Optimization of an energy system model coupled with a numerical hydrothermal groundwater simulation

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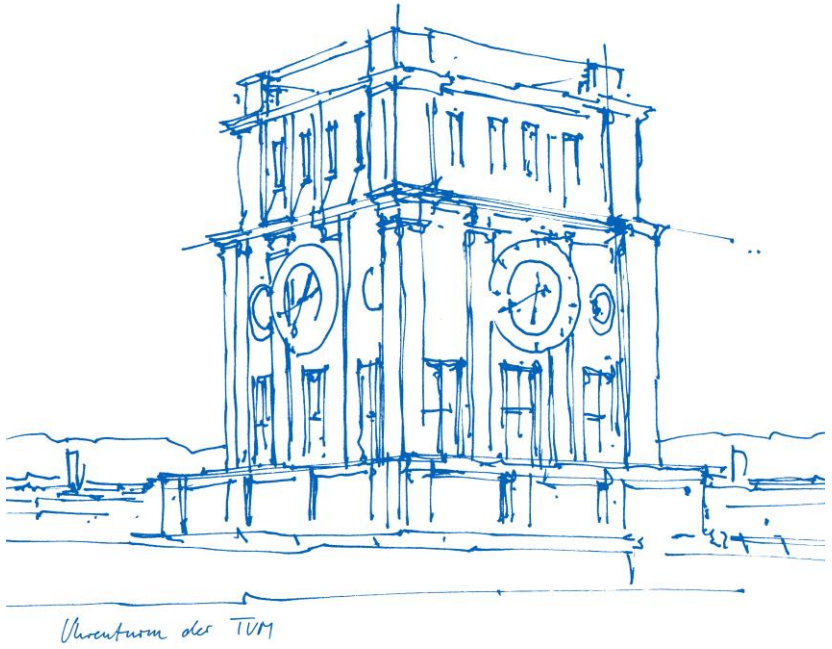
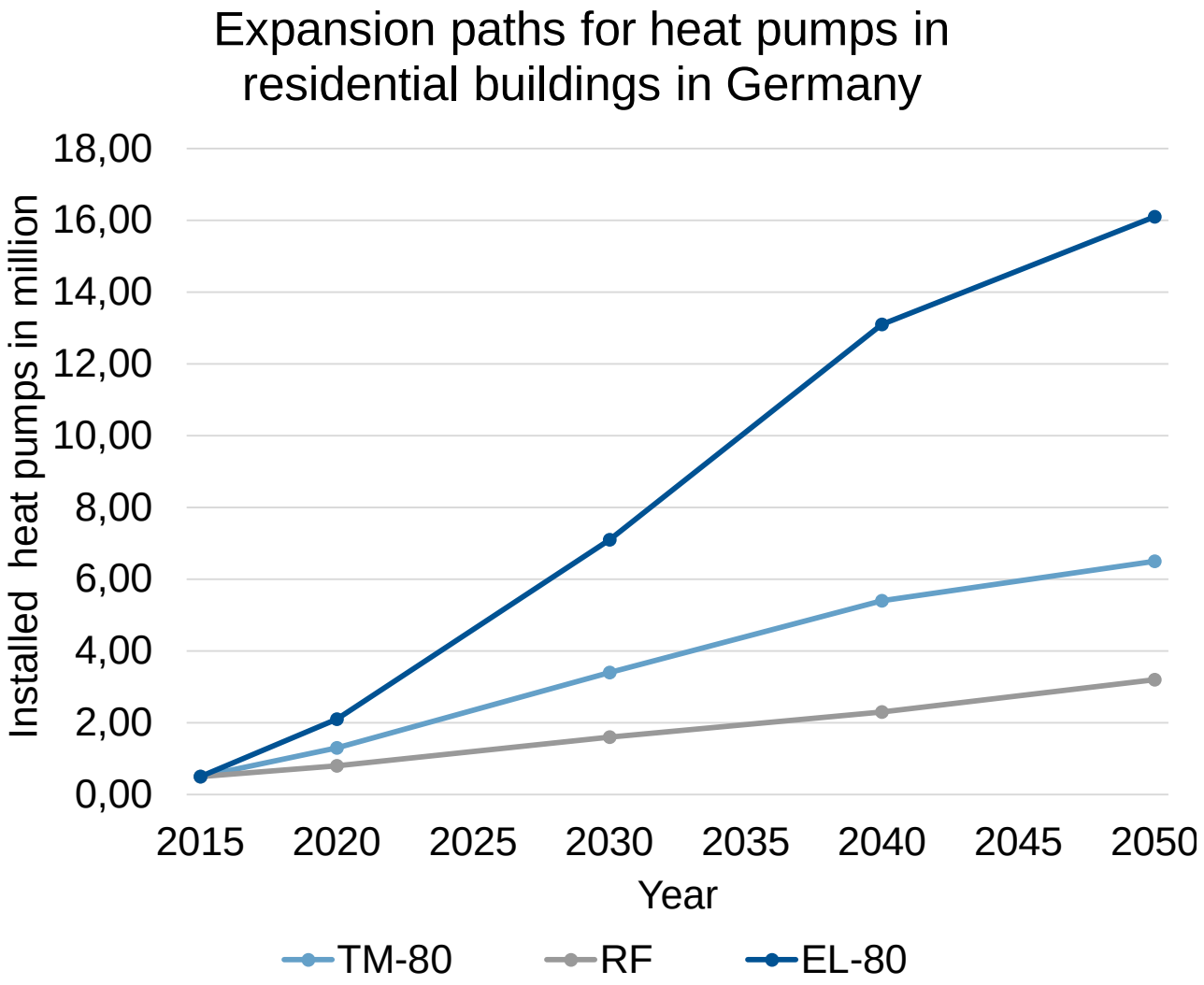


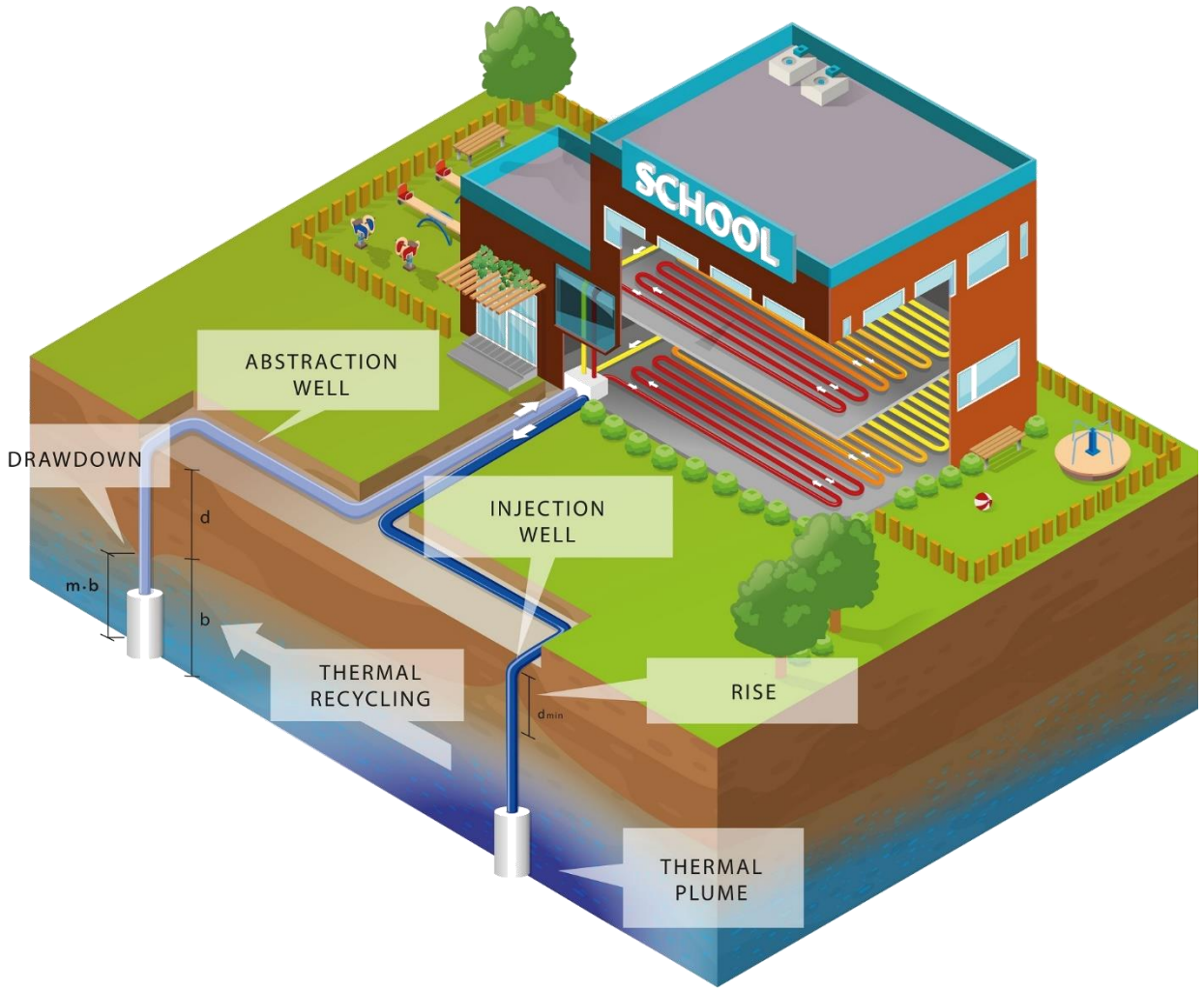
Importance of heat pumps



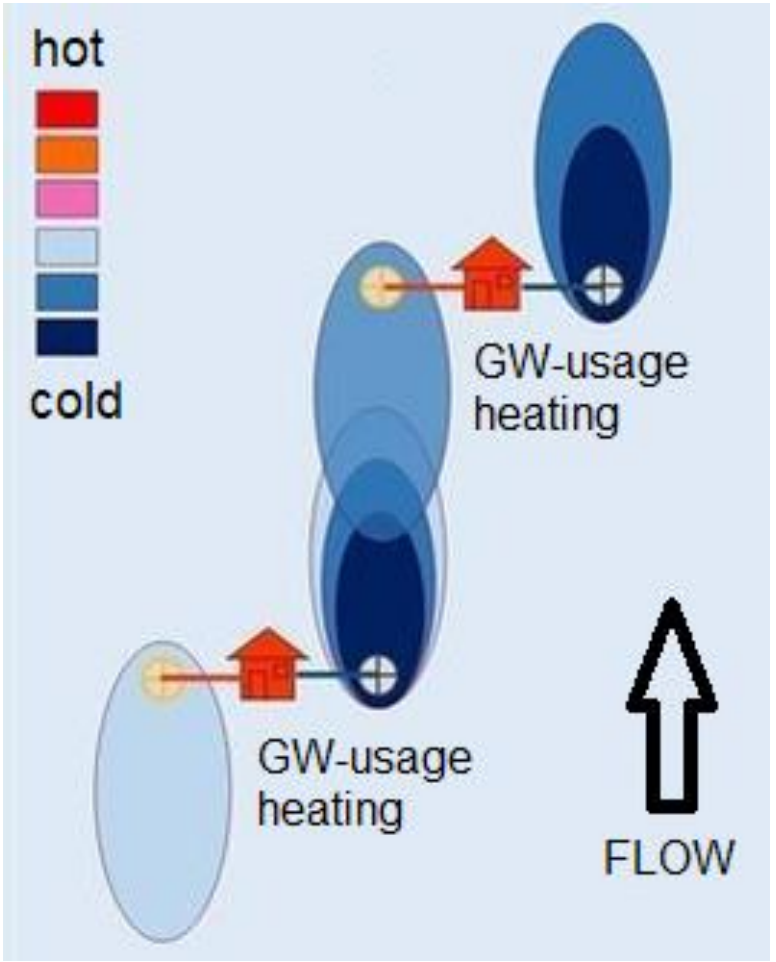
Project Geo.KW

Optimising the thermal use of groundwater for a decentralized heating and cooling supply in the city of Munich, Germany

Groundwater heat pumps (GWHPs)

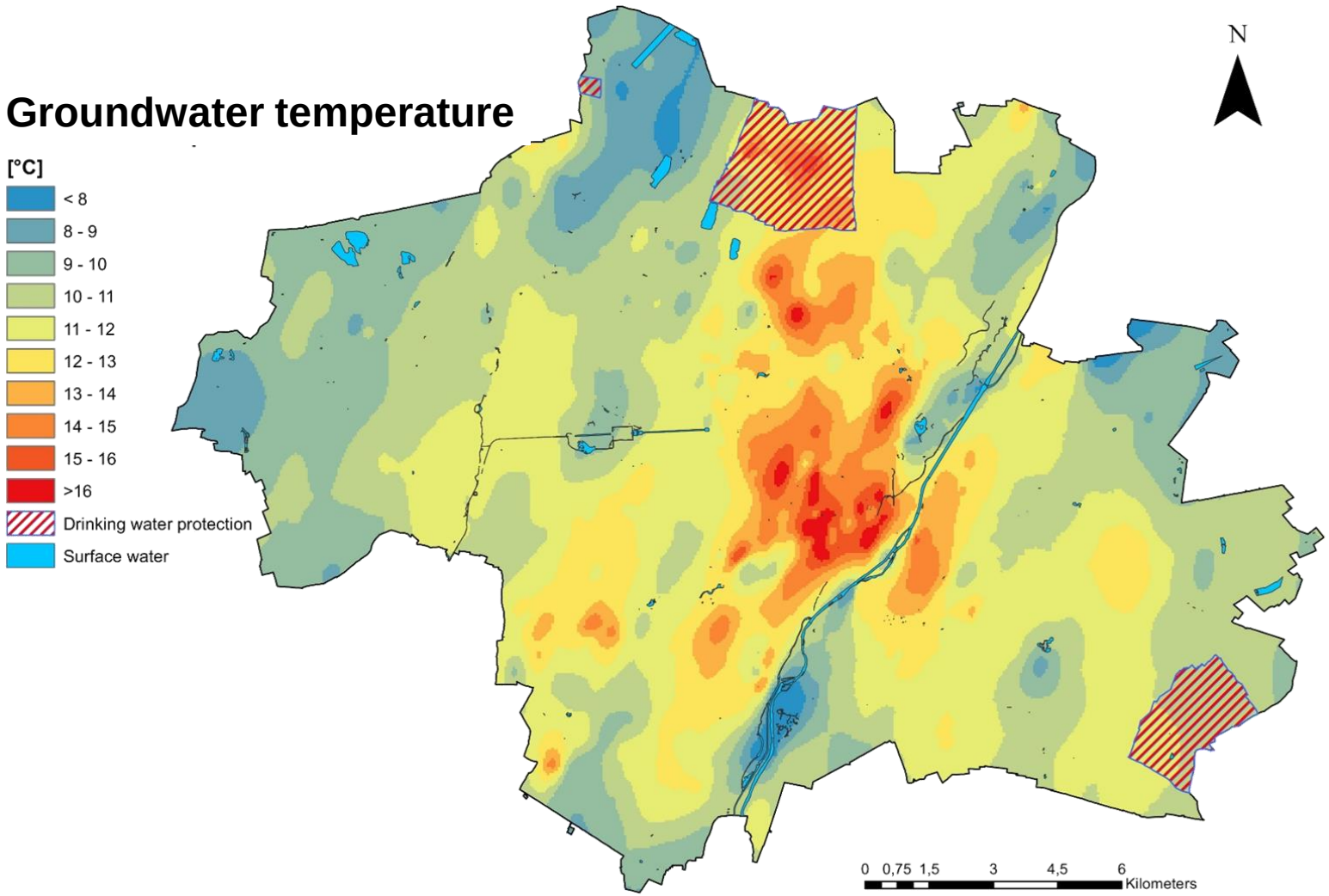


Working principle of GWHPs



Negative interaction between systems

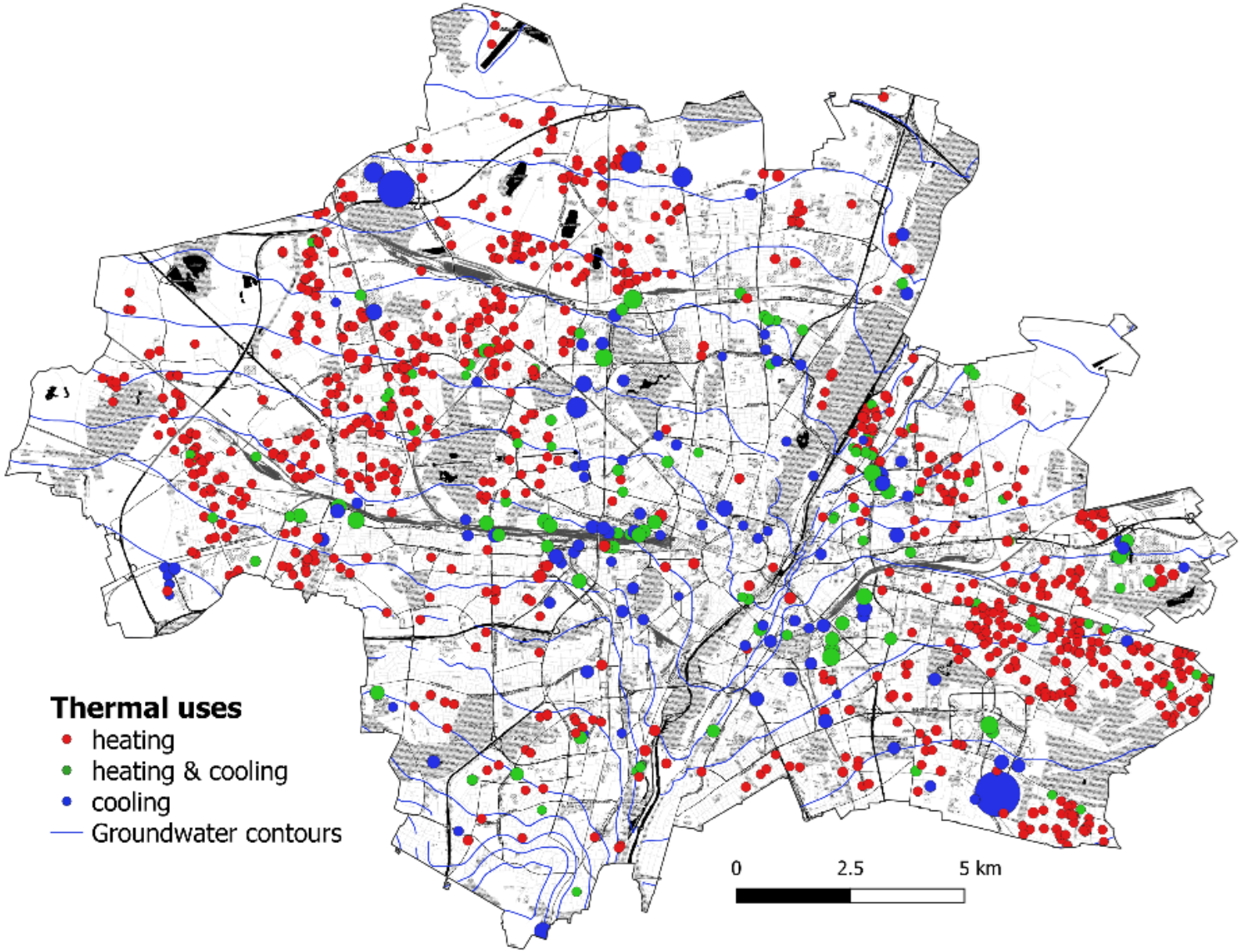
Hydrogeological conditions in Munich



The urban heat island effect

- Groundwater is already anthropologically heated
- Further heating can decrease the groundwater quality
- Increased efficiency of groundwater heat pumps

Thermal use of groundwater in Munich



The thermal use in numbers:

- over 2600 registered users
- heating: 25.1 Mio m^3/a (2257 user)
- cooling: 86.4 Mio m^3/a (242 user)
- heating & cooling: 31.5 Mio m^3/a (188 user)

The research question

How and where new groundwater heat pumps can be optimally installed in Munich?

With sustainable operation

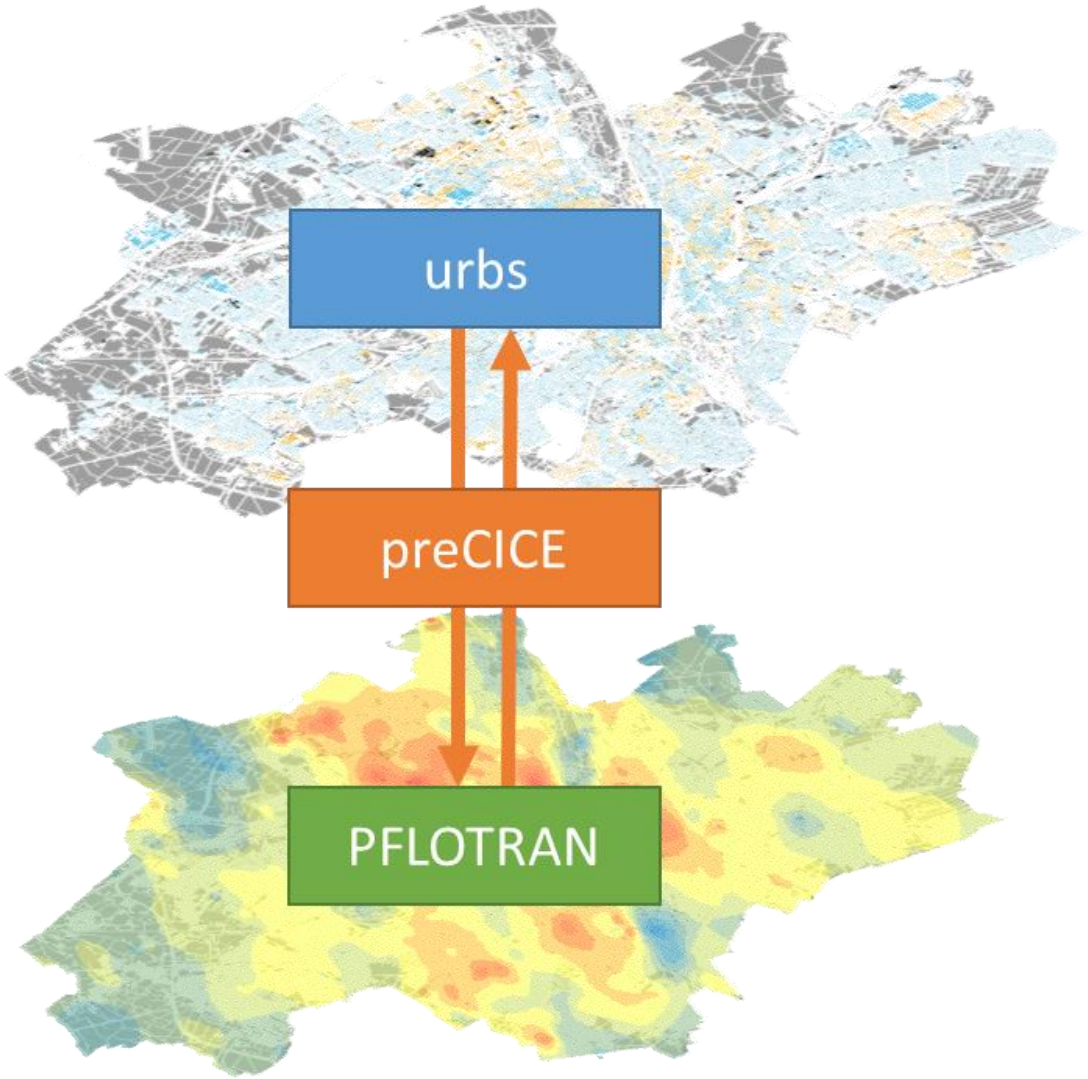
- No depletion or flooding while operation
- No thermal recycling from injection to extraction
- Within water protection law

With the use of synergies from surrounding thermal uses

→ While minimizing the cost for heating & cooling

→ While minimizing the greenhouse gas emissions

Methodology



Coupling of models:

- Energy system optimization model

  urbs

  https://github.com/tum-ens/urbs

- Coupling library

  preCICE

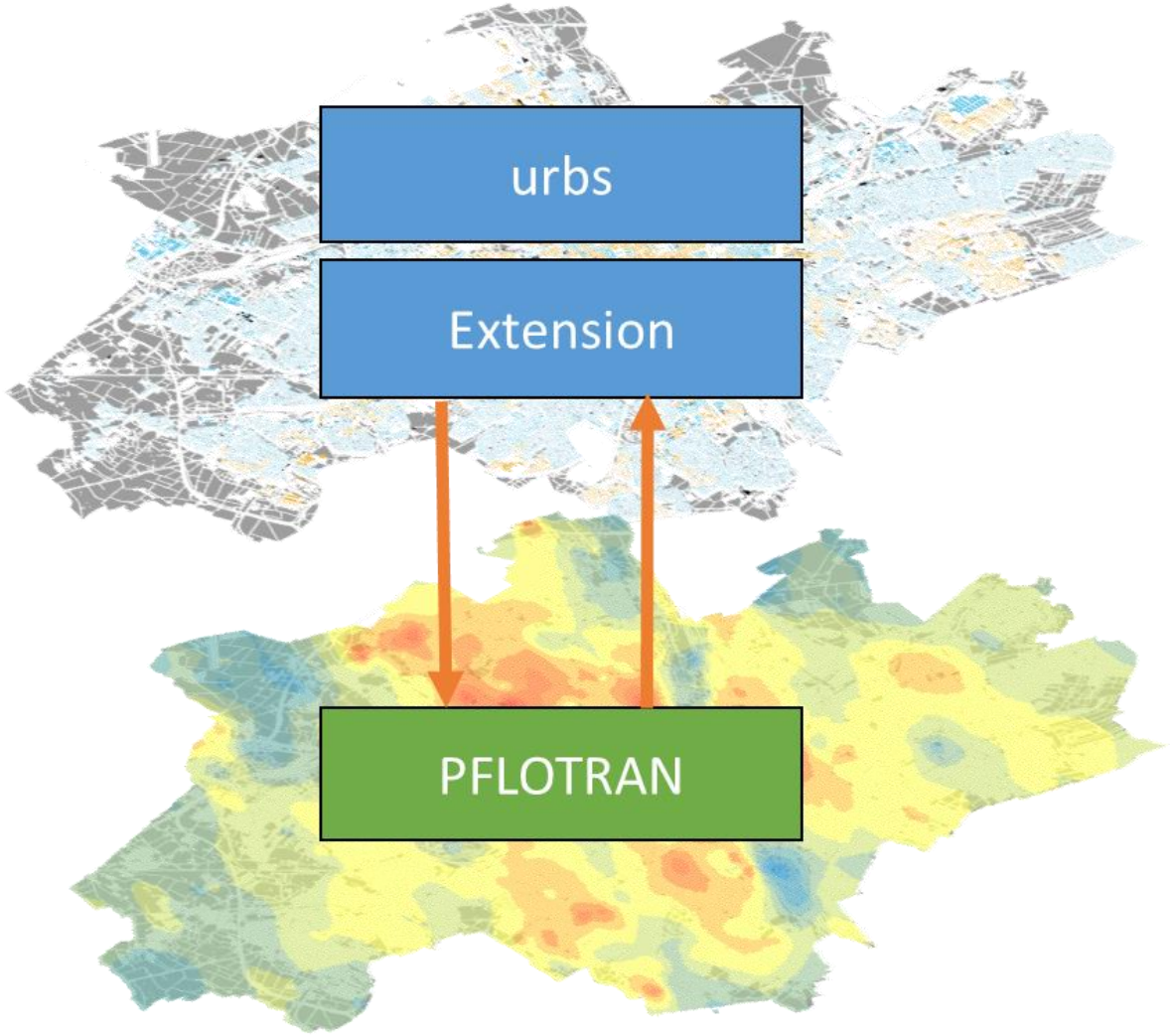
  https://precice.org

- Numerical groundwater simulation

  PFLOTRAN

  www.pflotran.org

Optimization problem



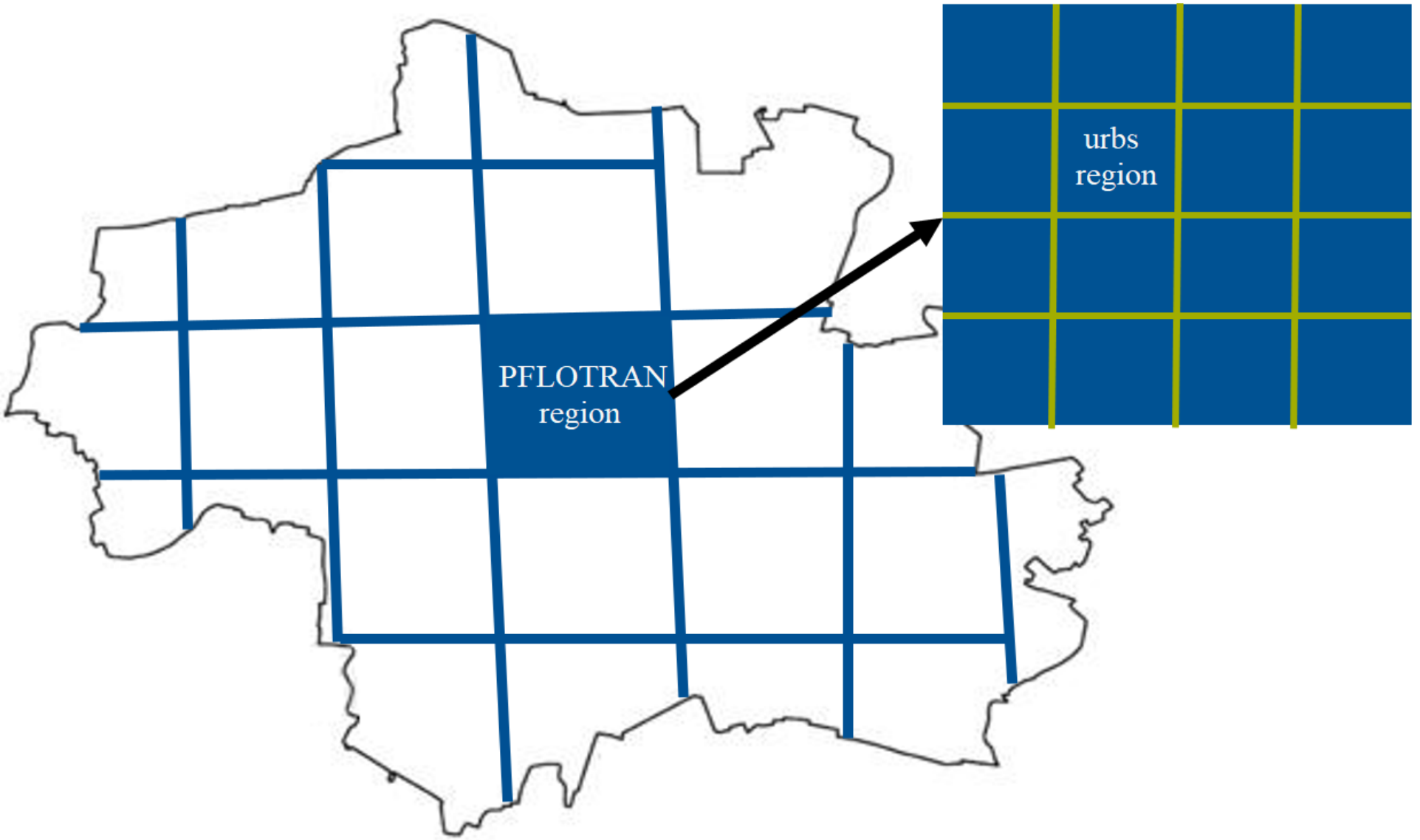
Optimization problem:

- HEB optimization problem (highly dimensional, expensive evaluations, black-box optimization)
- Decomposition, parallelization and new optimization methods required

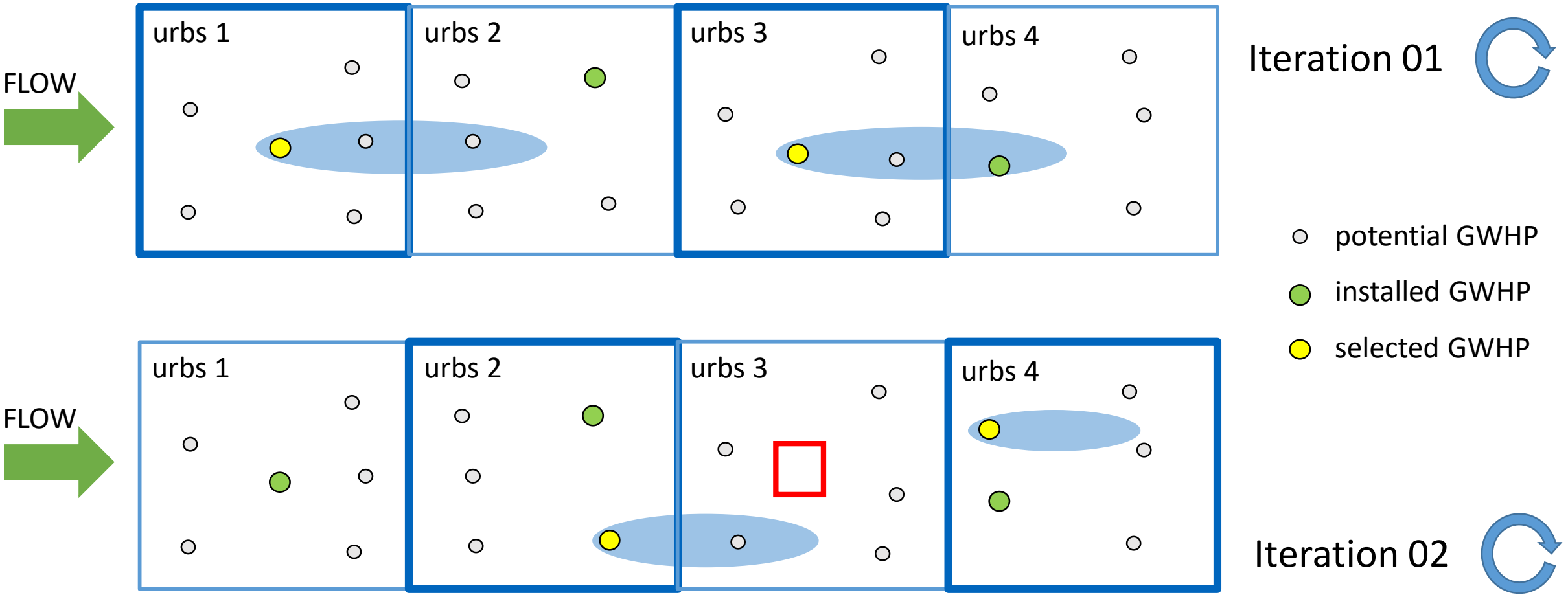
urbs extension:

- Check regulations for new GWHPs
- Update the efficiency of GWHPs

Concept for the overall problem decomposition



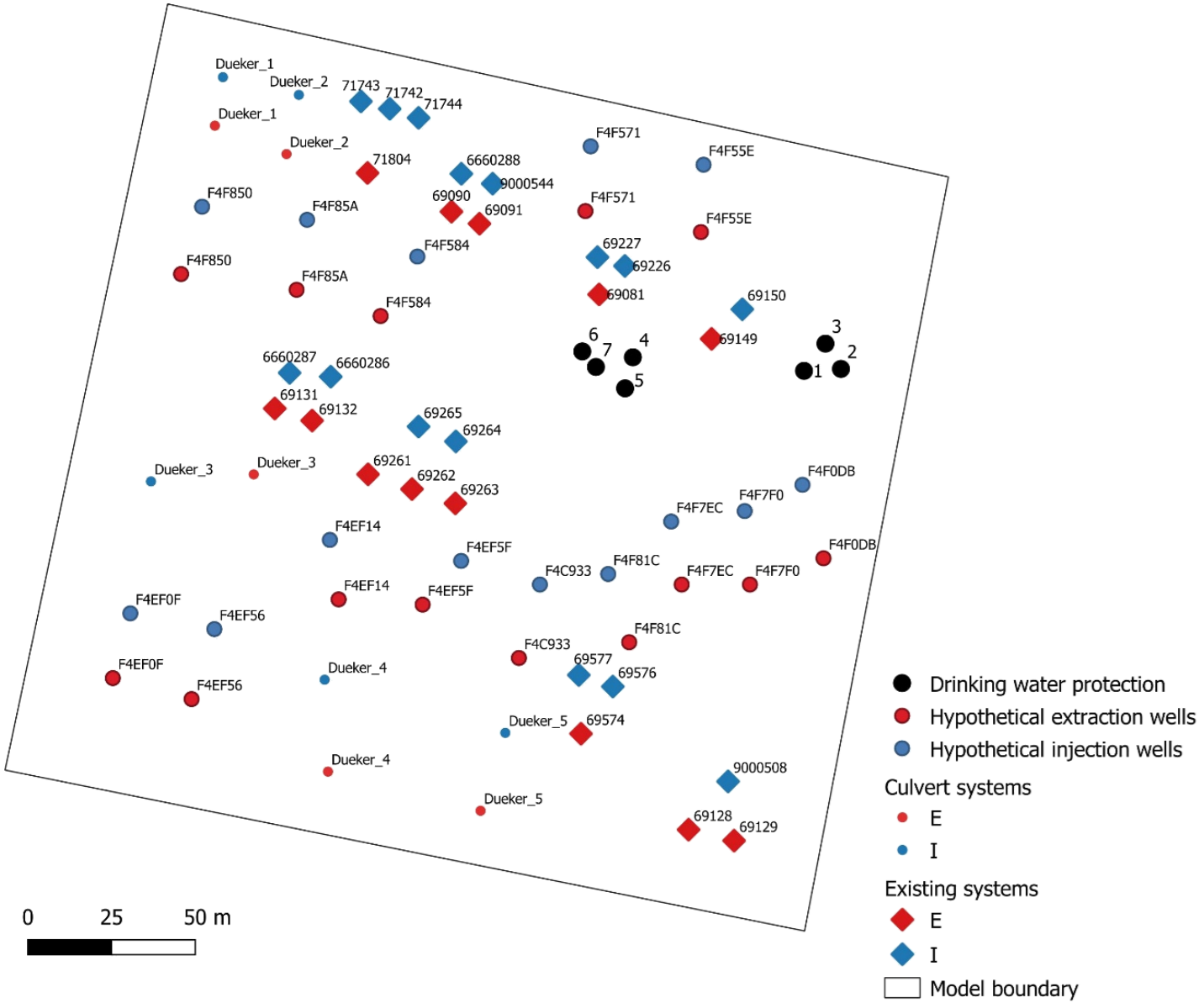
Iterative optimization approach



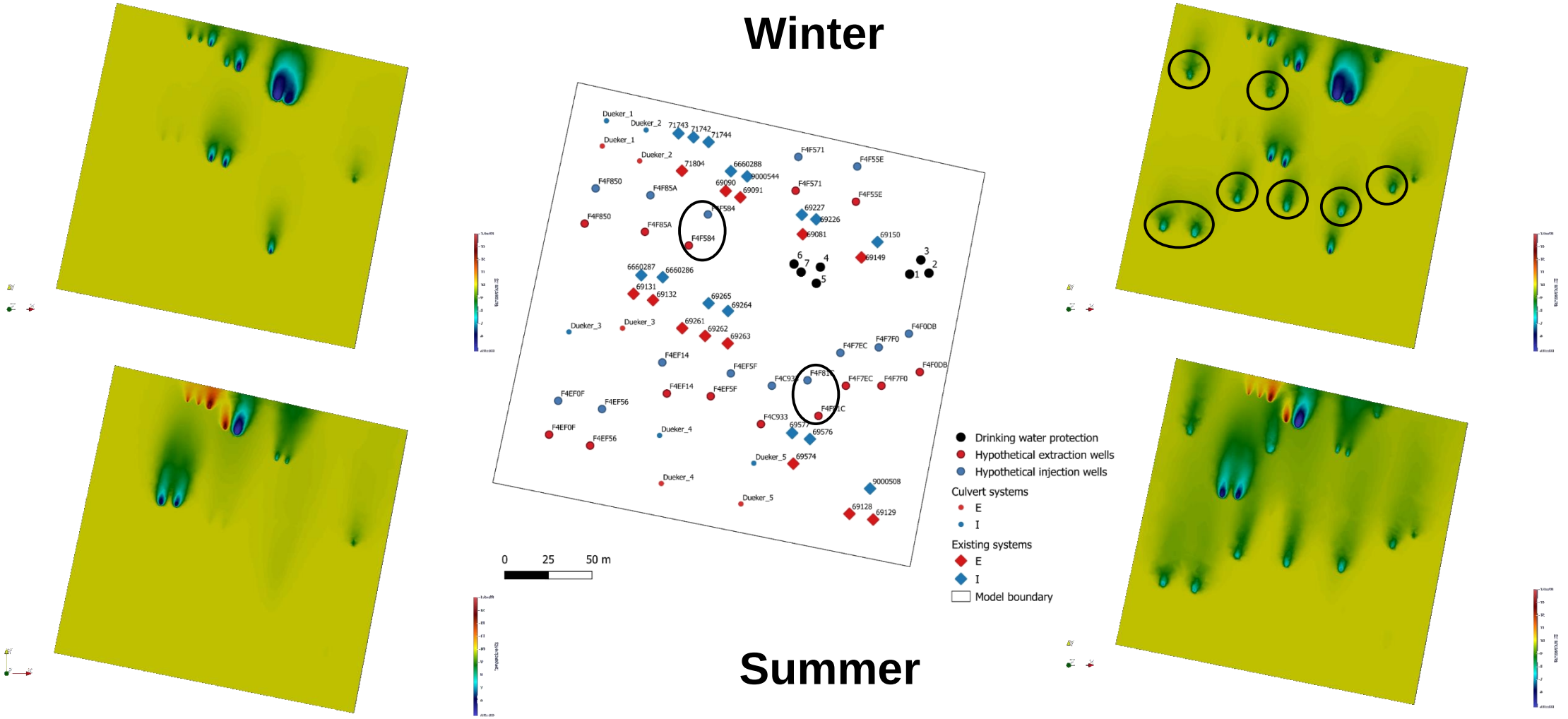
Small test model

Integration of all elements

- Hypothetical heat pumps each with one well pair (extraction and injection)
- Existing thermal uses
- Culvert (Düker) Systems
- Drinking water wells



Small test model - solution



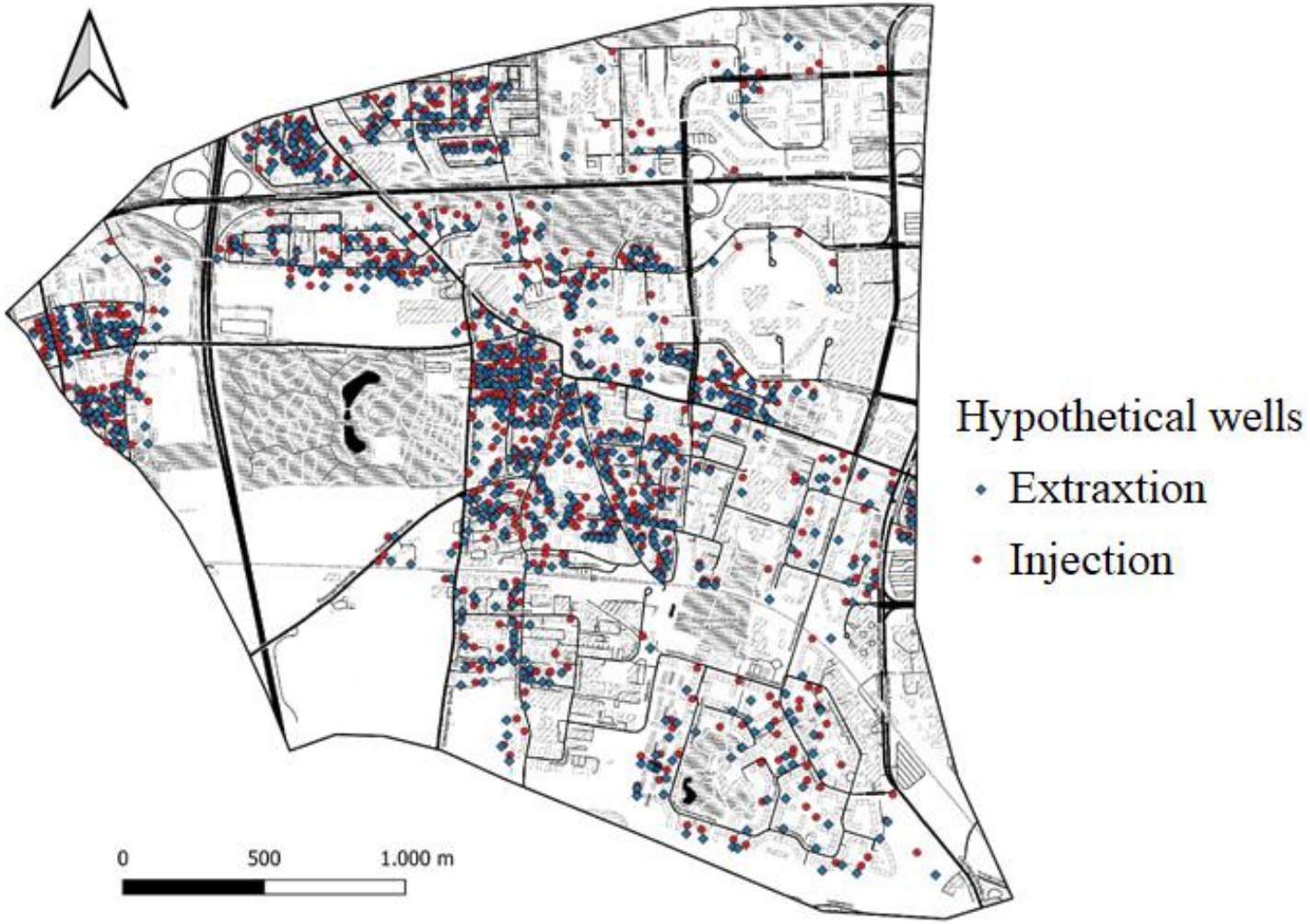
Temperature field: Present state

Temperature field: Optimized expansion

Conclusion and outlook

Real city region

- 1818 potential GWHP wells
- 80 existing wells
- Currently being tested on SuperMUC-NG



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