

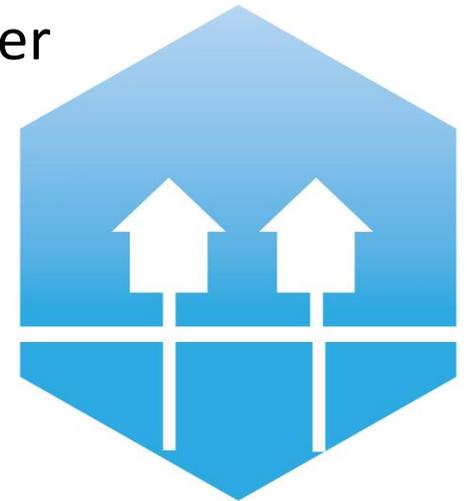
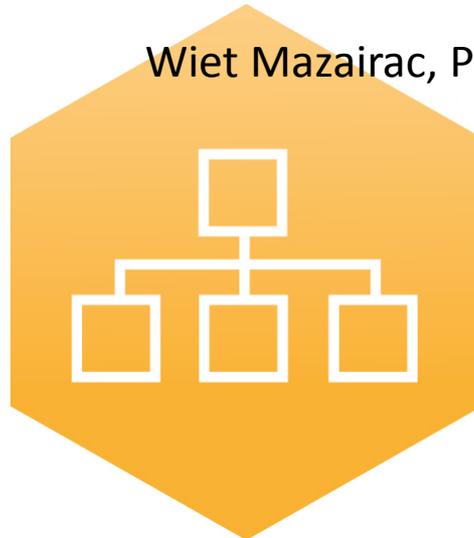
2nd International Conference on Smart Energy Systems and 4th Generation District Heating
Aalborg, 27-28 September 2016



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



Wiet Mazairac, Ph.D. Candidate



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Technologies and Systems

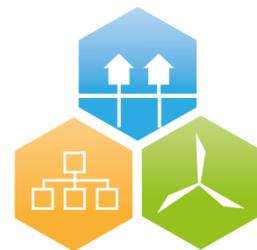
Ph.D. Research Project



- Ph.D. Research Project
 - Optimization of energy networks
 - Integrated optimization of multi-carrier energy networks
 - Subject to technical and economic uncertainty



Fossil vs. Renewable



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Global warming



Clean



Demand growth



Inexhaustible



Reserve depletion



Central



Local



Renewable Energy System



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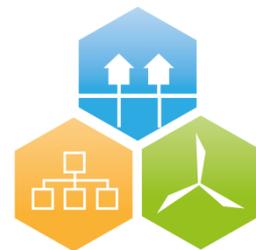


Distributed production

Renewable Energy System

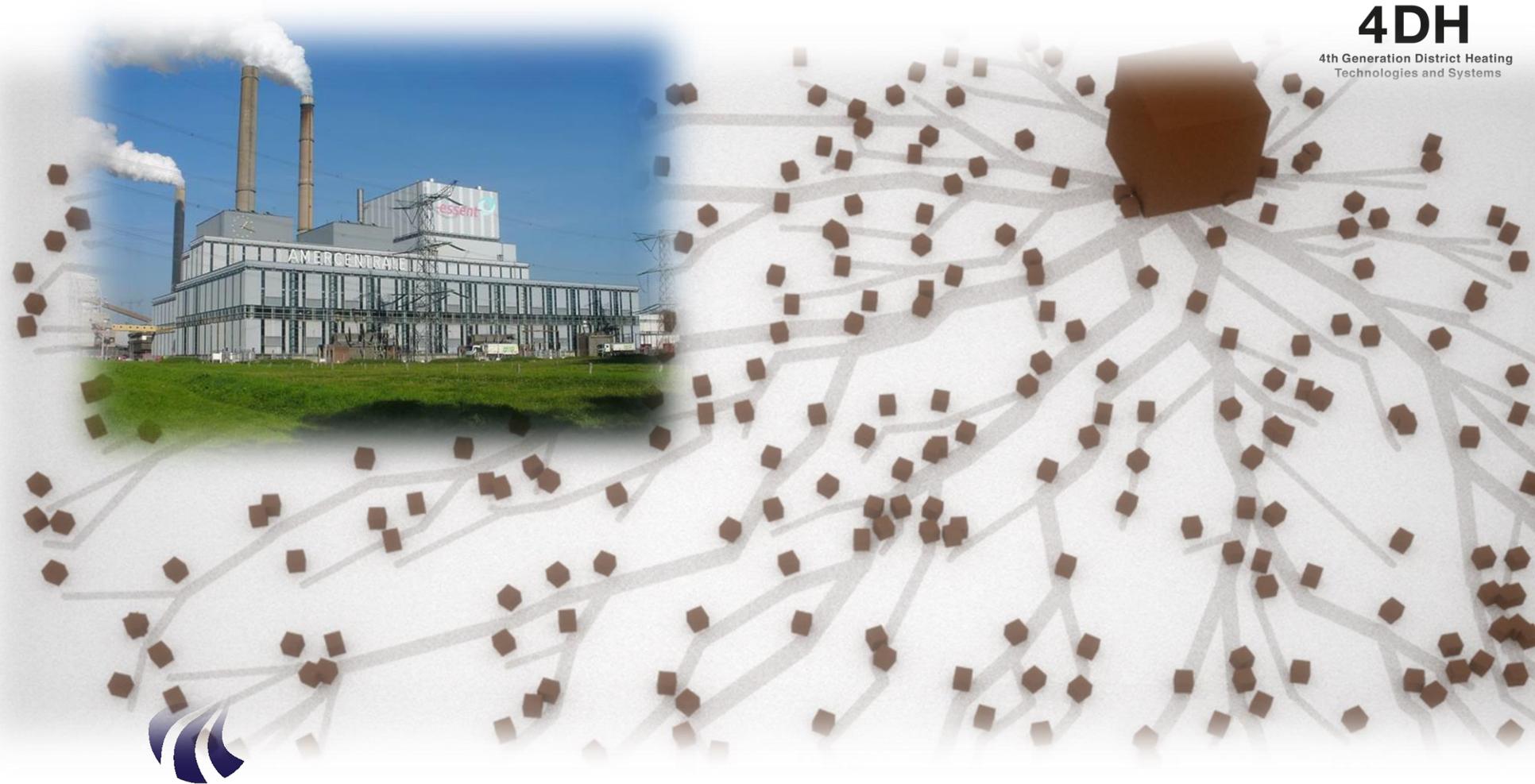


Fossil Energy System



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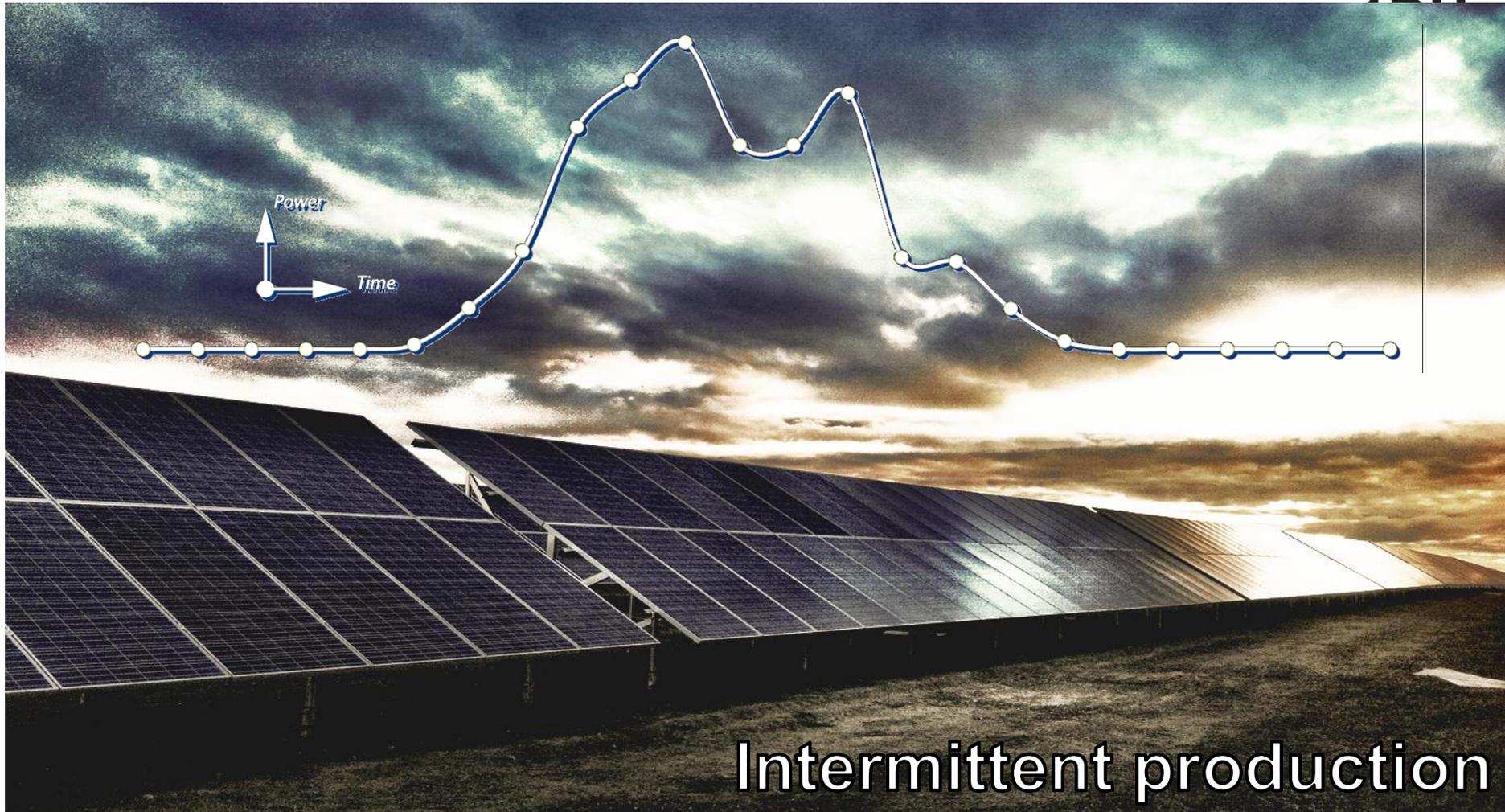
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Renewable Energy System



Intermittent production

Fossil Energy System



Central and controllable production

Energy System Reformation



From a centralized energy system...

...towards a decentralized system

Decentralized Multi-Energy System

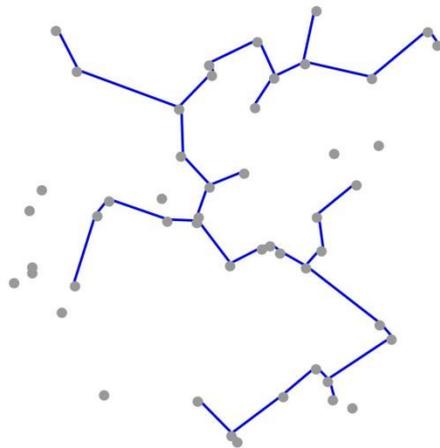


...towards a decentralized
multi-energy system

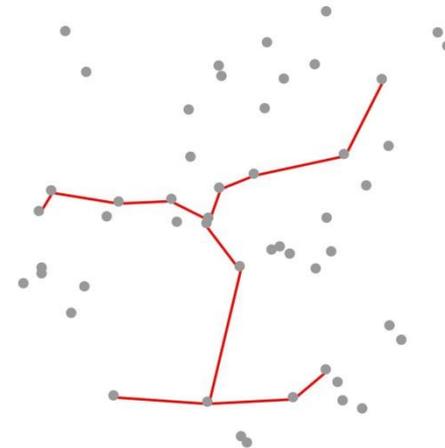
- Exchange
- Conversion
- Storage

Network Reformation

- From non-integrated to integrated optimization



Electric Power Network

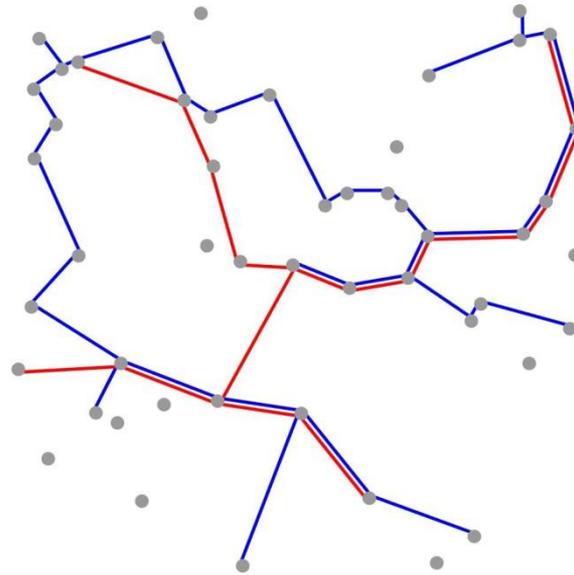


District Heating Network



Network Reformation

- From non-integrated to integrated optimization

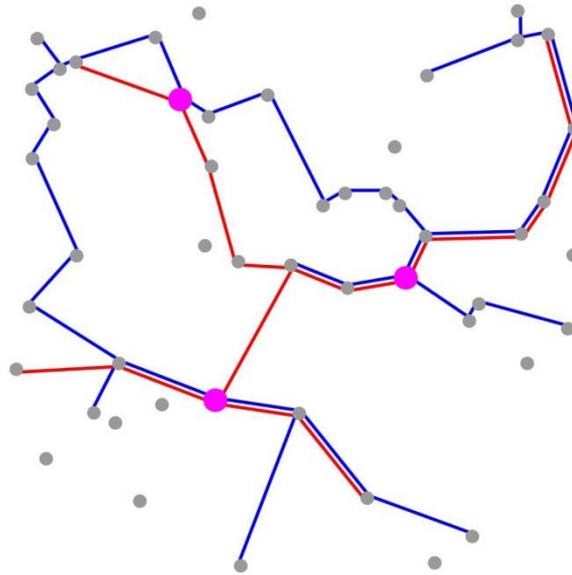


Multi-carrier network



Network Reformation

- From non-integrated to integrated optimization
- Conversion

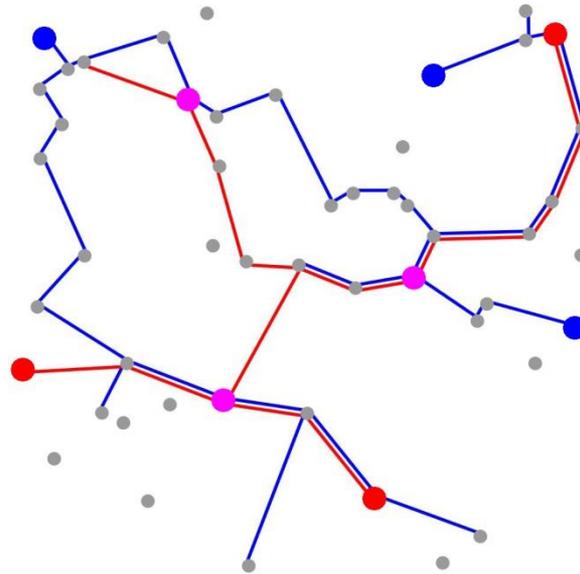


● Conversion unit



Network Reformation

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



- Conversion unit
- Electric storage unit
- Heat storage unit



Questions...



- Location and capacity of systems and lines?
- Uncertainties: technical failures, energy availability, economic future?
- How to get there?



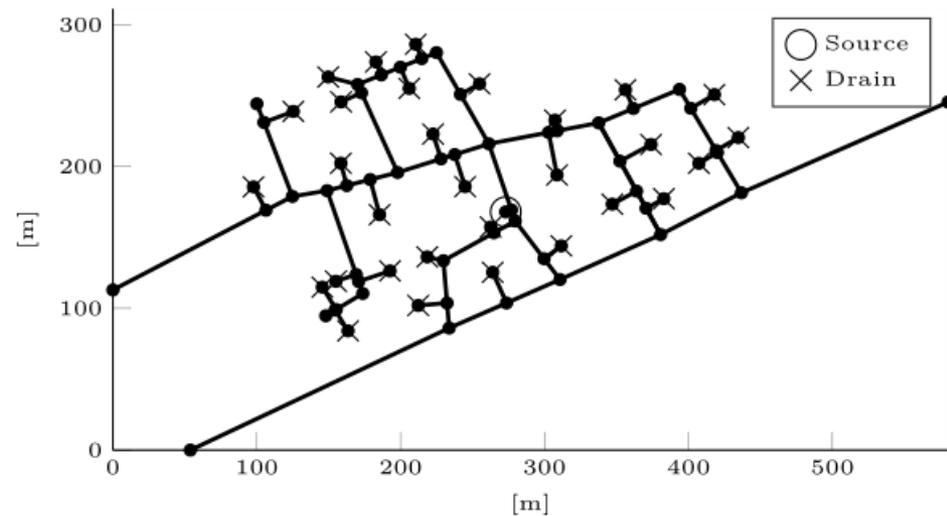
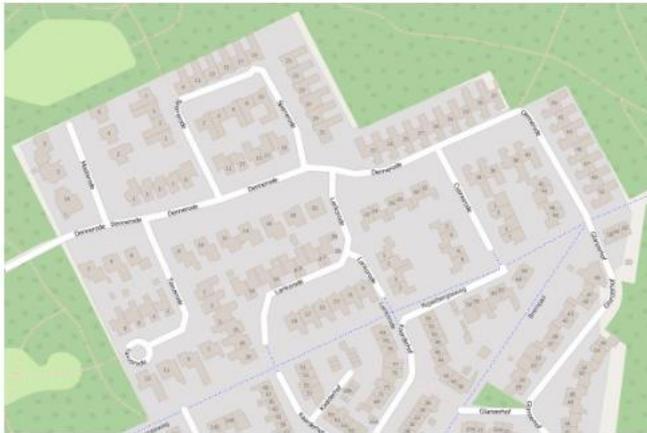
Location and Capacity



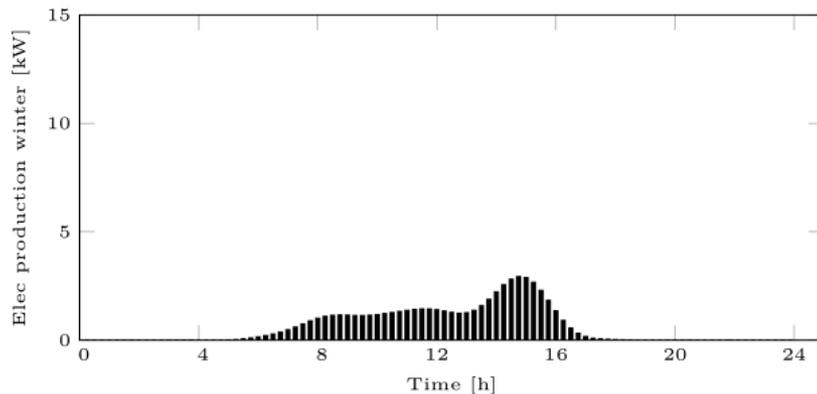
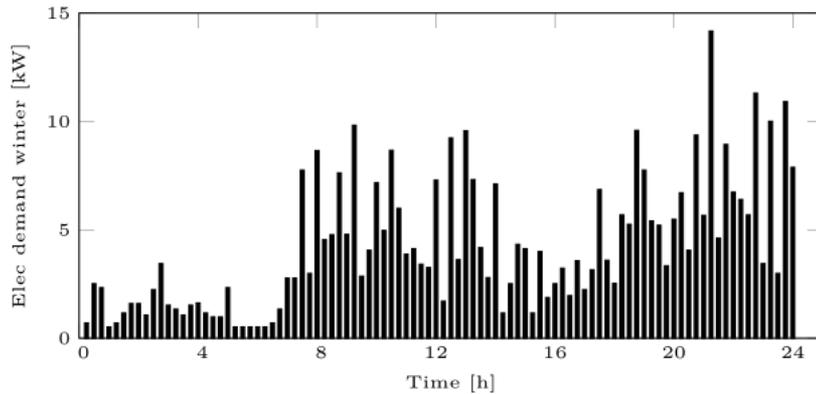
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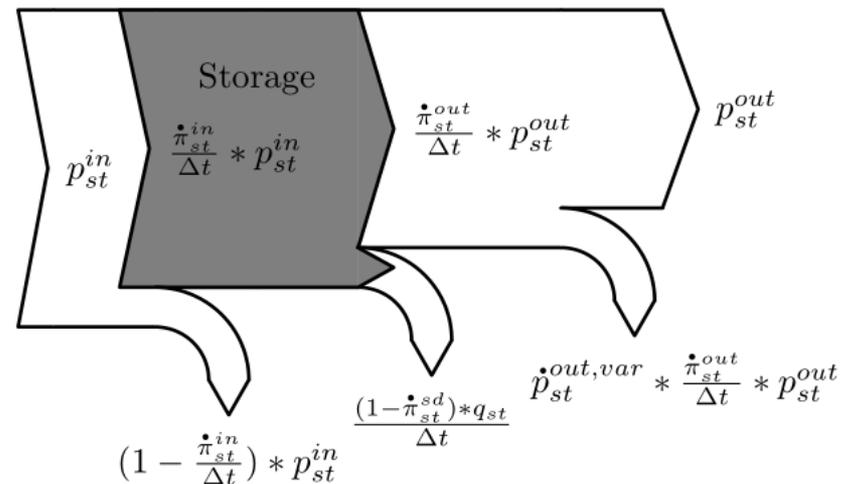
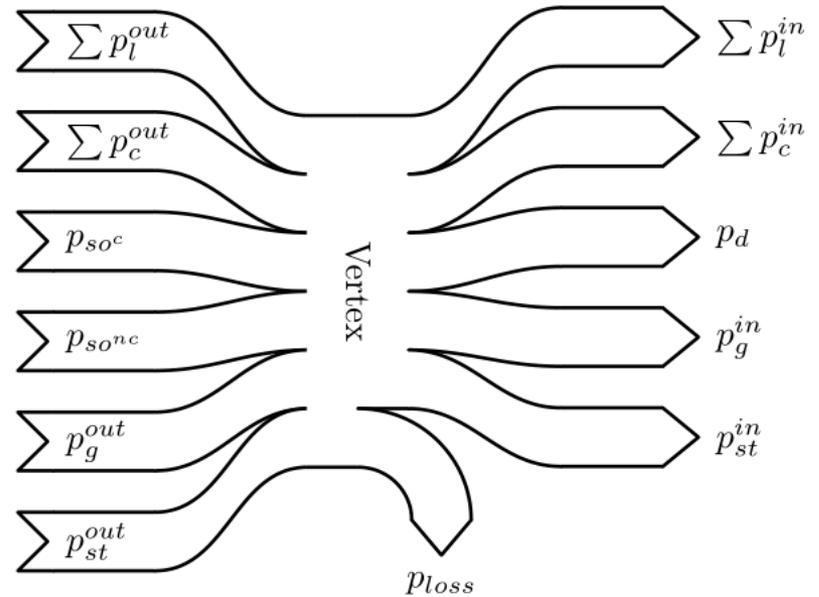
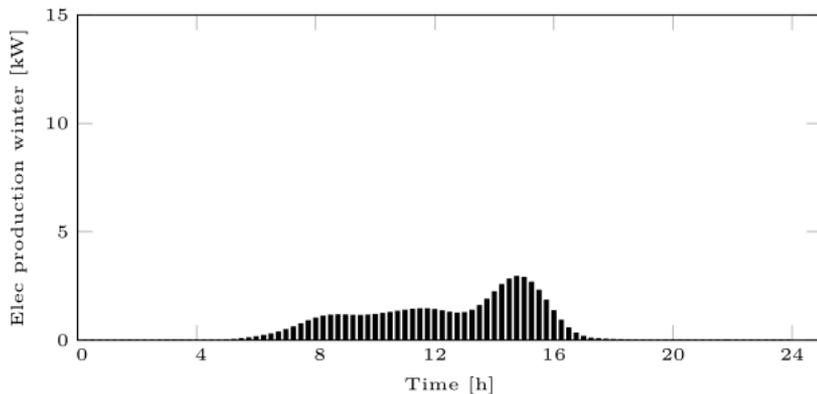
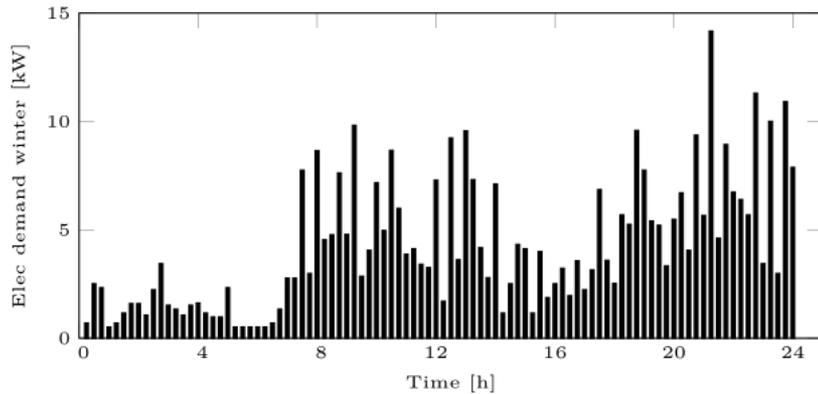
Location and Capacity: Example



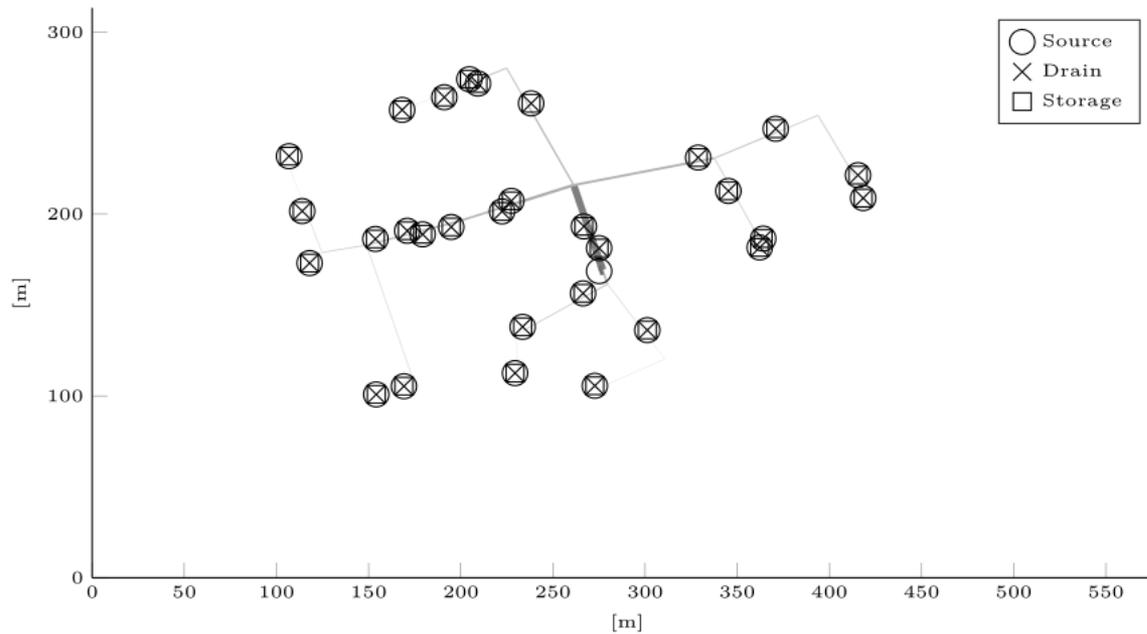
Location and Capacity: Example



Location and Capacity: Example

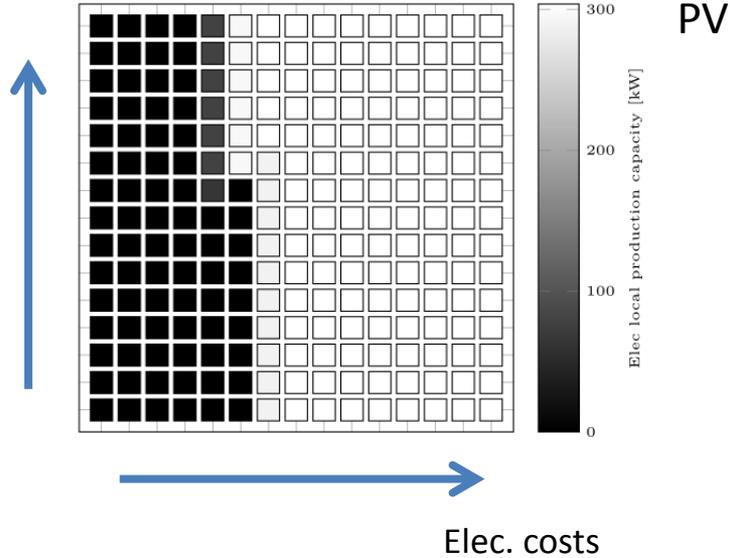


Location and Capacity: Example



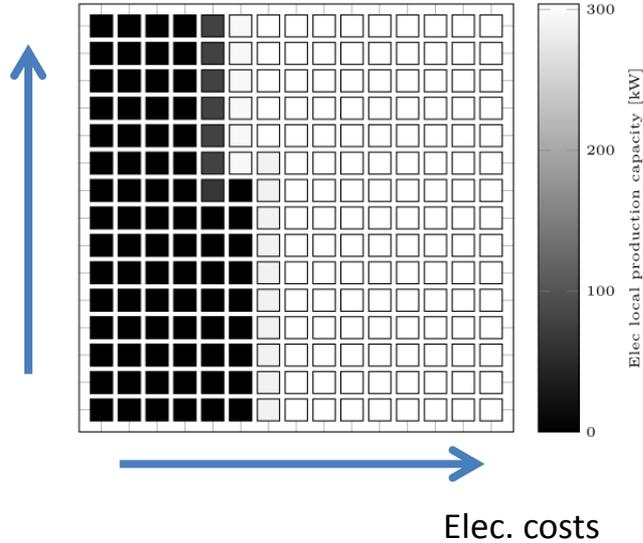
Location and Capacity: Example

Heat costs



Location and capacity: Example

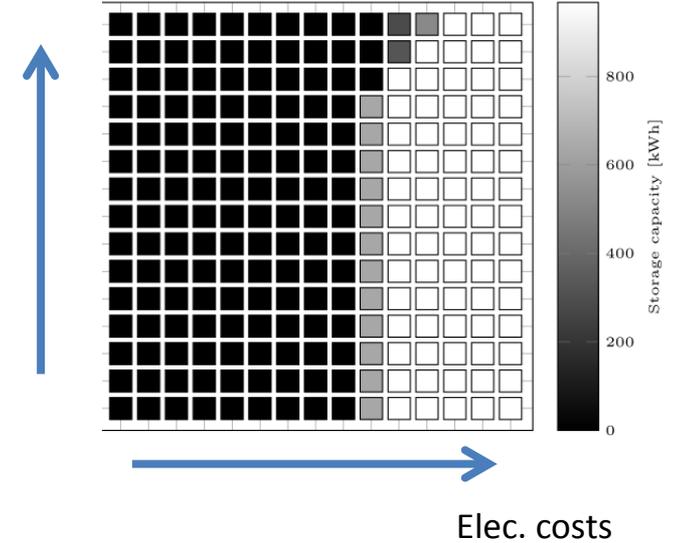
Heat costs



PV

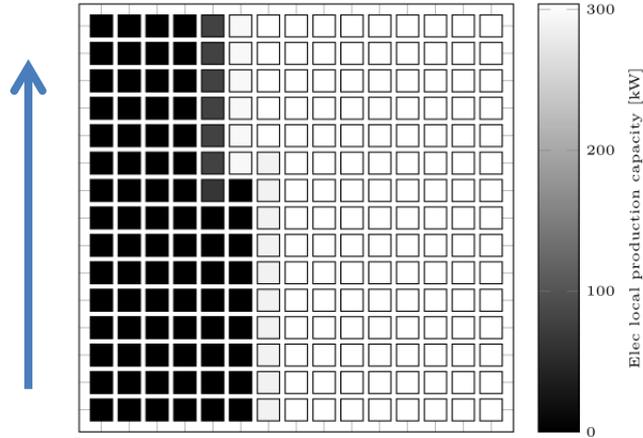
Battery

Heat costs



Location and Capacity: Example

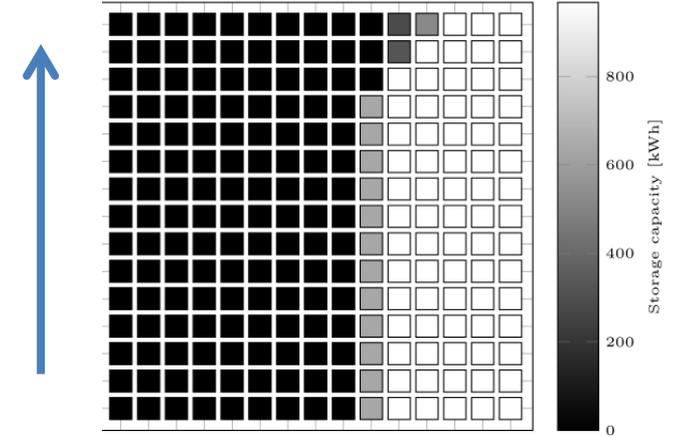
Heat costs



PV

Battery

Heat costs

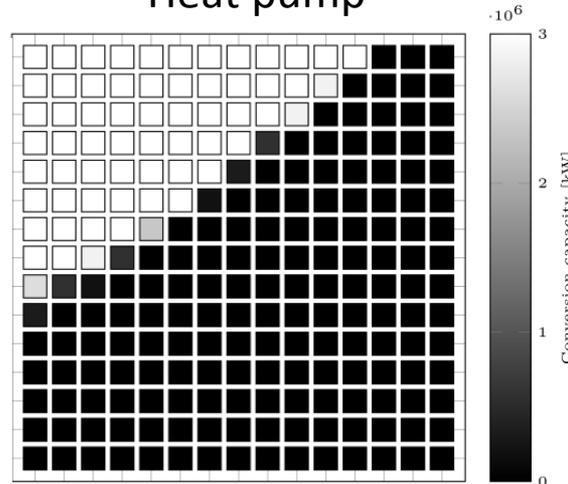


Elec. costs

Elec. costs

Heat pump

Heat costs



Elec. costs



Questions...



- Location and capacity of systems and lines?
- **Uncertainties: technical failures, energy availability, economic future?**
- How to get there?



Questions...



- Location and capacity of systems and lines?
- Uncertainties: technical failures, energy availability, economic future?
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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

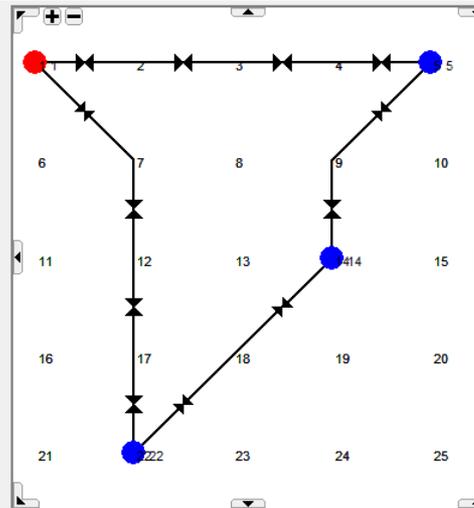
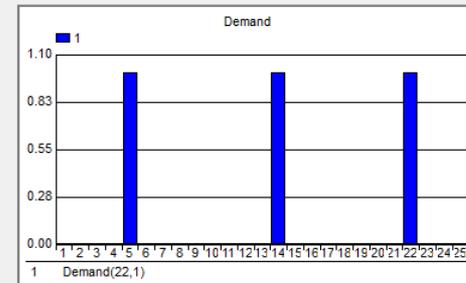
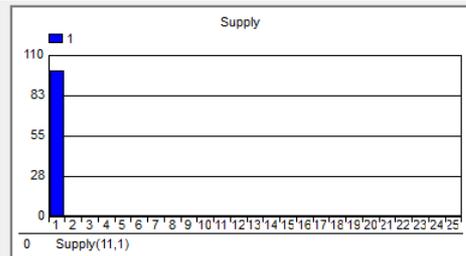


Stochastic Programming

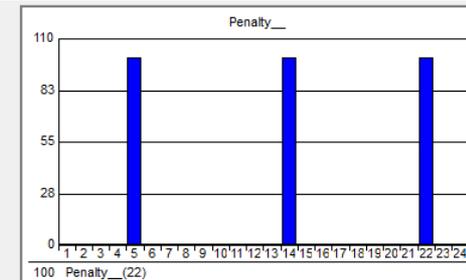
- Scenarios
- Probability
- (The chance it fails once within 10 years is 5%)
- Optimize expected value
- Historic data
- Redundancy vs. Damage



Uncertainty



Identifier	BuildLine	Stochastic
1	1	2
3	1	7
4	2	3
8	3	4
12	4	5
16	5	9
23	7	12
31	9	14
40	12	17
47	14	18
57	17	22
60	18	22
73	2	1
75	7	1
76	3	2
80	4	3
84	5	4
88	9	5
nc	1	7

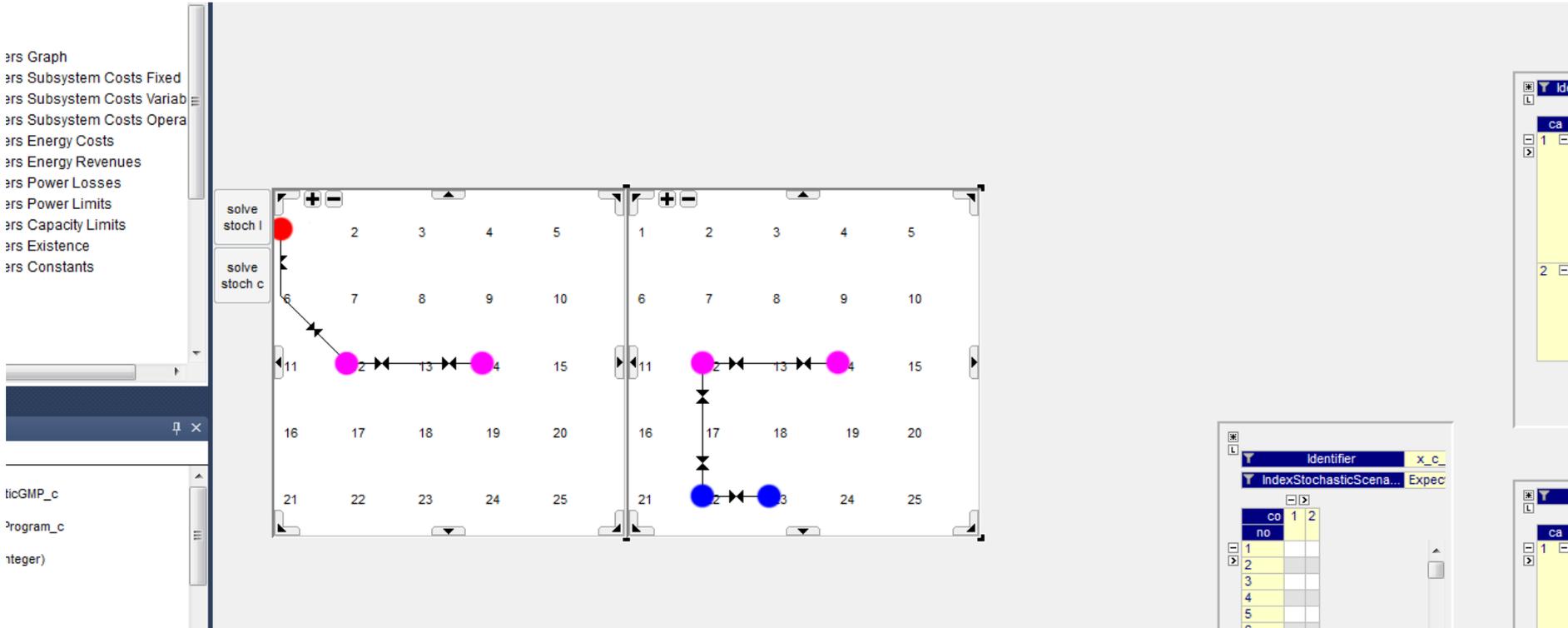


Identifier	TotalCost	Stochastic
sc1	-272.6864	
sc2	-272.6864	
sc3	-272.6864	
sc4	-272.6864	
sc5	-272.6864	
sc6	-272.6864	
sc7	-272.6864	
sc8	-272.6864	

Identifier	LineCap	Stochastic				
IndexStochasticScenarios	sc1	sc2	sc3	sc4	sc5	sc
1	1		100	100	100	10
2	1		100		100	10
3	1		100	100		10
4	1		100	100	100	10
5	1		100	100	100	10
6	1		100	100	100	10
7	1		100	100	100	10
8	1		100	100	100	10
9	1		100	100	100	10
10	1		100	100	100	10



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

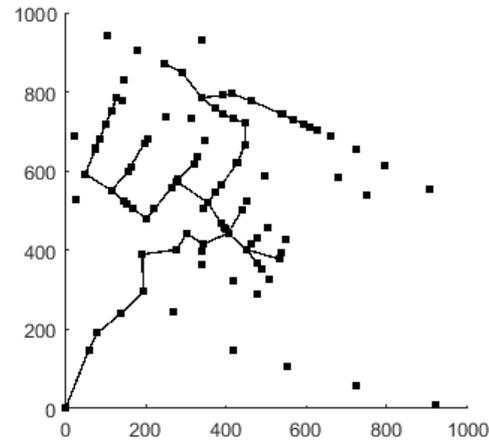
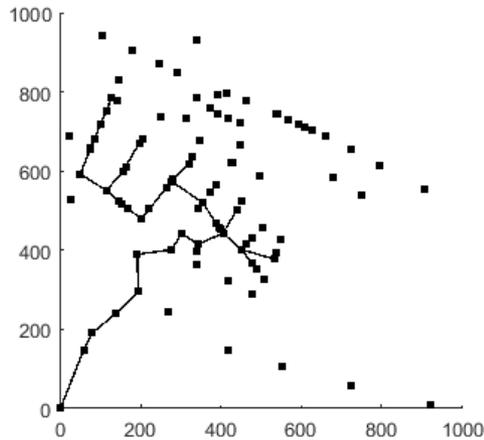
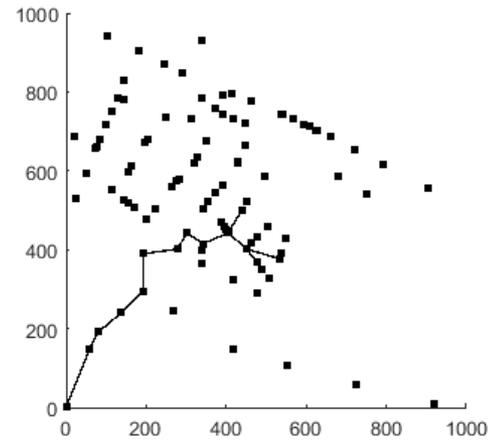
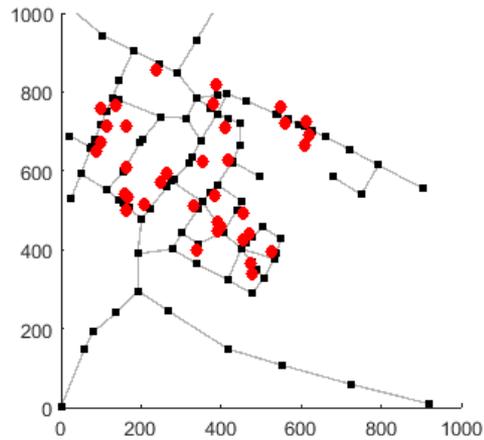


How to get there?



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Conclusions



Future planning and uncertainty

Clear goals and a road to achieve those goals

Stochastic programming

Increased solution space

