Optimization of the Transition towards a Sustainable Integrated Multi-Carrier Energy Network

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Ph.D. Research Project

- Optimization of energy networks
- Integrated optimization of multi-carrier energy networks
- Subject to technical and economic uncertainty
Renewable Energy System

Distributed production
Renewable Energy System

Distributed production
Fossil Energy System
Renewable Energy System

Intermittent production
Fossil Energy System
Energy System Reformation

From a centralized energy system...

...towards a decentralized system
Decentralized Multi-Energy System

...towards a decentralized multi-energy system

- Exchange
- Conversion
- Storage
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
Network Reformation

- From non-integrated to integrated optimization
- Conversion

Conversion unit
Network Reformation

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

• Location and capacity of systems and lines?

• Uncertainties: technical failures, energy availability, economic future?

• How to get there?
Location and Capacity

- **Location and capacity of systems and lines?**

- Uncertainties: technical failures, energy availability, economic future?

- How to get there?
Location and Capacity: Example
Location and Capacity: Example

![Graph 1](image1)

![Graph 2](image2)
Location and Capacity: Example

\[ \sum p^\text{out}_l \]
\[ \sum p^\text{out}_c \]
\[ p^\text{out}_{so} \]
\[ p^\text{out}_{soc} \]
\[ p^\text{out}_g \]
\[ p^\text{in}_g \]
\[ p^\text{in}_{st} \]
\[ p^\text{loss} \]

Storage

\[ \frac{\Delta t}{\Delta t} \]

\[ (1 - \frac{\Delta t}{\Delta t}) \] * \[ p^\text{in}_{st} \]

\[ \frac{\Delta t}{\Delta t} \]

\[ (1 - \frac{\Delta t}{\Delta t}) \] * \[ p^\text{out}_{st} \]

Elec demand winter [kW]

Elec production winter [kW]

Time [h] 0 4 8 12 16 20 24
Location and Capacity: Example
Location and Capacity: Example
Location and capacity: Example

Heat costs

Elec. costs

PV

Battery

Heat costs

Elec. costs
Location and Capacity: Example

- **Heat costs**
- **Elec. costs**

**PV**

**Battery**

**Heat pump**

**Elec. costs**
Questions...

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• How to get there?
Questions...

• Location and capacity of systems and lines?

• Uncertainties: technical failures, energy availability, economic future?

• How to get there?
Uncertainty

Stochastic Programming
• Scenarios

Robust Optimization
• Scenarios
Uncertainty

Stochastic Programming
• Scenarios
• Probability
• (The chance it fails once within 10 years is 5%)

Robust Optimization
• Scenarios
• Bounds
• (It will fail)
Uncertainty

Stochastic Programming
• Scenarios
• Probability
• (The chance it fails once within 10 years is 5%)
• Optimize expected value

Robust Optimization
• Scenarios
• Bounds
• (It will fail)
• Optimize worst case

Uncertainty

Stochastic Programming

- Scenarios
- Probability
  - (The chance it fails once within 10 years is 5%)
- Optimize expected value

- Historic data
- Redundancy vs. Damage

Uncertainty
Uncertainty
Questions...

• Location and capacity of systems and lines?

• Uncertainties: technical failures, energy availability, economic future?

• **How to get there?**
How to get there?

**Basic Model**
- Existing infrastructure
- Extension planning

**Extended Model**
- Existing infrastructure
- Extension planning
- Remaining lifetime
- Decommission planning
How to get there?
Conclusions

Future planning and uncertainty

Clear goals and a road to achieve those goals

Stochastic programming

Increased solution space