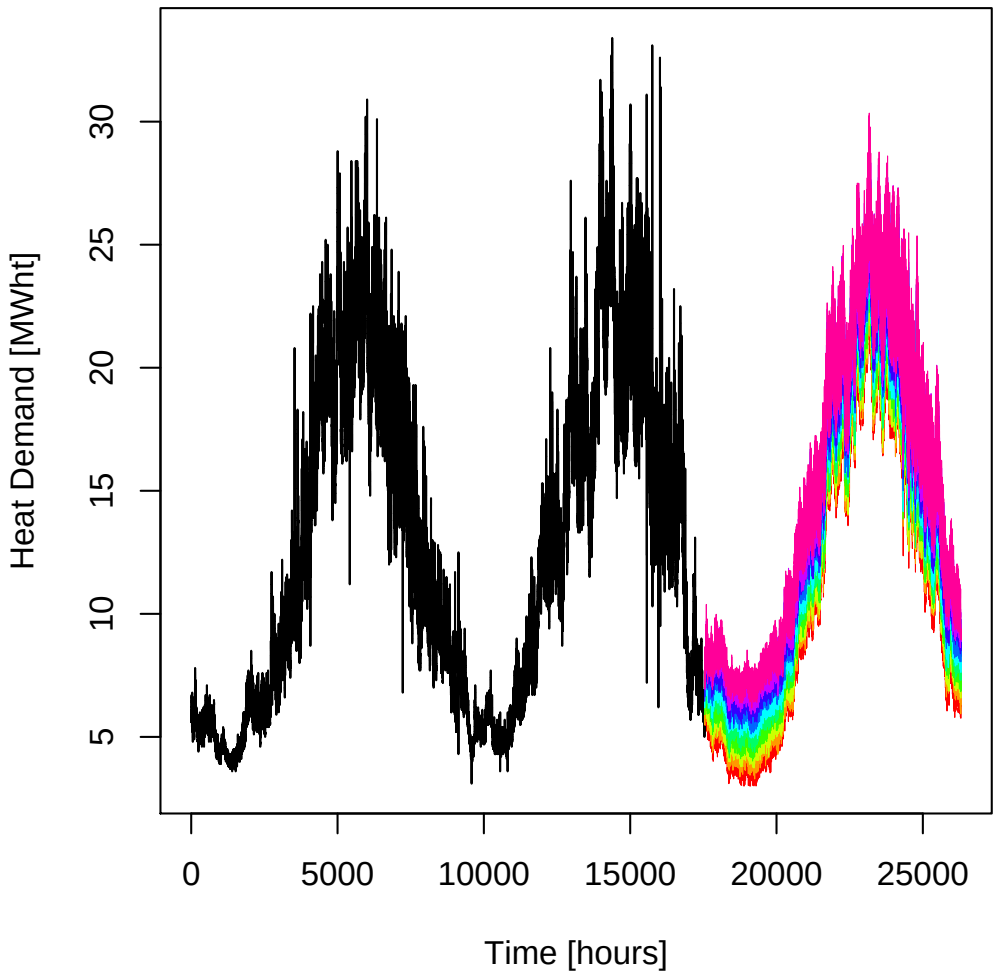
... and always satisfying the heat demand

Uncertainty

- Heat demand
- Electricity prices
- Natural gas prices

Biomass supply mass

Heat demand

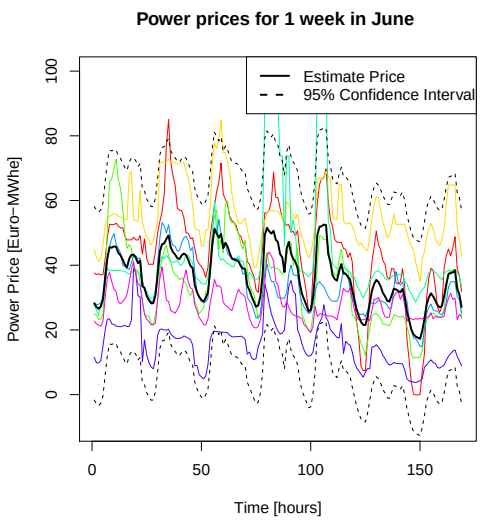


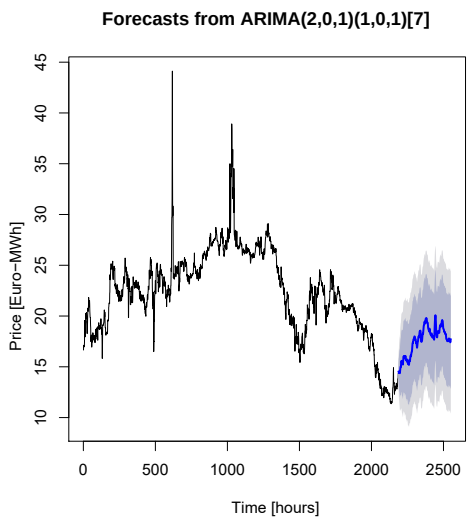
Biomass supply planning

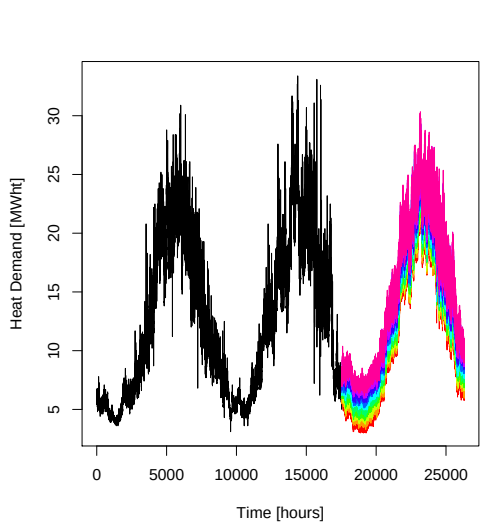
Stochastic programming with scenarios for heat demand, electricity prices and gas prices

Hybrid model combining stochastic programming and robust optimization

- Heat demand scenarios
- Confidence intervals for gas and electricity prices, due to variability.

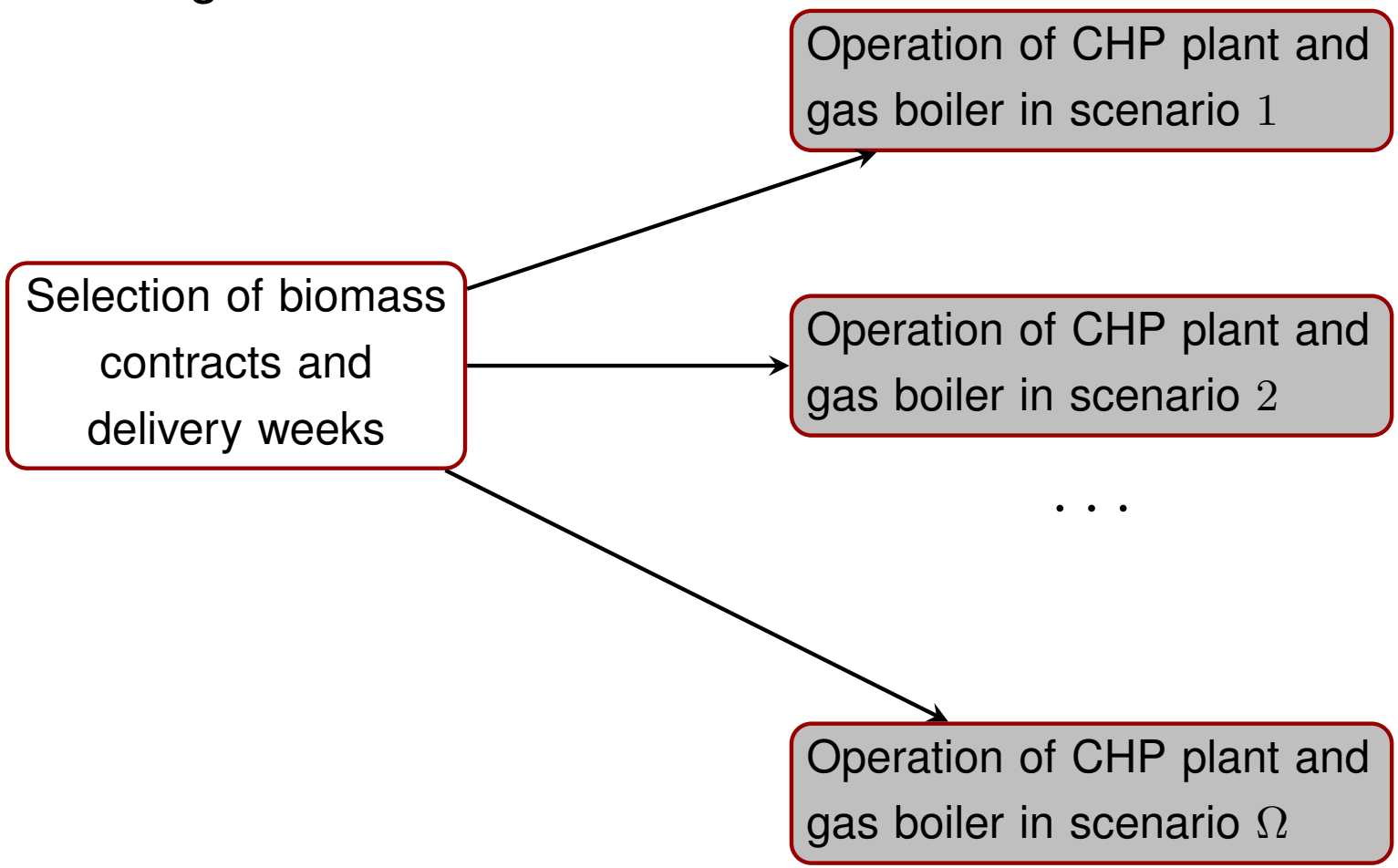






Biomass supply planning

Decision stages



Biomass supply planning

Integrated model:

- Time scale: Hourly for one year
- Long computation times due to complexity
- Apply decomposition techniques to reduce computation time

Two-phase approach:

- Divide in yearly planning and weekly planning
- Forecasts can be updated every week
- Loss of optimization potential, but closer to planning in practice

Biomass supply planning

Two-phase approach

Long-term planning

Selection of biomass contracts

based on heat demand scenarios

- Time scale: 1 year with weekly resolution
- Without most of the technical requirements

→

Operational planning

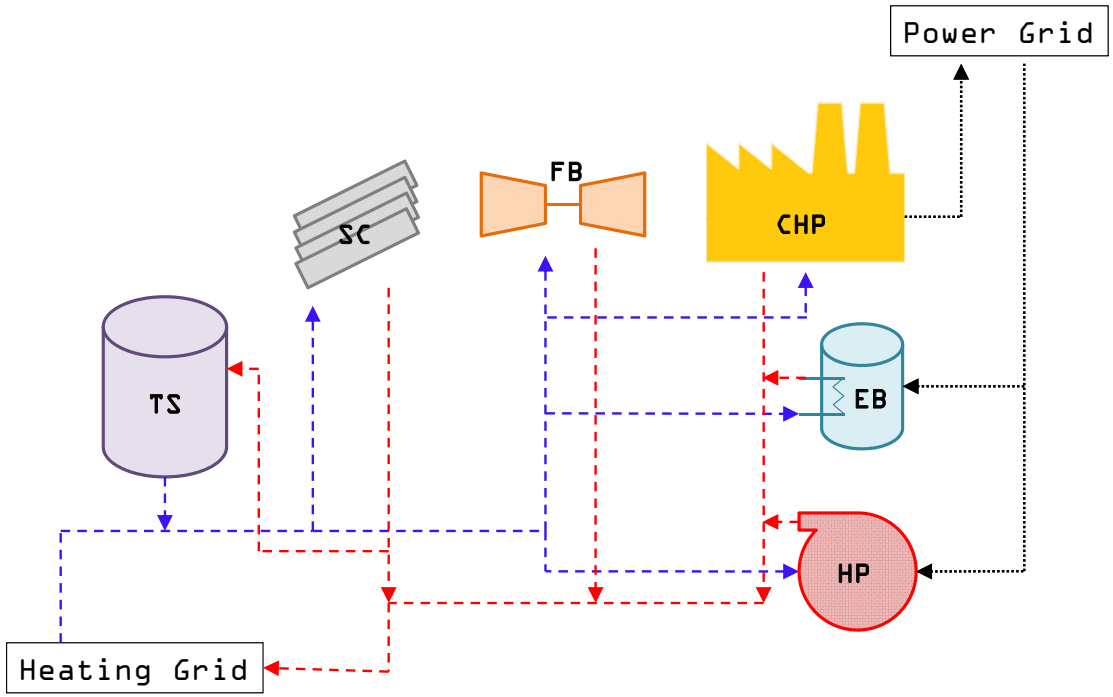
Weekly production scheduling

- Time scale: 1 week with hourly resolution
- Higher level of detail
- Uncertainty of heat demand, electricity price and gas price

Resembles the planning process in practice

Optimal heat production in district heating systems

Demo project with EMD International A/S and ENFOR A/S



Optimal heat production in district heating systems

1-stage decisions:
Unit commitment for slow dispatchable units
Participation in electricity market

→

2-stage decisions:
Unit commitment of fast dispatchable units

Based on forecasts regarding:

- Heat demand
- Solar thermal production
- Electricity price

Reactive decisions based on realizations of uncertainty

Optimal heat production in district heating systems

Requirements

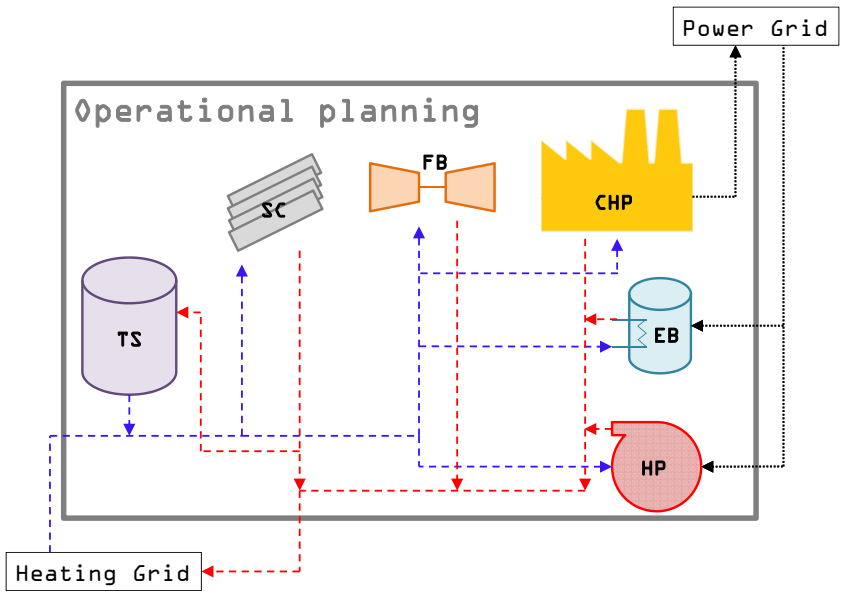
Heat demand fulfillment

Technical requirements of the producing units

Thermal storage characteristics

Costs

Network



Optimal heat production in district heating systems

Methodology

Two-stage stochastic program

Depending on the complexity and runtime experiments

$\rightarrow$ Decomposition techniques or heuristic solution approaches

Summary

CITIES aims at IT-intelligent solutions for integrated energy systems

CITIES WP 7 addresses decision making and planning problems for in companies in smart cities / integrated energy systems with special focus on uncertainties

We are currently addressing two planning problems

- Biomass supply planning for CHP plants
- Optimal operation of production in district heating networks

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