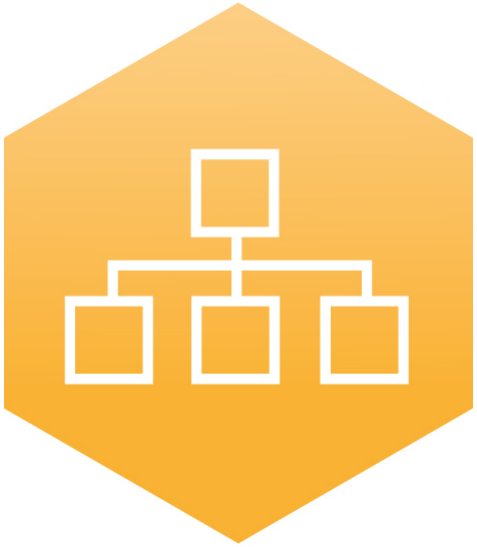
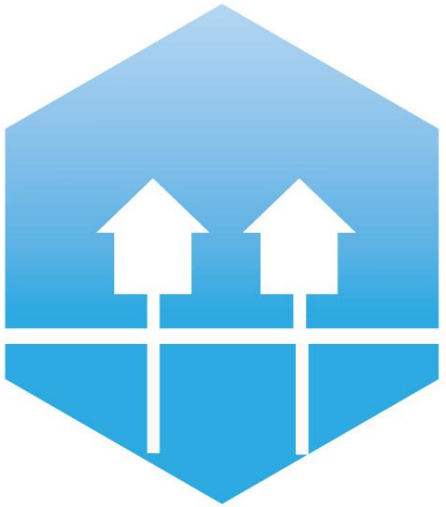
International Conference on Smart Energy Systems and 4th Generation District Heating
Copenhagen, 25-26 August 2015

Towards an Optimal Topology for Hybrid Energy Networks

Wiet Mazairac, Ph.D. Candidate





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Technologies and Systems

Ph.D. Research Project

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- Ph.D. Research Project
  - Optimization of energy distribution networks
  - Integrated optimization of multiple energy vectors
  - Optimization subject to uncertainty in future energy markets

- Aim
  - Development of an *Energy Network Optimization Model*
  - Integrated topology optimization of multi-carrier energy distribution networks

Current Energy System

Global warming

Demand growth

Reserve depletion

Political issues

Renewable Energy System

Global warming

Demand growth

Reserve depletion

Political issues

Clean

Inexhaustible

Local

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Renewable Energy System

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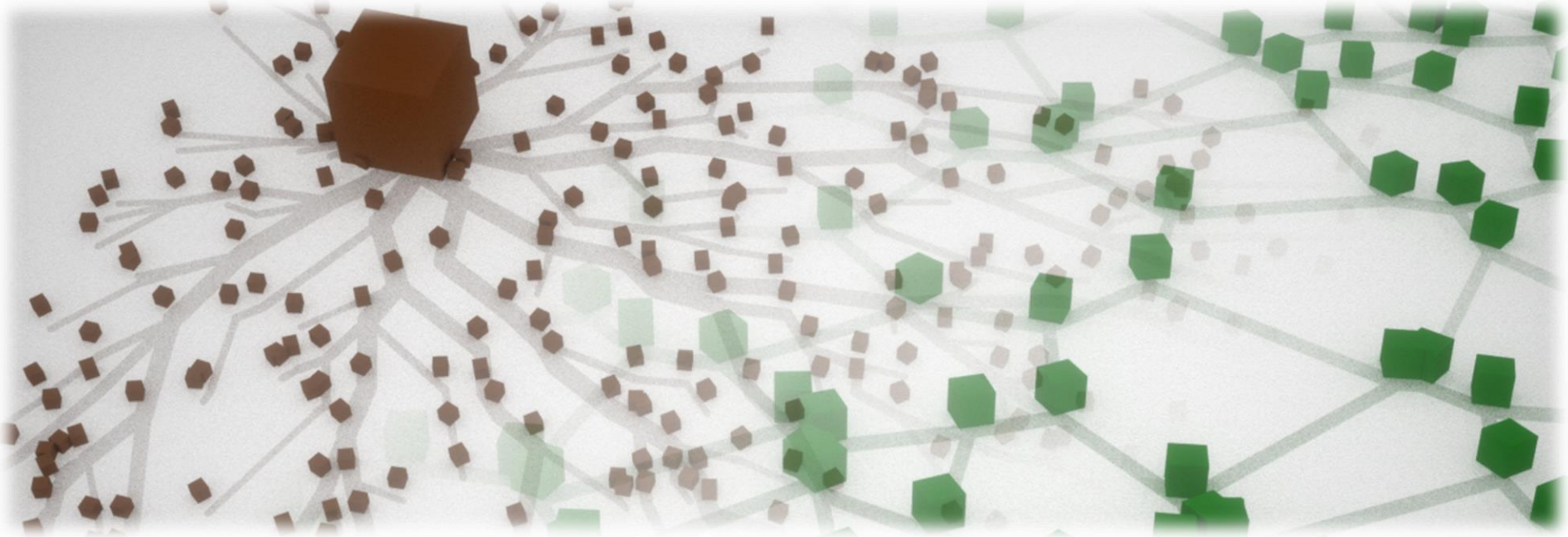
Distributed production

Network reformation

Central production

Distributed production

Exchange of energy between prosumers



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Renewable Energy System

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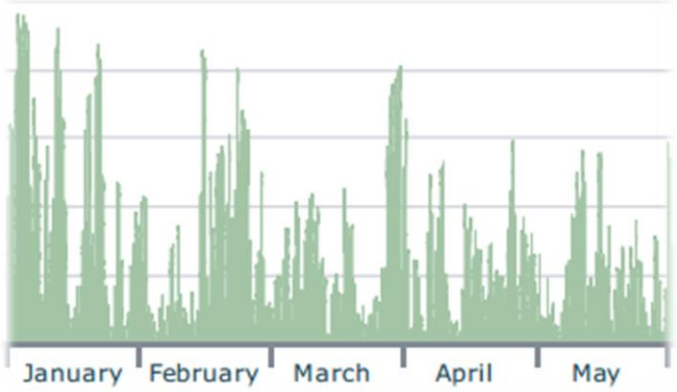
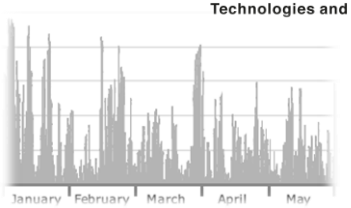
Distributed production

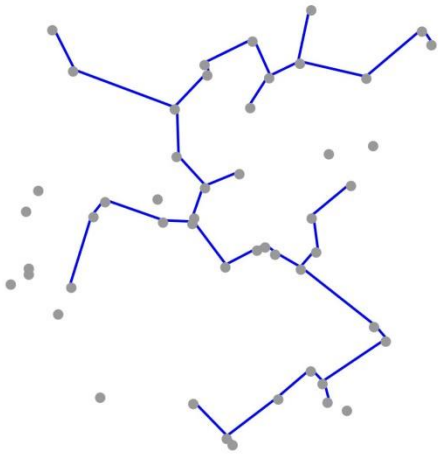
Intermittent production



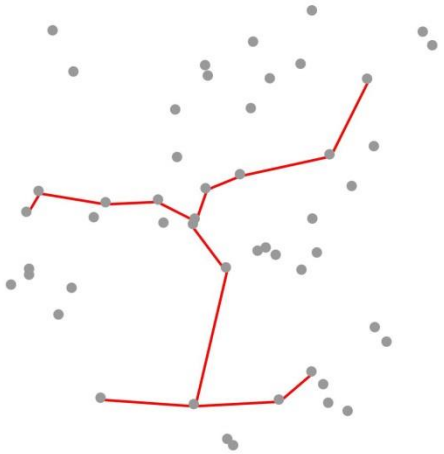
Network Reformation

- From non-integrated to integrated optimization





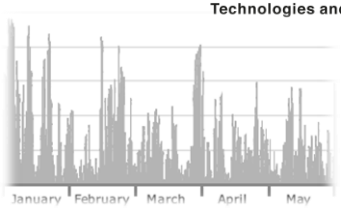
Electric Power Network

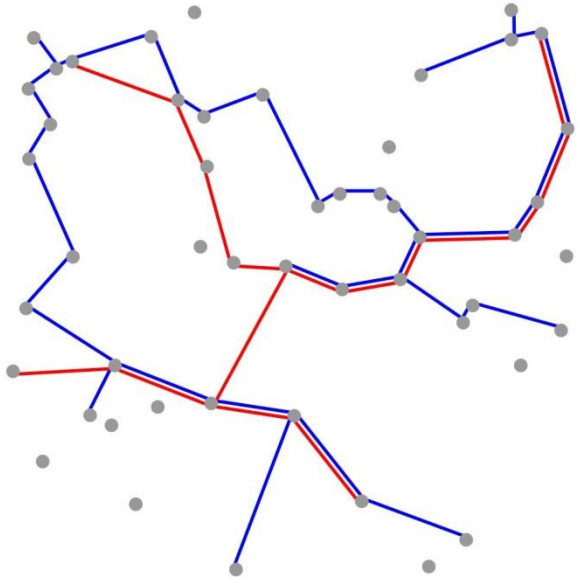


District Heating Network

Network Reformation

- From non-integrated to integrated optimization





Multi-carrier network

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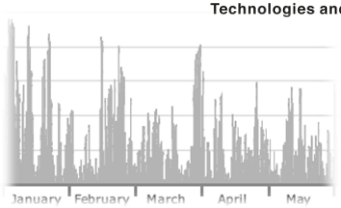
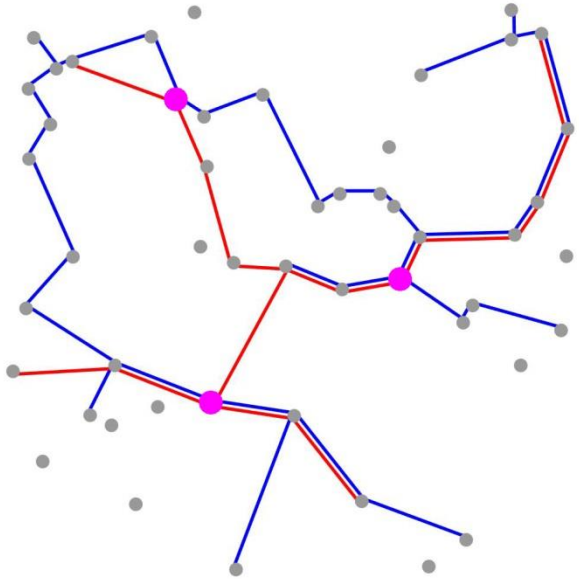
Network Reformation

- From non-integrated to integrated optimization
- Conversion





● Conversion unit

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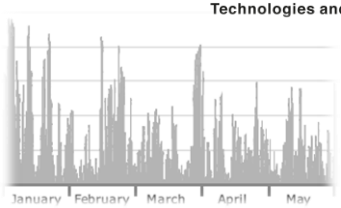
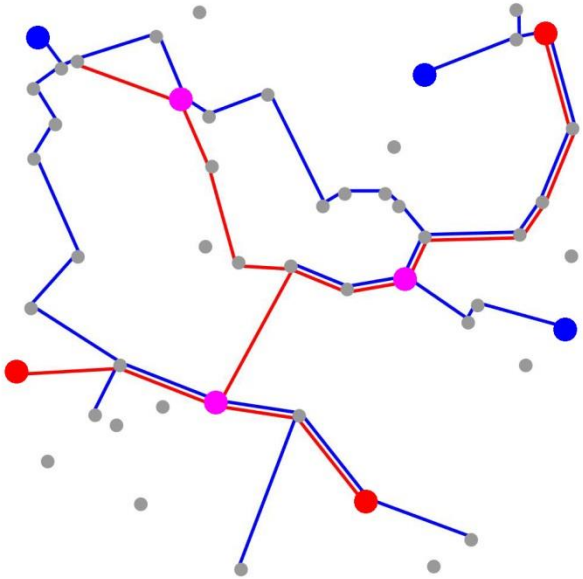
Network Reformation

- From non-integrated to integrated optimization
- Conversion
- Storage





- Conversion unit
- Electric storage unit
- Heat storage unit

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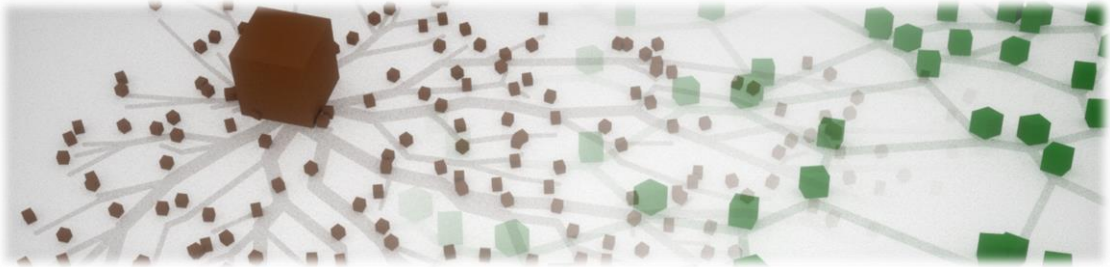
Network Reformation

Energy challenges

Fundamental change in energy supply

Network reformation



Energy Network Optimization Model

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- Select the optimal **location and capacity** of …
  - Energy distribution lines
  - Energy converion units
  - Energy storage units

- … **subject to** …
  - City structure
  - Network investment, operational and maintenance costs
  - Energy revenues
  - Energy demand
  - Energy availability

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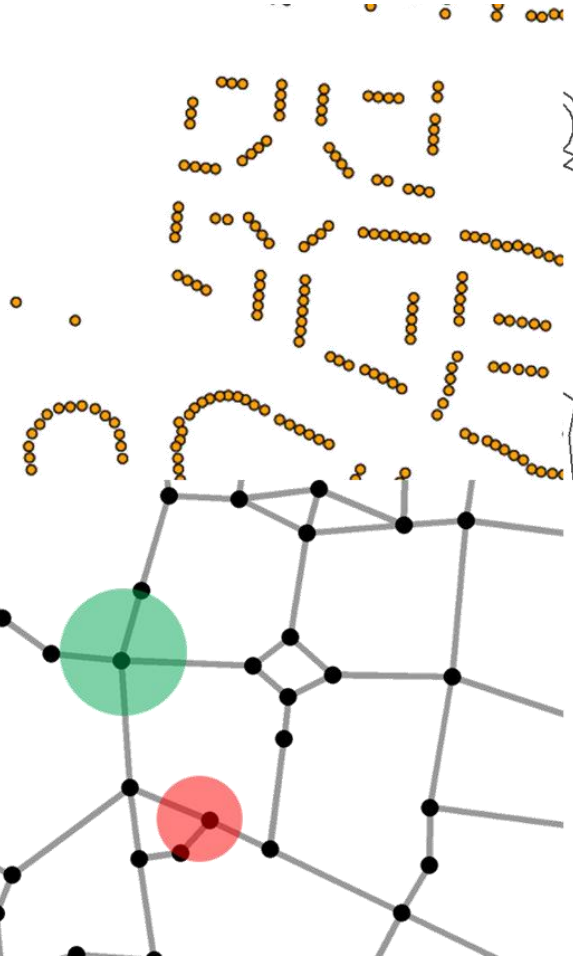
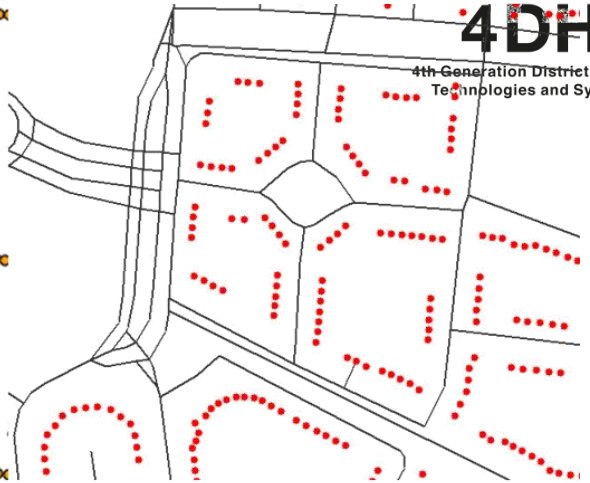
City Structure





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Energy Network Optimization Model

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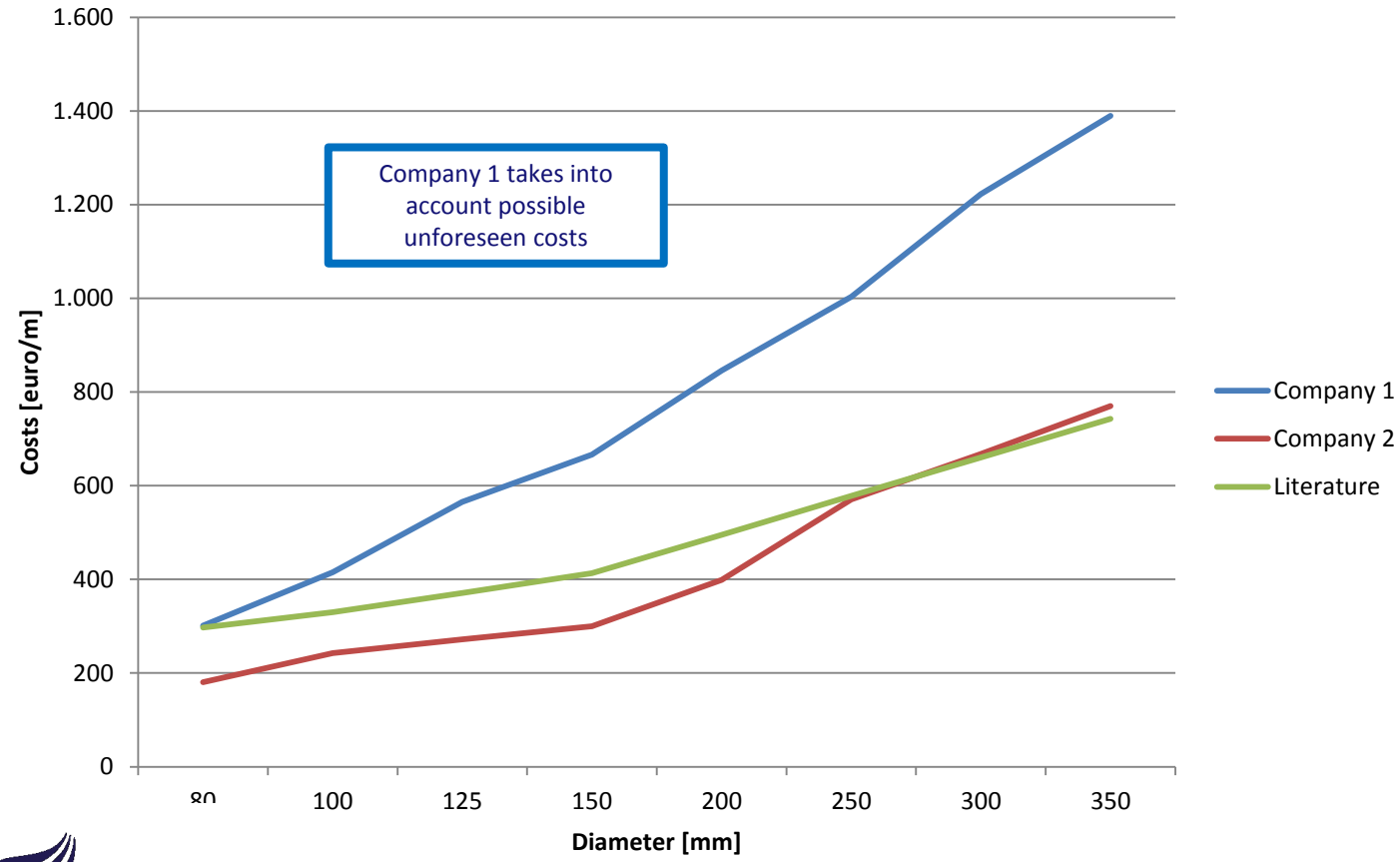
Network investment, operational and maintenance costs



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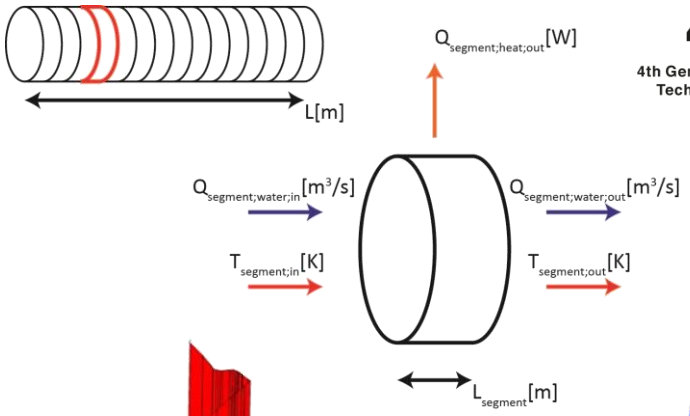
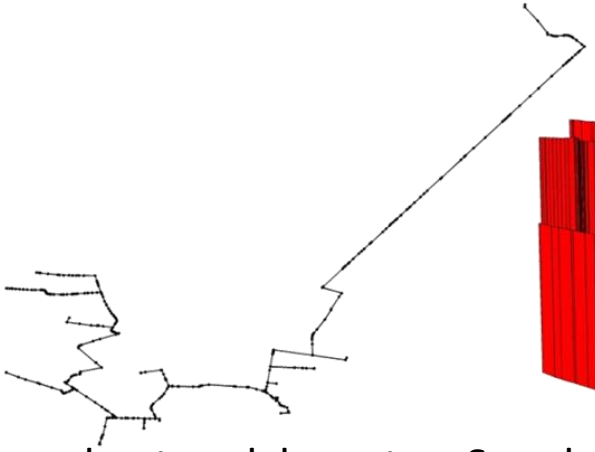
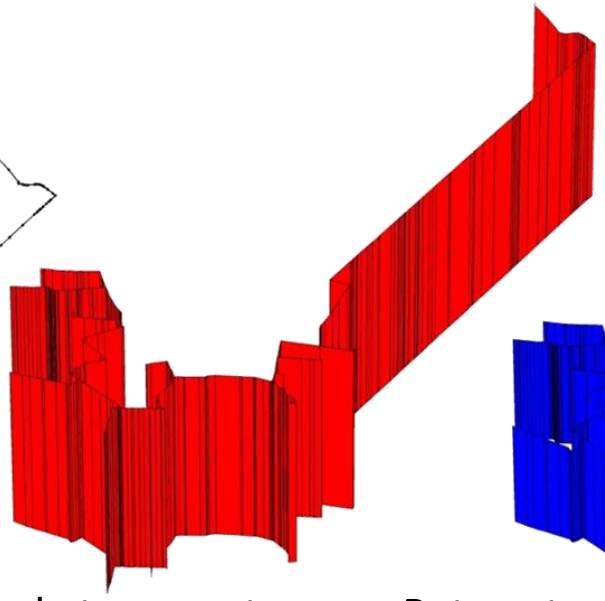
Network investment, operational and maintenance costs

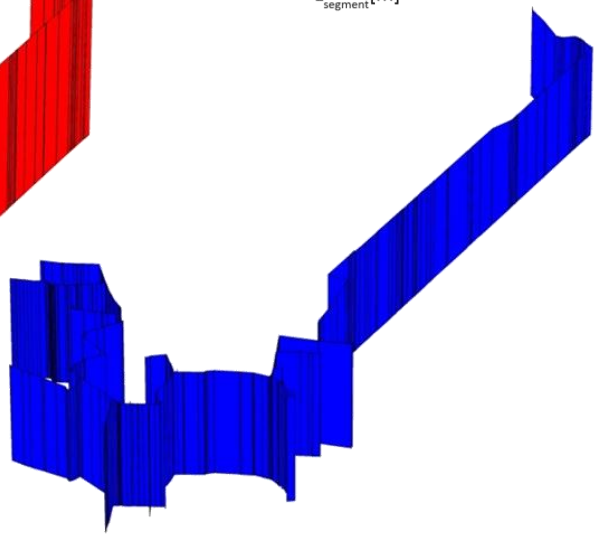




Thermal network layout



Supply temperature



Return temperature

Energy Network Optimization Model

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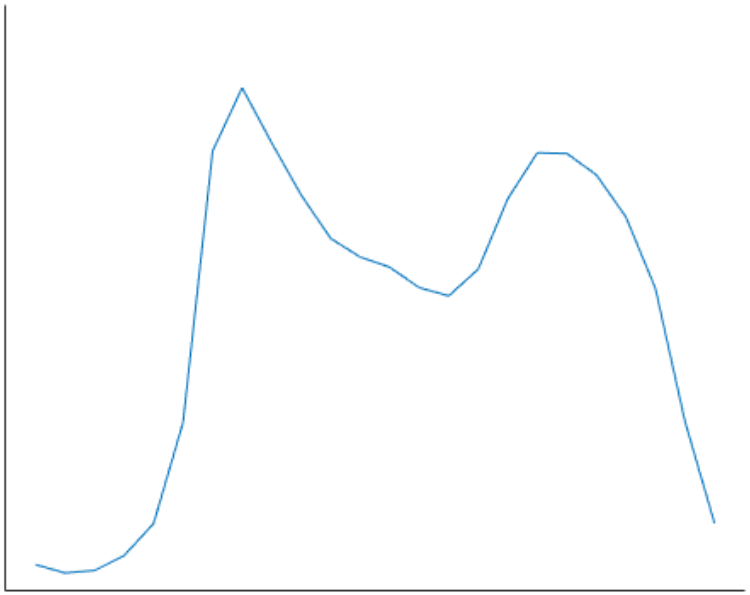
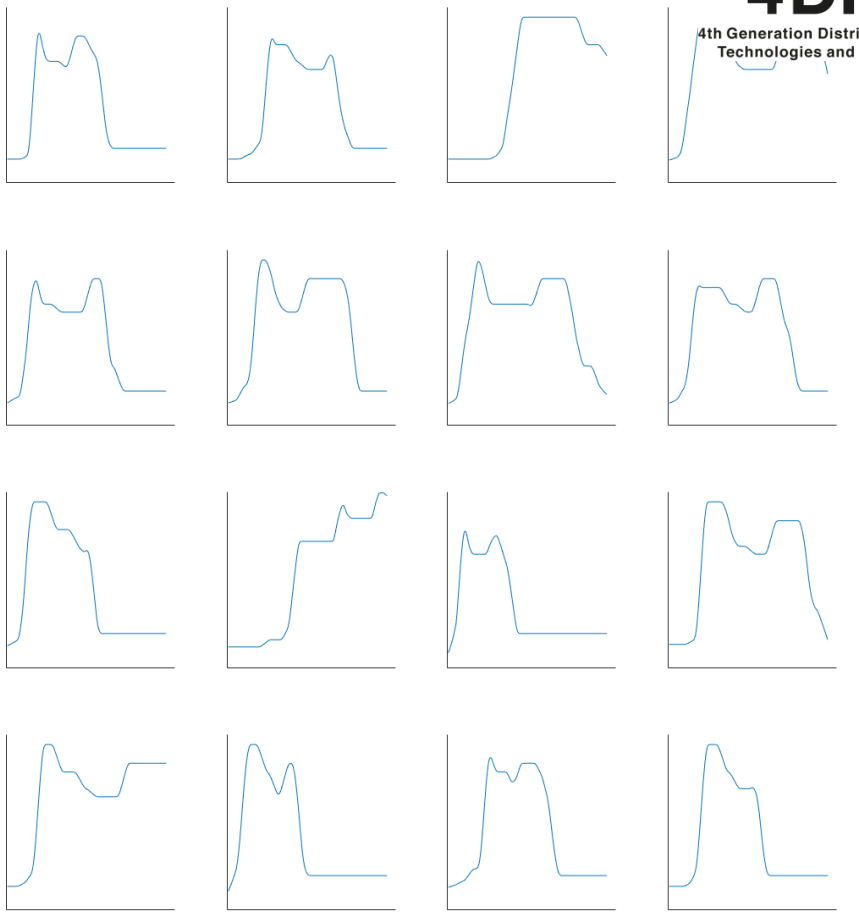
- Select the optimal **location and capacity** of …
  - Energy distribution lines
  - Energy converion units
  - Energy storage units

- … **subject to** …
  - City structure
  - Network investment, operational and maintenance costs
  - Energy revenues
  - **Energy demand**
  - Energy availability

Energy Demand





Hidden Markov Model generates many load profiles based on few load profiles

Energy Network Optimization Model

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- Select the optimal **location and capacity** of …
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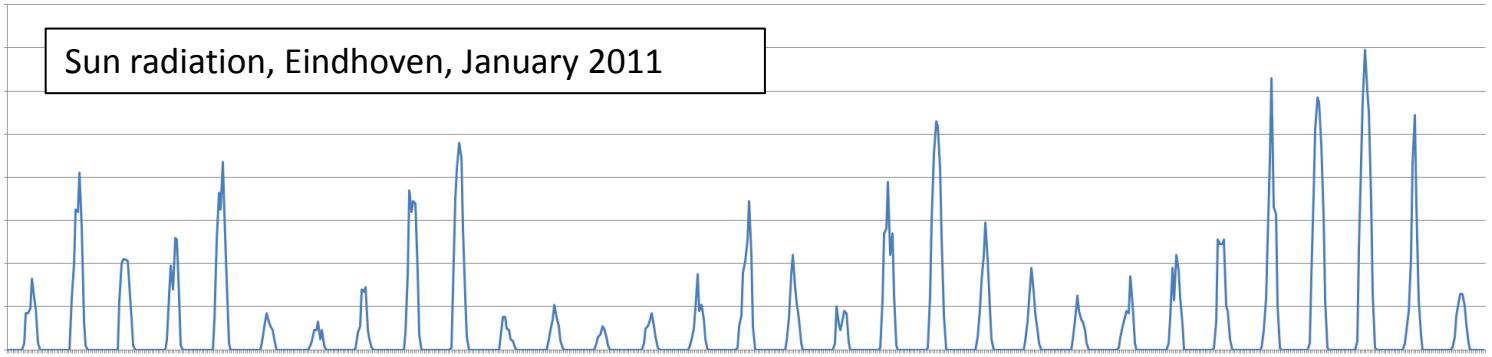
- … **subject to** …
  - City structure
  - Network investment, operational and maintenance costs
  - Energy revenues
  - Energy demand
  - **Energy availability**

Energy Availability

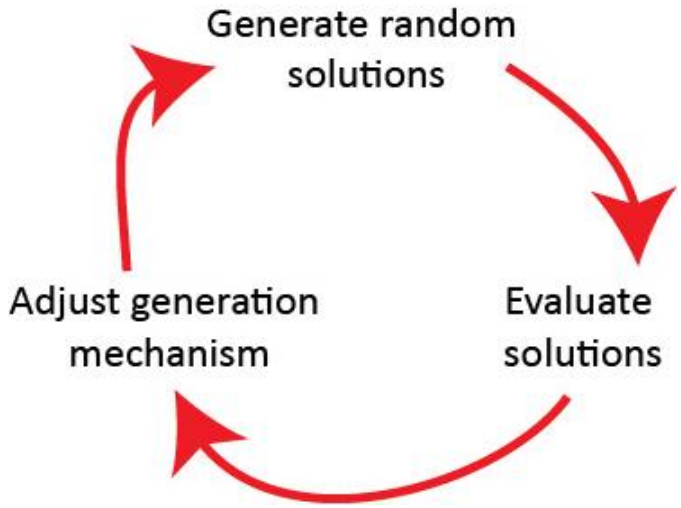
- Renewable power sources
  - Sun radiation profiles
  - Wind power profiles

- Classic power plants
  - Maximum capacity
  - Ramp-up time

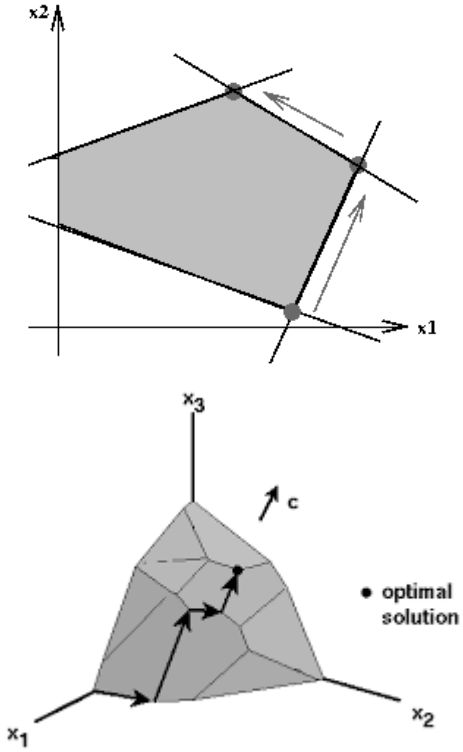


Optimization algorithms

- Cross-Entropy Method



- Mixed-integer linear program

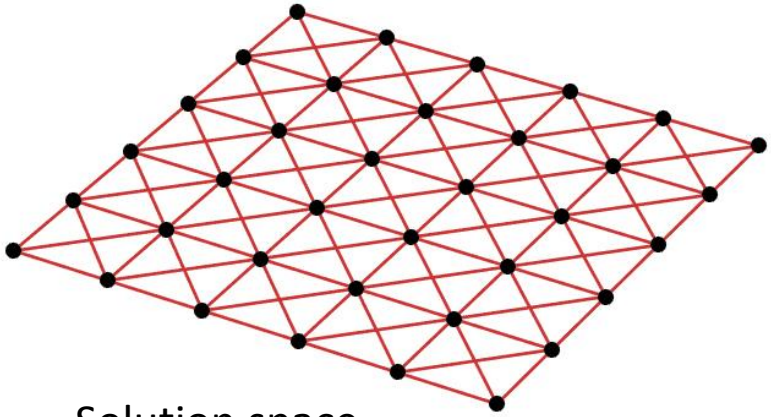


Results

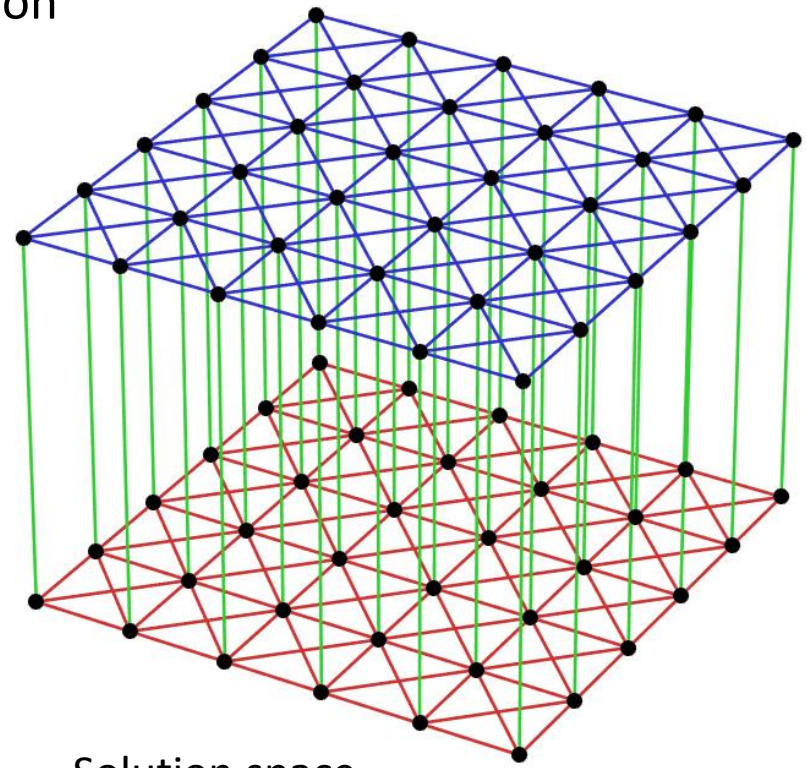
- Small scale experiment 1: conversion

------ Possible location for electric line
------ Possible location for heat pipe

------ Possible location for conversion unit



Solution space
single-carrier network



Solution space
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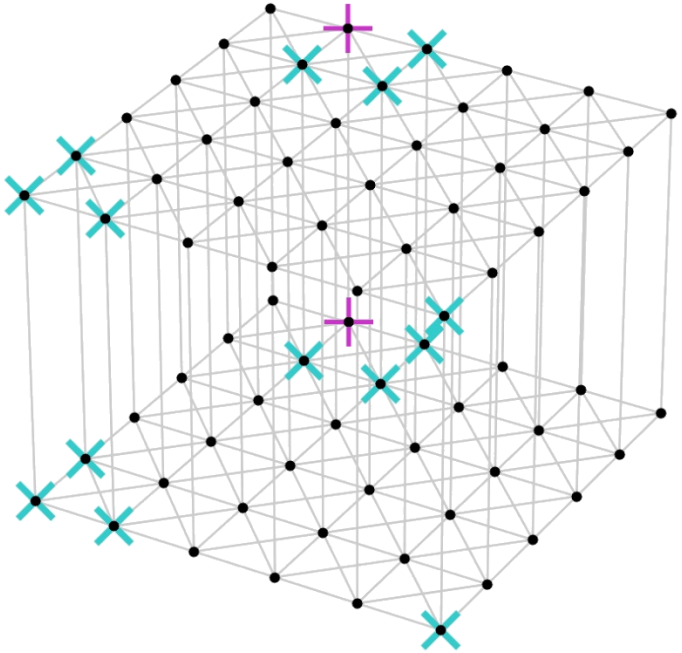
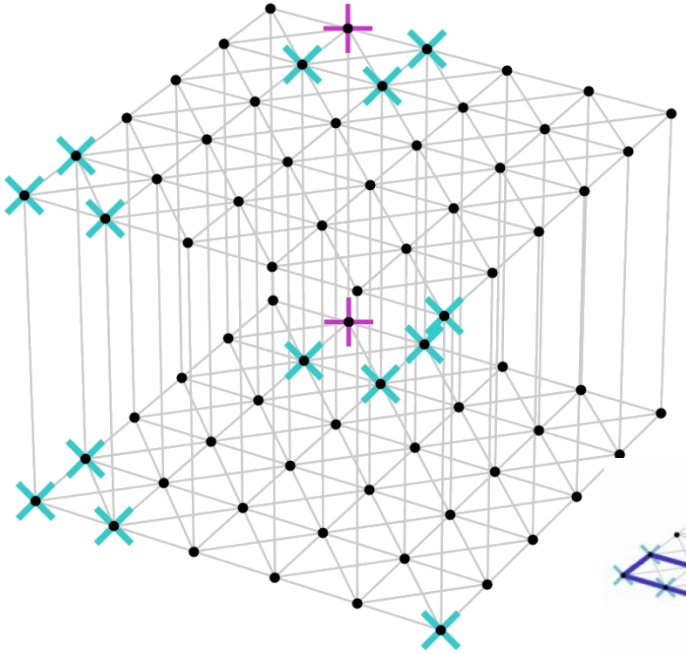
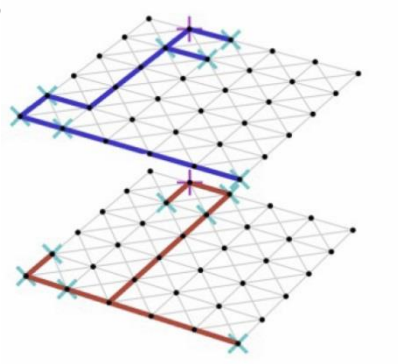


+ Producer (CHP)
x Consumer (Electricity and heat)

Results

- Small scale experiment 1: conversion





+ Producer (CHP)
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------ Electricity network
------ Heating network

------ Converion unit (Electricity to heat)

Results

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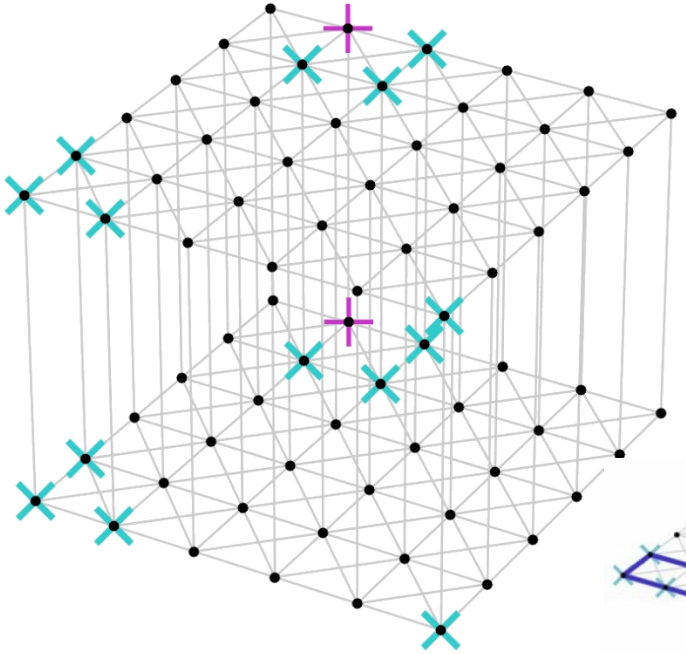

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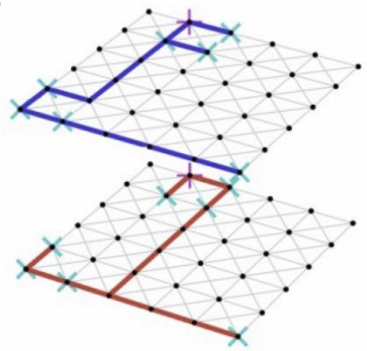

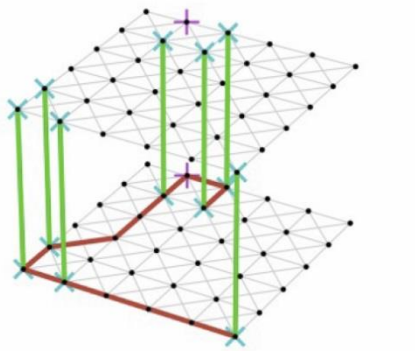

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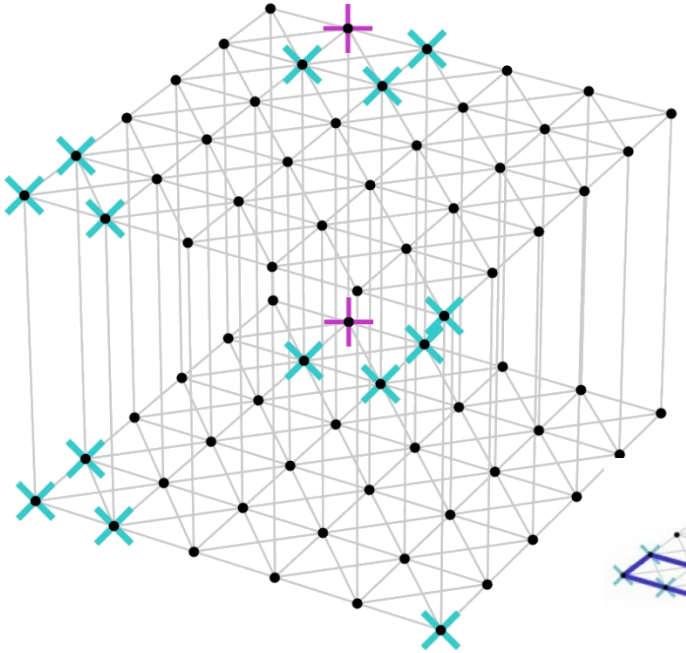

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------ Electricity network
------ Heating network

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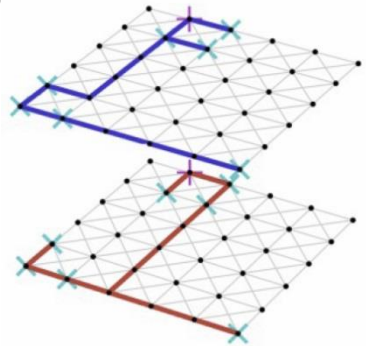

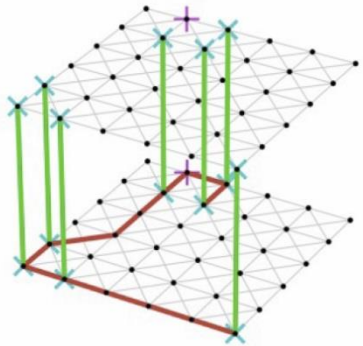

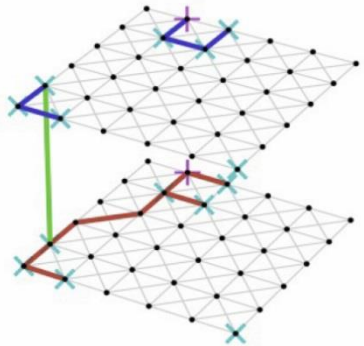

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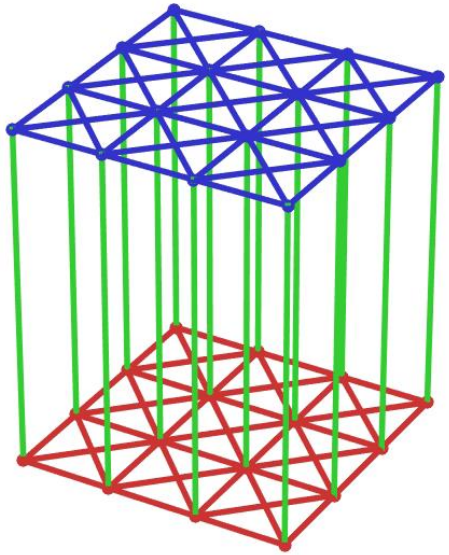
Results

- Small scale experiment 2: conversion and storage

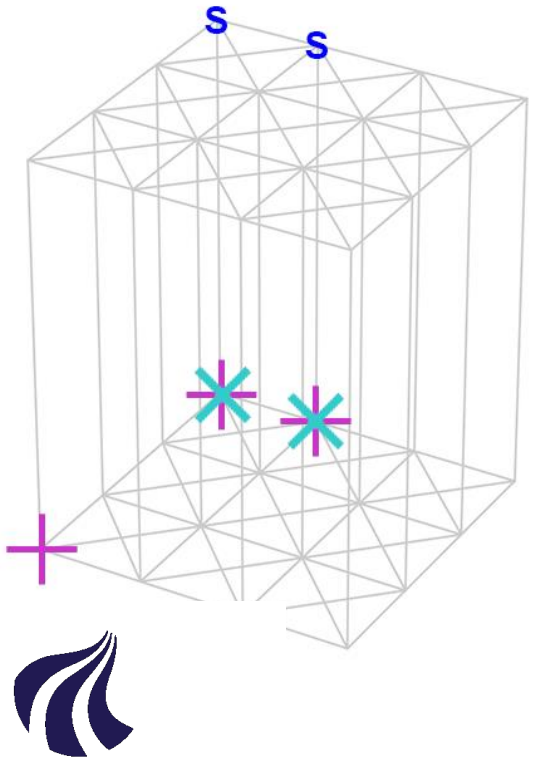


------ Possible location for electric line
------ Possible location for heat pipe

------ Possible location for conversion unit

Results

- Small scale experiment 2: conversion and storage

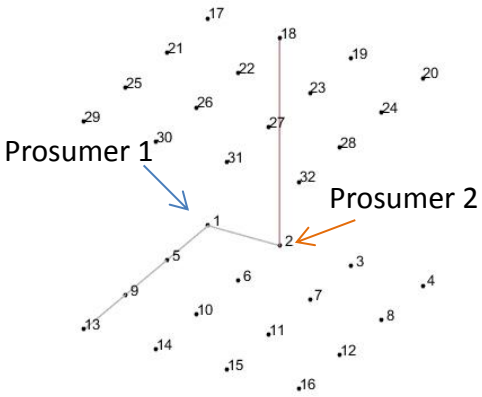


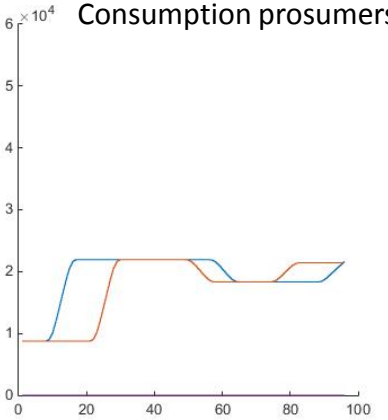
+ Producer
x Consumer

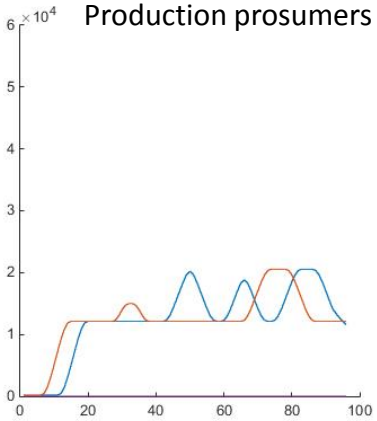
S Storage unit

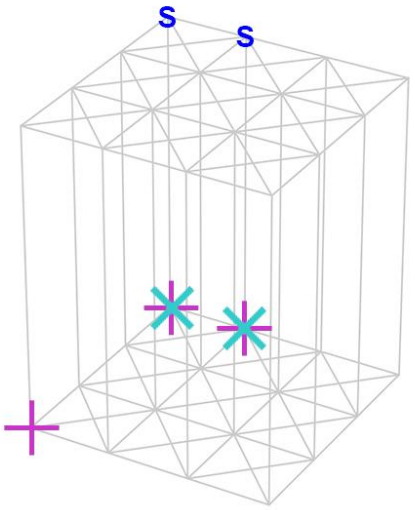
Results

- Small scale experiment 2: conversion and storage







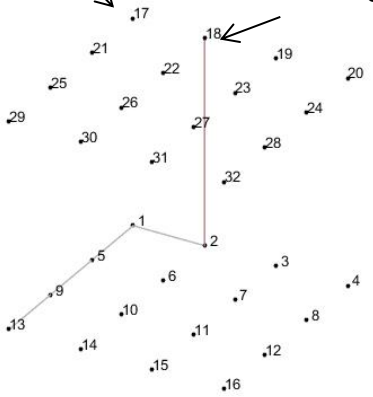


Results

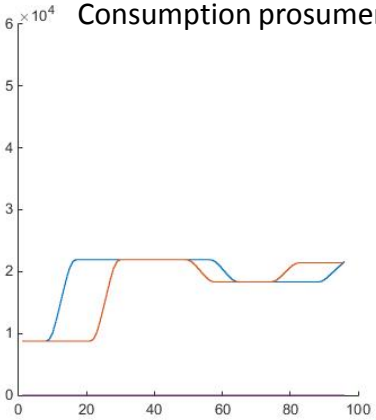
- Small scale experiment 2: conversion and storage

Storage 1

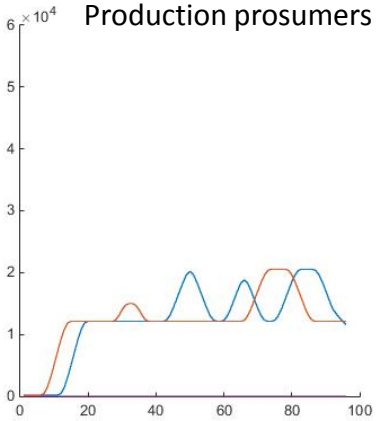
Storage 2



Consumption prosumers



Production prosumers



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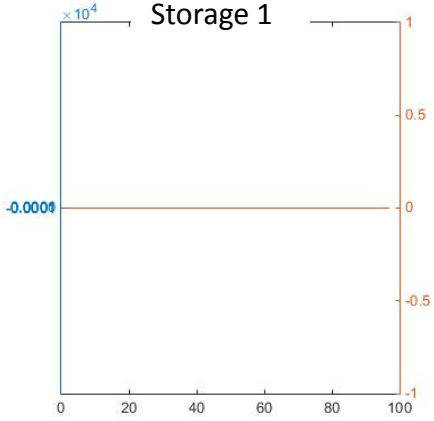
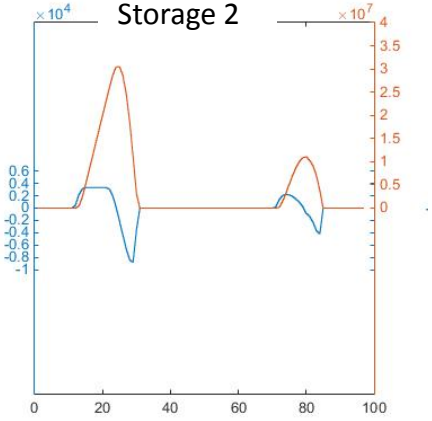
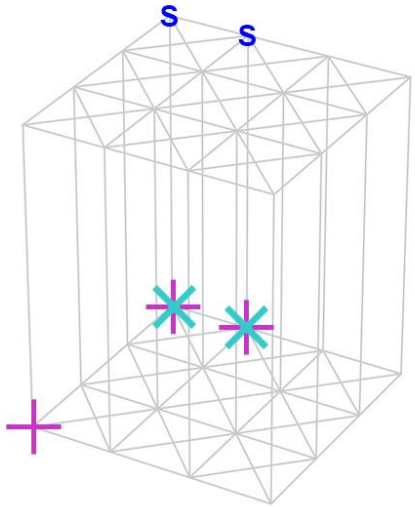


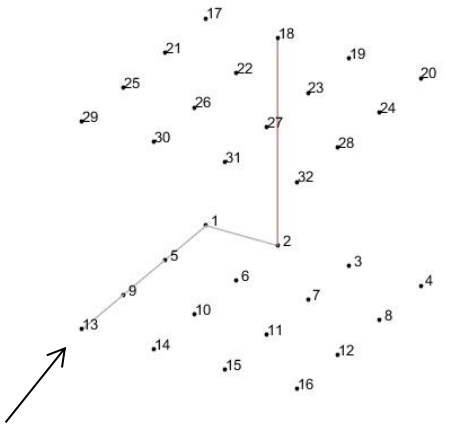
Storage 2



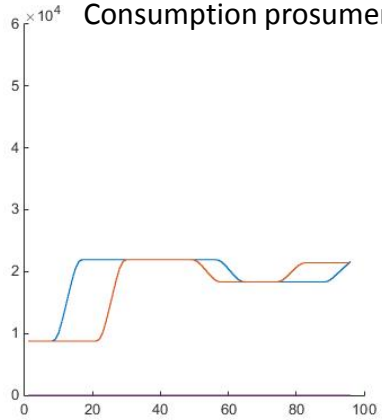


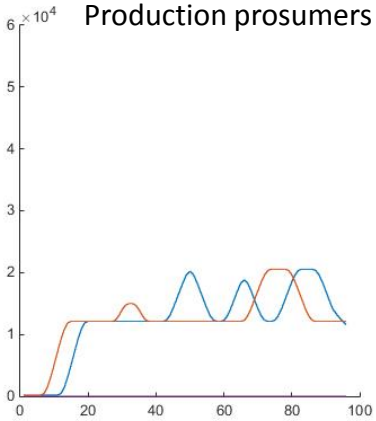
Results

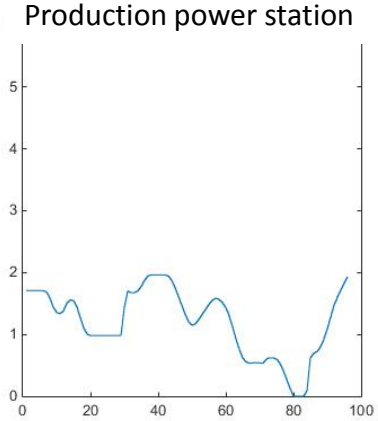
- Small scale experiment 2: conversion and storage

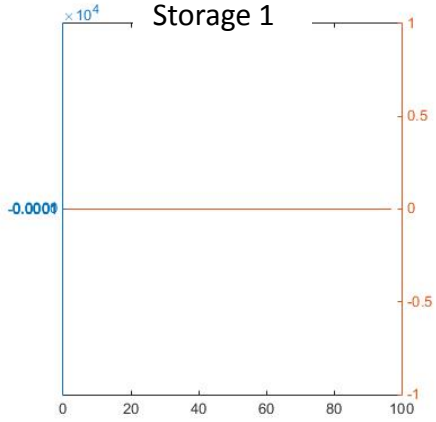


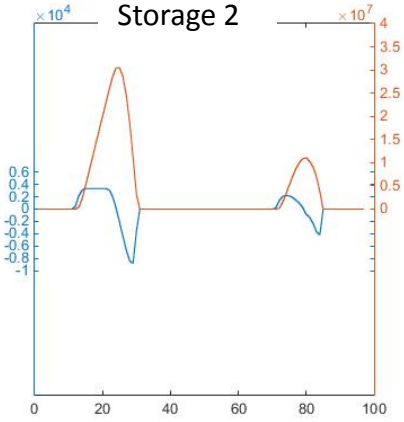
Power station

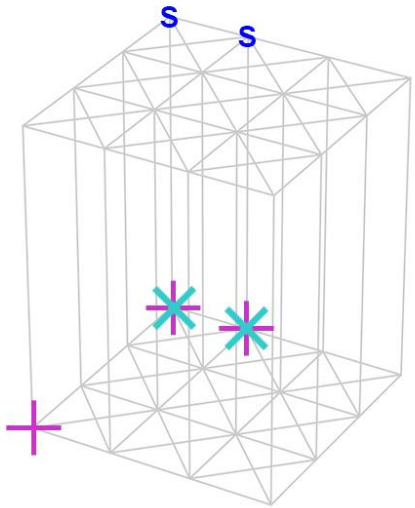






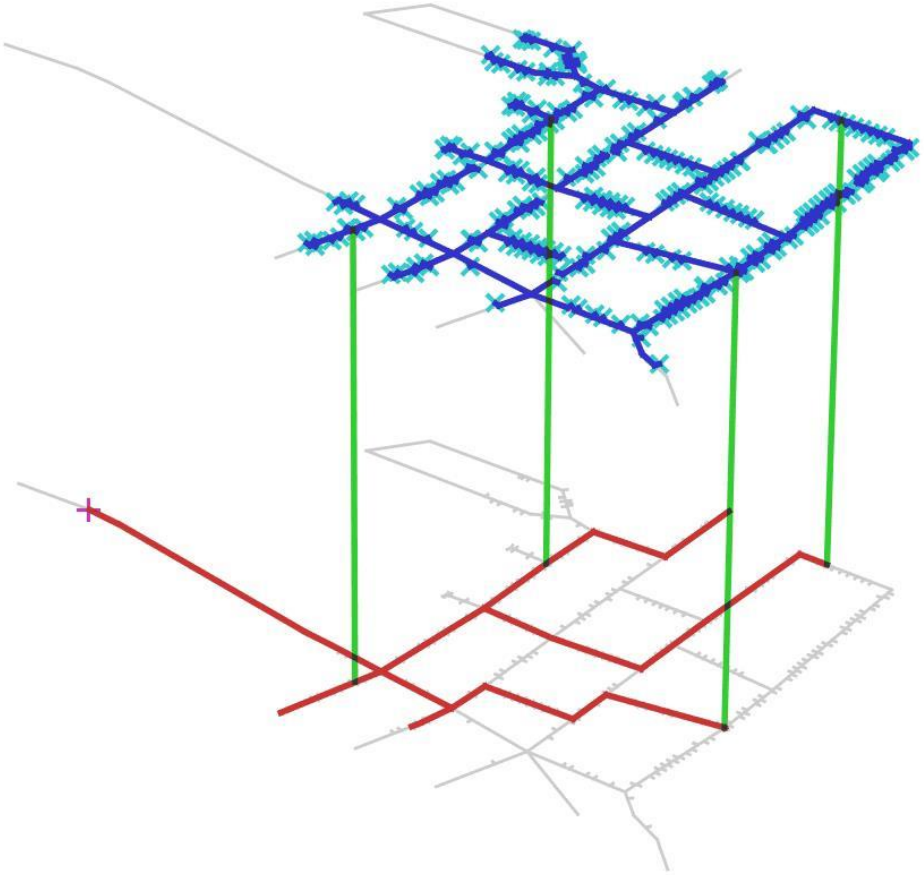






Results

- Large scale experiment 2: District heating network



------ Primary network
(high pressure, high temperature)
------ Secondary network
(low pressure, low temperature)

------ Substations

Conclusions

- The CE-method returns plausible results when the problem is small.
- A detailed model in combination with the CE-method returns a high quality solution.
- The CE-method is computationally very expensive. The combination of multiple carriers, storage units, conversion units, dense city structures and time dependency will increase CPU time dramatically.

- The MILP-method returns plausible results for small and large problems.
- The MILP-method requires linearization.
- The MILP-method is computationally less expensive.
- The MILP-method is most suitable for multi-carrier problems.