16. Symposium Energieinnovation 2020

WISSEN TECHNIK LEIDENSCHAFT TU Graz

EnInnov2020
16. Symposium Energieinnovation | 12.02.–14.02.2020

ENERGY FOR FUTURE – Wege zur Klimaneutralität

Der aktuelle Klimabericht der Weltwetterorganisation (WMO) weist für die Jahre von 2015 bis 2019 nach vorläufigen Berechnungen die heißeste Fünfjahresperiode seit Beginn der Messungen vor rund 150 Jahren aus. Die durchschnittliche Temperatur habe in diesem Zeitraum bereits um 1,1 Grad über jener der vorindustriellen Zeit gelegen. Die durch den fortschreitenden Klimawandel verursachten Auswirkungen (Gletscherschwund, Anstieg des Meeresspiegels, Umweltkatastrophen uvm.) werden dabei immer unmittelbarer für die Menschen spürbar. Eine vor allem von der jungen Generation initiierte und getragene weltweite Bewegung fordert entsprechende Maßnahmen ein, was durch zahlreiche Kundgebungen und Aktionen weltweit zum Ausdruck gebracht wird. Der

Technische Universität Graz
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ATLANTIS Electricity Model

NEWSLETTER

Kontakt

Assoc.Prof. Udo Bachhiesl

100% DEU 15:44 22.06.2020

District Heating Transmission Line Planning With Redundancy Constraints

Mostafa Fallahnejad

12 February 2020

Contents

Introduction: Why having a tool for DH grid planning?

- Objective of Art. 14 EED: identify potentials for increasing energy efficiency through **cogeneration**, **DHC** and the **utilization of excess heat sources**

- 78% of the total EU28 heat demand originates from dense urban areas

- Reaching a DH market share of 50% in EU's is economically feasible.

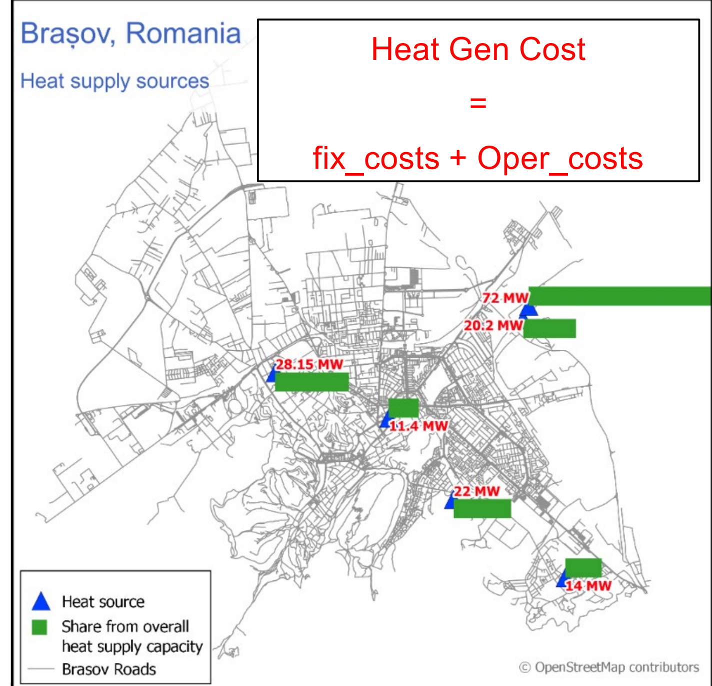
- **However**, the share of district heating in EU28 residential heat consumption has remained around 12% from 1990 to 2015.

- **Reason**: **Lack of knowledge and data** about the DH system can result in **higher uncertainties** about the implementation of this technology.

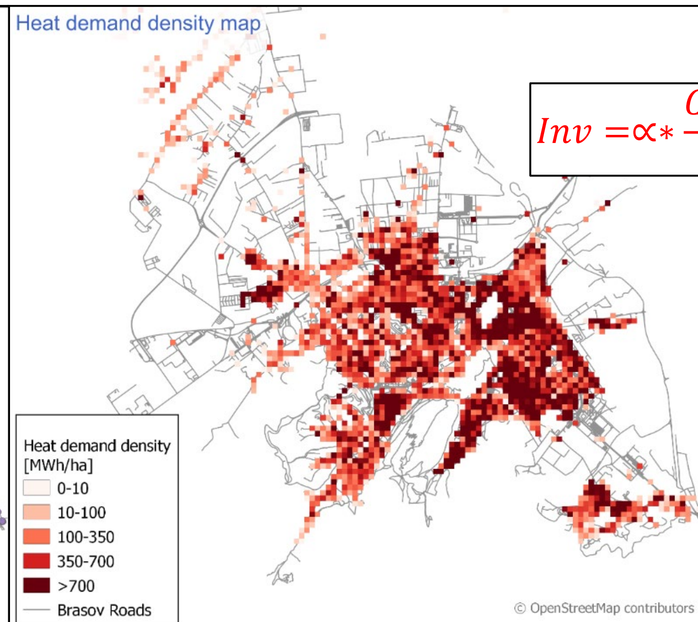
- We need data and models for supporting decision makers for taking necessary steps.

Urban areas & heat consumption

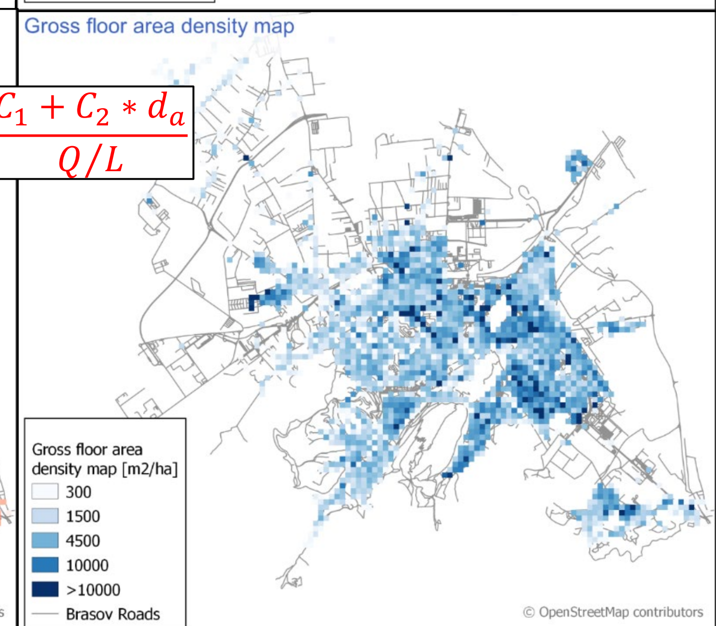
- For planning DH system, we should have a perspective to the **urban areas** and **distribution of heat consumers** and available **heat sources**.



Heat Gen Cost = fix_costs + Oper_costs



$$Inv = \propto * \frac{C_1 + C_2 * d_a}{Q/L}$$



Persson U, Wiechers E, Möller B, Werner S. Heat Roadmap Europe: Heat distribution costs. Energy 2019;176:604–22. doi:10.1016/j.energy.2019.03.189.

Determine potential DH areas (coherent DH areas)

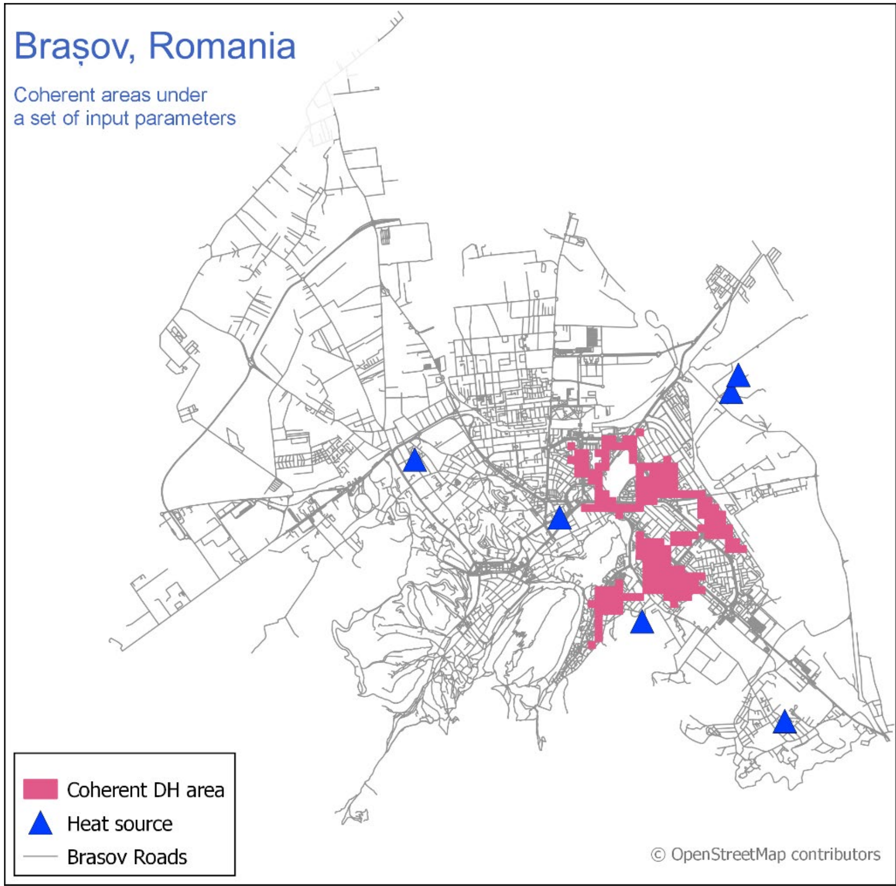
- Annualized specific investment cost per unit of delivered heat in each pixel

- **Economic parameters**: available capital for investment, interest rate, investment period, grid cost ceiling, construction cost constant & coefficient

- **Other parameters**: connection rate, energy saving, heat demand, plot ratio

- Priority of coherent areas with higher heat demand.

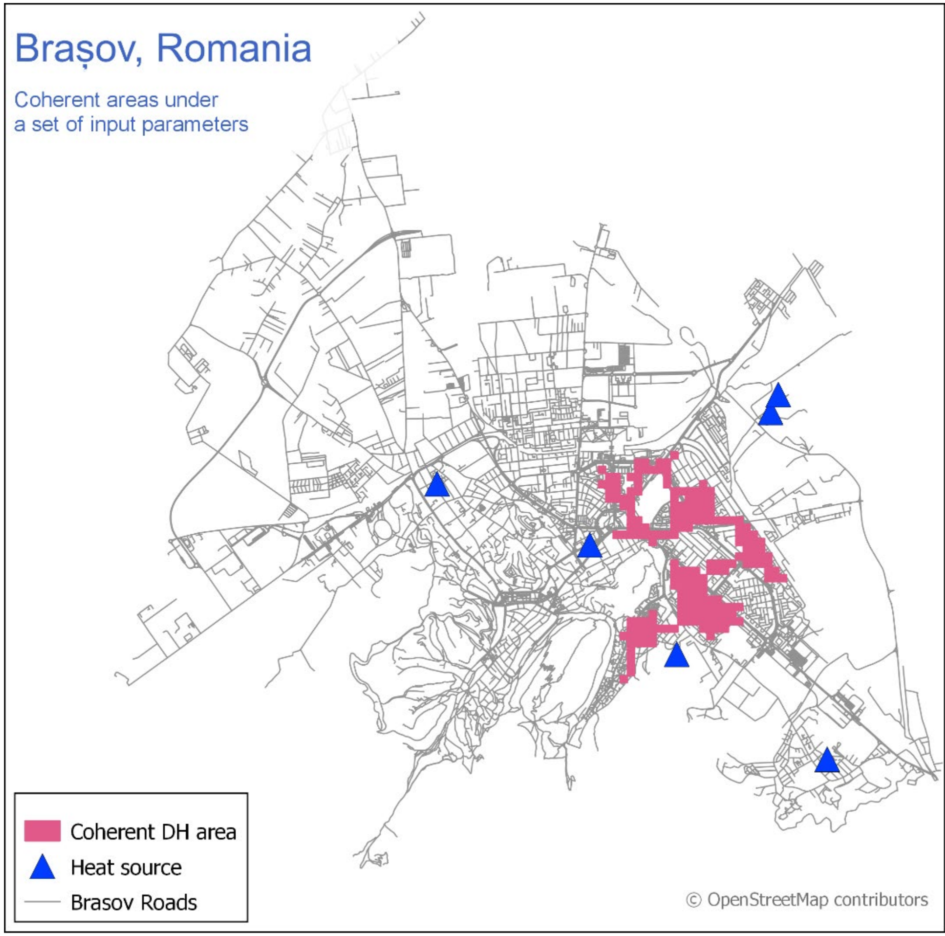
- Conditions:
  - Distribution grid cost ceiling (EUR/MWh),
  - Available capital for investment in **<u>grid</u>** (Million EUR)



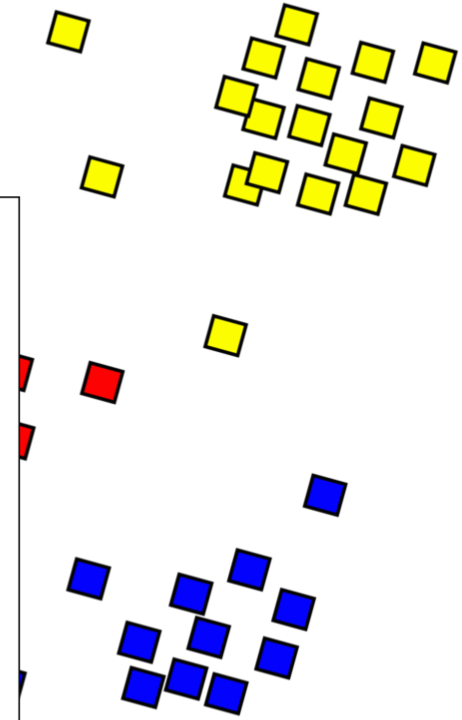
* Persson U, Wiechers E, Möller B, Werner S. Heat Roadmap Europe: Heat distribution costs. Energy 2019;176:604–22. doi:10.1016/j.energy.2019.03.189.

Research questions

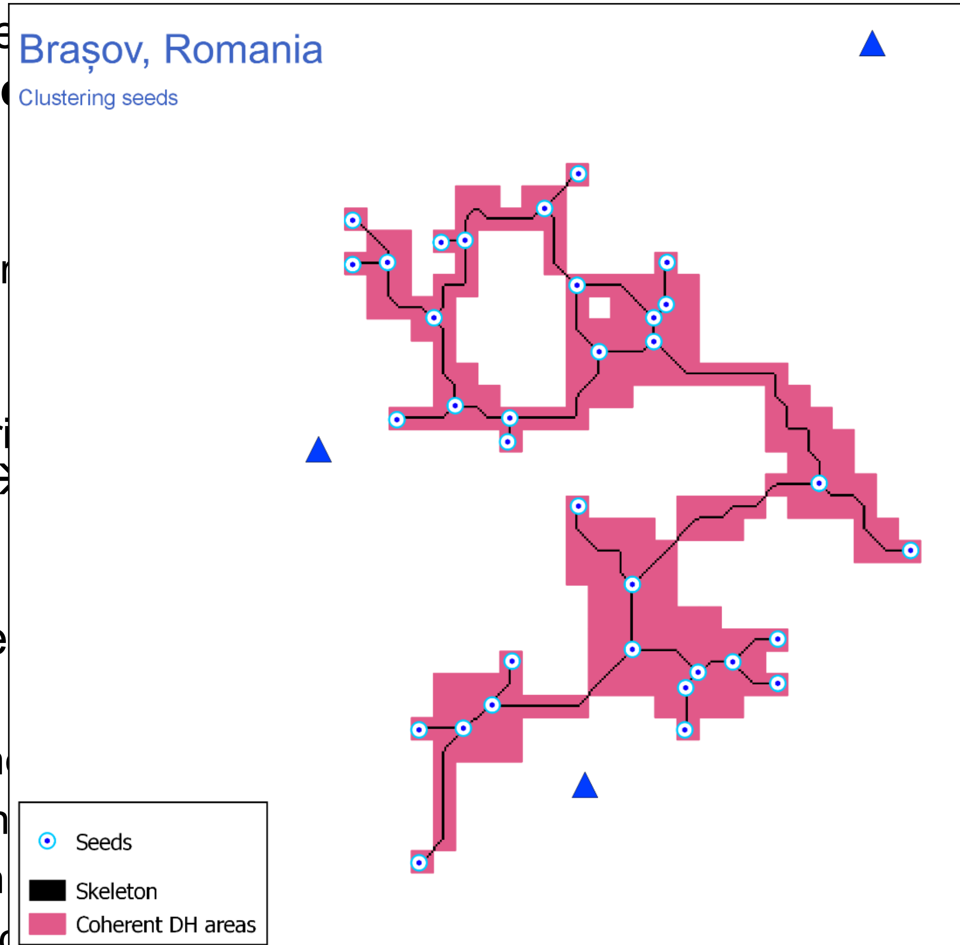
- Is implementation of DH in all potential DH areas economically viable?
- Which one of the available heat sources should be use?
- How much of their capacity is used?
- Which routes and capacities should be used for transmission lines? How much do they cost?
- What happens if one of the supply units is unavailable?



Clustering in coherent areas for answering to research questions



- Optimization-base
  in **reducing mode**
  tangibility,

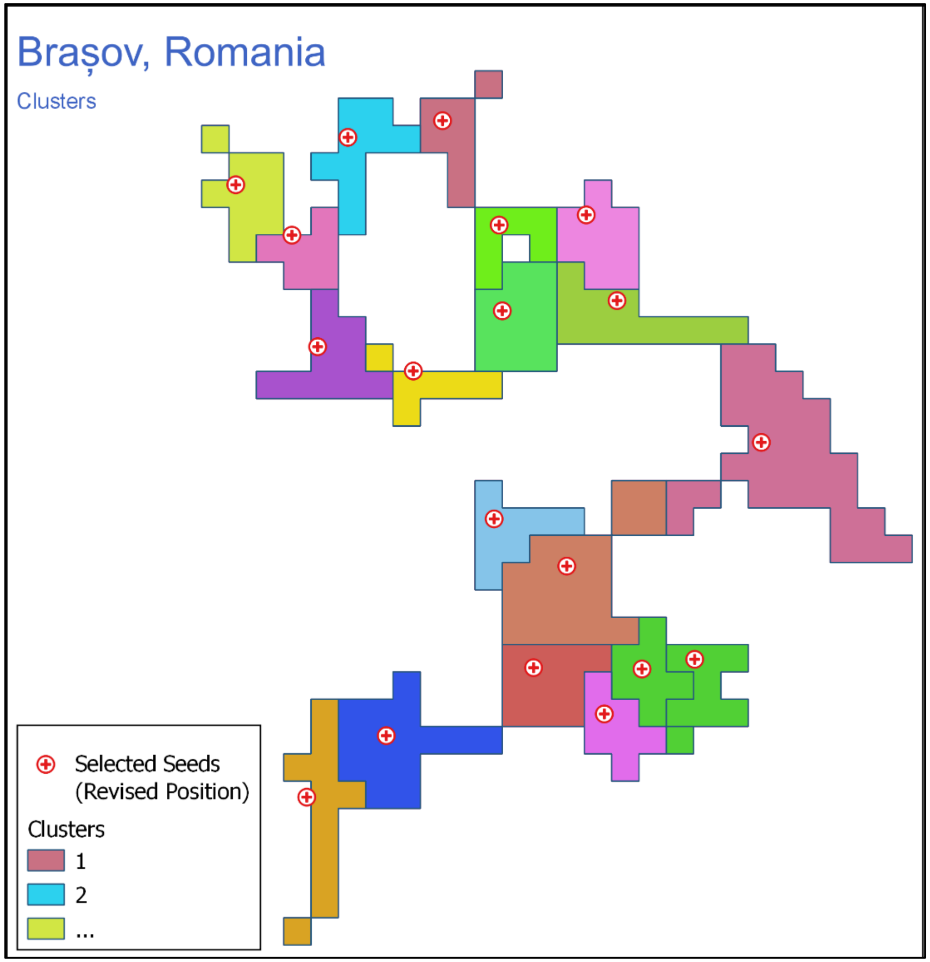


  - We can plan tr
    separately,
  - Distribution gri
    each cluster →

- Better control ove … se approach:
  - Exclusion of n
  - **Long-term** an … of DH system,
  - Determination
  - Estimation of c

Clustering model

- Criteria:
  - Sum of the heat supplied by DH in a cluster must be:
    - **greater than** user-defined lower band (here, 6.3 GWh/a),
    - **lower than** user-defined upper band (here, 17 GWh/a, For dense areas).
    - To have a uniform set of clusters.
    - Decided based on connection rate and local conditions.
  - Each pixel must belong to **only one cluster**.
- Objective:
  - Sum of distances of all pixels from their cluster center should be minimized



Optimization model – Inputs

- Distance matrix
  - The distance between all pairs of **cluster centroids** and **sources** are calculated using **Open Street Map** routes (all routes except private ones).
- Heat sources
  - Cost function
  - Availability (n-1 condition with a user-defined power availability)
- Distribution grid costs (currently the values come from Persson et al. method)
- Heat sale price
- Available pipeline dimensions and heat volume that can be transferred by them
- Heat loss level in the grid
- Peak load factor

Optimization model – Objective & expected outputs

- MILP optimization
- The objective of the MILP optimization model is:

Maximising the heat sale profit at 100% availability of all sources

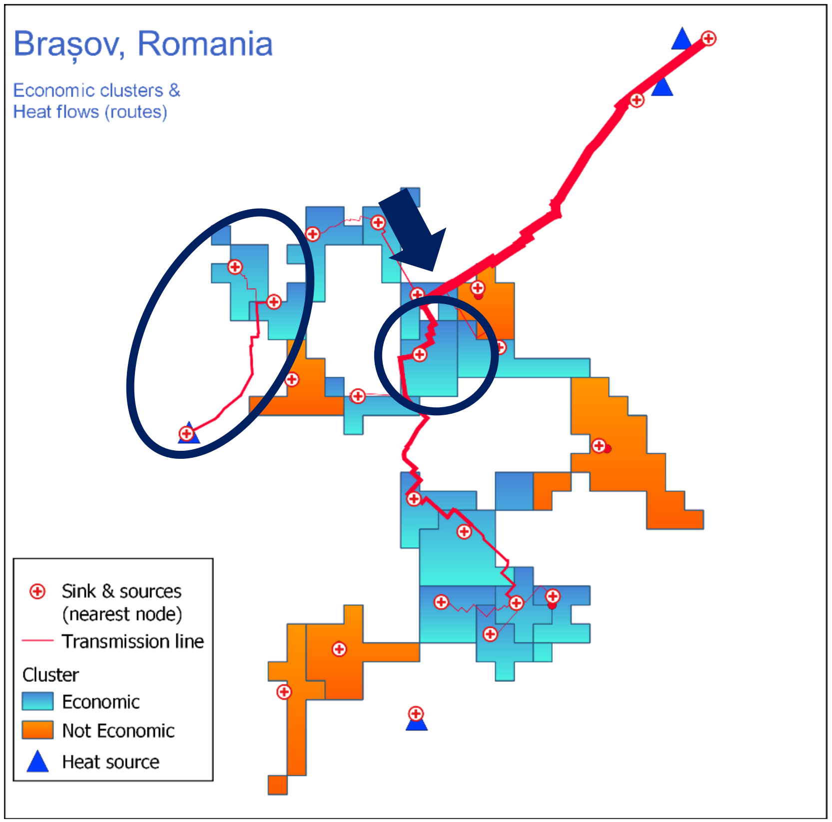
$$Max\ Profit = R_{HeatSale} - C_{HeatGen} - C_{Grid}$$

R := Revenue
C := Cost

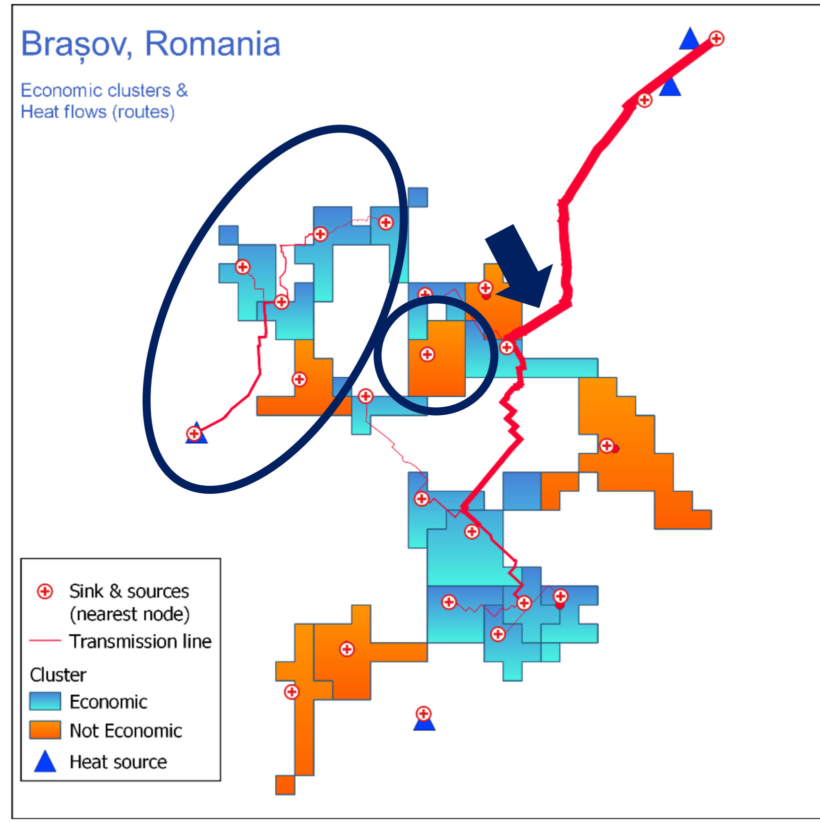
- Find economic clusters
- Determine the required sources
- Determine the transmission lines routes
- Determine the transmission lines dimensions

Economic clusters, heat flow direction & capacities

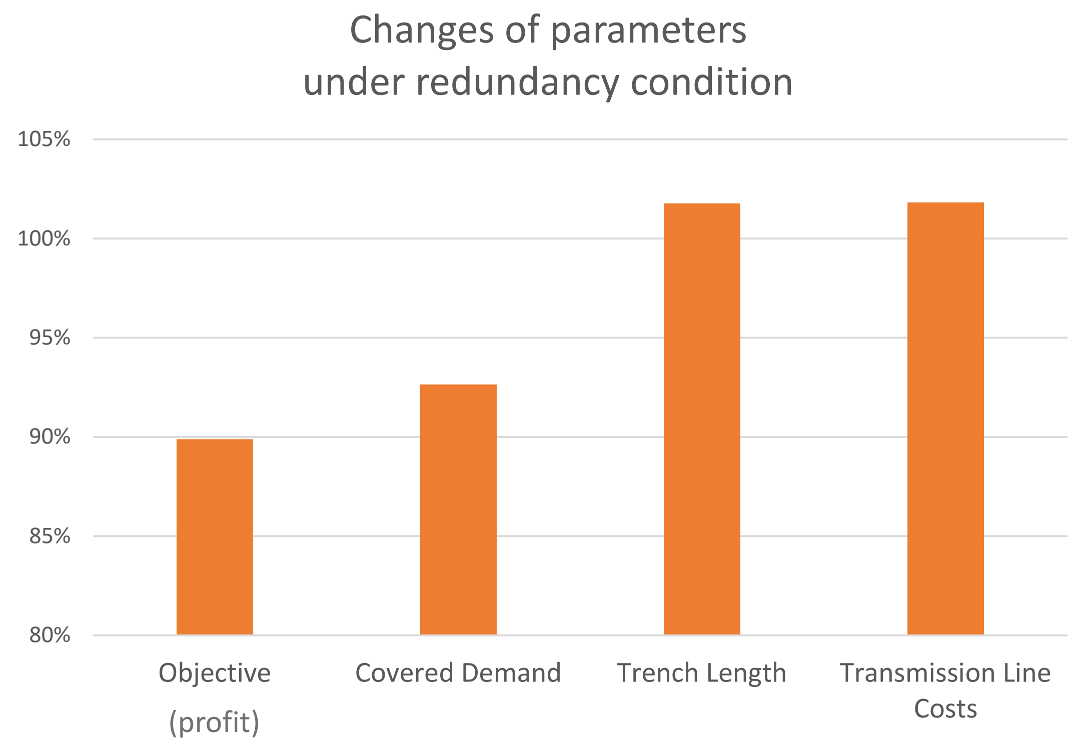
Without redundancy



With redundancy



Summary of Results



Limitations & next steps

- Current limitations:
  - It is assumed that grids operate at the same temperature level.
  - Heat losses are not function of pipe length and dimension.
  - Line costs are aggregation of field work, pipe work, materials, and digging. Therefore, in case of common routes for two pipes, digging costs are calculated twice.
  - Also distance matrix used in model considers distances between cluster centers. → over-estimation in model
    - Is recalculated after model calculation
  - CO_2 emissions should also be considered in the calculation.

Conclusions

- The proposed method:
  - Leads to reduced model complexity and increased tangibility by:
    - introduction of DH coherent areas,
    - optimization-based clustering,
  - Enables us for:
    - Transmission line planning under redundancy constraint,
    - Systematic planning (roll out phases) for extension and expansion of the DH grid,
    - Determination of profitable areas for starting the implementation,
    - Excluding non-profitable areas,
    - Estimation of costs and required capital in each phase,

- As expected, redundancy constraint reduces revenue and decrease DH coverage.

- To reflect a better cost estimation, the limitations should be removed in the next updates.

Thank you for your attention!

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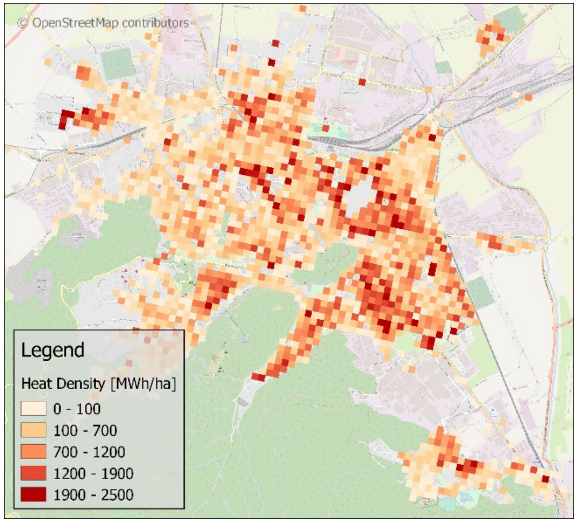
Orig. Photo: Patrick Stargardt

DH Distribution Costs



- Input GIS layers:
  - Heat demand density map (HDM) – 1ha resolution
  - Plot ratio map – 1ha resolution

- For each pixel of HDM in each year within the investment period, the followings should be calculated:
  - Annual heat demand (D_t) based on the expected accumulated energy saving (S),
  - Annual heat supply via DH system (Q_t) depending on the market shares (MS_0 & MS_m),
  - Annualized specific investment cost per unit of delivered heat: according to Persson & Werner** (audit were performed in 83 cities in DE, NL, FR, BE on over 1700 networks.

$$D_t = D_0 \cdot \sqrt[m]{(1-S)^t}$$

$$0 \le S \le 1 \quad ; \quad t \in \{0,1,2,\dots,m\}$$

$$Q_t = D_t \cdot \left[MS_0 + t \cdot \frac{MS_m - MS_0}{m} \right]$$

$$L = 1/w = 1/\left(61.8 \cdot e^{-0.15}\right) \quad [\mathrm{m}]$$

$$d_a = 0.0486 \cdot \ln\left(Q_t / L\right) + 0.0007 \quad [\mathrm{m}]$$

$$Inv_T = \frac{C_{1,T} + C_{2,T} \cdot d_a}{\left(\sum_{t=0}^{m} \frac{Q_{T+t}}{(1+r)^t} + \sum_{t=m+1}^{n} \frac{Q_{T+m}}{(1+r)^t} \right) / L} \quad [€/GJ]$$

$$Inv = \propto * \frac{C_1 + C_2 * d_a}{Q/L}$$

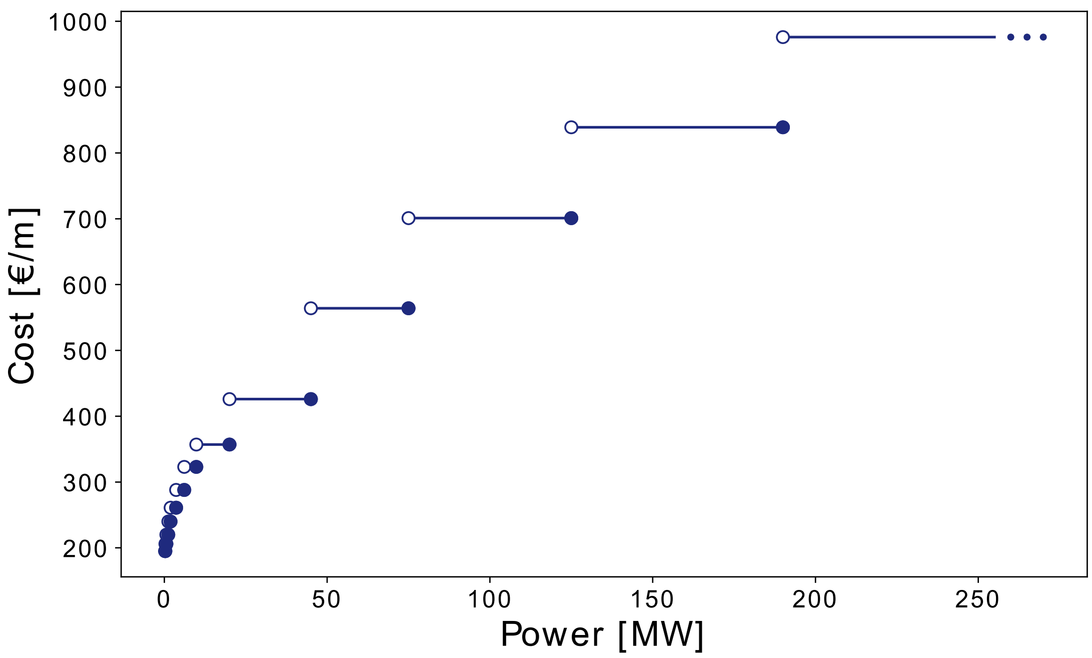
* www.progressheat.eu

** Persson U, Wiechers E, Möller B, Werner S. Heat Roadmap Europe: Heat distribution costs. Energy 2019;176:604–22. doi:10.1016/j.energy.2019.03.189.

Transmission Line Dimensions

- Total cost of transmission pipes including projecting, field work, pipe work, materials, and digging with 55°C temperature difference*.

Step (C)	Dimension DN	Water flow (m/s)	Capacity [MW] (PowStep)	Specific Cost [EUR/m] (SPCTL)
0	32	0.9	0.2	195
1	40	1	0.3	206
2	50	1.2	0.6	220
3	65	1.4	1.2	240
4	80	1.6	1.9	261
5	100	1.8	3.6	288
6	125	2	6.1	323
7	150	2.2	9.8	357
8	200	2.5	20	426
9	300	2.7	45	564
10	400	2.8	75	701
11	500	2.9	125	839
12	600	3	190	976



* Nielsen S, Möller B. GIS based analysis of future district heating potential in Denmark. Energy 2013;57:458–68. doi:10.1016/j.energy.2013.05.041.

Clustering

- For clustering, the number and location of center points of clusters are important.
- A skeleton of the DH areas is calculated and all cross-sections and end-points are considered candidate seeds for constituting clusters.
- In a clustering model, best seeds and consequently, clusters are determined with **conditions on heat demand of clusters**.
- Transmission lines transfer heat from sources to the center of clusters. Subsequently, the heat is distributed within the clusters via distribution grids.