Heat maps and GIS for analysis of district heating systems

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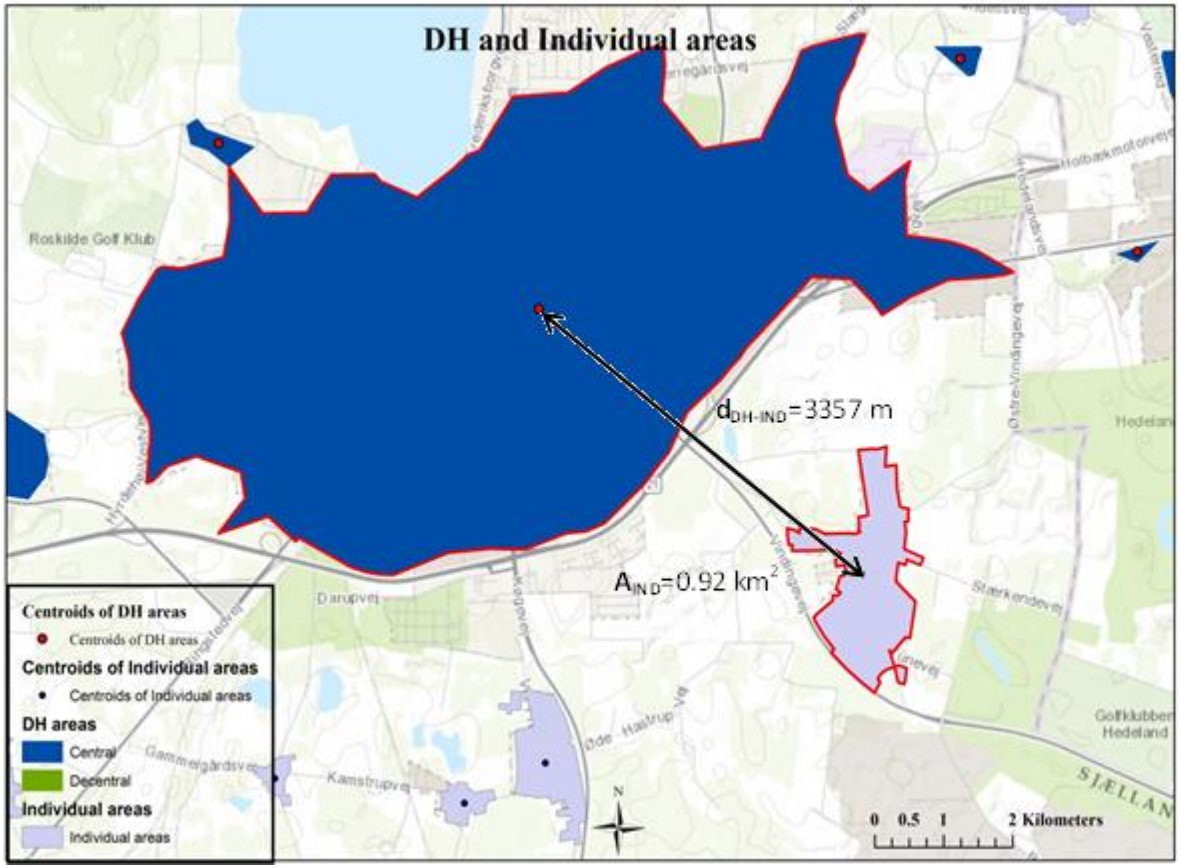
Plan of the presentation

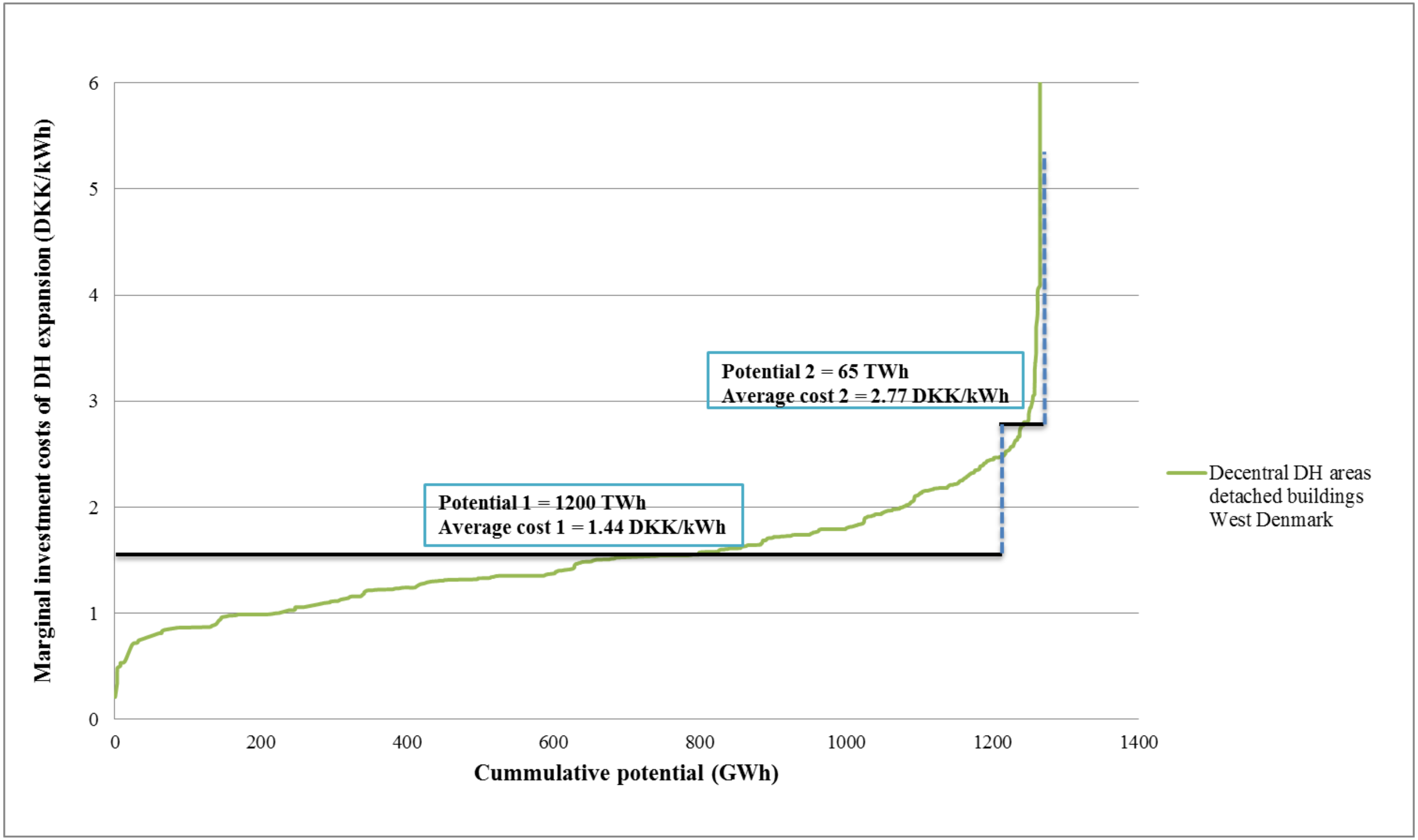
- Example 1: District heating expansion
- Example 2: Residential heat pumps
- Example 3: Excess heat from industries
- Example 4: Effect of climate change on heating and cooling demands
- Final remarks

Example 1: District heating expansion



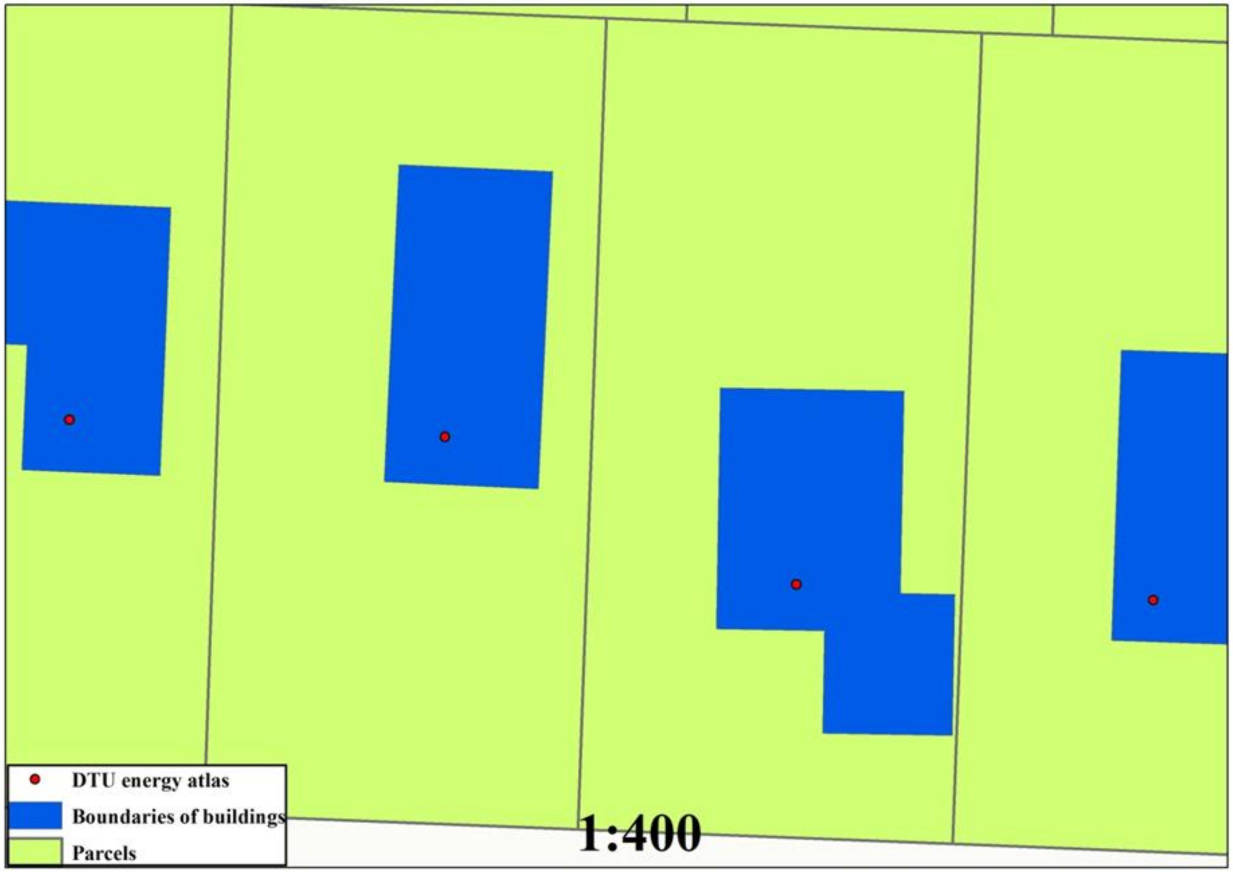
$$C = C_{TR} + C_{DIST} + C_{CONN} = c_{TR} \cdot d_{DH-IND} + c_{DIST} \cdot A + \left(c_{CONN,s} + c_{HE,s}\right) \cdot n_s + \left(c_{CONN,m} + c_{HE,m}\right) \cdot n_m + \left(c_{CONN,l} + c_{HE,l}\right) \cdot n_l$$

District heating in TIMES-DK – expansion curves



Example 2: Residential heat pumps

- Maybe there is not enough space to install ground source heat pumps



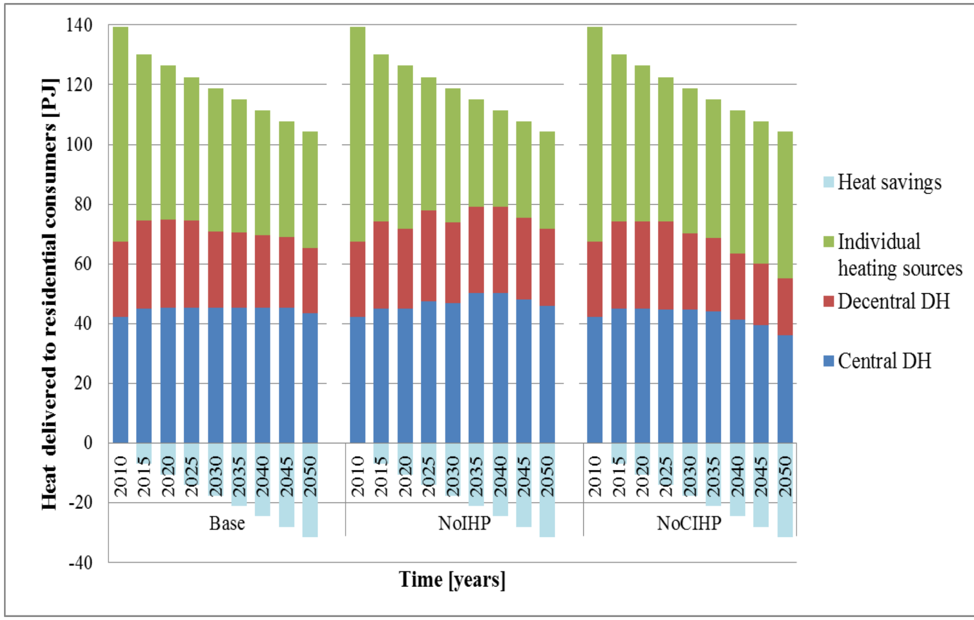
$$COP = \frac{W_h}{W_e} = \frac{W_h}{W_h - W_{gr}} \Rightarrow W_h = \frac{COP}{COP-1} \cdot W_{gr} \Rightarrow W_h = P_{h,spec} \cdot A_{av} \cdot k_{area} \cdot T_{flh} \cdot \frac{COP_{av}}{COP_{av} - 1}$$

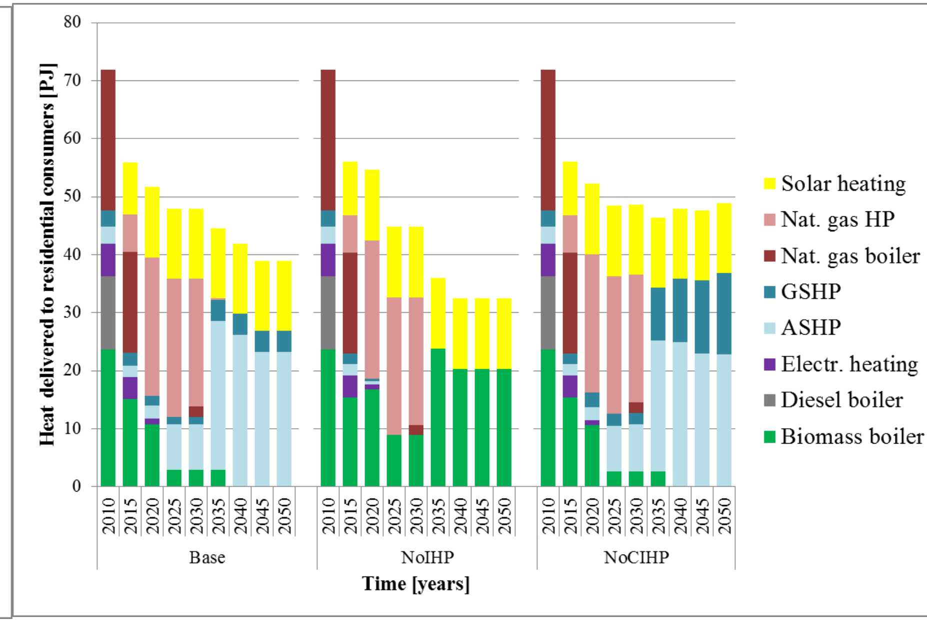
Example 2: Residential heat pumps

- Heat pump can only supply its own building's demand, not the neighbour's
- Example 1: Heat pump can cover 100 MWh, building's demand is 50 MWh → Heat pump can produce at most 50 MWh
- Example 2: Heat pump can cover 100 MWh, building's demand is 150 MWh → Heat pump can produce at most 100 MWh

Region	Building type	Useable area (km^2)	Heat demand (TWh)
DKE	Single-family	2194	4.8
DKE	Multi-family	37	0.7
DKW	Single-family	6402	6.7
DKW	Multi-family	45	0.3

Example 2 - Heat supply

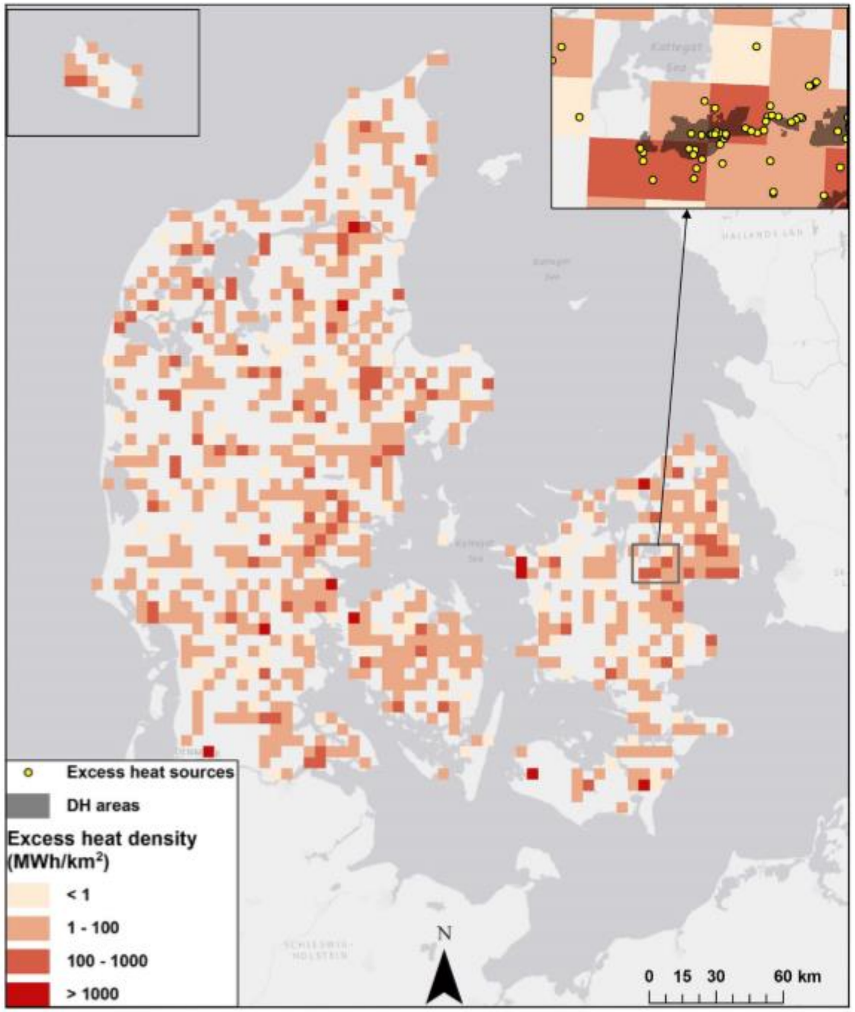




Heat delivered to residential consumers

Heat delivered to residential consumers from individual heating sources

Example 3: Excess heat from industries



Bühler F., Petrovic S., Karlsson K.B. & Elmegaard B. (2017). Industrial excess heat for district heating in Denmark. Applied Energy. 205. 991-1001.

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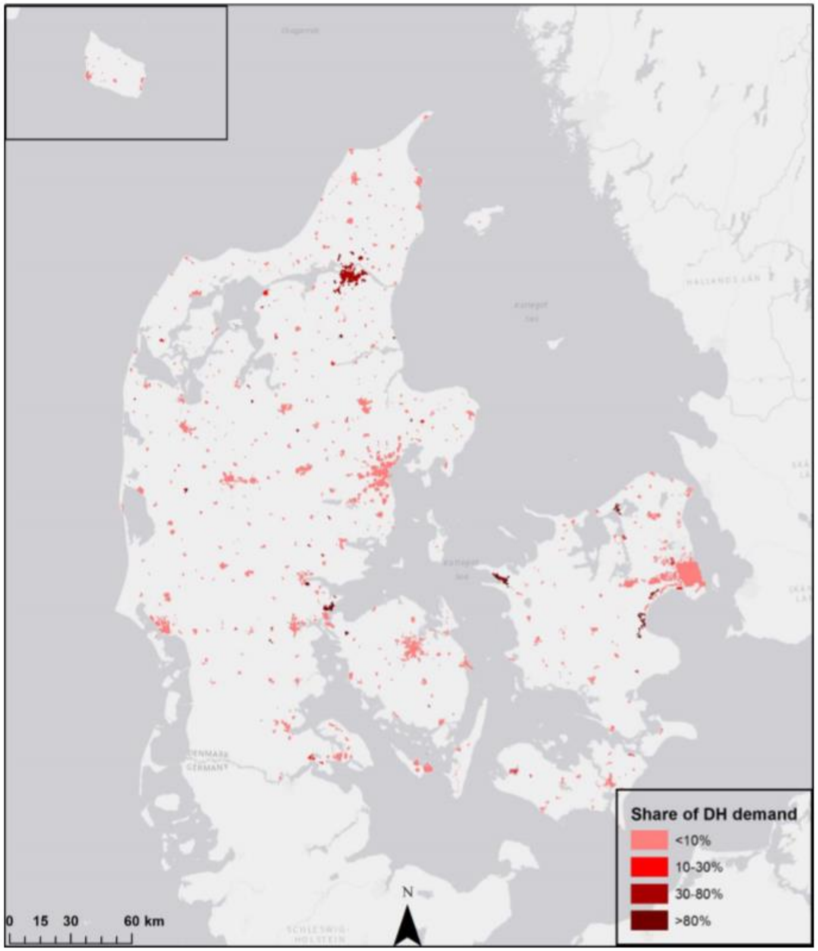

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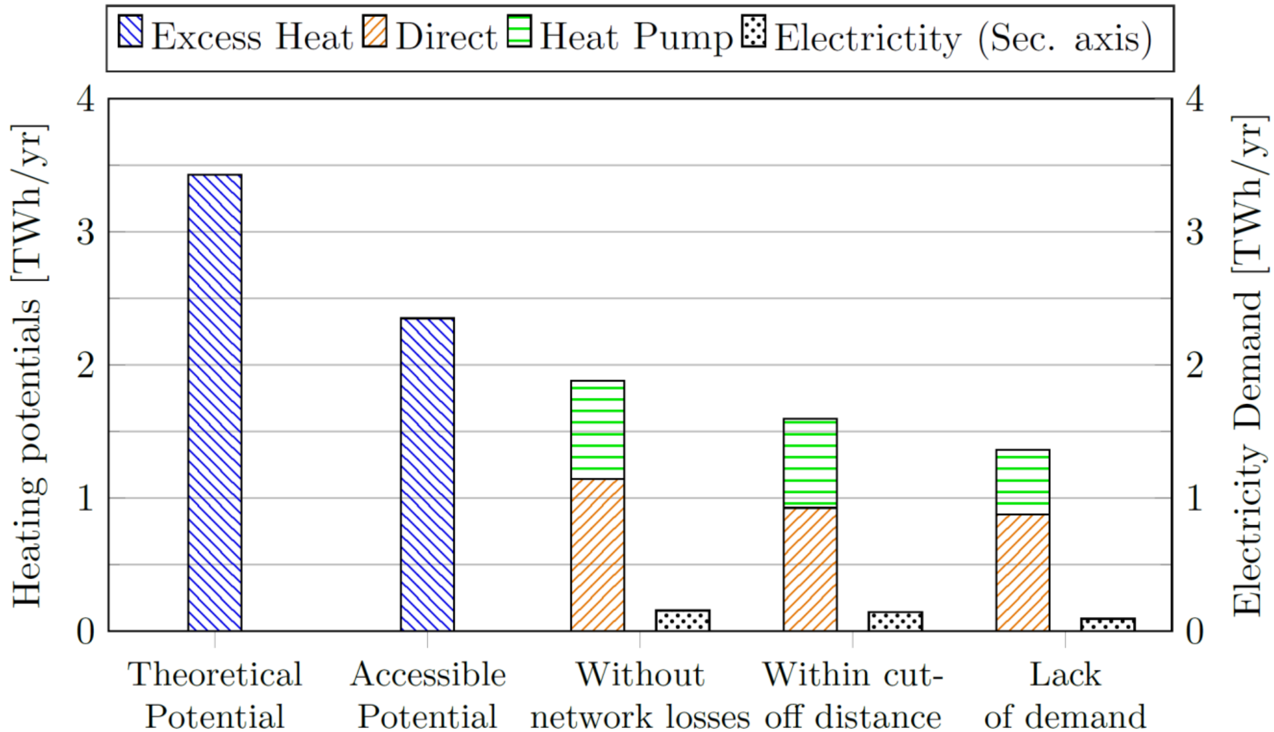
Share of DH demand which can be covered by industrial excess heat

Example 3: Excess heat from industries



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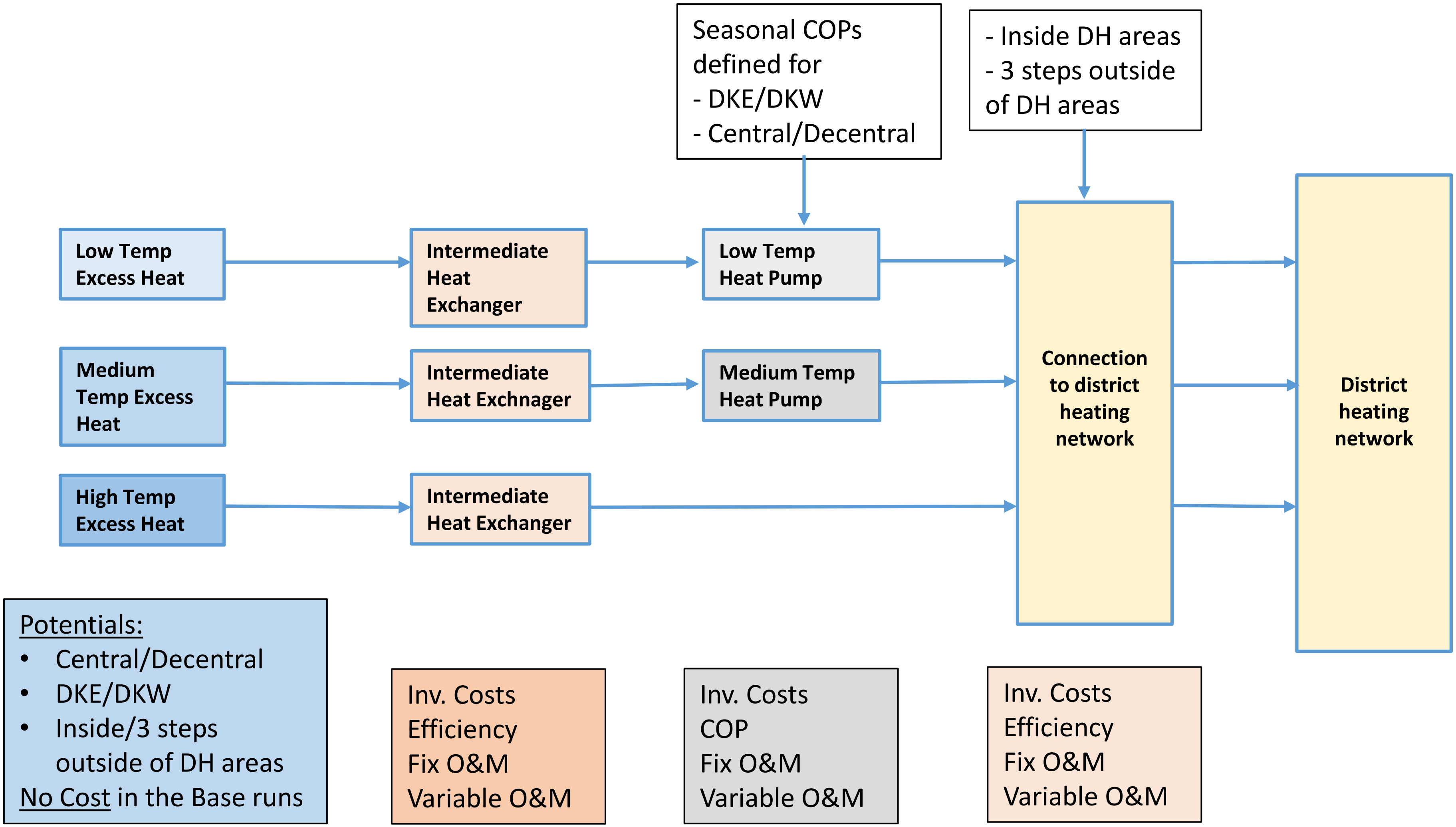
Previous work – from theoretical to practical potential

Example 3: Excess heat from industries



Industrial excess heat in TIMES-DK

Example 4: Effect of climate change on heating and cooling demands

- The development of the heating and cooling demands depends on the construction and demolition rates, energy efficiency standards of newly built and renovated buildings as well as behavioral factors.
- The factor which has the major influence on the future heating and cooling demands **is the outdoor temperature.**
- Development of the outside air temperature is very uncertain, but it is very unlikely that today's temperature patterns will remain the same in the long-term horizon.
- The Danish experience is that every 1 degree Celsius increase reduces the heating demand by 7%.

Example 4 - Methodology

$$\mathrm{HDD}_i = \begin{cases} T_b - T_M \\ \frac{T_b - T_N}{2} - \frac{T_X - T_b}{4} \\ \frac{T_b - T_N}{4} \\ 0 \end{cases} \text{if} \begin{cases} T_b \geq T_X \\ T_M \leq T_b < T_X \\ T_N \leq T_b < T_M \\ T_b \leq T_N \end{cases}$$

$$\text{with } T_b = 15.5\,°\mathrm{C} \quad (1)$$

$$\mathrm{HDD} = \sum_{i=1}^{183} \mathrm{HDD}_i \quad (2)$$

$$\mathrm{CDD}_i = \begin{cases} 0 \\ \frac{T_X - T_b}{4} \\ \frac{T_X - T_b}{2} - \frac{T_b - T_N}{4} \\ T_M - T_b \end{cases} \text{if} \begin{cases} T_b \geq T_X \\ T_M \leq T_b < T_X \\ T_N \leq T_b < T_M \\ T_b \leq T_N \end{cases}$$

$$\text{with } T_b = 22\,°\mathrm{C} \quad (3)$$

$$\mathrm{CDD} = \sum_{i=1}^{182} \mathrm{CDD}_i \quad (4)$$

Methodology used by EEA (Eurpoean Environment Agency)

HDD – Heating degree days
CDD – Cooling degree days

T_b- Base temperatures for heating and cooling
T_M- Mean daily temp
T_X- Max daily temp
T_N- Min daily temp

T_M, T_X,T_N are outputs from the climate model

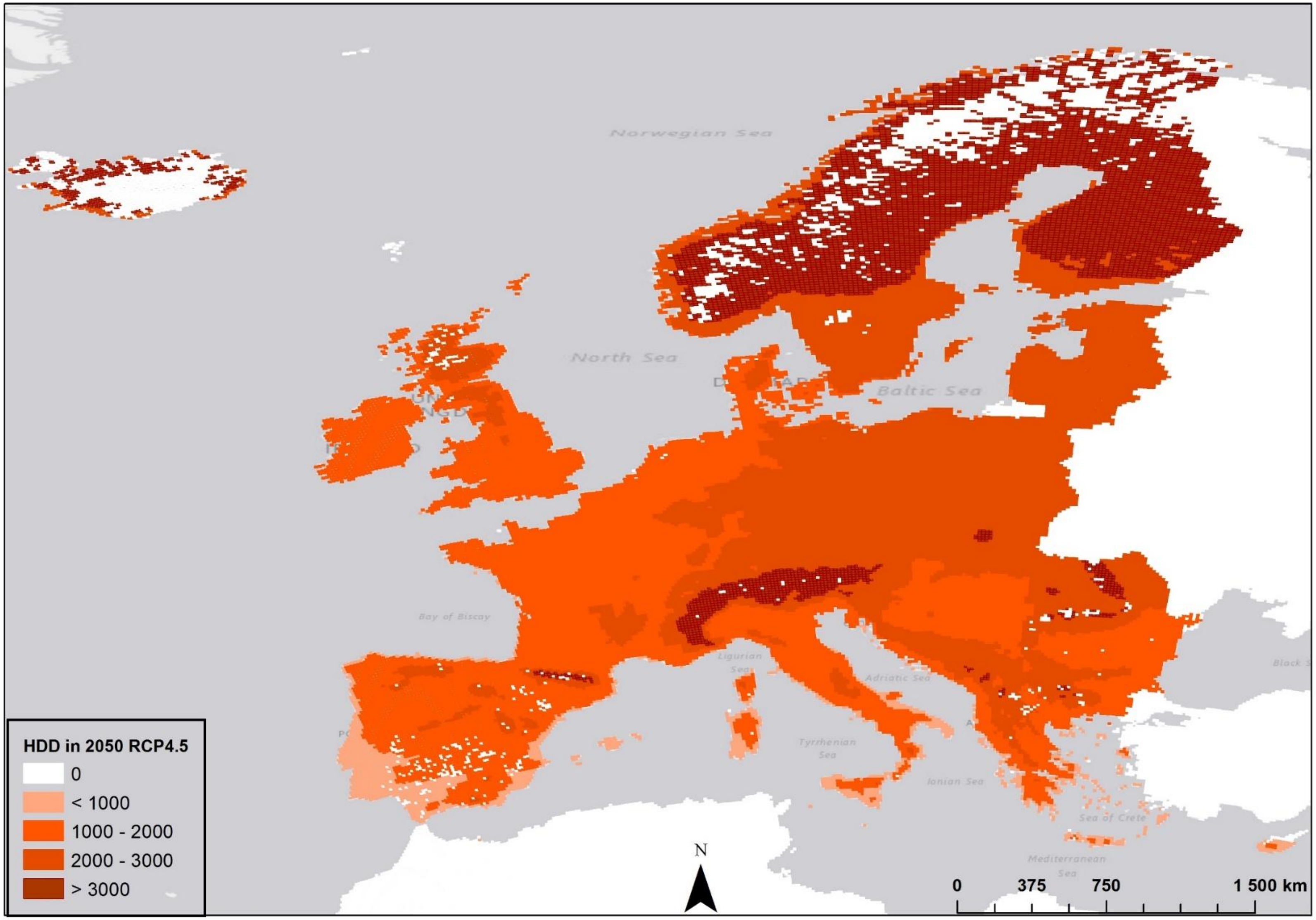
- for every day
- from 2010 to 2050 in 5-year steps
- In cells of 11x11km size (0.11^o)

This is how we calculate HDD and CDD for every 11x11 km cell

Example 4 - Methodology

- HDD and CDD are calculated for different climate scenarios for every 11x11 km cell from 2010 to 2050 in 5 year steps.
- Future heating/cooling demands are calculaetd by **scaling existing heating/cooling demands** with the ratio of future and current HDD and CDD for each 11x11 km cell.
- Not all cells are equaly imporatnt – it is important where is the demand located. **Population count** is used as an indicator where is the heating/cooling demands are located.
- Population count is aggreagted from 1x1 km to 11x11km cells.
- The methodology is to be repeated for 2 climate scenarios (RCP2.6, RCP4.5) from different climate models.

Example 4 - Results



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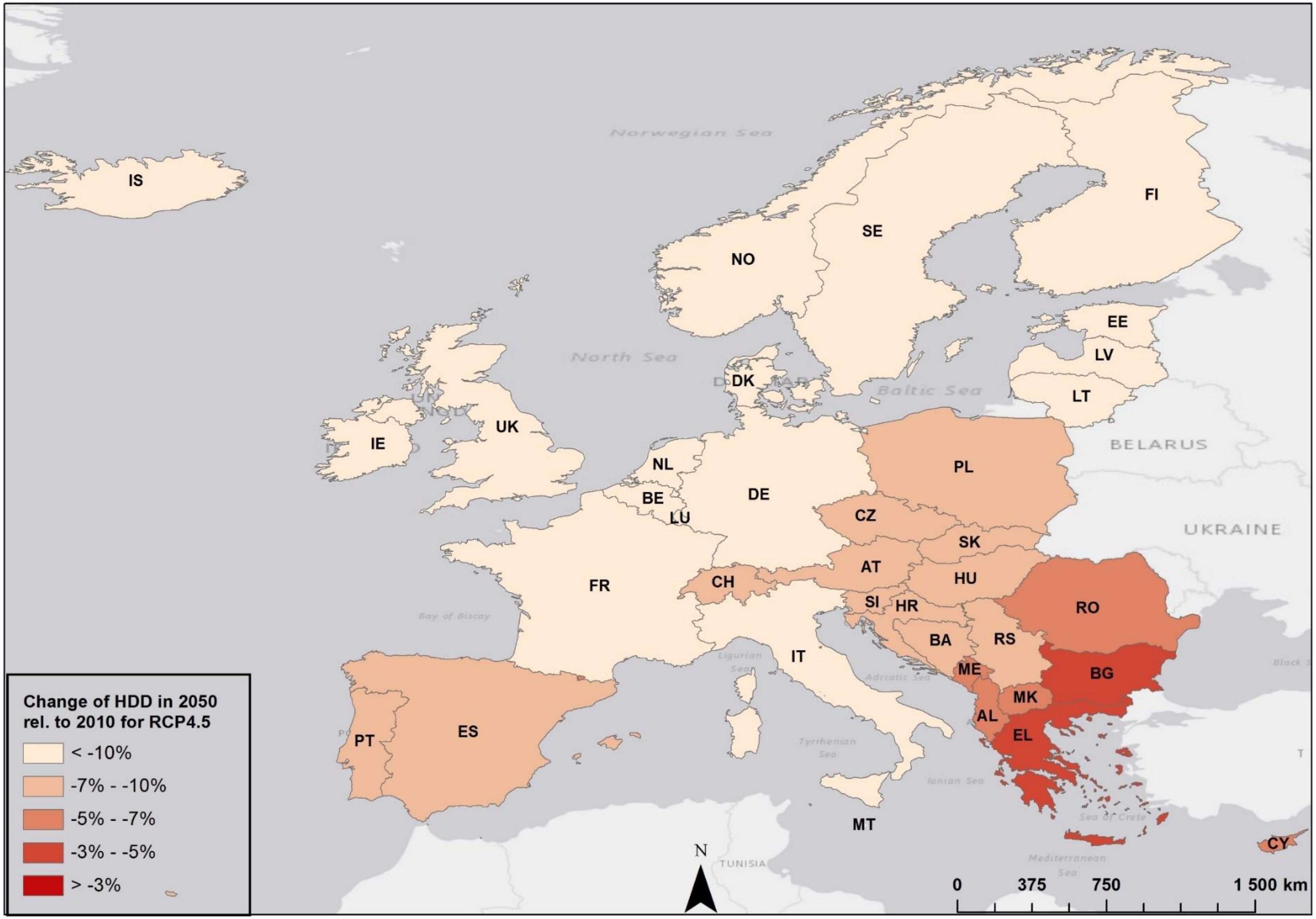

Final remarks

- The list of applications is not exclusive
- The examples are meant to be used as inspiration (for combining data)
- GIS is not used as a stand alone tool, but as pre-processing tool for energy system models
- Very useful for visual presentations, but…
- GIS is used for analysis, not only to create nice maps
- GIS “doesn’t differentiate between geographical areas”; however, the (good) data can be a problem

Thank you for your attention

- Questions
- Answers
- Comments
- Suggestions

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